Purchasing Division

ADDENDUM NO. 1

DATE: April 11, 2018
FROM: City of Grand Junction Purchasing Division
TO: All Offerors
RE: Design Services for Purdy Mesa Flowline – Sullivan Draw Plan Development RFP-4511-18-DH

Offerors responding to the above referenced solicitation are hereby instructed that the requirements have been clarified, modified, superseded and supplemented as to this date as hereinafter described.

Please make note of the following clarifications:

1. Q. What type of Tank is preferred by the City? Welded steel, etc.?

   A. Steel or concrete are the most logical options, but the city will entertain any realistic recommendation made by the Consultant.

2. Q. What firm is conducting the NEPA study?

   A. WestWater Engineering - http://westwaterco.com/

3. Q. Is there a recent survey (ROW, utilities, easements etc.) of the entire alignment?

   A. No, gound survey is the only recent survey in the project reach. The City does have 40'-wide easement along the length of the flowline.

4. See attached Purdy Mesa Flow Line Hydraulic Evaluation.

5. Awarded firm shall submit review sets of 30% and 90%, and a completed bid set. Engineers estimates of probable costs to be included with all submittals, and project specifications to be included with the 90% review set and completed bid set.

The original solicitation for the project noted above is amended as noted.

All other conditions of subject remain the same.

Respectfully,

Duane Hoff Jr., Senior Buyer
City of Grand Junction, Colorado

FINAL

PURDY MESA FLOW LINE HYDRAULIC EVALUATION

Grand Junction, Colorado

B&V PROJECT NO. 197600

PREPARED FOR

City of Grand Junction

6 APRIL 2018

BLACK & VEATCH

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1 Introduction

The Purdy Mesa Flow Line (PMFL) is a gravity transmission main of approximately 17.5 miles which currently conveys up to 7.6 mgd of raw water from the Juniata Reservoir to the Grand Junction Water Treatment Plant (WTP) in the City of Grand Junction, Colorado (City) as shown in Figure 1. The PMFL runs through the Sullivan Draw, which is an area of extreme elevation relief with grades of up to 40%. Approximately 1.25 miles of 18-inch and 20-inch steel pipe (shown in red in Figure 1) is approaching the end of its useful life and is in need of replacement. Due to the challenging site conditions associated with the steep terrain, the City would like the new Sullivan Draw pipeline to be installed with a diameter large enough that the segment does not create a hydraulic restriction (which the Sullivan draw currently does) or limit the ultimate desired flow rates of the PMFL in the future. The City has already replaced approximately 6.1 miles of the PMFL with 24-inch PVC and 3.7 miles with 20-inch PVC. An additional 6.5 miles of the PMFL are also planned to be replaced in the future.

Figure 1 Purdy Mesa Flow Line Overview

In addition to the replacement of the pipeline which runs through the Sullivan Draw, the City also recognizes that the PMFL is operationally challenging due to the existing flow control infrastructure and hydraulics under varying flow rates, which can cause air entrainment (manifested as milky water at the Grand Junction WTP) because of a variety of factors including partially full pipe flow and cavitation.

The primary objectives of the analyses described in this Technical Memorandum were to:

- Construct and validate a WaterGEMS hydraulic model of the PMFL to enable detailed analysis of the pipeline hydraulics under a variety of flow rates and system conditions
- Use the hydraulic model to confirm the existing hydraulic capacity of the 0.8 mile 18-inch segment of the Sullivan Draw portion of the PMFL
- Use the hydraulic model to evaluate the hydraulic benefits (and associated increases in maximum potential PMFL flow rates) of upsizing the 18-inch Sullivan Draw pipeline to 20-inch or 24-inch
- Use the hydraulic model to investigate potential causes for air entrainment in the PMFL and develop potential hydraulic improvement recommendations to both improve pipeline operation and reduce air entrainment in the future

2 Hydraulic Model Development and Validation

A hydraulic model of the PMFL was constructed in Bentley WaterGEMS as described in the following section.

2.1 DATA SOURCES

The City provided the following data sources to Black & Veatch which were used to build and calibrate the hydraulic model. In addition to the data listed below, a workshop was held with The City on 11/29/17 to confirm understanding of the current operation of the PMFL.

- 05019800-CleaningLiningHallenbeckWaterline-1968.pdf
- 05020200-HWY50_RawWaterlineRelocation-1998.pdf
- 05100600-PurdyMesaFlowlineReplacement-2008.pdf
- WaterLines.shp
- Purdy Mesa Flowline Hydraulic calcs.xlsx
- Roll Seal info to Cla-Val.doc
- Roll_Seal_Catalog.pdf

2.2 PURDY MESA FLOW LINE FACILITIES AND OPERATIONAL DESCRIPTION

Figure 2 displays a detailed overview of the PMFL from the Juniata Reservoir to the Grand Junction WTP and Figure 3 displays the pipeline profile, which was developed based on the data received as well as conversations with the City. The PMFL is currently operated as described below:

1. Raw water from the Juniata Reservoir (nominal water surface elevations of 5,741 ft to 5,754 ft) is released into the PMFL by an automatic Flow Control Valve (FCV) which can be set remotely to deliver a desired flow rate. The FCV automatically modulates to maintain the desired flow rate.
2. Raw water flows through approximately 3.4 miles of 20-inch steel pipe and discharges to atmosphere at the Pressure Control Tower (PCT). Because flow is controlled by the FCV at the upstream side of the PMFL, this section of pipe is not under constant positive pressure. Instead, it flows under a combination of partially full and full pipe flow between the FCV and the PCT. Based on conversations with the City, this section of pipe is currently in poor condition.
3. The PCT is a cylindrical tank 12 ft in height with a diameter of 5 ft and a total volume of 235 ft^3 (1,760 gallons). Raw water flows into the PCT from the 20-inch steel pipe and flows out of the PCT through the 18-inch steel Sullivan Draw pipe.
4. Flow continues from the PCT through 0.8 miles of 18-inch steel pipe to the Upper Roll Seal PSV, which is a 12-inch Cla-Val Roll Seal. The Upper Roll Seal is bypassed at flow rates of less than approximately 6.1 mgd and is used to control flow downstream of the PCT at flows greater than 6.1 mgd by manually adjusting the upstream pressure setting between approximately 63 psi to 68 psi.
5. Flow continues from the Upper Roll Seal PSV through 0.4 miles of 20-inch steel pipe to the Lower Roll Seal PSV, which is also a 12-inch Cla-Val Roll Seal. The Lower Roll Seal is bypassed at flows of less than approximately 6.1 mgd and is used to reduce pressures in the 20-inch steel pipeline between the Upper and Lower Roll Seals at flows of greater than 6.1 mgd by using an upstream pressure setting of approximately 101 psi.
6. Flow continues from the Lower Roll Seal PSV through 3.1 miles of 20-inch steel pipe, 3.7 miles of 20-inch PVC pipe and finally 6.1 miles of 24-inch PVC pipe before discharging to atmosphere at the raw water vault at the Grand Junction WTP at a water surface elevation of approximately 4,831 ft.

It is noted that the WaterGEMS hydraulic modeling software cannot accurately simulate hydraulics under partially full pipe flow conditions due to the unpredictable formation and movement of air pockets (which can cause hydraulic restrictions, air entrainment and flow anomalies). For this reason, the hydraulic model was developed for the PMFL from the PCT to the Grand Junction WTP only (as shown in Figure 3), excluding the 3.4 miles of 20-inch steel pipe from the FCV to the PCT.

It is also noted that there are five raw water taps along the PMFL between the PCT and the Grand Junction WTP which had a total combined 2017 average day usage of approximately 0.04 mgd. Because this usage is negligible (less than 1% of the total PMFL flow), these raw water taps were not included in the hydraulic model.

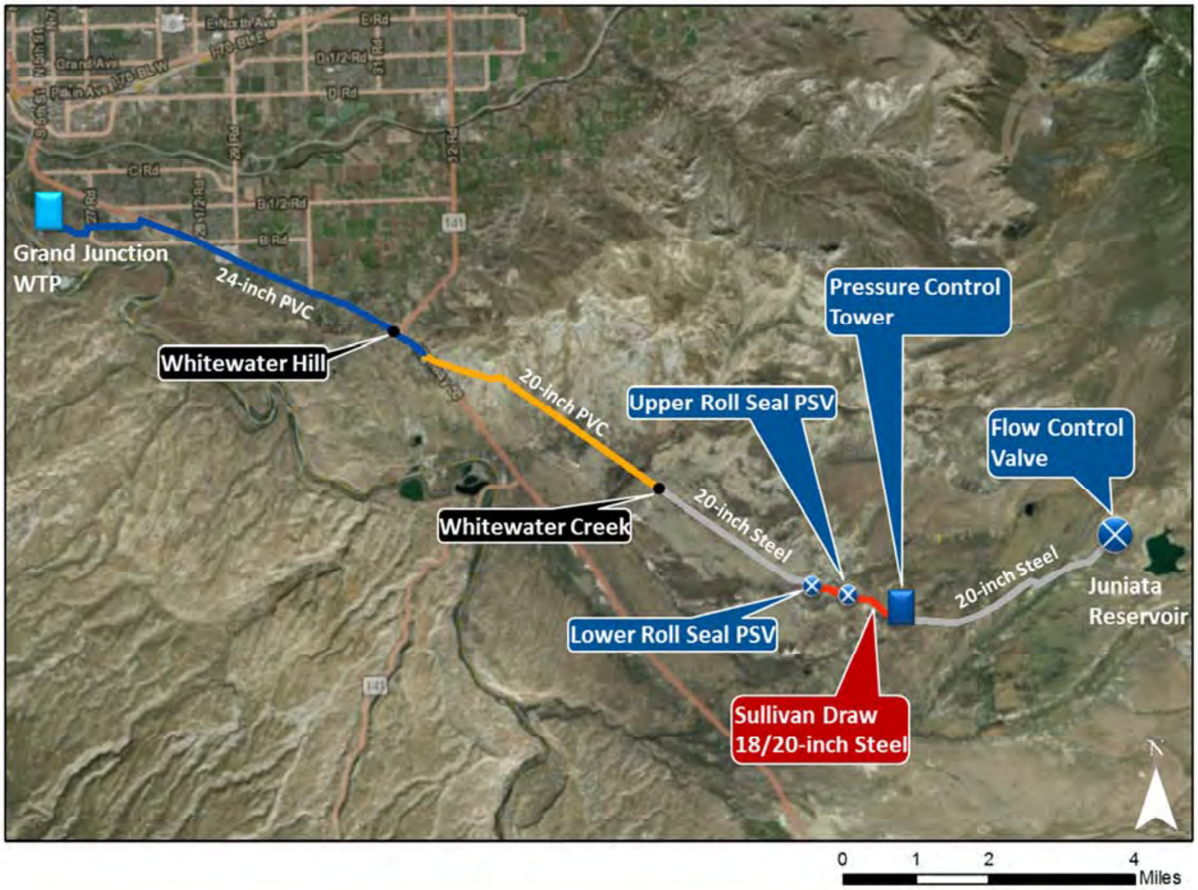

Figure 2 Purdy Mesa Flow Line and Facilities

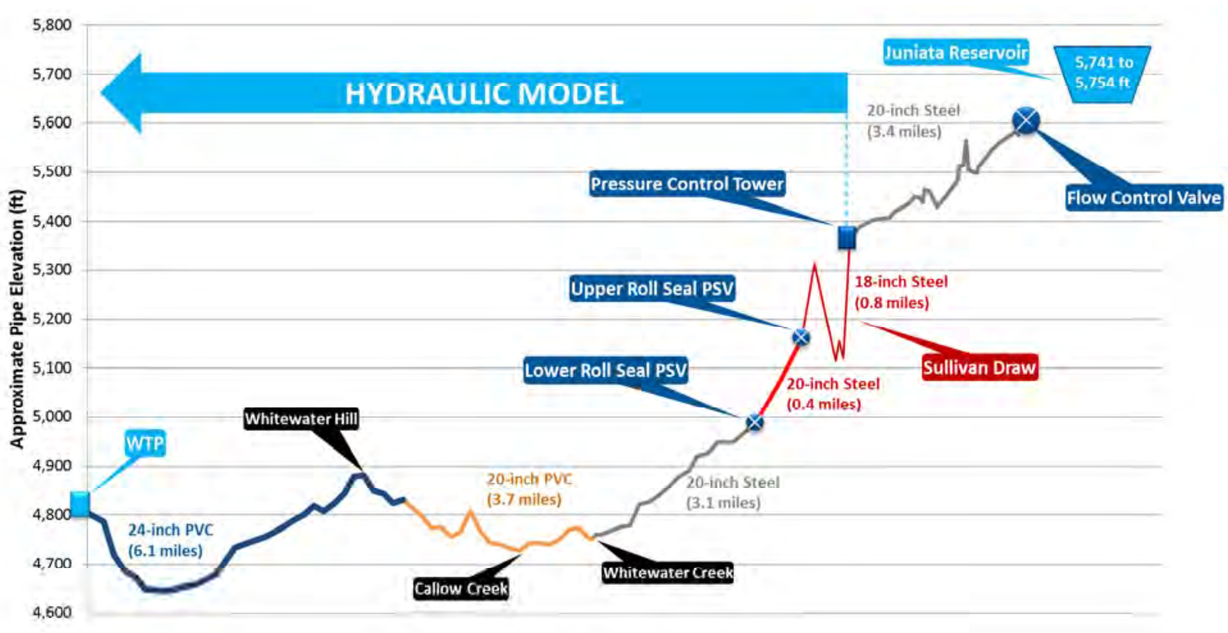

Figure 3 Purdy Mesa Flow Line – Profile

Table 1 displays a detailed summary of the PMFL pipelines based on information provided by the City. This information was used to build and validate the hydraulic model.

Table 1 Purdy Mesa Flow Line Pipe Summary

PIPE SIZE	MATERIAL	INTERNAL DIAMETER[1]	C-FACTOR[1]	LENGTH	INSTALLATION OR REHAB YEAR	DESCRIPTION
20-inch	Steel	19-inch	124	3.4 miles	Cleaned and cement mortar lined in 1968	Juniata Reservoir to PCT
18-inch	Steel	17-inch	112[2]	0.8 miles	Cleaned and cement mortar lined in 1968	PCT to Upper Roll Seal PSV
20-inch	Steel	19-inch	124	0.4 miles	Cleaned and cement mortar lined in 1968	Upper Roll Seal PSV to Lower Roll Seal PSV
20-inch	Steel	19-inch	124	3.1 miles	Cleaned and cement mortar lined in 1968	Lower Roll Seal PSV to Whitewater Creek
20-inch	PVC	19.75-inch	130	3.7 miles	Installed in 2009	Whitewater Creek to approximately the Orchard Mesa Park and Ride on US-50
24-inch	PVC	23.59-inch	130	6.1 miles	Installed circa 2001	Approximately Orchard Mesa Park and Ride on US-50 to Grand Junction WTP
Total				**17.5 miles**		

[1]Based on Purdy Mesa Flowline Hydraulic calcs.xlsx
[2]Based on model validation

2.3 HYDRAULIC MODEL CONSTRUCTION

Based on the information detailed in Section 2.2, a hydraulic model of the PMFL was constructed in Bentley WaterGEMS. The pipeline alignment and critical pipeline elevations were based on spatial, as-built and GPS information provided by the City. Pipe lengths, materials, internal diameters and C-Factors were based on the information summarized in Table 1.

As described previously, the hydraulic model was built to represent the existing PMFL from the PCT to the Grand Junction WTP, excluding the 20-inch steel pipe from the Juniata Reservoir to the PCT, which flows under partially full pipe conditions (and cannot be simulated with the hydraulic model) under all existing PMFL flow rates. Figure 4 displays a screenshot of the PMFL Bentley WaterGEMS hydraulic model.

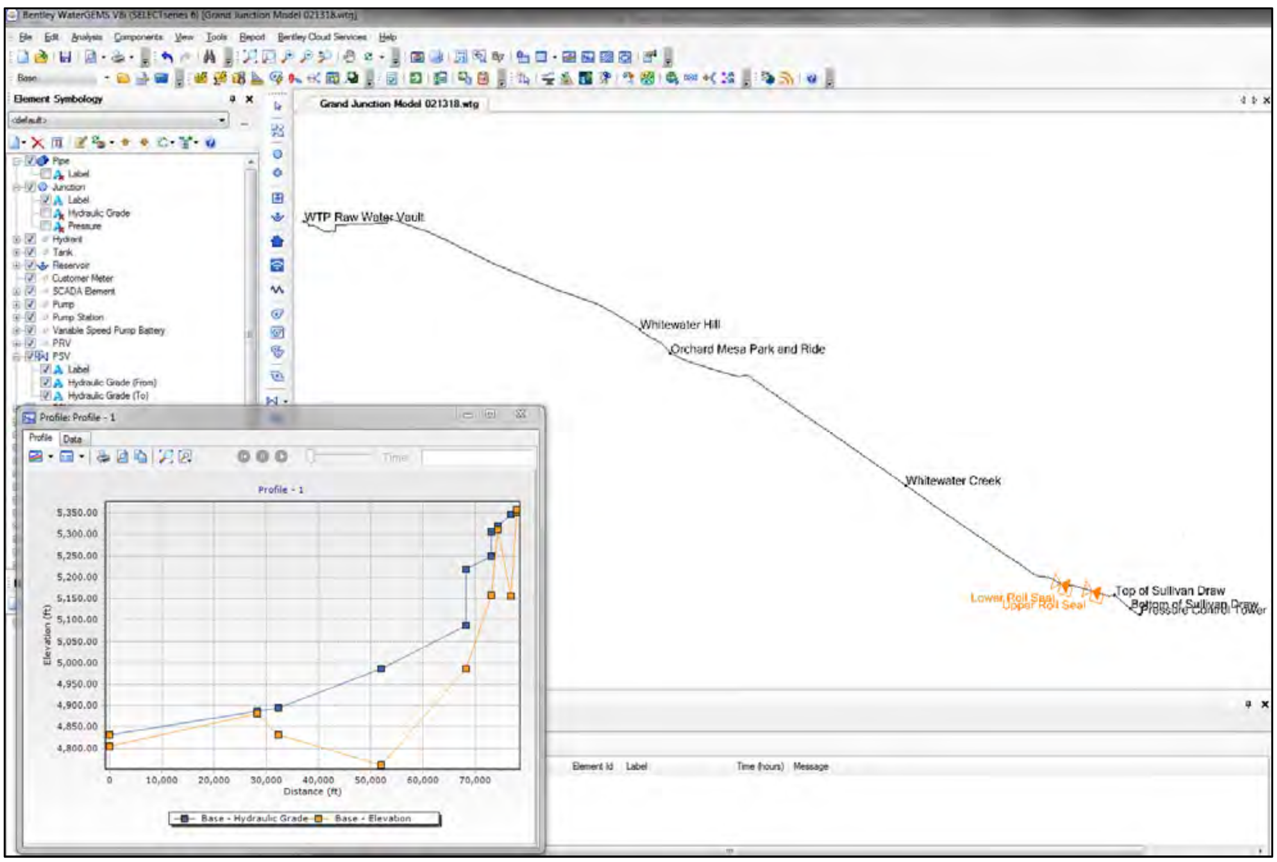

Figure 4 Purdy Mesa Flow Line Bentley WaterGEMS Hydraulic Model Screenshot

3 Hydraulic Model Validation

Validation of a hydraulic model is generally completed using recent field data (e.g. pressures and flow) to ensure that the model accurately simulates reality. Recent field data (specifically pressures along the PMFL) was not available, so model validation was completed using the hydraulic spreadsheet provided by the City (Purdy Mesa Flowline Hydraulic calcs.xlsx) which was developed based on field data collected in 2010.

It is noted that length discrepancies were noted between the hydraulic spreadsheet and the as-built drawings, survey and GIS records for the Sullivan Draw pipeline between the PCT and the Lower Roll Seal PSV. The C-Factor of the 18-inch steel pipe was reduced from 124 to 112 in order to maintain the calculated hydraulics of the spreadsheet with the reduced pipe lengths. A C-Factor of 112 was also used for the 18-inch steel pipeline in the WaterGEMS hydraulic model.

Model validation was completed by comparing pressures / hydraulic grade line (HGL) simulated by the Bentley WaterGEMS hydraulic model to the hydraulic spreadsheet under a high flow condition, which produced the high dynamic head losses required to validate the model with a high degree of confidence.

Key model validation assumptions:

- PMFL Flow Rate: 7.45 mgd
- PCT Water Surface Elevation: 5,358 ft
- Upper Roll Seal PSV Setting: 64 psi (5,305 ft)
- Lower Roll Seal PSV Setting: 101 psi (5,220 ft)
- Grand Junction WTP Water Surface Elevation: 4,831 ft (12 psi in raw water vault)

Figure 5 displays the results of the model validation simulation (shown as the simulated blue HGL line) compared at key locations to the hydraulic spreadsheet. Table 2 displays the model validation results in tabular form. As shown, the Bentley WaterGEMS hydraulic model was shown to simulate HGLs within 1 ft of the HGLs in the hydraulic spreadsheet, indicating a high degree of agreement. Based on this validation, the PMFL Bentley WaterGEMS hydraulic model could be used with confidence as an analysis tool to analyze existing hydraulics and evaluate potential improvement alternatives for the PMFL.

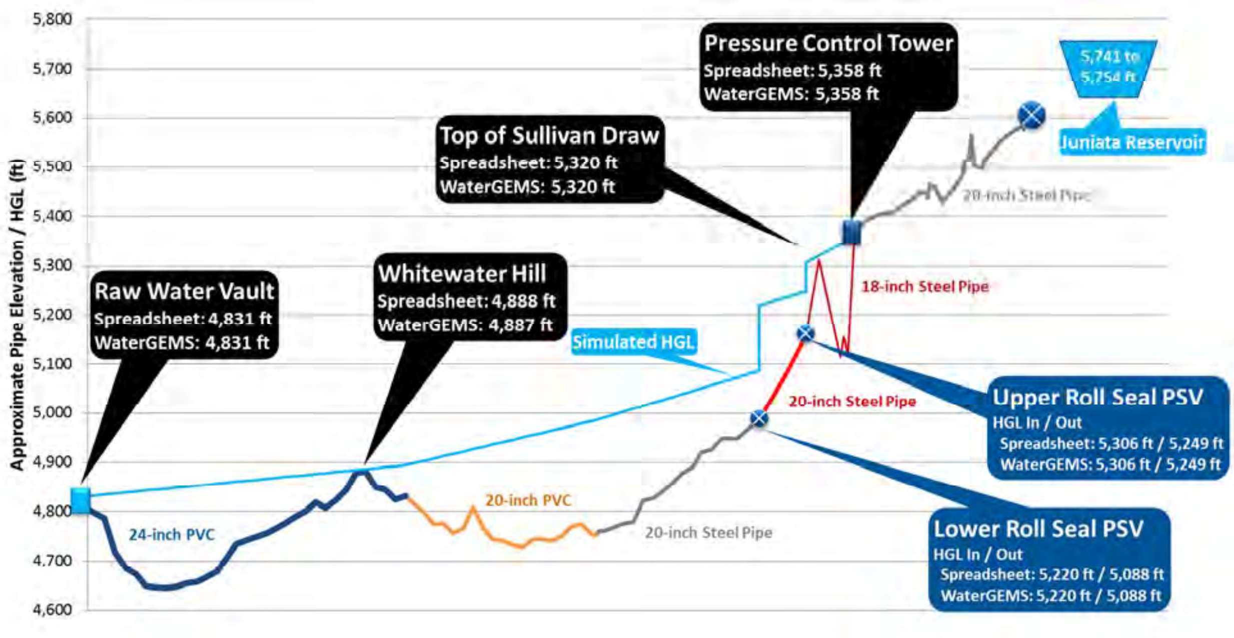

Figure 5 Model Validation Results Figure

Table 2 Model Validation Results Table

LOCATION	GRAND JUNCTION HYDRAULIC SPREADHEET HGL	BENTLEY WATERGEMS HYDRAULIC MODEL SIMULATED HGL	DIFFERENCE[1]
Pressure Control Tower	5,358 ft	5,358 ft	0 ft
Top of Sullivan Draw	5,320 ft	5,320 ft	0 ft
Upper Roll Seal PSV (Upstream)	5,306 ft	5,306 ft	0 ft
Upper Roll Seal PSV (Downstream)	5,249 ft	5,249 ft	0 ft
Lower Roll Seal PSV (Upstream)	5,220 ft	5,220 ft	0 ft
Lower Roll Seal PSV (Downstream)	5,088 ft	5,088 ft	0 ft
Whitewater Hill	4,888 ft	4,887 ft	1 ft
Raw Water Vault	4,831 ft	4,831 ft	0 ft

[1]Grand Junction Hydraulic Spreadsheet HGL – Bentley WaterGEMS Hydraulic Model Simulated HGL

4 Hydraulic Analyses

The validated Bentley WaterGEMS hydraulic model of the PMFL was used to analyze the pipeline hydraulics under six scenarios as described in the following section.

- Sullivan Draw Pipeline Analyses
  - Scenario 1: Existing 18-inch Sullivan Draw Pipeline
  - Scenario 2: New 20-inch Sullivan Draw Pipeline
- Existing Purdy Mesa Flow Line Analyses
  - Scenario 3: Existing Purdy Mesa Flow Line, 3.0 mgd
  - Scenario 4: Existing Purdy Mesa Flow Line, 6.7 mgd
  - Scenario 5: Existing Purdy Mesa Flow Line, 7.6 mgd
- Future Purdy Mesa Flow Line Analysis

  Scenario 6: Purdy Mesa Flow Line Upsized to 24-inch

4.1 SULLIVAN DRAW PIPELINE ANALYSES

4.1.1 Scenario 1: Existing 18-inch Sullivan Draw Pipeline

4.1.1.1 Objective

The existing 0.8 miles of 18-inch steel pipe which runs from the PCT through the Sullivan Draw to the Upper Roll Seal PSV is the smallest diameter pipe in the PMFL. Additionally, the pipeline experiences significant elevation relief which includes a low point of approximately 5,114 ft and a high point of approximately 5,312 ft, before terminating at the Upper Roll Seal at an elevation of approximately 5,158 ft.

Due to the 18-inch diameter as well as the 5,312 ft high point, the 18-inch Sullivan Draw steel pipe is currently the hydraulic bottleneck of PMFL, limiting the total flow rate which can be delivered from the Juniata Reservoir to the Grand Junction WTP.

The objective of this analysis was to evaluate the hydraulic performance of the existing 18-inch Sullivan draw pipeline under two flow conditions:

- 6.7 mgd: Normal "high flow" rate for PMFL
- Maximum Flow: Maximum flow rate which can be conveyed through the existing 18-inch Sullivan Draw pipeline

4.1.1.2 Assumptions

- PCT water surface elevation: 5,358 ft (approximately half full)
- Upper Roll Seal PSV Setting: modulated to produce desired flow rate through Sullivan Draw pipeline

4.1.1.3 Results

The hydraulic model was used to evaluate the existing 18-inch Sullivan Draw pipeline under a 6.7 mgd flow rate as shown in Figure 6. A flow rate of 6.7 mgd was simulated by adjusting the setting of the Upper Roll Seal PSV to 68 psi (5,315 ft). HGLs between the Upper Roll Seal PSV and the PCT were predicted by the model based on dynamic head loss due to the flow rate, the pipe diameter, pipe length and pipe C-Factor. At a flow rate of 6.7 mgd the model predicted an HGL of 5,327 ft at the Sullivan Draw high point, which exceeds the pipe elevation at a positive pressure of approximately 6 psi.

The maximum flow rate which can be conveyed from the PCT through the Sullivan Draw is the flow rate which results in dynamic head losses between the PCT and the Sullivan Draw high point such that the HGL at the high point is just above the pipe elevation of 5,312 ft. In practicality, 1-2 psi of positive pressure (HGL of 5,316 ft) should be maintained at the Sullivan Draw high point. The maximum flow rate of the existing 18-inch Sullivan Draw pipeline was determined using the hydraulic model by iteratively adjusting the upstream setting of the Upper Roll Seal PSV until the HGL at the Sullivan Draw high point was approximately 1 psi above the pipe elevation. As shown in Figure 6, the maximum flow rate through the Sullivan Draw was predicted to be approximately 8.0 mgd, corresponding to an upstream pressure setting of the Upper Roll Seal PSV of approximately 61 psi (5,298 ft).

Based on this analysis, the existing 18-inch Sullivan Draw pipeline limits the overall maximum flow rate of the PMFL to 8.0 mgd.

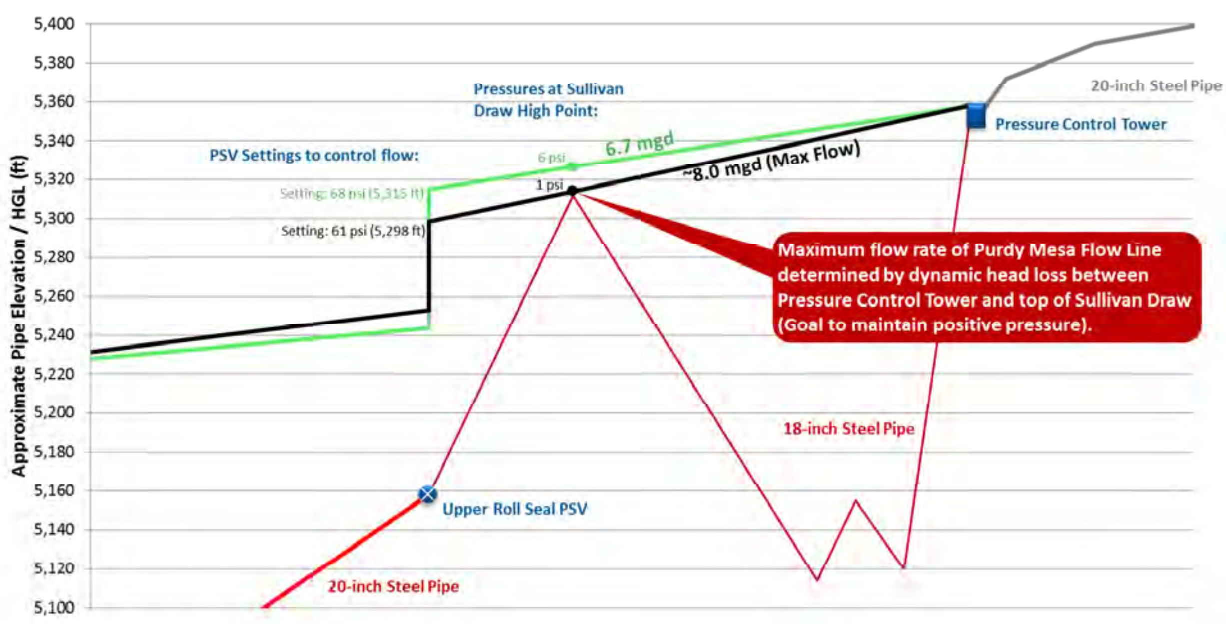

Figure 6 Existing 18-inch Sullivan Draw Hydraulic Analysis

4.1.2 Scenario 2: New 20-inch Sullivan Draw Pipeline

4.1.2.1 Objective

Replacement of the existing 0.8 miles of 18-inch steel pipe which runs from the PCT to the Upper Roll Seal PSV as well as the 0.4 miles of 20-inch steel pipe from the Upper Roll Seal PSV to the Lower Roll Seal PSV is currently part of the City's 10 Year CIP. Currently, the City Plans to replace (abandon in place) the existing 18-inch and 20-inch steel pipe and replace them with a new 20-inch PVC pipe.

The objective of this analysis was to evaluate the hydraulic performance of the proposed new 20-inch Sullivan draw pipeline under two flow conditions:

- 6.7 mgd: Normal "high flow" rate for PMFL
- Maximum Flow: Maximum flow rate which can be conveyed through the proposed new 20-inch Sullivan Draw pipeline to the Grand Junction WTP

4.1.2.2 Assumptions

- 1.25 miles of PMFL from PCT to Lower Roll Seal PSV replaced with 20-inch pipe (internal diameter: 19-inch, C-Factor: 130)
- PCT water surface elevation: 5,358 ft (approximately half full)
- Upper Roll Seal PSV Setting: modulated to produce desired flow rate through Sullivan Draw pipeline
- Grand Junction WTP Water Surface Elevation: 4,831 ft

4.1.2.3 Results

The hydraulic model was used to evaluate the proposed 20-inch Sullivan Draw pipeline under a 6.7 mgd flow rate as shown in Figure 7. A flow rate of 6.7 mgd was simulated by adjusting the upstream setting of the Upper Roll Seal PSV to 77.7 psi (5,337 ft). HGLs between the Upper Roll Seal PSV and the PCT were predicted by the model based on dynamic head loss due to the flow rate, the pipe diameter, pipe length and pipe C-Factor. At a flow rate of 6.7 mgd the model predicted an HGL of 5,344 ft at the Sullivan Draw high point, which exceeds the pipe elevation at a positive pressure of approximately 14 psi.

The maximum flow rate of the PMFL with the proposed 20-inch Sullivan Draw pipeline was estimated by bypassing the Upper Roll Seal PSV and allowing water to flow unrestricted from the PCT to the Grand Junction WTP. As shown in Figure 7, the maximum flow rate with the Upper Roll Seal PSV bypassed was predicted to be 10.1 mgd. At this flow rate, the HGL at the Sullivan Draw high point was predicted to be approximately 5,329 ft (7 psi of positive pressure), which confirms that the proposed 20-inch Sullivan Draw would no longer be the bottleneck restricting flow through the PMFL.

Figure 8 displays the PMFL hydraulic profile from the PCT to the Grand Junction WTP with the proposed 20-inch Sullivan Draw pipeline and both the Upper and Lower Roll Seal PSVs bypassed. As shown, the maximum flow rate of 10.1 mgd is limited by dynamic head losses through the existing PMFL pipelines downstream of the Lower Roll Seal PSV. The maximum pressure along the

PMFL was predicted to be 159 psi in the vicinity of Whitewater Creek, which is below the 160 psi pressure rating of the 20-inch steel pipe. If flow rates of more than 10.1 mgd are desired in the future, upsizing of other segments of the PMFL must be completed.

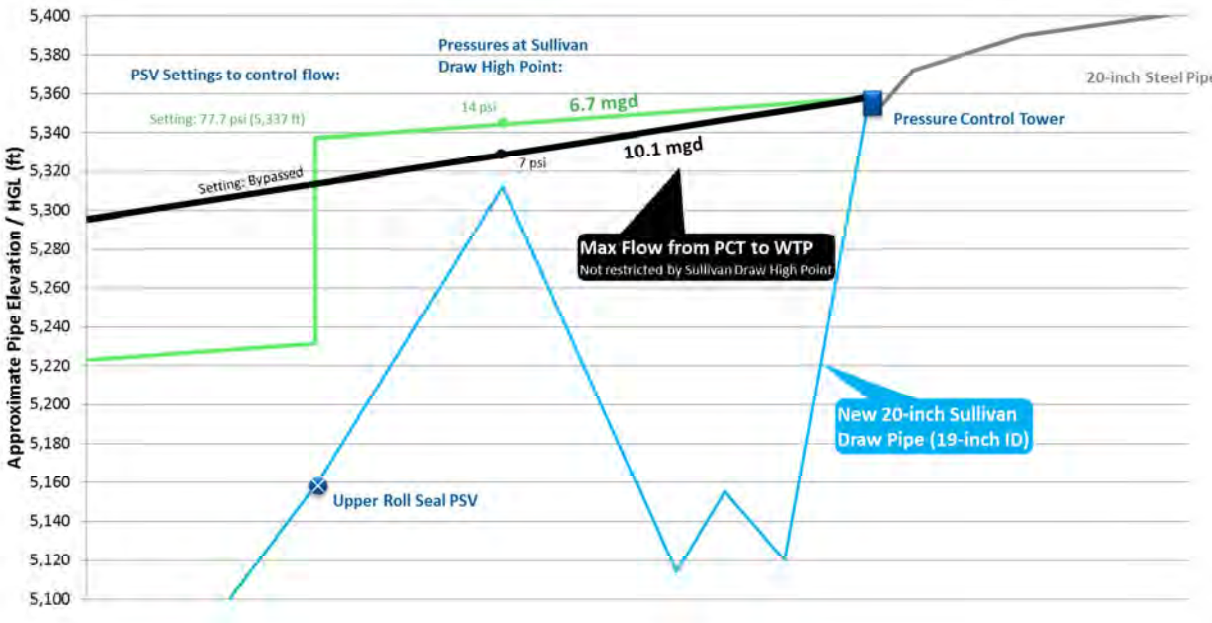

Figure 7 Proposed 20-inch Sullivan Draw Hydraulic Analysis

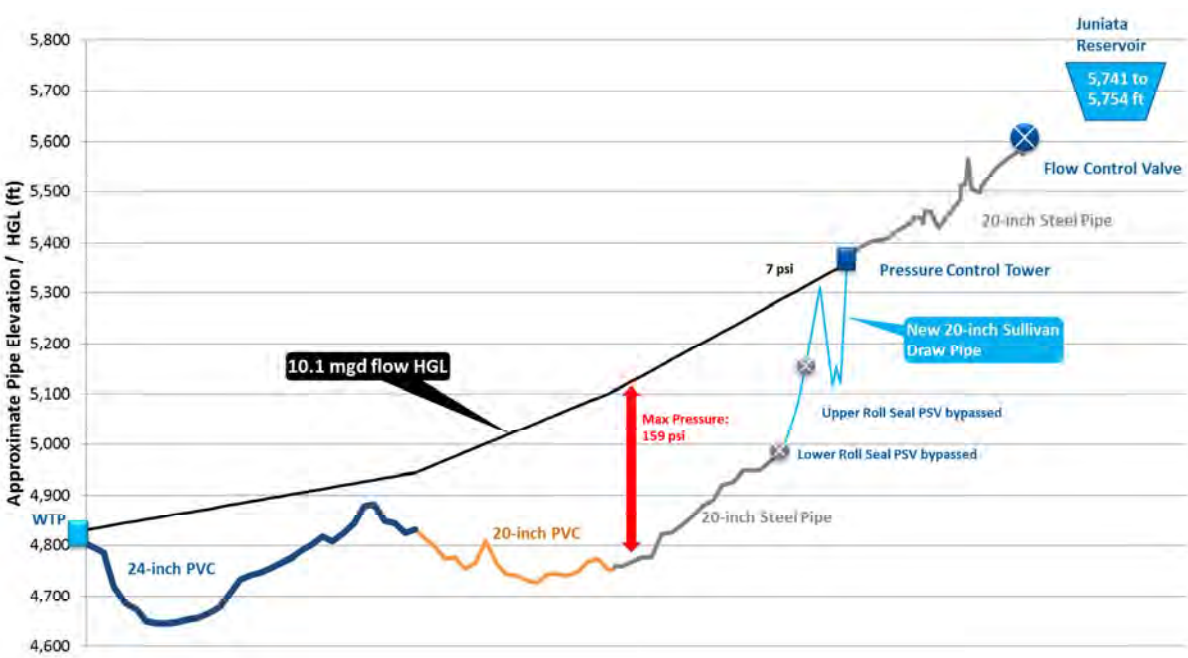

Figure 8 Purdy Mesa Flow Hydraulic Profile - Maximum Flow Rate with 20-inch Sullivan Draw Pipe

4.2 EXISTING PURDY MESA FLOW LINE ANALYSES

The PMFL is operationally challenging due to the existing flow control infrastructure and hydraulics under varying flow rates, which can cause air entrainment (manifested as milky water at the Grand Junction WTP) due to a variety of factors including partially full pipe flow and cavitation. The existing PMFL was analyzed under three flow rates to facilitate understanding of existing hydraulics and enable identification of operational issues and the development of potential hydraulic solutions. The following scenarios were evaluated and are detailed in the following section:

- Scenario 3: Existing Purdy Mesa Flow Line, 3.0 mgd
  - PMFL under a normal "low flow" condition
- Scenario 4: Existing Purdy Mesa Flow Line, 6.7 mgd
  - PMFL under a normal "high flow" condition
- Scenario 5: Existing Purdy Mesa Flow Line, 7.6 mgd
  - PMFL under a near maximum flow condition

4.2.1 Scenario 3: Existing Purdy Mesa Flow Line, 3.0 mgd

4.2.1.1 Objective

Based on conversations with the City, during low flow rates (e.g. 3.0 mgd), the FCV at the Juniata Reservoir is set to the desired flow rate and Upper and Lower Roll Seal PSVs are bypassed. The objective of this scenario was to evaluate the PMFL hydraulics at a flow rate of 3.0 mgd.

4.2.1.2 Assumptions

- Flow rate of 3.0 mgd delivered to the PCT from the Juniata Reservoir FCV (modeled as a 3.0 mgd inflow at the PCT)
- Upper and Lower Roll Seal PSVs bypassed
- Grand Junction WTP Water Surface Elevation: 4,831 ft

4.2.1.3 Results

The hydraulic model was used to evaluate the existing PMFL under a 3.0 mgd flow rate as shown in Figure 9. A flow rate of 3.0 mgd was simulated using an inflow of 3.0 mgd at the PCT, mimicking the actual system conditions of 3.0 mgd being delivered to the PCT by the Juniata Reservoir FCV.

Figure 9 - Existing Purdy Mesa Flow Line, 3.0 mgd- Hydraulic Profile

The following is a description of the predicted PMFL hydraulics from the Juniata Reservoir to the Grand Junction WTP under a flow rate of 3.0 mgd:

- Water from the Juniata Reservoir is released into the 20-inch steel PMFL by the FCV at a flow rate of 3.0 mgd
- A combination of full and partially full pipe flow occurs in the 20-inch steel pipe from the FCV to the PCT. The pipe will be full upstream of high points (where water will "back up" in the pipeline until a sufficient HGL is established to flow over the high point. On the downstream side of high points, the pipe will flow partially full (with the rest of the pipe filled with air)
- Water will flow into the PCT, however, without a sufficient downstream HGL to maintain water level in the PCT, the PCT will drain into the 18-inch Sullivan Draw pipe
- An HGL will be established through the Sullivan Draw which is defined by the high point of the Sullivan Draw and the dynamic head losses associated with the 18-inch Sullivan Draw pipe at a flow rate of 3.0 mgd
- Downstream of the Sullivan Draw high point, partially full pipe flow will occur as water falls from the high point. Significant air accumulation is likely to occur in this portion of the PMFL. Partially full pipe flow was predicted to continue until reaching the HGL established by the Whitewater Hill high point and the dynamic head loss in the PMFL at a flow rate of 3.0 mgd, at which point flow will continue full pipe (under pressure) to the White Water Hill high point
- Downstream of the Whitewater Hill high point, partially full pipe flow was predicted to occur as water falls from the high point. Significant air accumulation is likely to occur in this portion of the PMFL. Partially full pipe flow was predicted to continue until reaching the HGL established by the water surface elevation at the Grand Junction WTP and the dynamic head loss in the

pipeline at 3.0 mgd, at which point flow was predicted to continue full pipe (under pressure) to the Grand Junction WTP

As described and detailed above, significant air accumulation was predicted to be likely to occur in the existing PMFL under flow rates of 3.0 mgd. Accumulated air (air pockets) are unpredictable and can become lodged in various locations, causing hydraulic restrictions (by artificially reducing the flowable cross-sectional area of the pipe) when flow rates in the PMFL are increased.

4.2.2 Scenario 4: Existing Purdy Mesa Flow Line, 6.7 mgd

4.2.2.1 Objective

Based on conversations with the City, during high flow rates (e.g. 6.7 mgd), the FCV at the Juniata Reservoir is set to the desired flow rate and the upstream setting of the Upper Roll Seal PSV is manually set to establish a constant water surface elevation in the PCT. In practice, the City manually adjusts the setting of the Upper Roll Seal PSV by having one staff member at the Upper Roll Seal PSV and one staff member at the PCT, communicating by radio. The staff member at the Upper Roll Seal PSV adjusts the upstream setting until the staff member at the PCT can visually see that the level has stabilized in the middle of the PCT head range. Under ideal circumstances, the Juniata Reservoir FCV will control flow into the PCT and the Upper Roll Seal PSV will control flow out of the PCT at an identical rate, allowing the PCT water surface elevation to remain constant. Based on conversations with the City, however, it was noted that following manual adjustment of the Upper Roll Seal PSV, flow in and out of the PCT generally becomes unbalanced quickly, leading to the PCT either draining or overflowing.

The objective of this scenario was to evaluate the PMFL hydraulics at a flow rate of 6.7 mgd under an ideal case where the flow into and out of the PCT are matched, enabling the PCT to float at a consistent water surface elevation in the middle of its head range of approximately 5,358 ft.

4.2.2.2 Assumptions

- PCT water surface elevation: 5,358 ft (middle of PCT head range, assumes flow into the PCT controlled by the Juniata Reservoir FCV is equal to the flow out of the PCT controlled by the upstream setting of the Upper Roll Seal PSV)
- Upper Roll Seal PSV upstream setting: 68 psi, 5,315 ft (set to control 6.7 mgd of flow downstream of the PCT)
- Lower Roll Seal PSV upstream setting: 101 psi, 5,220 ft (set to maintain positive pressure between the Lower Roll Seal PSV and Upper Roll Seal PSV and eliminate the partially pipe flow which would be otherwise predicted to occur downstream of the Upper Roll Seal PSV. It is noted that the Lower Roll Seal PSV does not impact the flow rate of the PMFL downstream of the PCT)
- Grand Junction WTP Water Surface Elevation: 4,831 ft

4.2.2.3 Results

The hydraulic model was used to evaluate the existing PMFL under a 6.7 mgd flow rate as shown in Figure 10. A flow rate of 6.7 mgd was simulated by setting the water surface elevation of the PCT to 5,358 ft and adjusting the upstream setting of the Upper Roll Seal PSV to 68 psi (5,315 ft).

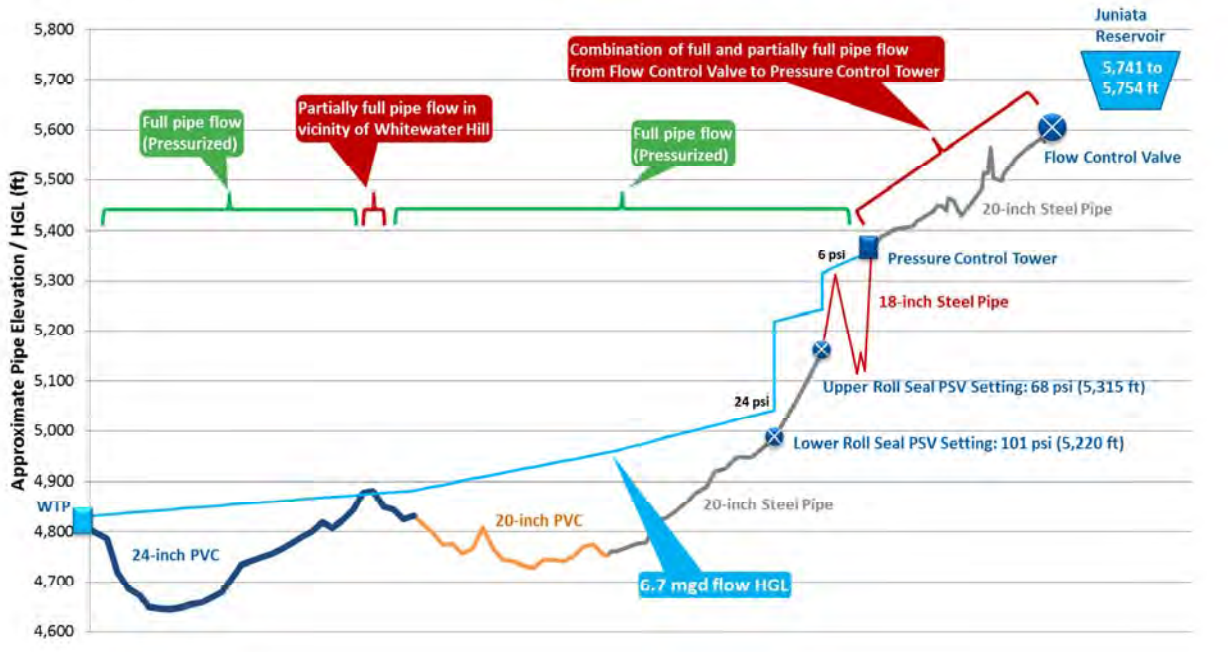

Figure 10 - Existing Purdy Mesa Flow Line, 6.7 mgd - Hydraulic Profile

The following is a description of the predicted PMFL hydraulics from the Juniata Reservoir to the Grand Junction WTP under a flow rate of 6.7 mgd:

- Water from the Juniata Reservoir is released into the 20-inch steel PMFL by the FCV at a flow rate of 6.7 mgd
- A combination of full and partially full pipe flow occurs in the 20-inch steel pipe from the FCV to the PCT. The pipe will be full upstream of high points (where water will "back up" in the pipeline until a sufficient HGL is established to flow over the high point. On the downstream side of high points, the pipe will flow partially full (with the rest of the pipe filled with air).
- Water will flow into the PCT, and, assuming that flow out of the PCT is effectively controlled by the Upper Roll Seal PSV to match the flow into the PCT, the water surface elevation will remain constant at 5,358 ft.
- Full pipe flow is predicted through the Sullivan Draw, including a positive pressure of approximately 6 psi at the Sullivan Draw high point.
- The Upper Roll Seal PSV was predicted to maintain an upstream pressure of 68 psi (5,315 ft).
- The Lower Roll Seal was predicted to maintain an upstream pressure of 101 psi (5,220 ft). Under this flow scenario, the Lower Roll Seal serves the critical function of creating back pressure which enables positive pressure to be maintained on the downstream side of the Upper Roll Seal PSV. Without the Lower Roll Seal PSV, the HGL downstream of the Upper Roll Seal PSV would be

controlled by the water surface elevation at the Grand Junction WTP as well as head loss in the PMFL.

- As shown in Figure 10, if the 6.7 mgd HGL line were to continue past the Lower Roll Seal PSV (without the HGL being raised by the automatic throttling of the PSV to maintain the upstream pressure setting), it would hit the pipe at an elevation of approximately 5,050 ft, which is more than 100 ft below the elevation of the Upper Roll Seal PSV. Without the Lower Roll Seal PSV creating back pressure, the Upper Roll Seal PSV would be likely to cavitate (due to low/negative pressures on the downstream side) and the PMFL would be predicted to experience partially full pipe flow, between the Upper Roll Seal PSV and the HGL line, which could lead to significant air accumulation.
- Following the Lower Roll Seal PSV, an HGL was predicted to be established based on the Whitewater Hill high point and the head loss through the PMFL at a flow rate of 6.7 mgd.
- Downstream of the Whitewater Hill high point, partially full pipe flow was predicted to occur as water falls from the high point. Some air accumulation is likely to occur in this portion of the PMFL. Partially full pipe flow was predicted to continue until reaching the HGL established by the water surface elevation at the Grand Junction WTP and the dynamic head loss in the pipeline at 6.7 mgd, at which point flow was predicted to continue full pipe (under pressure) to the Grand Junction WTP.

As described and detailed above, some air accumulation was predicted to be likely to occur in the existing PMFL under flow rates of 6.7 mgd in the vicinity of Whitewater Hill. Accumulated air (air pockets) are unpredictable and can become lodged in various locations, causing hydraulic restrictions (by artificially reducing the flowable cross-sectional area of the pipe) when flow rates in the PMFL are increased.

4.2.3 Scenario 5: Existing Purdy Mesa Flow Line, 7.6 mgd

4.2.3.1 Objective

Based on conversations with the City, during maximum flow rates (e.g. 7.6 mgd), the FCV at the Juniata Reservoir is set to the desired flow rate and the upstream setting of the Upper Roll Seal PSV is manually set to establish a constant water surface elevation in the PCT. In practice, the City manually adjusts the setting of the Upper Roll Seal PSV by having one staff member at the Upper Roll Seal PSV and one staff member at the PCT, communicating by radio. The staff member at the Upper Roll Seal PSV adjusts the upstream setting until the staff member at the PCT can visually see that the level has stabilized in the middle of the PCT head range. Under ideal circumstances, the Juniata Reservoir FCV will control flow into the PCT and the Upper Roll Seal PSV will control flow out of the PCT at an identical rate, allowing the PCT water surface elevation to remain constant. Based on conversations with the City, however, it was noted that following manual adjustment of the Upper Roll Seal PSV, flow in and out of the PCT generally becomes unbalanced quickly, leading to the PCT either draining or overflowing.

The objective of this scenario was to evaluate the PMFL hydraulics at a flow rate of 7.6 mgd under an ideal case where the flow into and out of the PCT are matched, enabling the PCT to float at a consistent water surface elevation in the middle of its head range of approximately 5,358 ft.

4.2.3.2 Assumptions

- PCT water surface elevation: 5,358 ft (middle of PCT head range, assumes flow into the PCT controlled by the Juniata Reservoir FCV is equal to the flow out of the PCT controlled by the upstream setting of the Upper Roll Seal PSV)
- Upper Roll Seal PSV upstream setting: 63 psi, 5,304 ft (set to control 7.6 mgd of flow downstream of the PCT)
- Lower Roll Seal PSV upstream setting: 101 psi, 5,220 ft (set to maintain positive pressure between the Lower Roll Seal PSV and Upper Roll Seal PSV and eliminate the partially pipe flow which would be otherwise predicted to occur downstream of the Upper Roll Seal PSV. The Lower Roll Seal PSV does not impact the flow rate of the PMFL downstream of the PCT)
- Grand Junction WTP Water Surface Elevation: 4,831 ft

4.2.3.3 Results

The hydraulic model was used to evaluate the existing PMFL under a 7.6 mgd flow rate as shown in Figure 11. A flow rate of 7.6 mgd was simulated by setting the water surface elevation of the PCT to 5,358 ft and adjusting the upstream setting of the Upper Roll Seal PSV to 63 psi (5,304 ft).

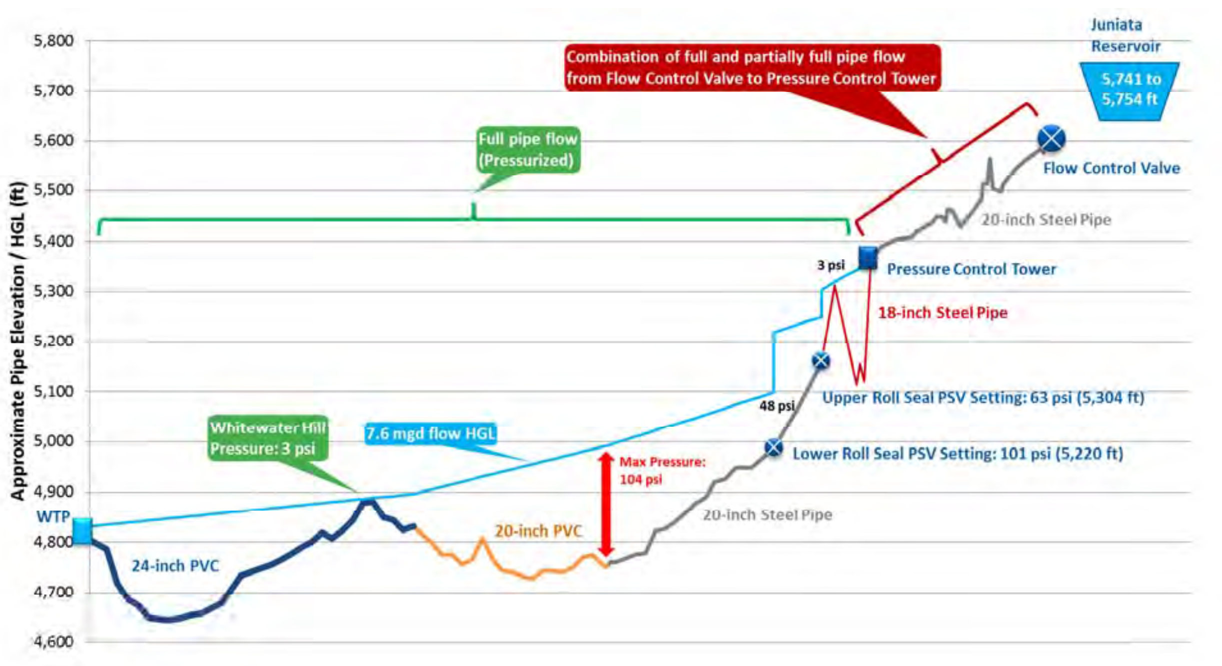

Figure 11 - Existing Purdy Mesa Flow Line, 7.6 mgd - Hydraulic Profile

The following is a description of the predicted PMFL hydraulics from the Juniata Reservoir to the Grand Junction WTP under a flow rate of 7.6 mgd:

- Water from the Juniata Reservoir is released into the 20-inch steel PMFL by the FCV at a flow rate of 7.6 mgd
- A combination of full and partially full pipe flow occurs in the 20-inch steel pipe from the FCV to the PCT. The pipe will be full upstream of high points (where water will "back up" in the pipeline

until a sufficient HGL is established to flow over the high point. On the downstream side of high points, the pipe will flow partially full (with the rest of the pipe filled with air)

- Water will flow into the PCT, and, assuming that flow out of the PCT is effectively controlled by the Upper Roll Seal PSV to match the flow into the PCT, the water surface elevation will remain constant at 5,358 ft
- Full pipe flow is predicted through the Sullivan Draw, including a positive pressure of approximately 3 psi at the Sullivan Draw high point
- The Upper Roll Seal PSV was predicted to maintain an upstream pressure of 63 psi (5,304 ft)
- The Lower Roll Seal was predicted to maintain an upstream pressure of 101 psi (5,220 ft). Under this flow scenario, the Lower Roll Seal serves the critical function of creating back pressure which enables positive pressure to be maintained on the downstream side of the Upper Roll Seal PSV. Without the Lower Roll Seal PSV, the HGL downstream of the Upper Roll Seal PSV would be controlled by the water surface elevation at the Grand Junction WTP as well as head loss in the PMFL. As shown in Figure 11, if the 7.6 mgd HGL line were to continue to the past the Lower Roll Seal PSV (without the HGL being raised by the automatic throttling of the PSV to maintain the upstream pressure setting), it would hit the pipe at an elevation of approximately 5,130 ft, which is below the elevation of the Upper Roll Seal PSV. Without the Lower Roll Seal PSV creating back pressure, the Upper Roll Seal PSV would be likely to cavitate (due to low/negative pressures on the downstream side) and the PMFL would be predicted to experience partially full pipe flow, between the Upper Roll Seal PSV and the HGL line, which could lead to significant air accumulation.
- Following the Lower Roll Seal PSV, an HGL was predicted to be established based on the water surface elevation at the Grand Junction WTP and the dynamic head loss in the PMFL at 7.6 mgd. It is noted that under this high flow rate, dynamic head losses were predicted to be sufficient maintain full pipe (pressurized) flow from the PCT to the Grand Junction WTP, including a positive pressure of approximately 3 psi at Whitewater Hill.

At a PMFL flow rate of 7.6 mgd, full pipe flow was predicted to occur in the PMFL from the PCT to the Grand Junction WTP. With the PMFL fully pressurized, no air accumulation was predicted.

4.3 FUTURE PURDY MESA FLOW LINE ANALYSIS

4.3.1 Scenario 6: Purdy Mesa Flow Line Upsized to 24-inch

4.3.1.1 Objective

Based on conversations with the City, it may be desirable to increase the flow capacity of the PMFL in the future both to be capable of meeting the required capacity of future growth and to enable the delivery of sufficient raw water capacity to the Grand Junction WTP with the Kannah Creek Flow Line out of service.

If flow capacities of more than approximately 9.8 mgd (maximum flow capacity with new 20-inch Sullivan Draw pipeline) are desired in the future, it may be beneficial to upsize the Sullivan Draw pipe now so it supports the future desired PMFL flow rate without causing a hydraulic bottleneck.

The objective of this analysis was to analyze and determine the maximum hypothetical flow rate of the PMFL (from the PCT to the Grand Junction WTP) it were upsized to 24-inch.

4.3.1.2 Assumptions

- PMFL upsized to 24-inch from the PCT to the existing 24-inch PVC pipe in the vicinity of the Orchard Mesa Park and Ride
- New 24-inch assumed to have an internal diameter of 23.6-inch, C-Factor of 130
- This analysis was focused on the flow capacity of a future 24-inch PMFL from the PCT to the Grand Junction WTP only, and did not consider the flow capacity of 20-inch steel pipe between the Juniata Reservoir and the PCT.
- PCT water surface elevation: 5,358 ft (middle of PCT head range, assumes flow into the PCT controlled by the Juniata Reservoir FCV is equal to the flow out of the PCT)
- Upper and Lower Roll Seal PSVs bypassed
- Grand Junction WTP Water Surface Elevation: 4,831 ft

4.3.1.3 Results

The hydraulic model was used to evaluate the flow capacity of a future 24-inch PMFL from the PCT to the Grand Junction WTP. With the Upper and Lower Roll Seal PSVs bypassed, the model predicted a maximum flow rate of approximately 14.8 mgd as shown in Figure 12.

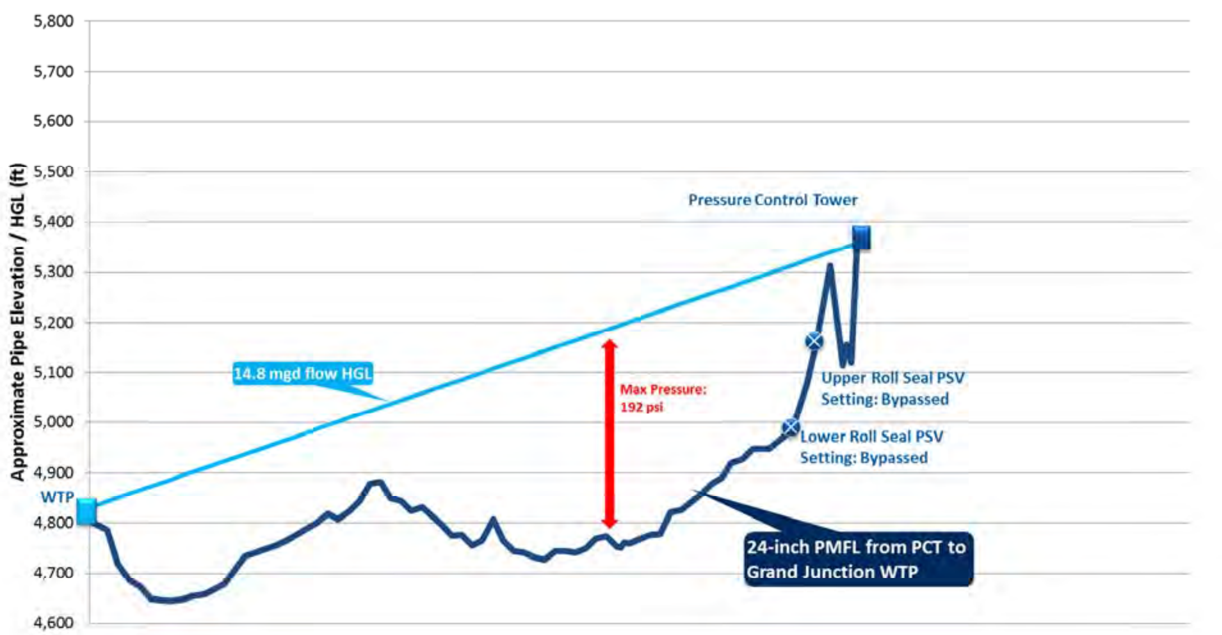

Figure 12 - Purdy Mesa Flow Line Upsized to 24-inch - Hydraulic Profile

The following is a description of the predicted PMFL hydraulics from the PCT to the Grand Junction WTP with the entire pipeline 24-inch and a flow rate of 14.8 mgd:

- It is noted that this analysis did not consider the capacity of the existing 20-inch steel pipe between the Juniata Reservoir and the PCT. While this existing 20-inch steel pipe could be sufficient to support a flow rate of 14.8 mgd depending on the prevailing C-Factor, it is likely undersized as the velocity under full pipe flow would exceed 10 ft/sec. If the City desires to upsize the PMFL to 24-inch (from the PCT to the Grand Junction WTP) in the future, the existing 20-inch between the Juniata Reservoir and the PCT should be evaluated and likely upsized in kind.

- The maximum flow rate of 14.8 mgd was determined using the hydraulic model such that the dynamic head loss in the 24-inch PMFL was equal to the static head difference between the PCT water surface elevation of 5,358 ft and the Grand Junction WTP water surface elevation of 4,831 ft. At this flow rate, a straight HGL line was established between the Grand Junction WTP and the PCT as shown in Figure 12.
- At a flow rate of 14.8 mgd, velocities of approximately 7.5 ft/sec were predicted in the future 24-inch PMFL.
- Based on the HGL line and the ground elevations of the 24-inch pipe, pressures of up to 192 psi were predicted in the vicinity of Whitewater Creek under a flow rate of 14.8 mgd.

With a future 24-inch PMFL from the PCT to the Grand Junction WTP, the maximum flow capacity was predicted to be approximately 14.8 mgd. It is noted that due to high dynamic head losses at the high flow rate, pressures along the PMFL at low points were predicted to be as high as 192 psi. Any new pipeline should be designed with a sufficient pressure class to sustain the highest predicted dynamic pressures.

5 Hydraulic Issues

Based on the hydraulic analyses conducted and described previously, four primary hydraulic issues were identified as likely causes for the air entrainment observed by the City at the Grand Junction WTP as well as the operational challenges with the PMFL. The following four hydraulic issues are described in this section:

- Roll Seal PSV Cavitation
- Pipeline Air Accumulation
- Pressure Control Tower Volume
- Flow Control Upstream and Downstream of the Pressure Control Tower

5.1 ROLL SEAL PSV CAVITATION

A Roll Seal PSV modulates to maintain an upstream pressure setting. Pressures on the downstream side are determined by system hydraulics independent of the PSV. In the case of the PMFL, the HGL downstream of the Lower Roll Seal PSV is determined by two factors: the water surface elevation at the Grand Junction WTP and the dynamic head loss (determined by pipe diameter, length, C-Factor and flow rate) between the Lower Roll Seal PSV and the Grand Junction WTP.

Cavitation can occur downstream of a Roll Seal PSV if the relationship between the inlet pressure and outlet pressure is within the Cavitation Zone shown in Figure 13 (from the Roll_Seal_Catalog.pdf). The City currently operates the Lower Roll Seal PSV at an upstream pressure setting (inlet pressure) of approximately 101 psi. As shown, this corresponds to a minimum downstream pressure (outlet pressure) of approximately 10 psi to avoid cavitation.

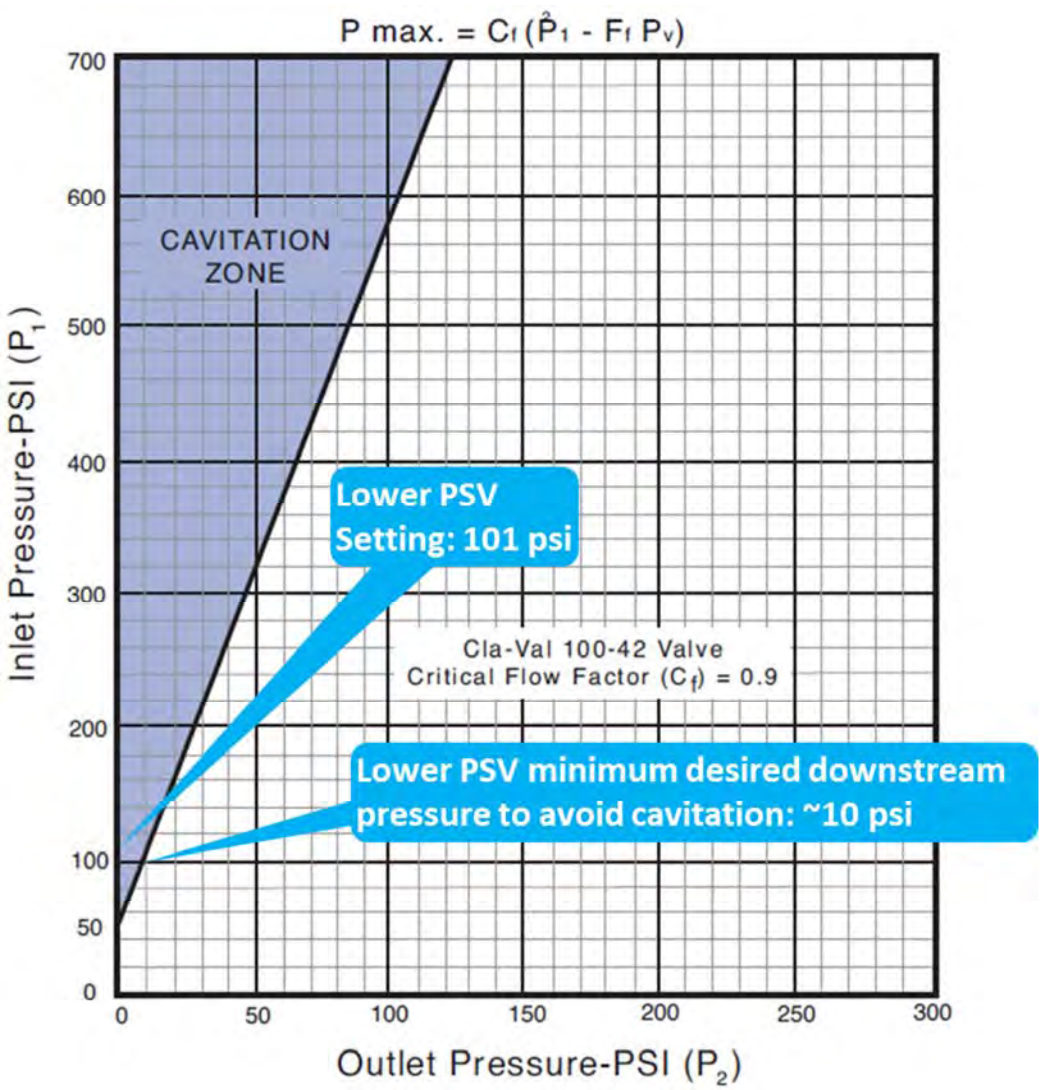

Figure 13 Cla-Val 100-42 Valve Cavitation Chart

Because the outlet pressure of Lower Roll Seal PSV is controlled by the water surface elevation at the Grand Junction WTP (which was assumed to be constant at approximately 4,831 ft) and the dynamic head loss in the PMFL (which varies based on flow rate), it was possible to calculate the minimum required PMFL rate to avoid cavitation of the Lower Roll Seal PSV. Figure 14 displays the relationship between flow rate in the PMFL and outlet pressure of the Lower Roll Seal PSV. As shown, at flow rates of approximately 6.1 mgd and below, the Lower Roll Seal PSV will be predicted to operate within the cavitation zone, which could lead to cavitation and subsequent air entrainment in the PMFL. At PMFL flow rates of greater than 6.1 mgd, the Lower Roll Seal PSV will not be predicted to cavitate.

Based on the analysis detailed above, to avoid cavitation the Lower Roll Seal PSV should be used under PMFL flow rates of approximately 6.1 mgd or greater. Under flow rates of less than 6.1 mgd, the Lower Roll Seal PSV should be bypassed to avoid cavitation. Additionally, the Upper Roll Seal PSV should also be bypassed any time that the Lower Roll Seal PSV is bypassed to avoid cavitation at the Upper Roll Seal PSV.

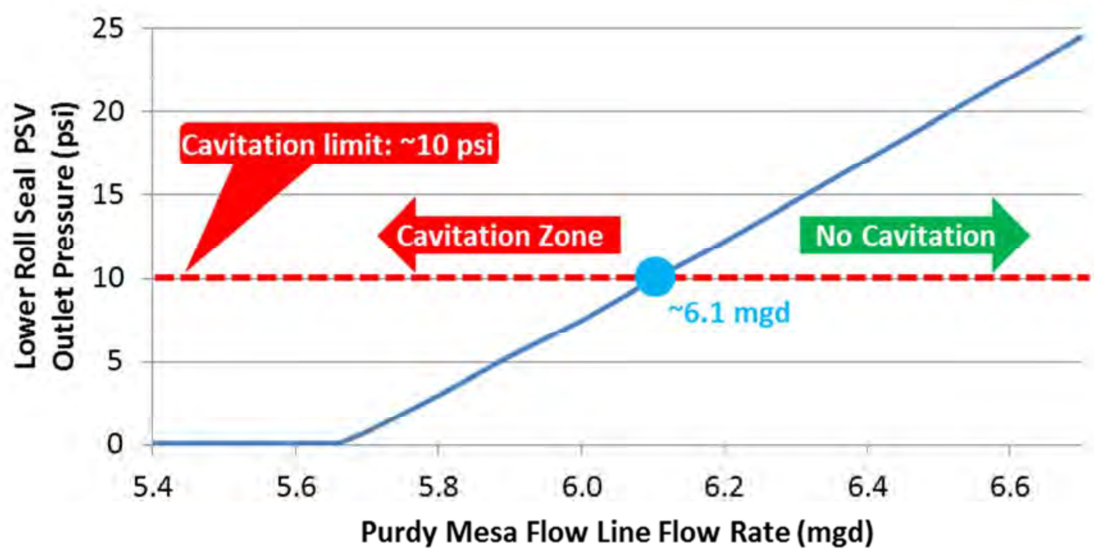

Figure 14 Lower Roll Seal PSV – Required Flow Rate to Avoid Cavitation

5.2 PIPELINE AIR ACCUMULATION

When pipelines flow under positive pressure, they flow full and minimize the accumulation of air within the pipeline. When the HGL of water within a pipeline drops below the elevation of the pipeline, partially full pipe flow can occur, which can lead to the accumulation of air. Accumulated air in the pipeline can lead to a variety of negative consequences including the unpredictable formation and movement of air pockets, temporary hydraulic restrictions due to air pockets (which effectively reduce the flowable cross-sectional area of a pipe until the air is expelled through an air valve), uncertain time durations to fully expel air from the pipeline as well as air entrainment and other flow anomalies.

Based on the hydraulic analyses described in the previous section, there is potential for air accumulation due to partially full pipe flow between the PCT and the Grand Junction WTP under the following flow conditions:

- PMFL flow rates of less than 6.1 mgd with the Upper and Lower Roll Seal PSVs bypassed
    - Significant potential for air accumulation between the PCT (which was predicted to operate fully drained with the outflow pipe flowing partially full) and the dynamic HGL determined by the flow rate (illustrated in Figure 9).
    - Additional potential for air accumulation on the downstream side of the Whitewater Hill high point. Utilizing the Roll Seal PSVs under PMFL flow rates of less than 6.1 mgd are not recommended due to the cavitation potential of the Lower Roll Seal PSV (as described in Section 5.1)
- PMFL flow rates between 6.1 mgd and 7.1 mgd with the Upper Roll Seal PSV upstream setting set to match the flow rate of the Juniata Reservoir PSV and the Lower Roll Seal PSV upstream setting of 101 psi

- Potential for air accumulation on the downstream side of the Whitewater Hill point, which was predicted to flow partially full at PMFL flow rates of less than approximately 7.1 mgd and flow full at PMFL flow rates in excess of approximately 7.1 mgd

5.3 PRESSURE CONTROL TOWER VOLUME

Under flow rates in excess of approximately 6.1 mgd, the City currently attempts to maintain the water surface elevation of the PCT by manually adjusting the Upper Roll Seal PSV such that the outflow of the PCT is equal to the inflow to the PCT from the Juniata Reservoir FCV. Based on discussions with the City, maintaining a consistent water surface elevation in the PCT is challenging, with the City generally observing either the overflowing of the PCT (inflow greater than outflow) or draining of the PCT (outflow greater than inflow) shortly after adjusting the water surface elevation by manually adjusting the upstream setting of the Upper Roll Seal PSV.

An overview of the PCT is shown in Figure 15. The cylindrical PCT is 12 ft in height (approximately 5,252 ft to 5,364 ft) with a diameter of 5 ft and a nominal total volume of approximately 235 ft^3 (1,760 gallons). Water flows into the PCT from the 20-inch steel pipe which conveys water from the Juniata Reservoir and flows out through the existing 18-inch steel Sullivan Draw pipe. As shown, the outflow pipe is located approximately 4 ft above the bottom of the PCT and the overflow pipe (which discharges water out of the PCT if inflow is greater than outflow) is located approximately 2 ft below the top. In practice, this leaves a 6 ft desired level range (between 5,256 ft and 5,362 ft) in the PCT. When operating the PCT within this desired level range, the outflow pipe flows full (no air accumulation) and the PCT does not overflow.

The volume corresponding to the desired PCT level range of 6 ft is approximately 118 ft^3 (881 gallons), which is a small volume relative to the normal flow rates of the PMLF. For example, under a flow rate of 6.7 mgd, a 1% discrepancy in flow in versus flow out of PCT would be predicted to result in the PCT either overflowing or draining within 10 to 15 minutes. Increasing the volume of the PCT would result in an increased ability to maintain the water surface elevation of the PCT without overflowing or draining.

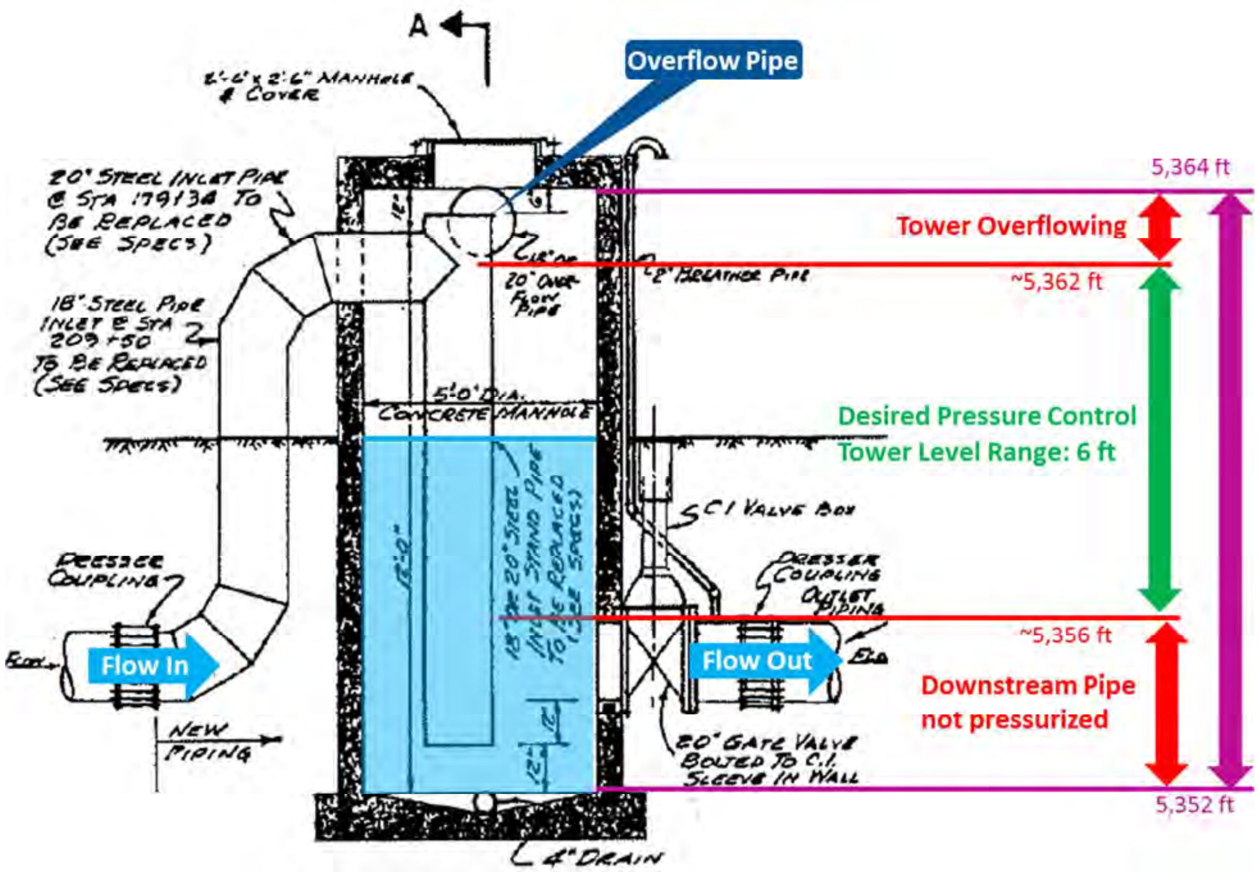

Figure 15 Pressure Control Tower Overview

5.4 FLOW CONTROL UPSTREAM AND DOWNSTREAM OF THE PRESSURE CONTROL TOWER

Based on conversations with the City, maintaining a consistent, stable water level in the PCT is a challenge. This challenge is primarily due to the small volume of the PCT as described in Section 5.3 as well as the difficulty of matching flow into the PCT with flow out of the PCV, which is necessary to maintain a stable water level. Existing flow control into and out of the PCT is described below:

- Flow into PCT
  - At all PMFL flow rates, flow into the PCT is controlled by the FCV at the Juniata Reservoir as shown in Figure 16
  - The flow rate delivered to the PMFL (and subsequently delivered to the PCT) is set by the City and the FCV automatically modulates to maintain the flow setpoint.
- Flow out of PCT
  - At PMFL flow rates of approximately 6.1 mgd or greater, flow out of the PCT is controlled by manually adjusting the upstream pressure setting of Upper Roll Seal PSV until the flow out of the PCT is equal to the flow into the PCT and City staff can visually confirm that the PCT water level has stabilized within its desired head range.

- At PMFL flow rates of less than 6.1 mgd, cavitation of the Lower Roll Seal PSV is likely (Section 5.1) and both the Upper and Roll Seal PSVs should be bypassed, leaving no ability to control flow out of the PCT. Without the Upper Roll Seal PSV controlling flow (and creating back pressure to full pipe flow through the Sullivan Draw), the PCT was predicted to drain completely (as shown in Figure 9).

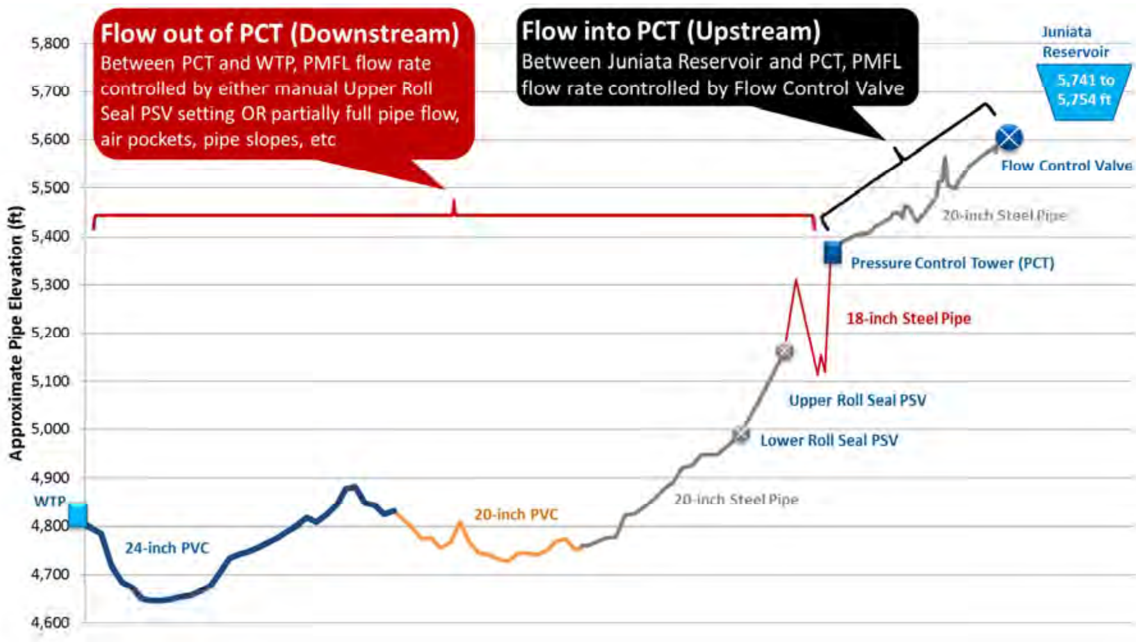

Figure 16 Flow Control Upstream and Downstream of the Pressure Control Tower

6 Potential Hydraulic Improvements

Based on the hydraulic analyses detailed in Section 4 and the hydraulic issues described in Section 5, potential hydraulic improvements were developed for the PMFL to accomplish two primary objectives:

1. Enable the PMFL to flow fully pressurized between the PCT and the Grand Junction WTP under all desired flow rates. This will significantly reduce the potential for air accumulation in the pipeline and cavitation of the Roll Seal PSVs, which are currently believed to be the primary causes of air entrainment seen by City staff at the Grand Junction WTP.

2. Simplify operation of the PMFL for the City by enabling automatic flow control on both the upstream and downstream side of the PCT.

The potential hydraulic improvement projects identified as part of this analysis are shown in Figure 17 and detailed in the following section.

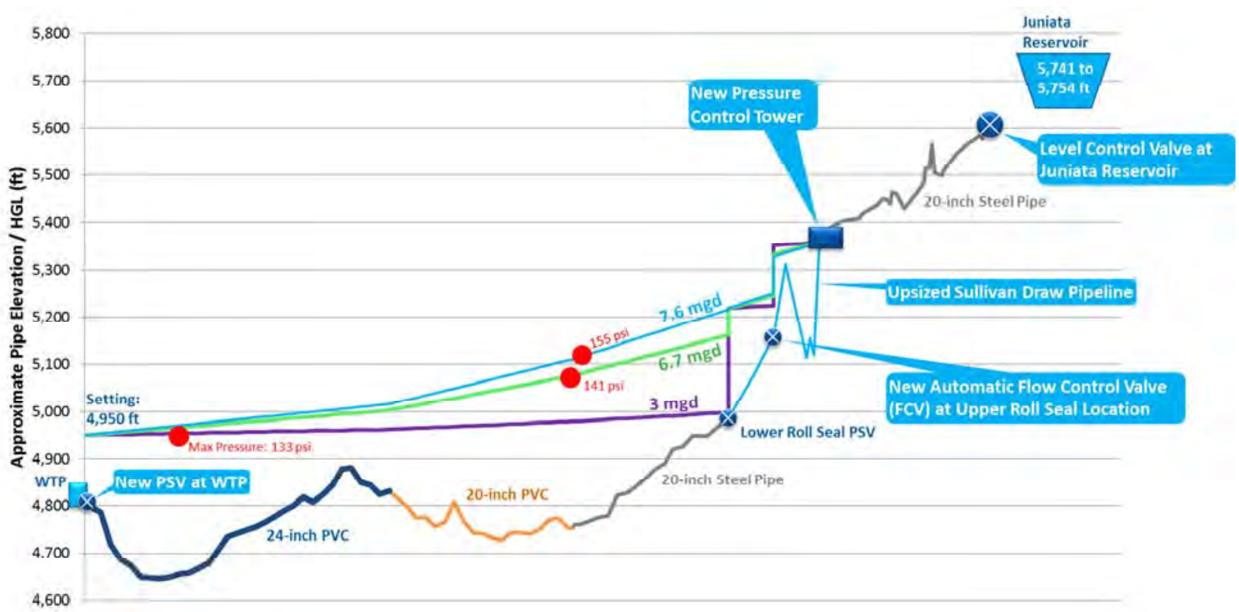

Figure 17 Purdy Mesa Flow Line - Potential Hydraulic Improvements

6.1 UPSIZED SULLIVAN DRAW PIPELINE

Upsizing of the Sullivan Drive pipeline from the PCT to the Lower Roll Seal PSV to 20-inch to facilitate future PMFL flow rates of up to 9.8 mgd as described in Section 4.1.1. If PMFL flow rates in excess of 9.8 mgd are desired in the future (which will requiring upsizing additional portions of the PMFL), the Sullivan Drive pipeline should be upsized to support that desired future flow rate. As described in Section 4.3, a 24-inch PMFL from the PCT to the Grand Junction WTP was predicted to be capable of delivering flows of up to 14.4 mgd.

6.2 NEW AUTOMATIC FLOW CONTROL VALVE AT UPPER ROLL SEAL LOCATION

Installation of a new automatic flow control valve at the current Upper Roll Seal PSV location would enable the City to send a desired PMFL flow setpoint to the new FCV, which would modulate to deliver that flow rate from the PCT to the Grand Junction WTP. The key benefit of locating the new FCV at this location is that this valve will naturally create back pressure while modulating to control flow. This back pressure will ensure that the PMFL is fully pressurized (full pipe flow) from the PCT to the new automatic FCV at the Upper Roll Seal PSV location under all potential PMFL flow rates.

The Upper Roll Seal PSV location is a desirable location for the new automatic flow control valve as it allows the City to maintain the Lower Roll Seal PSV at its current location while maintaining PMFL pressures of less than approximately 100 psi between the new automatic flow control valve and the Lower Roll Seal PSV. If the new automatic flow valve is desired to be installed at an alternate location (with easier access, better site conditions, available power), between the Sullivan Draw High point and the Lower Roll Seal PSV, the setting of the Lower Roll Seal PSV would need to be modified and the City could expect to see PMFL pressures as high as 150 psi, depending on the selected location of the new automatic flow control valve. If an alternate location is selected, the new Sullivan Draw pipeline should be designed with pressure class which exceeds the predicted pressures.

The automatic FCV will require reliable power to modulate continuously. Options for electrification of the Upper Roll Seal site location could include working with the Grand Valley Rural Power Authority, installation of a hydropower turbine, or a combination.

6.3 AUTOMATIC LEVEL CONTROL VALVE AT JUNIATA RESERVOIR

With the PMFL flow rate controlled by the new automatic FCV at the Upper Roll Seal location, the existing FCV at the Juniata Reservoir would be proposed to be modified to an automatic level control valve, which would modulate to maintain a desired water surface elevation in the PCT under all potential PMFL flow rates.

6.4 NEW PRESSURE CONTROL TOWER

As described in Section 5.3, the existing PCT volume is small, leading to significant operational challenges when attempting to maintain a consistent water level, which is required to achieve fully pressurized full pipe flow from the PCT to the Grand Junction WTP. With the proposed new automatic flow control valve at the Upper Roll Seal PSV location and the automatic level control valve at the Juniata Reservoir, a consistent water level in the PCT could theoretically be maintained under ideal hydraulic conditions. However, in reality, changes in flow rate (due to transient events, etc.) would be likely to cause rapid level change in the existing PCT due to its small volume, causing the level control valve at the Juniata Reservoir to constantly “hunt” for the correct level and leading to system instability.

Installation of a new, larger PCT at or near the existing PCT site would give the automatic level control valve at the Juniata time to modulate while maintaining the PCT within a desired head range and enable full automatic control of the PMFL from the Juniata Reservoir to the Grand Junction WTP.

The exact size of the larger PCT should be confirmed with detailed design, but is preliminarily anticipated to be approximately 430,000 gallons (maximum PMFL flow rate of 10.1 mgd) to 610,000 gallons (maximum PMFL flow rate of 14.8 mgd), depending on the desired maximum flow rate of the PMF, as detailed in the following section.

6.4.1 Preliminary New Pressure Control Tower Sizing Calculations

A preliminary PCT sizing tool was developed as shown in Figure 18. This tool is based on a given maximum PMFL (assumed to be 14.8 mgd in the example shown) as well as a cylindrical PCT geometry. If the City determines the maximum future flow rate of the PMFL to be less than 14.8 mgd, the new PCT volume could be reduced accordingly.

The new PCT was sized based on three primary components: Operating Range, Deadband and Freeboard:

6.4.1.1 Operating Range

The volume required for the operating range of the PCT was assumed to be 30 minutes at the maximum anticipated flow rate of the PMFL. At a maximum potential future flow rate of 14.8 mgd, this corresponds to a volume of 308,000 gallons as shown in Figure 18. An operating range of 8 ft (corresponding to 38,500 gal/ft) was selected to give the automatic level control valve at the Juniata Reservoir sufficient buffer time to modulate and maintain the level near the desired level setpoint, even if the PMFL flow rate is modified significantly at the new automatic flow control valve located at the Upper Roll Seal PSV.

6.4.1.2 Deadband

Deadband is the volume of water required below the operating range to ensure that vortexing does not occur. The deadband calculations are shown in Figure 18 and were predicted to require approximately 5.3 ft of height, corresponding to a volume of approximately 203,000 gallons.

6.4.1.3 Freeboard

Freeboard is the additional head in the tank above the operating range which is available to prevent overfilling/overflowing under certain conditions. For the PCT, this volume was assumed to be approximately 50% of the 20-inch steel pipe upstream of the PCT to the intermediate high point, which could potentially flow into the tank by gravity following the shutdown of flow through the PMFL at the new automatic flow control valve at the Upper Roll Seal location. The approximate required freeboard was calculated to be 2.5 ft of height, corresponding to a volume of 97,000 gallons.

6.4.1.4 Total Required PCT Volume and Dimensions

The total required volume of the PCT (assuming a maximum PMFL flow rate of 14.4 mgd) was calculated to be approximately 608,000 gallons as shown in Figure 18. With a cylindrical geometry, the required volume and total head range corresponds to approximate tank dimensions of 16 ft in height with a diameter 81 ft. If a cylindrical geometry does not fit the available site or right of way, the shape of the PCT could be modified while maintaining the same volume per ft of head range (gal/ft) and height. Potential alternate dimensions would be a square tank 16 ft in height with sides of 71 ft or a rectangular tank 16 ft in height with dimensions of 60 ft by 85 ft.

Operating Range Calcs	PMFL Max Flow Rate	14.8	mgd	*Entered Value*
	Desired Duration of Max Flow Rate	30	min	*Entered Value*
	Required Working Volume of PCT	**308,000**	**gal**	*Purdy Mesa Max Flow Rate * Duration*
	Desired Working Head Operating Range	8.0	ft	*Entered Value*
	Operating Range gal/ft	38,500	gal/ft	*Gallons per ft of Operating Range*
	Required Balance Tank Diameter	81	ft	
Deadband Calcs	Assumed Balance Tank Outlet Pipe Diameter	36	in	*Entered Value*
	Outlet Velocity at Purdy Mesa Max Flow Rate	3.2	ft/s	*Purdy Mesa Max Flow Rate / Outlet Pipe Area*
	Froude Number	0.33		*Fd = V / sqrt(g*D)*
	Required Deadband to Prevent Vortexing	5.3	ft	*S = Outlet Pipe Diameter * (1 + 2.3*Fd)*
	Required Deadband Volume	**203,000**	**gal**	*Assuming cylindrical tank*
Freeboard Calcs	Pipe Distance From High Point Upstream of PCT	11,943	ft	*Entered Value*
	Pipe Diameter Upstream of PCT	20	in	*Entered Value*
	Total Potential Volume in Pipeline Upstream of PCT to High Point	194,896	gal	*Pipe Area x Length*
	Assume % Pipe Volume Potential to Flow into PCT on Shutdown	50%		*Entered Value*
	Required Freeboard Volume	**97,000**	**gal**	
	Required Freeboard	2.5	ft	
	Total Required PCT Volume	**608,000**	**gal**	Working + Deadband + Freeboard Volume
	Tank Diameter	81	ft	
	Tank Height	16	ft	

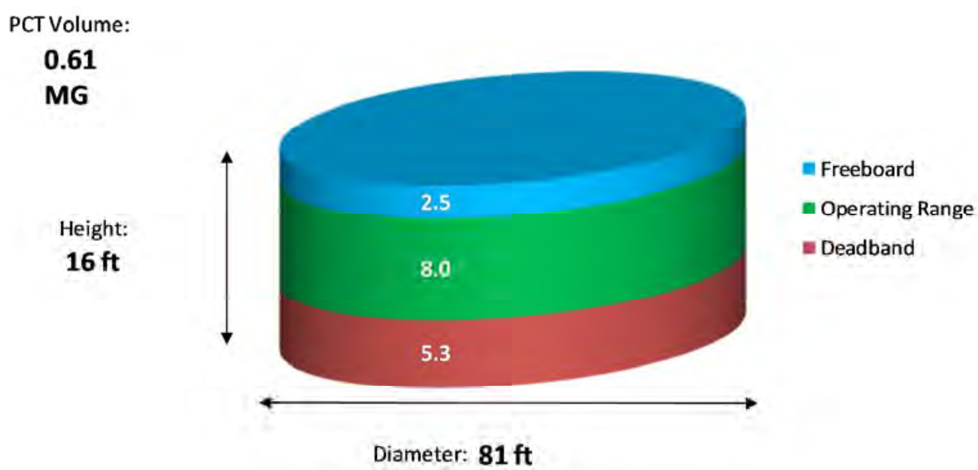

Figure 18 Preliminary Pressure Control Tower Sizing Tool – 14.8 mgd Maximum PMFL Flow Rate

6.5 NEW PRESSURE SUSTAINING VALVE AT GRAND JUNCTION WTP

As described in Section 5.1, the Lower Roll Seal PSV is predicted to cavitate due to low downstream pressures at PMFL flow rates of less than approximately 6.1 mgd. This is because the HGL on the downstream side of the Lower Roll Seal PSV is determined by the water surface elevation of the Grand Junction WTP and the dynamic head loss in the PMFL – and the dynamic losses are only sufficient to create sufficient downstream pressure at flow rates greater than 6.1 mgd. In order to prevent cavitation of the Lower Roll Seal PSV under all potential PMFL flow rates (including flow rates below 6.1 mgd), a new pressure sustaining valve is proposed to be installed at the Grand Junction WTP, which will enable the HGL to be raised to any desired level between the Grand Junction WTP and the Lower Roll Seal PSV.

Figure 17 displays an example hydraulic profile with all potential hydraulic improvements described above in place under PMFL flow rates of 3.0, 6.7 and 7.6 mgd. As shown in this example, the new PSV at the Grand Junction WTP was set to maintain an upstream setting of 4,950 ft, which enables the HGL at 3.0 mgd to exceed the elevation of the Lower Roll Seal PSV (creating positive downstream pressure and preventing cavitation). Without this PSV operational, the HGL line at 3.0 mgd would be predicted to be below the elevation of the Lower Roll Seal PSV as shown in Figure 9 in Section 4.2.1.

With the new PSV at the Grand Junction WTP, the upstream setting could be modified to enable pressurized (full pipe) flow from the PCT to the Grand Junction WTP under all potential desired PMFL flow rates. It is noted that at higher flow rates the City would be required to lower the upstream setting of the new PSV at the Grand Junction WTP to maintain maximum pressures along the PMFL to within the 160 psi pressure rating of the existing pipe.

7 Summary

A Bentley WaterGEMS hydraulic model was built and validated to facilitate analysis of the PMFL under a variety of conditions. A summary of the key findings and conclusions detailed in this technical memorandum is included below:

7.1 SULLIVAN DRAW PIPELINE

The existing 18-inch Sullivan Draw pipeline was predicted to be an existing hydraulic bottleneck, limiting the maximum flow rate of the PMFL to approximately 8.0 mgd. If the Sullivan Draw pipeline is upsized to 20-inch (as currently planned), the maximum flow rate of the PMFL was predicted to be increased to approximately 9.8 mgd.

7.2 EXISTING PURDY MESA FLOW LINE

Accumulation of air – which could lead to hydraulic issues, including air entrainment – was predicted to occur within the PMFL at all flow rates up to approximately 7.1 mgd, with more significant potential for air accumulation at lower flow rates.

7.3 FUTURE PURDY MESA FLOW LINE

If the PMFL from the PCT to the Grand Junction WTP (including the Sullivan Draw pipeline) was upsized to 24-inch in the future, the maximum flow capacity was predicted to be approximately 14.4 mgd. It was noted that if the PMFL downstream of the of the PCT were upsized to 24-inch, it is likely that the existing 20-inch steel pipe upstream of the PCT (from the Juniata Reservoir to the PCT) would also likely be required to be upsized in kind.

7.4 HYDRAULIC ISSUES

7.4.1 Roll Seal PSV Cavitation

To avoid cavitation (and potential air entrainment) of the Roll Seal PSVs, the PSVs should be bypassed if the PMFL flow rate is 6.1 mgd or lower. The PSVs should be utilized under all PMFL flow rates greater than 6.1 mgd. The Upper Roll Seal PSV should not be utilized if the Lower Roll Seal is bypassed.

7.4.2 Pipeline Air Accumulation

Potential for pipeline air accumulation – which can lead to a variety of negative consequences including the unpredictable formation and movement of air pockets, temporary hydraulic restrictions due to air pockets uncertain time durations to fully expel air from the pipeline as well as air entrainment and other flow anomalies – was predicted under all PMFL flow rates of less than 7.1 mgd.

7.4.3 Pressure Control Tower Volume

In order for the level in the PCT to remain constant, flow into the PCT must equal flow out of the PCT. Due to the small volume of the existing PCT, small discrepancies in flow in versus flow out lead to rapid changes in the water level in the PCT, leading to the tank either overflowing or draining.

7.4.4 Flow Control Upstream and Downstream of the Pressure Control Tower

Flow into the PCT is controlled by the Juniata Reservoir FCV at all flow rates, which is modulated to maintain the given flow setpoint. Flow out of the PCT is controlled by manual adjustment of the upstream setting of the Upper Roll Seal PSV (at flow rates greater than 6.1 mgd) or uncontrolled (dictated solely by open channel pipe hydraulics) when the PSVs are bypassed at flow rates of less than 6.1 mgd. The lack of precise control of flow going both into and out of the PCT at all flow rates leads to operational challenges for the City.

7.5 POTENTIAL HYDRAULIC IMPROVEMENTS

Hydraulic improvements were identified which were predicted to enable the PMFL to be operated automatically (no manual adjustments required) while flowing fully pressurized (no air accumulation, no Roll Seal cavitation) from the PCT to Grand Junction WTP. The potential improvements are listed below and detailed in Section 6.

- Upsize Sullivan Draw pipeline to 20-inch
- New automatic flow control valve at the Upper Roll Seal PSV location which modulates to maintain a PMFL flow setpoint given by the City
- Automatic level control valve at the Juniata Reservoir which modulates to maintain a water level within a desired range at the PCT
- A new PCT with a volume of approximately 430,000 to 610,000 gals (depending on maximum future PMFL flow rate) to enable stable automatic level control
- A new pressure sustaining valve at the Grand Junction WTP to prevent partially full pipe flow and/or cavitation of the Lower Roll Seal PSV under all PMFL flow rates

7.6 OPINION OF PROBABLE CONSTRUCTION COSTS FOR POTENTIAL HYDRAULIC IMPROVEMENTS

Estimated construction costs were developed for the improvements identified as well as two other segments of the pipeline: Reservoir to the PCT and from the Lower Roll Seal to the Whitewater Creek. The cost estimates included in this TM are considered to be Class 5, as outlined by the Association for the Advancement of Cost Engineering (AACE) Cost Estimate Classification System. Costs are based on the current design information from April 2018 with a scope development at approximately a 10% stage of design. The opinion of construction costs includes factors for construction general conditions, contingencies, engineering, and construction management. No allowance was made for irregular construction or environmental difficulties.

The estimate was based on PVC pipe, a prestressed concrete balance tank, and 1.5 miles of electrical power distribution lines. Table 3 summarizes the construction costs for the various segments.

Table 3 Opinion of Probable Construction Costs

DESCRIPTION	LENGTH/ VOLUME	CONSTRUCTION COST
Sullivan Draw		
Pipeline	1.25 miles	2,247,000
Electrical Power to Site	1.5 miles	892,000
Valve Vaults	2	234,000
Balance Tank	0.5 MG	1,208,000
Existing Flow Control Vault SCADA Upgrades	N/A	97,000
SubTotal		4,678,000
Pipeline – Reservoir to PCT	3.4 miles	5,251,000
Pipeline – Lower Roll Seal to Whitewater Creek	3.1 miles	4,644,000
Total		**14,574,000**