Appendix H – ID1-ID2 Booster Station Impact Analysis TM

WATER SYSTEMS CONSULTING, INC.

Technical Memorandum

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SUBJECT: ID1-ID2 BOOSTER STATION IMPACT ANALYSIS

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1 BACKGROUND AND PURPOSE

On behalf of the Victorville Water District (District), the City of Victorville (City) has requested that WSC perform a hydraulic analysis to evaluate the impacts of a proposed new booster station, assess the capacity of the existing pipelines that the booster station will discharge into, and determine whether pipeline upgrades are required. Additionally, the City would like to confirm the required size of proposed new Turnout #5 (TO5) transmission main from the Mojave Water Agency (MWA) R-Cubed System.

The proposed booster station will have the ability to pump from the District's Improvement District 1 (ID1) to Improvement District 2 (ID2) and will provide the District with additional supply capacity in ID2. It will also improve operational flexibility to meet water quality blending targets. The proposed ID1/ID2 Booster Station will be located near the intersection of Sycamore Street and Amethyst Road on the Zone 3290 tank site, and will consist of two 2,000 gpm pumps which will pump water from the Zone 3290 tanks (which can also be filled by the TO5 connection); these are referred to as the "high head" pumps. The station will also include a third "low head" 2,000 gpm pump designed to pump directly from TO5. The ID1/ID2 Booster Station will be able to discharge into a Raw Water Blending Line or directly to the Zone 3485 distribution system. Well 129 is also located on the same site and will be modified to discharge into the same pipeline as the booster station (the Booster Discharge Line).

The Raw Water Blending Line is a manifold pipeline that conveys groundwater from several of the District's wells to the Avenal Blending Station. Blending of the various well sources occurs in the pipeline prior to reaching the Avenal Blending Station, which is the compliance point for water quality before entering the District's Zone 3485 distribution system. At the Avenal Blending Station, the water is discharged into a 20" Potable Water Main which connects to the Zone 3485 distribution system. For the purposes of this analysis, the Raw Water Blending Line was broken into three segments: Amethyst/Sierra Blending Line (ASBL) Parts 1 and 2, and the Avenal Blending Line. The location of the project area, ID1/ID2 Booster Station, wells and mains are shown in Figure 1. The key objectives for this hydraulic analysis are to:

- Determine the required diameter of the R-Cubed TO5 transmission main;
- Determine if existing transmission mains (the Booster Discharge Main, Raw Water Blending Line, and 20" Potable Water Main) will need to be upsized in order to accommodate additional flows from the booster station;
- Determine the total capacity of the existing 24" Avenal Blending Line;
- Determine the capacity of the existing 20" Potable Water Main;
- Evaluate whether the existing Zone 3485 distribution system near the ID1/ID2 Booster Station can receive the proposed flow from the ID1/ID2 booster station;
- Prioritize system improvement projects based on this analysis.

This study incorporates data from the District's 2010 Water Master Plan (WMP), facility inventory data as of October 2014 and water production data for the 2013 calendar year. WSC used the District's existing hydraulic model to determine the flow availability, pipeline velocities and pipeline pressures in the project area.

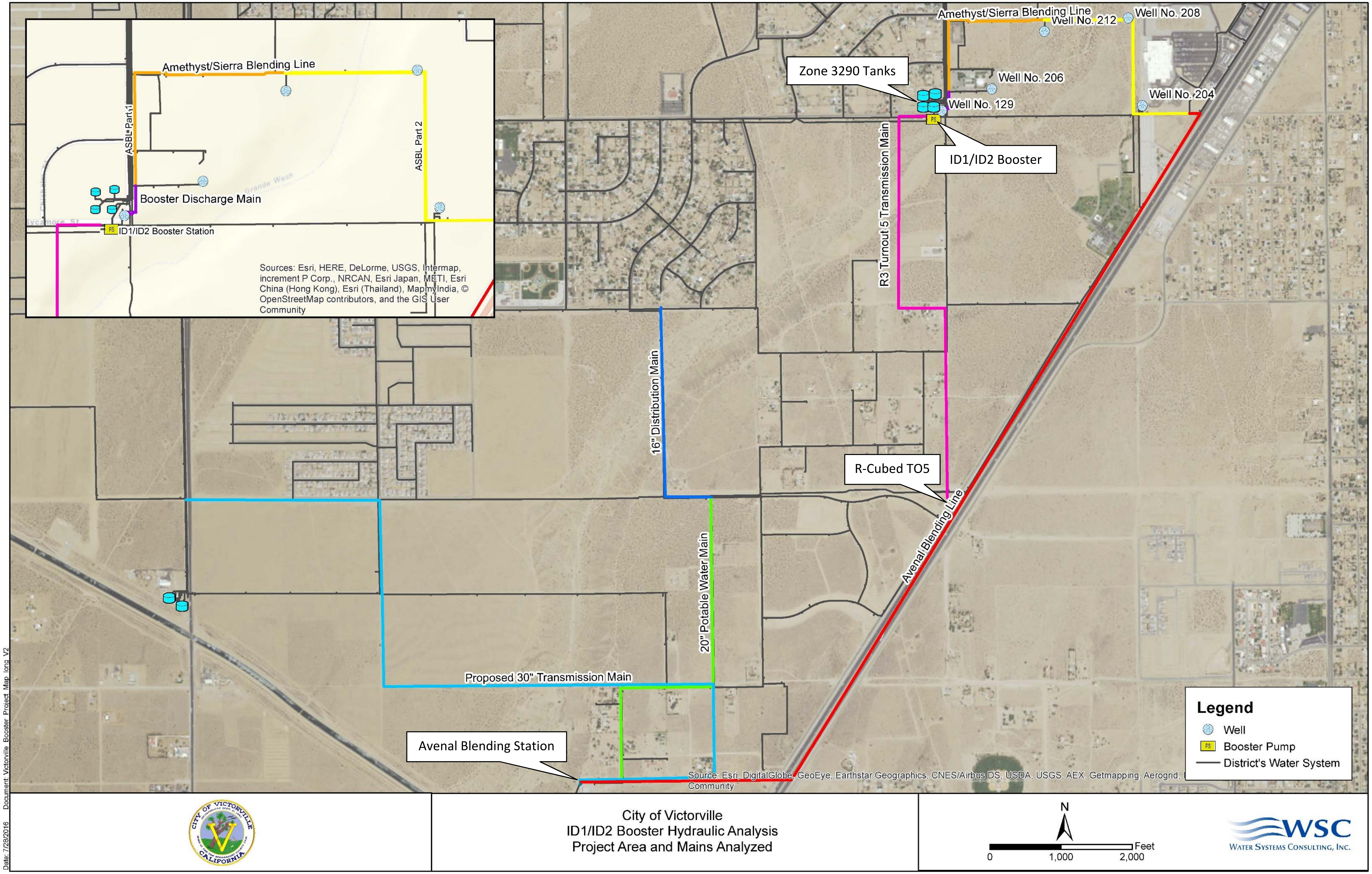


Figure 1. Project Area and Mains Analyzed

2 EVALUATION CRITERIA

Evaluation criteria presented in the WMP were used for this hydraulic analysis and are summarized in Table 1.

Table 1. Main Velocity Criteria

Main Diameter, in	Evaluation Condition	Velocity, ft/s	Headloss ft/1,000 ft
Existing Mains	MDD	7	10
New Mains (Less than 12")	MDD	5	5
New Mains (Equal to or greater than 12")	MDD	4	

3 ID 2 WATER DEMANDS AND FACILITIES

The current water demands loaded in the model and projected water demands for ID 2 (Zone 3485, 3675 and 3820) are presented in Table 2.

Table 2. ID 1 Current and Project Water Demands

	Demands (gpm)		
	Loaded in Model	MDD 2020[1]	MDD 2030[1]
Zone 3485	3474	4861	6458
Zone 3675	933	1111	1736
Zone 3820	232	278	278
ID 2 Total	**4640**	**6250**	**8472**

Notes:
1. Projected demands are from the 2010 VWD WMP Table 3.17

This hydraulic analysis focused on the wells, located on the east side of Zone 3485, which discharge to the Raw Water Blending Line. Capacity information for the wells that were included in the project area is summarized in Table 3.

Wells 203, 205, and 207 are also located in Zone 3485 and are treated at the La Mesa Arsenic Treatment Plant (ATP) and have a combined capacity of approximately 1,750 gpm. These wells are not commonly used to supply ID2 due to the increased cost of treatment.

ID2 can also receive water from R-Cubed Turnout 6 (TO6), which is located on Mesa View Drive and discharges into Zone 3485. Due to hydraulic constraints (primarily tank levels) in the operation of the R-cubed and District water systems, the typical flow the District is able to receive through TO6 is approximately 2,400 gpm.

Table 3. Supply for ID 2

Facility	Capacity (gpm)
Well 201	919
Well 204	979
Well 206	785
Well 208	837
Well 209	690
Well 212	1,374
Well 129	1,000
Total Well Flow to Raw Water Blending Line	6,584
Well 203	724
Well 205	883
Well 207	145
Total Well Flow to La Mesa ATP	1,752
Total Well Flow into ID 2[1]	
R-Cubed Turnout 6 Capacity	2,400
Total Flow into ID 2 with R-Cubed TO6	10,736
Proposed ID1/ID2 Booster Station Flow[2]	4,000
Proposed Total Flow from all Sources into ID2	14,736
Maximum Flow from Wells and Booster to Raw Water Blending Line	10,584
Firm Capacity for ID2[3]	10,336

Notes:
1. All wells in ID2 pump into the Raw Water Blending Line or the La Mesa ATP.
2. The maximum capacity of the booster station is 4,000 gpm with 2 pumps running. The source of water can be either R-Cubed from TO5 or groundwater from Zone 3290. The average flow available from TO5 is 3,400 gpm based on a design capacity of 5,500 acre-feet per year (AFY)
3. The Firm Capacity for ID2 is defined as the Proposed Total Flow for All Sources, less R-Cubed (which is not a guaranteed supply) and the largest pump in the system, which is one of the 2,000 gpm booster pumps.

4 ID 1 – ID 2 BOOSTER HYDRAULIC ANALYSIS

This section presents the results of the hydraulic analysis. The runs were preformed using the Existing System MDD scenario within the model.

4.1 R-CUBED TURNOUT 5 TRANSMISSION MAIN

WSC evaluated the sizing of the transmission main from R-Cubed TO5 to the ID1/ID2 Booster Station. MWA stated that the planned capacity of TO5 is 5,500 AFY, which equates to an average flow of 3,411 gpm. The maximum design velocity in the turnout itself is 10 ft/sec and the maximum design velocity in the MWA transmission main ins 7 ft/sec. WSC evaluated the pipeline size for flows of 3,411 gpm, as well as 4,000 gpm, which is the maximum capacity of the ID1/ID2 Booster Station. The results are presented in Table 4.

Table 4. R^3 Turnout 5 Transmission Main Sizing

Flow, gpm	Dia, in	HL/1000 ft	Velocity, ft/s
3,411	16”	6.06	5.44
	18”	3.41	4.3
	20”	2.04	3.48
	24”	0.84	2.42
4,000	18”	4.58	5.04
	20”	2.74	4.08
	24”	1.13	2.84

To meet the evaluation criteria in Table 1, a 20-inch transmission main is required to convey a flow of 3,411 gpm to the proposed booster station. At 4,000 gpm, a 20-inch line exceeds the velocity criteria, but only by only a small margin. To provide flexibility to potentially convey flows above 4,000 gpm in the future, the District prefers a 24-inch main for the TO5 Transmission Main.

4.2 BOOSTER DISCHARGE LINE AND AMETHYST/SIERRA BLENDING LINE

The maximum flow into the Booster Discharge Line is 5,000 gpm, including Well 129, which is located on the same site. Well 206 discharges into the beginning of the Amethyst/Sierra Blending Line, bringing the total maximum flow in the ASBL Part 1 to 5,785 gpm. ASBL Part 2 also includes Wells 201, 212, 208, 204, and 209. With all wells on, approximately 6,575 gpm could be pumped to the Avenal Blending Line. The addition of the booster station will add up 4,000 gpm to the total maximum flow in the 24” Avenal Blending Line.

The existing 8-inch and 12-inch lines in Amethyst and Sierra do not have adequate capacity to accommodate the proposed booster station flow; therefore, new lines will need to be constructed. To provide the District with the most flexibility to manage water sources in ID2, the Booster Discharge Main and the Amethyst/Sierra Blending Line were sized to convey the maximum flow that could be conveyed through these lines. For the new pipes, WSC evaluated both replacement of the existing mains and the addition of new parallel mains.

4.2.1 Option 1 – Replacing Existing Mains

WSC evaluated the Booster Discharge Main and the Amethyst/Sierra Blending Line to determine if the existing mains would be able to meet the evaluation criteria while conveying the maximum amount of flow from the ID1/ID2 Booster Station. Run 1 used the existing distribution mains to convey the flow to the Avenal Blending Line. This run determined that the existing mains would not be able to meet the evaluation criteria. Therefore, additional Runs 2 through 4 were completed using larger diameter mains. The hydraulic analysis showed that the existing Booster Discharge Main and the Amethyst/Sierra Blending Line would need to be upsized to 24-inch mains. The results from these runs are presented in Appendix A.

4.2.2 Option 2 – Parallel Mains

WSC also evaluated the option of installing parallel lines and keeping the existing 8-inch and 12—inch lines in service to provide additional capacity. Through several model runs, it was determined that 24-inch parallel mains would need to be installed alongside that existing mains in order to meet the evaluation criteria. Appendix A presents the results for this option.

For both options, 24-inch mains will need to be installed. The parallel option results in a lower velocity and headloss in the new 24-inch main, but both options meet the evaluation criteria. Depending on available right-of-way for the new 24-inch main, the District can decide whether or not to abandon or parallel the existing lines.

4.3 24-INCH AVENAL BLENDING LINE

Since additional flow is proposed to go through the 24” Avenal Blending Line, WSC evaluated the headloss and velocity for a total flow of 8,475 gpm, which corresponds to the ID2 MDD in 2030. WSC also evaluated the maximum capacity of the existing 24-inch Avenal Blending Line. The results are presented in 5.

Table 5. Avenal Blending Line Capacity

Condition	Flow, gpm	HL/1000 ft	Velocity, ft/s
2030 MDD for ID2	8,475	4.52	6.00
Maximum capacity of existing 24-inch line	10,000	6.15	7.08

Based on this evaluation, it was determined that the existing 24” Avenal Blending Line has adequate capacity to convey up to approximately 10,000 gpm without exceeding the velocity criteria of 7 ft/sec. This is sufficient to convey the maximum flow from the booster station plus all but one of the wells that pump into this line.

4.4 20” POTABLE WATER TRANSMISSION MAIN

The 20” Potable Water Main conveys flow from the Avenal Blending Line to two 16” mains that distribute flow to the rest of Zone 3485. Similar to the Avenal Blending Line, the capacity of the main was evaluated to determine the amount of additional flow that could be conveyed. Table 6 presents the hydraulic analysis results for the 20” Potable Water Main along with the two 16” mains.

Table 6. 20" Potable Water Main Capacity

Flow, gpm	Condition	20" Potable Water Main		Pipe 25949 (16")	
		HL/1000 ft	Velocity, ft/s	HL/1000 ft	Velocity, ft/s
6,250	Maximum capacity of existing 16" distribution main	7.23	6.36	10.07	6.61
7,250	Maximum capacity of existing 20-inch Potable Water Main	9.52	7.38	13.26	7.67

The maximum capacity of the 20" Potable Water Main is approximately 7,250 gpm without exceeding the velocity criteria of 7 ft/sec; however, this causes Pipe 25949 to exceed the headloss and velocity criteria. The maximum capacity of the existing 16-inch mains is approximately 6,250 gpm without exceeding the headloss criteria of 10 ft per 1,000 ft. Because the existing 16-inch main is a bottleneck in the system, additional improvements were considered to convey more flow into this part of Zone 3485.

Additional model runs were completed with the Proposed 30" Balancing Main that is proposed to run from the Avenal Blending Station to a transmission main located in Highway 395. As presented in Table 7, the Proposed 30" Balancing Main will alleviate the headloss and velocity constraints in the existing 16-inch and 20-inch lines. With the Proposed 30" Balancing Main active, these mains together will be able to convey flow in excess of the 2030 ID 2 demands and the maximum of 10,000 gpm that the Avenal Blending Line is able to convey. Therefore, the limiting factor in the capacity of the eastern part of Zone 3485 is the capacity of the Avenal Blending Line, which is approximately 10,000 gpm.

Note that the 30" Balancing Main was used in this analysis because it was proposed in the 2010 WMP for another purpose (to restore Reservoir 201 to service) and also alleviates the bottleneck identified in this analysis. However, alternative improvements could be considered to alleviate this bottleneck if the District does not intend to install the 30" Balancing Main to restore Reservoir 201 to service.

Table 7. 20" Potable Water Main Capacity with Proposed 30" Transmission Main Active

Condition	Flow, gpm	20" Potable Water Main		Proposed 30" Main		Pipe 25949	
		HL/1000 ft	Velocity, ft/s	HL/1000 ft	Velocity, ft/s	HL/1000 ft	Velocity, ft/s
2030 MDD for ID2	8,475	0.55	1.58	1.05	3.14	0.76	1.64
At maximum capacity of Avenal Blending Line	10,000	0.78	1.91	1.41	3.68	1.09	1.99
Maximum capacity of 30-inch Balancing Main*	10,700	0.91	2.07	1.59	3.93	1.27	2.16

*The 30" Balancing Main provides this capacity in addition to the 20" Potable Water Main. However, the Avenal Blending Line has a lower capacity and is therefore the limiting factor.

4.5 BOOSTER STATION DISCHARGE DIRECTLY TO ZONE 3485 DISTRIBUTION SYSTEM

The ID1/ID2 Booster Station is planned to have the option to discharge to the Zone 3485 distribution system through an existing main on-site. Under existing conditions, an increase of 4,000 gpm at the ID1/ID2 Booster Station would increase the headloss up to 20 ft/1000 ft along Sycamore Street west of Amethyst Road, up to 14 ft/1000 ft along Sycamore Street east of Amethyst Road and up to 15 ft/1000 ft along Amethyst Road north of Sycamore to Bear Valley Road, as shown in Figure 2.

The maximum flow that could be pumped into Zone 3485 at this location without exceeding headloss and velocity criteria in the existing system is approximately 2,700 gpm. If the District plans to pump 4,000 gpm from the booster station into the Zone 3485 system at this location, additional system improvements would be needed. A 12-inch parallel main would be required along Sycamore Street from Amethyst Road to Cobalt Road, with a connection to the existing mains at Birdwood Avenue. With the installation of this main, the headloss would drop to 6 ft/1000 ft along Sycamore Street and Amethyst Road, as presented in Figure 3. The results for this analysis are presented in Appendix A.

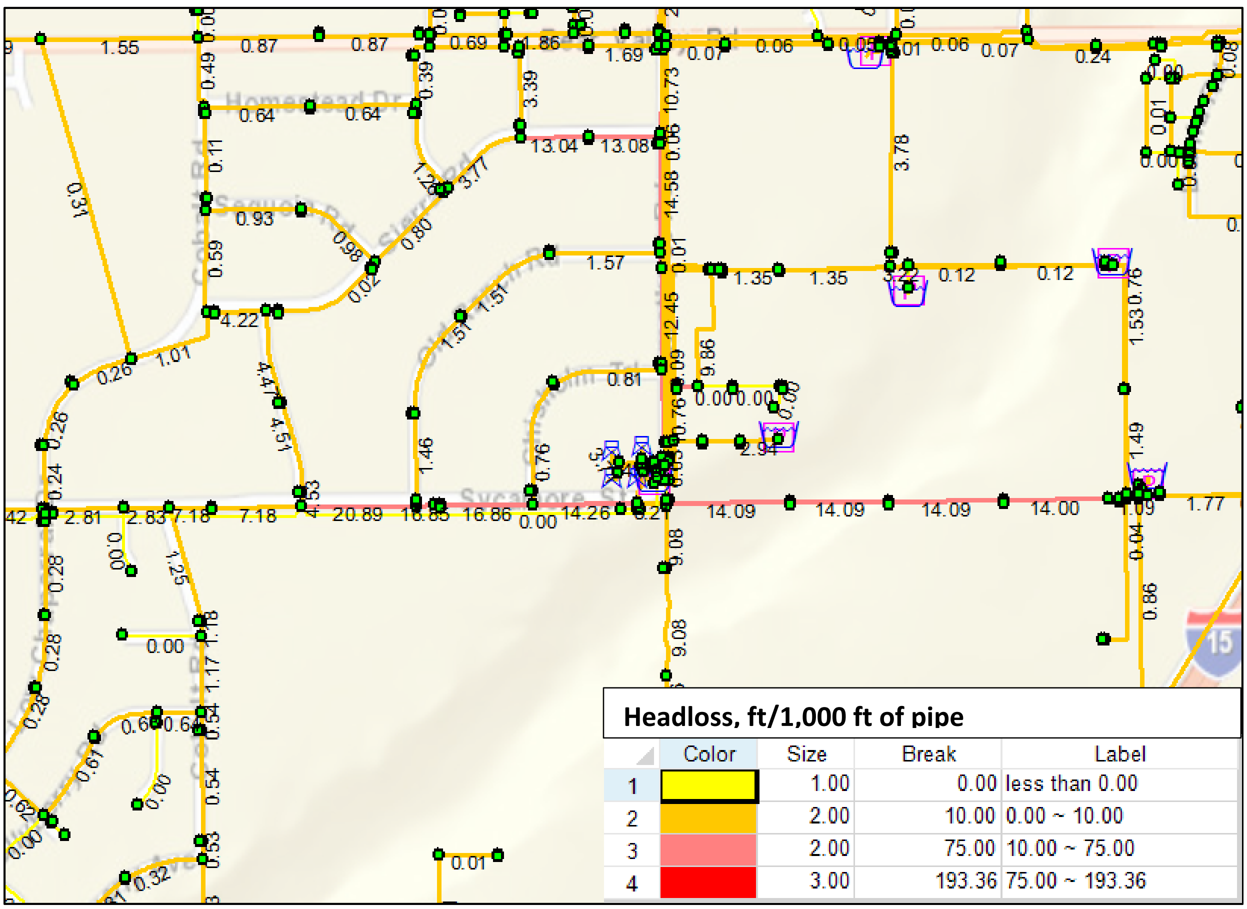


Figure 2. Existing Water System with 4,000 gpm from ID1/ID2 Booster Station

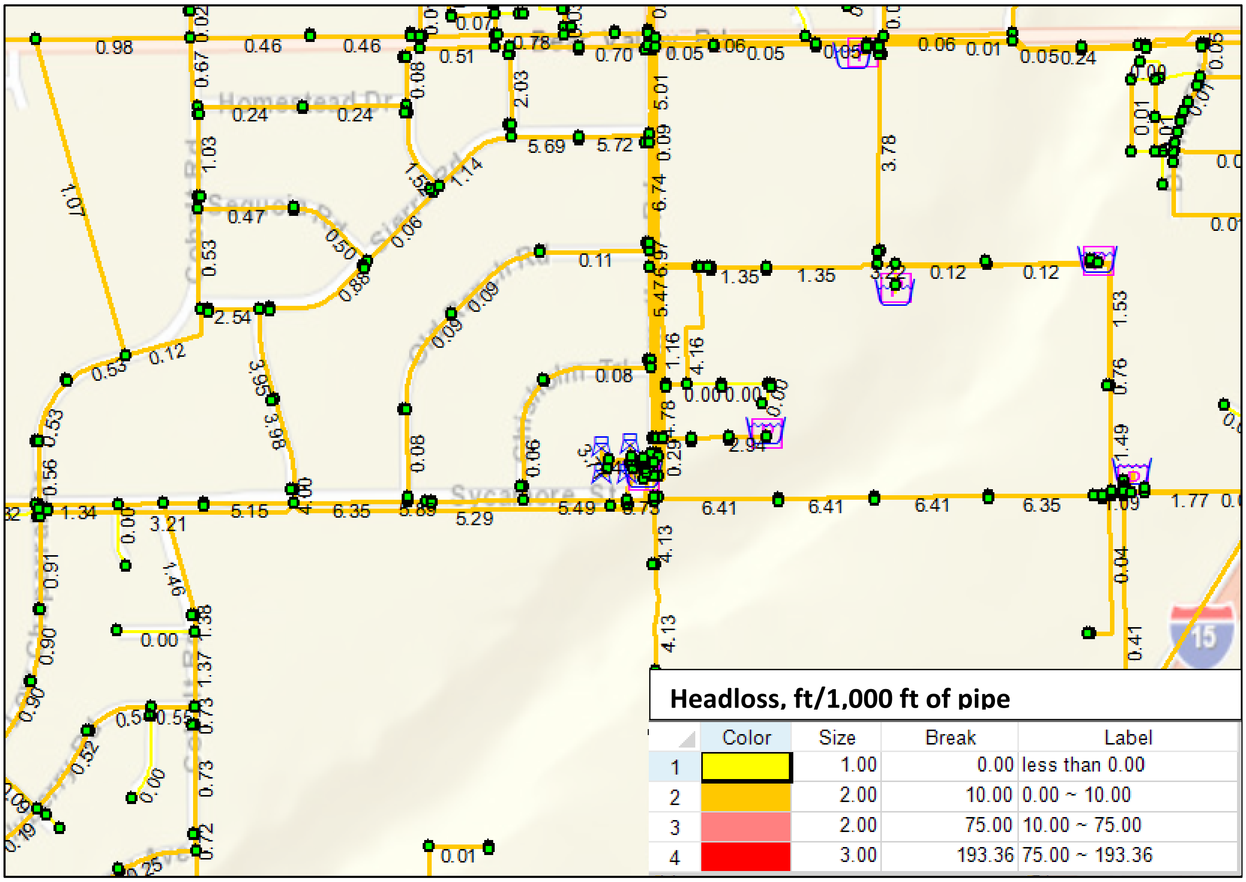


Figure 3. System with Improvements and 4,000 gpm from ID1/ID2 Booster Station

5 CONCLUSIONS AND RECOMMENDATIONS

This hydraulic analysis concludes the following:

- The R-Cubed Turnout 5 Transmission Main should be a 24-inch main in order to convey up to 4,000 gpm from TO 5 to the Zone 3290 tank site without exceeding the City's velocity standard of 4 feet per second and provide additional capacity for potential future flows;
- Approximately 2,700 ft of 24-inch main should be installed for the Booster Discharge Line and a portion of the Amethyst/Sierra Blending Line. The District has the flexibility to abandon or parallel the existing 8-inch and 12-inch mains;
- The Avenal Blending Line has a maximum capacity of approximately 10,000 gpm without exceeding the velocity criteria of 7 ft/sec;
- The bottleneck in the Zone 3485 system is a 16-inch distribution main which limits the capacity into the east side of the zone to 6,250 gpm without exceeding the headloss critiera of 10 ft per 1,000 ft of pipe;
- The proposed 30" Balancing Main will alleviate this bottleneck and increase the capacity of the east side to more than 10,000 gpm. That would result in the Avenal Blending Line being the controlling factor with a capacity of approximately 10,000 gpm. Other improvements could be evaluated to alleviate this bottleneck if the District does not plant to construct the 30-inch Balancing Main.
- The existing system near the booster station can accept a maximum of 2,700 gpm from the booster station before pipeline improvements are needed;
- Approximately 3,600 ft of 12" main is required to discharge the full 4,000 gpm directly into the distribution system;

The recommended system improvements are presented in Table 8, along with the conceptual cost, and implementation triggers. These improvements are depicted in Figure 4.

Based on the recommended pipeline improvements and the range of potential operating conditions that are anticipated for the low head and high head booster pumps at the ID1/ID2 Booster Station, WSC prepared a set of system head curves for each pump. In each set, one curve is identified as the most common operating condition and should be used as the design curve for the purposes of pump selection. The remaining curves reflect potential operating conditions that the District may need and the selected pumps should be evaluated to determine their performance capabilities under these less common operating conditions. The goal is to find a pump that will operate efficiently at the design point but also be capable of operating on each of the remaining curves within the recommended operating range for the pump, likely at reduced speeds and flows. The system head curves and supporting information for each is included in Appendix B. The excel file containing the raw data for these curves was transmitted to the City via email.

Table 8. Recommended System Improvements

Pipe ID	Pipe Description	Length, ft	Diameter, in	Conceptual Capital Cost[1,2]	Implementation Timeline
P1	R-Cubed TO5 Transmission Main[3]	6,700	24	$ 2,517,000	Near term to provide additional supply and flexibility to Zone 3485
P2a	Booster Discharge Main	375	24	$ 104,000	Prior to startup of the ID1/ID2 Booster Station
P2b	Amethyst/Sierra Blending Line - Part 1 Upgrade	2,400	24	$ 654,000	Prior to startup of the ID1/ID2 Booster Station
P3	30" Balancing Main	13,200	30	$ 5,775,000	Once flow needs in the east part of Zone 3485 exceed 6,250 gpm, the maximum capacity of the existing distribution system; or Once Reservoir 201 needs to be returned to service
P4	Booster Discharge Main to 3485 System Main	3,500	12	$ 551,000	If more than 2,700 gpm is desired to be pumped directly to the Zone 3485 distribution system

Notes:

1. Conceptual Capital Cost was calculated using the unit cost presented in the WMP Table 9.2. Unit costs ($/ft of pipe) were converted to 2016 dollars using the Los Angeles Area ENR ratio of (July 2016/October 2009) = (11155/9761). Where applicable, the jack and bore unit cost was used for pipes that cross the wash.
2. Per the WMP methodology, 20% of the construction cost was added for contingency and 20% of construction cost and contingency was added for implementation costs. Implementation costs include engineering, administration, legal and construction management.
3. Cost for pipeline only, does not include turnout facilities.

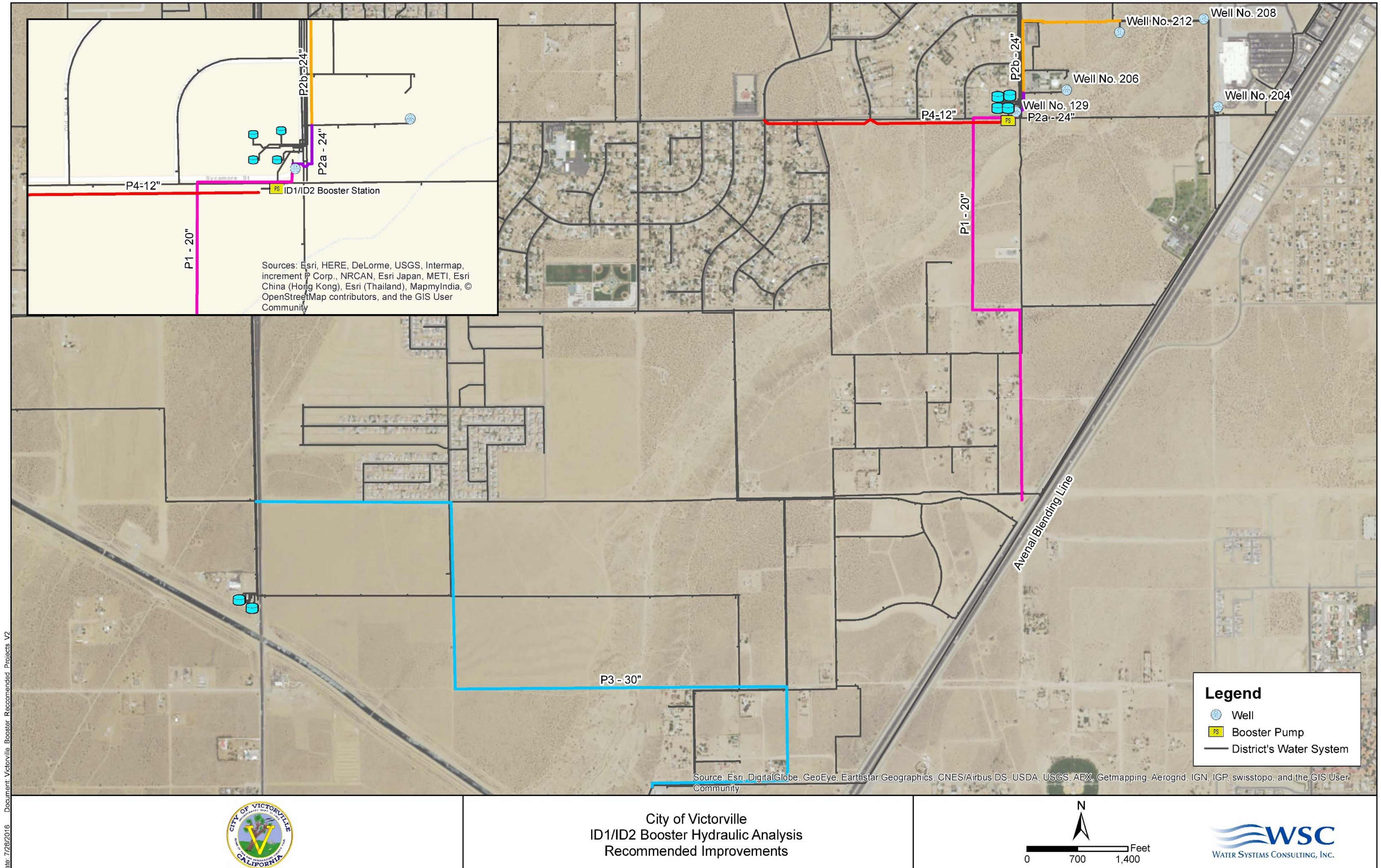


Figure 4. Recommended Projects

APPENDIX A. MODEL RUN RESULTS

Table A-1. Replacement of Existing Mains to Meet 2030 ID 1 Demands Test Results

Pipeline	Evaluation Criteria		Run 1			Run 2			Run 3			Run 4		
	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s
Booster Discharge	5	4	8	133.97	31.91	20	4.15	5.11	24	1.71	3.55	20	4.15	5.11
ASBL -Part 1	5	4	12	65.42	16.41	20	5.43	5.91	24	2.24	4.10	24	2.24	4.10
ASBL -Part 2	5	4	12	75.87	16.41	20	6.30	5.91	24	2.59	4.10	24	2.59	4.10
ASBL -Part 3	5	4	12	99.63	19.01	20	8.27	6.84	24	3.40	4.75	24	3.40	4.75
Existing ASBL - Part 4	10	7	12/ 24	3.23/ 3.20	2.98/ 4.98	12/ 24	3.23/ 3.20	2.98/ 4.98	12/ 24	3.23/ 3.20	2.98/ 4.98	12/24	3.23/ 3.20	2.98/ 4.98
Existing Avenal Blending Line	10	7	24	4.82	6.21	24	4.82	6.21	24	4.82	6.21	24	4.82	6.21

Notes:
Runs consist of booster station pumping 4000 gpm with Well 129, 201, 206, 209, and 212 running to reach the 2030 ID 1 demands.

Table A-2. Parallel Mains with Existing Mains to Meet 2030 ID 1 Demands Test Results

Pipeline	Evaluation Criteria		Run 1			Run 2			Run 3			Run 4		
	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s	Dia, in	HL/1000 ft	Velocity, ft/s
Booster Discharge	10/5	7/4	8/ 16	9.38/ 9.31	4.45/ 6.87	8/ 18	5.67/ 5.63	3.39/ 5.63	8/20	3.56/ 3.53	2.64/ 4.68	8/24	1.55/ 1.54	1.69/ 3.36
ASBL -Part 1	10/5	7/4	12/ 16	7.39/ 8.14	5.06/ 6.39	12/ 18	4.88/ 5.38	4.04/ 5.50	12/ 20	3.27/ 3.61	3.26/ 4.74	12/24	1.56/ 1.72	2.18/ 3.56
ASBL -Part 2	10/5	7/4	12/ 16	8.57/ 8.14	5.06/ 6.39	12/ 18	5.66/ 5.38	4.04/ 5.50	12/ 20	3.80/ 3.61	3.26/ 4.74	12/24	1.81/ 1.72	2.18/ 3.56
ASBL -Part 3	10/5	7/4	12/ 16	14.48/ 9.45	6.71/ 6.92	12/ 18	9.80/ 6.39	5.43/ 6.03	12/ 20	6.70/ 4.37	4.43/ 5.25	12/24	3.27/ 2.13	3.01/ 4.00
Existing ASBL - Part 4	10	7	12/ 24	3.23/ 3.20	2.98/ 4.98	12/ 24	3.23/ 3.20	2.98/ 4.98	12/ 24	3.23/ 3.20	2.98/ 4.98	12/ 24	3.23/ 3.20	2.98/ 4.98
Existing Avenal Blending Line	10	7	24	4.82	6.21	24	4.82	6.21	24	4.82	6.21	24	4.82	6.21

Notes:
Runs consist of booster station pumping 4000 gpm with Well 129, 201, 206, 209, and 212 running to reach the 2030 ID 1 demands.

Table A-3. Maximum Capacity of 4,000 gpm from ID1/ID2 Booster to Existing System Results

Pipeline	Diameter, in	Headloss/ 1000 ft	Velocity, ft/s		Junction	Pressure, psi
20321	**6**	**2.73**	**6.14**		20294	**125.52**
20323	**12**	**7.36**	**17.17**		20296	**125.62**
21113	**8**	**0.69**	**0.35**		21608	**103.79**
21115	**8**	**5.64**	**16.85**		21610	**112.06**
21117	**8**	**6.34**	**20.89**		21612	**112.19**
21119	**8**	**3.56**	**7.18**		21614	**113.2**
21121	**8**	**5.64**	**16.86**		21616	**113.62**
21305	**8**	**1.98**	**2.43**		21618	**119.33**
21307	**8**	**1.74**	**1.91**		22088	**105.95**
21311	**8**	**0.92**	**0.59**		23416	**104.12**
21313	**8**	**2.66**	**4.2**		23424	**107.89**
21385	**8**	**2.67**	**4.22**		23426	**126.04**
21529	**8**	**2.76**	**4.47**		23550	**118.53**
21541	**8**	**2.15**	**2.83**		23552	**118.23**
21543	**8**	**2.15**	**2.81**		23614	**127.2**
21545	**8**	**1.98**	**2.42**		23684	**123.32**
22387	**8**	**0.24**	**0.05**		23704	**123.24**
22511	**8**	**5.64**	**16.85**		23706	**119.83**
22515	**8**	**3.56**	**7.18**		23978	**129.11**
22517	**8**	**1.38**	**1.25**		23980	**129.37**
22841	**8**	**2.77**	**4.51**		24046	**125.71**
22843	**8**	**2.78**	**4.53**		24048	**125.57**
22845	**8**	**0.38**	**0.11**		24504	**120.97**
22849	**8**	**0.37**	**0.11**		24508	**124.24**
22851	**6**	**3.69**	**10.76**		24512	**124.6**
22935	**6**	**1.16**	**1.26**		24516	**115.67**
23033	**6**	**0.88**	**0.76**		24518	**119.68**
23035	**6**	**0.91**	**0.81**		24528	**111.66**
23233	**6**	**4.26**	**14**		24530	**108.13**
23303	**6**	**0.97**	**0.89**		24532	**110.88**
23613	**6**	**0.14**	**0.02**		26268	**113.55**
23617	**6**	**0.15**	**0.03**		26552	**112.26**
24437	**6**	**0.01**	**0**		26560	**115.73**
24553	**6**	**3.52**	**9.86**		26562	**111.24**
24555	**6**	**3.69**	**10.74**		26564	**116.09**
24559	**6**	**0.97**	**0.9**		26570	**123.43**
24563	**6**	**4.27**	**14.09**		26574	**125.33**
24567	**6**	**4.27**	**14.09**		26576	**120.55**
24571	**6**	**4.27**	**14.09**		26582	**127.73**
25497	**6**	**1.23**	**1.4**		26584	**125.63**
25503	**6**	**0.98**	**0.93**		26586	**127.67**
25505	**6**	**1.01**	**0.98**		26590	**126.8**
25509	**6**	**0.91**	**0.8**		26594	**126.87**

25511	**6**	**0.12**	**0.02**		26598	**125.46**
25513	**6**	**0.93**	**0.84**		26600	**125.38**
25517	**6**	**2.1**	**3.77**		26966	**127.29**
25519	**6**	**1.16**	**1.26**		27096	**126.73**
25523	**6**	**1.98**	**3.39**		27118	**127.13**
25525	**6**	**1.97**	**3.36**		27144	**124.96**
25529	**6**	**1.99**	**3.43**		27154	**125.91**
25531	**6**	**4.1**	**13.04**		27614	**125**
25533	**6**	**4.1**	**13.08**		J236	**127.54**
25535	**6**	**22.83**	**313.88**		22104	**97.47**
25541	**6**	**1.25**	**1.46**		22106	**98.73**
25543	**6**	**1.28**	**1.51**		23084	**100.32**
25545	**6**	**1.28**	**1.51**		26270	**100.24**
25547	**6**	**1.31**	**1.57**		21862	**93.27**
25553	**6**	**0.87**	**0.73**		21864	**93.47**
25919	**16**	**0.46**	**0.07**		22108	**95.31**
25977	**16**	**0.46**	**0.07**		22110	**95.24**
26133	**12**	**0.24**	**0.03**		27094	**95.13**
26177	**12**	**6.18**	**12.45**		25458	**94.85**
26179	**12**	**7.06**	**15.93**		20290	**126.04**
26181	**12**	**0.88**	**0.34**		20298	**125.52**
26235	**12**	**5.71**	**10.73**		21766	**91.35**
26237	**12**	**5.71**	**10.72**		21870	**106.07**
26239	**12**	**2.11**	**1.69**		21868	**109.83**
26315	**12**	**6.42**	**13.33**		21872	**106.28**
26321	**12**	**2.76**	**3.03**		22966	**88.73**
26379	**12**	**6.42**	**13.33**		21626	**94.91**
26385	**12**	**1.59**	**1.01**		23418	**109.85**
26387	**12**	**0.76**	**0.26**		23420	**113.33**
26389	**12**	**0.76**	**0.26**		25604	**125.77**
26391	**12**	**0.73**	**0.24**		23936	**127.06**
26435	**12**	**0.84**	**0.31**		23938	**127.52**
26439	**12**	**1.08**	**0.49**		25488	**95.36**
26529	**12**	**4.87**	**7.99**		25610	**126.59**
26531	**12**	**0.88**	**0.32**		25614	**126.19**
26817	**12**	**1.25**	**0.64**		23288	**125.68**
26819	**12**	**1.25**	**0.64**		23976	**133.39**
26821	**12**	**0.96**	**0.39**		23540	**128.11**
26823	**12**	**2.11**	**1.69**		27146	**127.32**
26825	**12**	**6.73**	**14.57**		27174	**102.58**
26827	**12**	**6.73**	**14.58**		24068	**100.44**
26829	**12**	**6.74**	**14.59**		24072	**97.62**
26831	**12**	**6.19**	**12.46**		26998	**112.24**
27333	**12**	**7.36**	**17.17**		23422	**113.62**
27341	**12**	**0.81**	**0.28**		26996	**116.11**
27359	**12**	**0.96**	**0.39**		24320	**116.09**

27361	**12**	**1.72**	**1.16**		24316	**120.55**
27363	**12**	**2.6**	**2.5**		27042	**126.05**
27859	**12**	**0.81**	**0.28**		27594	**120.96**
27861	**12**	**0.8**	**0.28**		21922	**122.96**
27863	**8**	**5.15**	**14.26**		25462	**91.42**
27865	**8**	**3.83**	**8.21**		20126	**125.16**
27867	**12**	**3.99**	**5.53**		21772	**87.87**
27873	**12**	**7.34**	**17.1**		25602	**125.82**
29697	**18**	**5.04**	**4.39**			

Table A-4. Maximum Flow to Existing System fromID1/ID2 Booster Station Results

Pipeline	Diameter, in	Headloss/ 1000 ft	Velocity, ft/s		Junction	Pressure, psi
20321	**6**	**1.86**	**3.02**		20126	**113.58**
20323	**12**	**4.97**	**8.32**		20290	**114.29**
21113	**8**	**0.45**	**0.16**		20294	**114.12**
21115	**8**	**3.79**	**8.08**		20296	**114.25**
21117	**8**	**4.25**	**9.96**		20298	**114.06**
21119	**8**	**2.35**	**3.33**		21608	**99.78**
21121	**8**	**3.79**	**8.08**		21610	**104.95**
21305	**8**	**1.57**	**1.58**		21612	**105.07**
21307	**8**	**1.5**	**1.44**		21614	**105.69**
21311	**8**	**0.54**	**0.22**		21616	**105.96**
21313	**8**	**1.79**	**2.01**		21618	**109.67**
21385	**8**	**1.8**	**2.02**		21626	**92.39**
21529	**8**	**1.88**	**2.2**		21766	**89.3**
21541	**8**	**1.47**	**1.4**		21772	**85.94**
21543	**8**	**1.47**	**1.39**		21862	**91.13**
21545	**8**	**1.57**	**1.58**		21864	**91.31**
22387	**8**	**0.07**	**0.01**		21868	**107.17**
22511	**8**	**3.79**	**8.08**		21870	**103.52**
22515	**8**	**2.35**	**3.33**		21872	**103.69**
22517	**8**	**0.85**	**0.51**		21922	**119.99**
22841	**8**	**1.89**	**2.23**		22088	**102.54**
22843	**8**	**1.9**	**2.24**		22104	**94.89**
22845	**8**	**0.17**	**0.02**		22106	**95.99**
22849	**8**	**0.16**	**0.02**		22108	**93.01**
22851	**6**	**2.52**	**5.3**		22110	**92.94**
22935	**6**	**0.78**	**0.6**		22966	**86.6**
23033	**6**	**0.58**	**0.35**		23084	**97.18**
23035	**6**	**0.62**	**0.39**		23288	**114.39**
23233	**6**	**2.86**	**6.69**		23416	**100.19**
23303	**6**	**0.66**	**0.44**		23418	**107.19**
23613	**6**	**0.13**	**0.02**		23420	**110.66**
23617	**6**	**0.14**	**0.03**		23422	**110.94**

24437	**6**	**0.01**	**0**		23424	**105.02**
24553	**6**	**2.35**	**4.66**		23426	**114.65**
24555	**6**	**2.52**	**5.29**		23540	**119.82**
24559	**6**	**0.66**	**0.44**		23550	**115.7**
24563	**6**	**2.87**	**6.76**		23552	**115.38**
24567	**6**	**2.87**	**6.76**		23614	**123.76**
24571	**6**	**2.87**	**6.76**		23684	**120.26**
25497	**6**	**0.81**	**0.66**		23704	**113.46**
25503	**6**	**0.68**	**0.47**		23706	**110.16**
25505	**6**	**0.71**	**0.5**		23936	**121.92**
25509	**6**	**0.61**	**0.38**		23938	**124.29**
25511	**6**	**0.11**	**0.02**		23976	**130.03**
25513	**6**	**0.63**	**0.41**		23978	**125.74**
25517	**6**	**1.41**	**1.82**		23980	**126**
25519	**6**	**0.78**	**0.6**		24046	**114.31**
25523	**6**	**1.32**	**1.61**		24048	**114.18**
25525	**6**	**1.31**	**1.58**		24068	**98.06**
25529	**6**	**1.33**	**1.63**		24072	**95.28**
25531	**6**	**2.76**	**6.25**		24316	**117.7**
25533	**6**	**2.76**	**6.29**		24320	**113.34**
25535	**6**	**15.36**	**150.67**		24504	**117.59**
25541	**6**	**0.83**	**0.67**		24508	**119.66**
25543	**6**	**0.85**	**0.71**		24512	**116.87**
25545	**6**	**0.85**	**0.71**		24516	**108.39**
25547	**6**	**0.88**	**0.75**		24518	**112.17**
25553	**6**	**0.57**	**0.34**		24528	**108.9**
25919	**16**	**0.32**	**0.04**		24530	**105.25**
25977	**16**	**0.32**	**0.04**		24532	**108.01**
26133	**12**	**0.17**	**0.01**		25458	**92.55**
26177	**12**	**4.17**	**6**		25462	**89.19**
26179	**12**	**4.76**	**7.65**		25488	**92.78**
26181	**12**	**0.59**	**0.16**		25602	**115.8**
26235	**12**	**3.84**	**5.15**		25604	**115.46**
26237	**12**	**3.84**	**5.15**		25610	**119.36**
26239	**12**	**1.41**	**0.8**		25614	**117.18**
26315	**12**	**4.33**	**6.42**		26268	**105.89**
26321	**12**	**1.85**	**1.45**		26270	**97.1**
26379	**12**	**4.33**	**6.42**		26552	**105.14**
26385	**12**	**1.04**	**0.46**		26560	**112.76**
26387	**12**	**0.23**	**0.03**		26562	**108.36**
26389	**12**	**0.23**	**0.03**		26564	**113.11**
26391	**12**	**0.21**	**0.02**		26570	**120.41**
26435	**12**	**0.8**	**0.28**		26574	**122.15**
26439	**12**	**0.82**	**0.29**		26576	**117.12**
26529	**12**	**3.26**	**3.8**		26582	**121.97**
26531	**12**	**0.7**	**0.21**		26584	**121.03**

26817	12	0.9	0.35		26586	121.77
26819	12	0.9	0.35		26590	118.85
26821	12	0.7	0.22		26594	119.07
26823	12	1.41	0.8		26598	115.66
26825	12	4.53	7		26600	115.48
26827	12	4.53	7		26966	123.92
26829	12	4.53	7.01		26996	113.47
26831	12	4.17	6		26998	109.85
27333	12	4.97	8.31		27042	114.18
27341	12	0.16	0.01		27094	92.83
27359	12	0.7	0.22		27096	118.45
27361	12	1.14	0.55		27118	123.8
27363	12	1.73	1.18		27144	113.83
27859	12	0.16	0.02		27146	124.03
27861	12	0.16	0.01		27154	114.51
27863	8	3.47	6.87		27174	100.17
27865	8	2.57	3.93		27594	118.1
27867	12	2.69	2.66		27614	113.87
27873	12	4.96	8.26		J236	115.67
29697	18	3.4	2.2			

Table A-5. Max Capacity of 4,000 gpm from ID1/ID2 Booster to System with Improvements Results

Pipeline	Diameter, in	Headloss/ 1000 ft	Velocity, ft/s		Junction	Pressure, psi
20321	6	1.76	2.72		20126	115.37
20323	12	4.65	7.34		20290	116.06
21113	8	0.13	0.01		20294	115.93
21115	8	3.2	5.89		20296	116.06
21117	8	3.33	6.35		20298	115.86
21119	8	2.97	5.15		21608	103.6
21121	8	3.2	5.89		21610	107.74
21305	8	2.7	4.32		21612	107.87
21307	8	2.21	2.98		21614	108.38
21311	8	0.87	0.53		21616	108.62
21313	8	2.02	2.53		21618	111.83
21385	8	2.03	2.54		21626	95.33
21529	8	2.58	3.95		21766	91.73
21541	8	1.45	1.36		21772	87.94
21543	8	1.44	1.34		21862	93.86
21545	8	2.7	4.32		21864	94.08
22387	8	0.49	0.18		21868	109.85
22511	8	3.2	5.88		21870	106.39
22515	8	2.97	5.14		21872	106.57
22517	8	1.5	1.46		21922	122.31
22841	8	2.59	3.98		22088	105.89

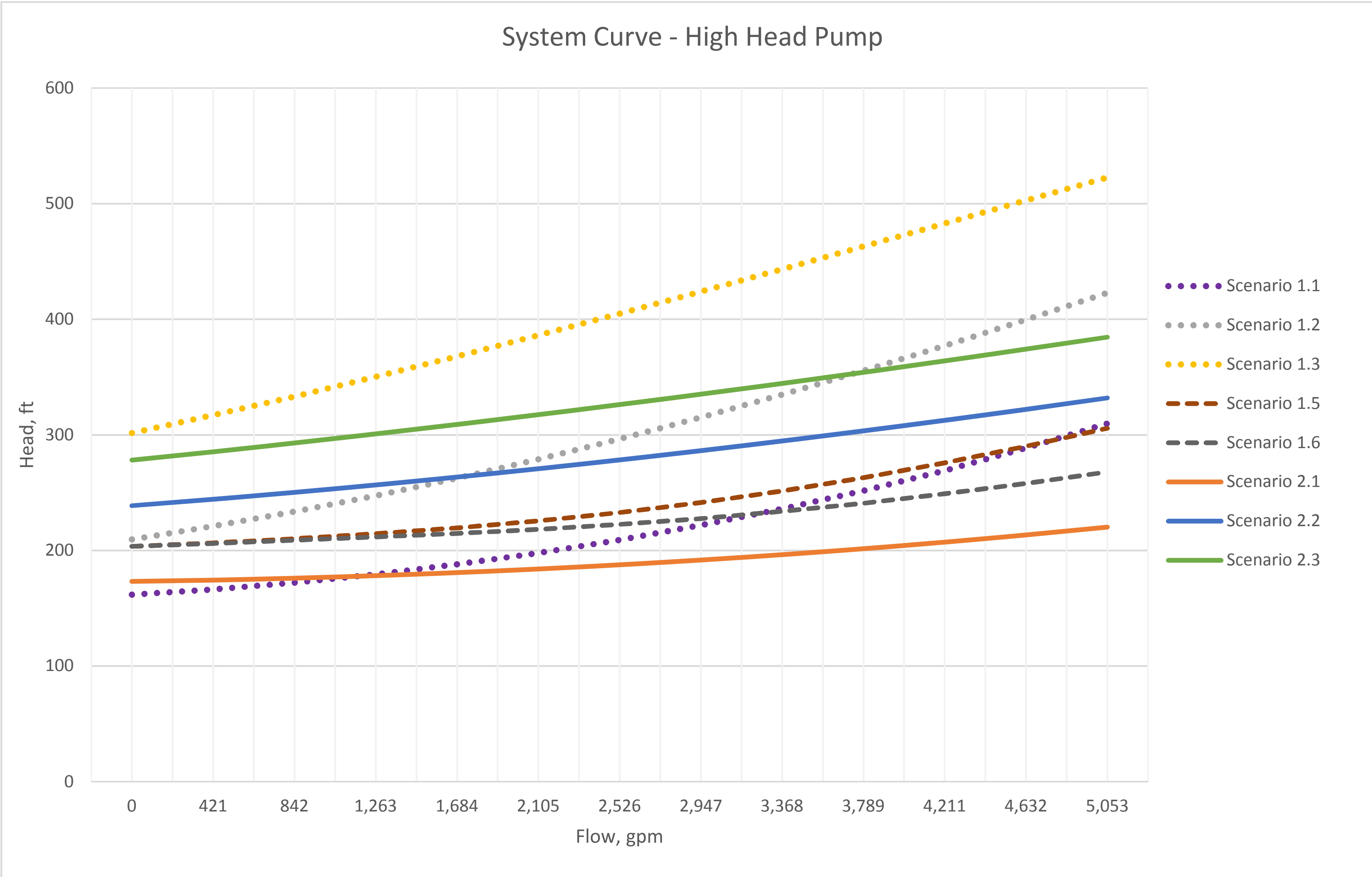
22843	**8**	**2.6**	**4**		22104	**98.12**
22845	**8**	**1.25**	**1.03**		22106	**99.21**
22849	**8**	**1.25**	**1.04**		22108	**96.24**
22851	**6**	**2.38**	**4.78**		22110	**96.18**
22935	**6**	**1.28**	**1.52**		22966	**89.27**
23033	**6**	**0.23**	**0.06**		23084	**100.59**
23035	**6**	**0.26**	**0.08**		23288	**116.2**
23233	**6**	**2.78**	**6.35**		23416	**103.95**
23303	**6**	**0.62**	**0.4**		23418	**109.84**
23613	**6**	**0.96**	**0.88**		23420	**113.08**
23617	**6**	**0.97**	**0.9**		23422	**113.35**
24437	**6**	**0.01**	**0**		23424	**107.97**
24553	**6**	**2.21**	**4.16**		23426	**116.46**
24555	**6**	**2.38**	**4.76**		23540	**121.93**
24559	**6**	**0.62**	**0.4**		23550	**118.05**
24563	**6**	**2.79**	**6.41**		23552	**117.75**
24567	**6**	**2.79**	**6.41**		23614	**126.03**
24571	**6**	**2.79**	**6.41**		23684	**122.58**
25497	**6**	**0.24**	**0.07**		23704	**115.52**
25503	**6**	**0.68**	**0.47**		23706	**112.31**
25505	**6**	**0.71**	**0.5**		23936	**124.03**
25509	**6**	**0.22**	**0.06**		23938	**126.48**
25511	**6**	**0.94**	**0.85**		23976	**132.3**
25513	**6**	**0.19**	**0.04**		23978	**128.02**
25517	**6**	**1.1**	**1.14**		23980	**128.27**
25519	**6**	**1.28**	**1.52**		24046	**116.13**
25523	**6**	**1.5**	**2.03**		24048	**115.99**
25525	**6**	**1.49**	**2**		24068	**101.11**
25529	**6**	**1.51**	**2.06**		24072	**98.43**
25531	**6**	**2.62**	**5.69**		24316	**120.03**
25533	**6**	**2.62**	**5.72**		24320	**115.71**
25535	**6**	**15.13**	**146.51**		24504	**119.99**
25541	**6**	**0.26**	**0.08**		24508	**121.97**
25543	**6**	**0.28**	**0.09**		24512	**119.19**
25545	**6**	**0.28**	**0.09**		24516	**111.05**
25547	**6**	**0.31**	**0.11**		24518	**114.66**
25553	**6**	**0.21**	**0.05**		24528	**111.58**
25919	**16**	**0.4**	**0.05**		24530	**108.18**
25977	**16**	**0.4**	**0.05**		24532	**110.7**
26133	**12**	**0.16**	**0.01**		25458	**95.76**
26177	**12**	**3.97**	**5.47**		25462	**92.19**
26179	**12**	**4.52**	**6.97**		25488	**96.01**
26181	**12**	**0.55**	**0.14**		25602	**117.74**
26235	**12**	**3.78**	**5.01**		25604	**117.38**
26237	**12**	**3.78**	**5.01**		25610	**121.36**
26239	**12**	**1.31**	**0.7**		25614	**119.1**

26315	**12**	**4.04**	**5.65**		26268	**108.55**
26321	**12**	**1.75**	**1.3**		26270	**100.51**
26379	**12**	**4.04**	**5.65**		26552	**107.93**
26385	**12**	**0.51**	**0.12**		26560	**115.33**
26387	**12**	**1.13**	**0.53**		26562	**111.04**
26389	**12**	**1.13**	**0.53**		26564	**115.67**
26391	**12**	**1.15**	**0.56**		26570	**122.72**
26435	**12**	**1.64**	**1.07**		26574	**124.44**
26439	**12**	**1.28**	**0.67**		26576	**119.53**
26529	**12**	**3.06**	**3.37**		26582	**124.19**
26531	**12**	**1.2**	**0.61**		26584	**123.27**
26817	**12**	**0.73**	**0.24**		26586	**123.98**
26819	**12**	**0.73**	**0.24**		26590	**120.99**
26821	**12**	**0.41**	**0.08**		26594	**121.22**
26823	**12**	**1.31**	**0.7**		26598	**117.65**
26825	**12**	**4.44**	**6.73**		26600	**117.46**
26827	**12**	**4.44**	**6.74**		26966	**126.19**
26829	**12**	**4.44**	**6.74**		26996	**115.81**
26831	**12**	**3.97**	**5.48**		26998	**112.16**
27333	**12**	**4.65**	**7.34**		27042	**115.94**
27341	**12**	**1.51**	**0.91**		27094	**96.06**
27359	**12**	**0.41**	**0.08**		27096	**120.56**
27361	**12**	**1.1**	**0.51**		27118	**126.07**
27363	**12**	**1.68**	**1.11**		27144	**115.67**
27859	**12**	**1.51**	**0.91**		27146	**126.32**
27861	**12**	**1.5**	**0.91**		27154	**116.33**
27863	**8**	**3.08**	**5.49**		27174	**103.13**
27865	**8**	**2.5**	**3.73**		27594	**120.42**
27867	**12**	**2.48**	**2.29**		27614	**115.71**
27873	**12**	**4.63**	**7.3**		J236	**117.43**
29691	**12**	**4.22**	**5.29**			
29695	**12**	**3.22**	**3.21**			
29697	**18**	**3.17**	**1.95**			

APPENDIX B. SYSTEM HEAD CURVES

High Head System Curve Summary												
				ID2 Wells Used in Scenario								
Scenario	Description	Discharge Location	Pipe Upgrades Assumed to be Completed	Wells (1)	Total Well Flow, gpm	Estimated Booster Max Flow, gpm (3)	Total Supply with max from Booster, gpm (4)	3290 Tank Levels	3485 Tank Levels	Demands	Notes	Desired Booster Performance Under This Scenario
1.1	Near Term Low Head Scenario	Blending Line	24" to Well 212	None	0	4000	4000	100%	50%	MDD		For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
1.2	Near Term Mid Head Scenario	Blending Line	24" to Well 212	208, 212	2597	4000	6084	100%	50%	MDD	Max capacity of distribution system is 6250 gpm (4000 gpm boosters + ~2 wells)	For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
1.3	Near Term High Head Scenario	Blending Line	24" to Well 212	206, 208, 212, 229	4171	2800	6220	50%	100%	ADD	Max capacity of distribution system is 6250 gpm (~2800 gpm booster + ~4 wells)	For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
1.5	Near Term to System Scenario	3485 System	None	None	0	2700	2700	50%	100%	ADD	Max capacity of distribution system: ~2700 gpm booster	For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
1.6	Long Term to System Scenario	3485 System	12" Line on Sycamore	None	0	4000	4000	50%	100%	ADD	Can accommodate full booster flow of 4,000 gpm	For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
2.1	Long Term Low Head Scenario	Blending Line	30" Balancing Line	None	0	4000	4000	100%	50%	MDD		For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
2.2	Long Term Mid Head Scenario	Blending Line	30" Balancing Line	206, 208, 212, 229	4541	4000	8176	50%	100%	ADD		For the proposed pumps, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
2.3	Long Term High Head Scenario	Blending Line	30" Balancing Line	All	7304	3300	10015	50%	100%	ADD	Max capacity of distribution system is 10,000 gpm	Design pumps to operate nearest BEP at 4,000 gpm (with both pumps on)

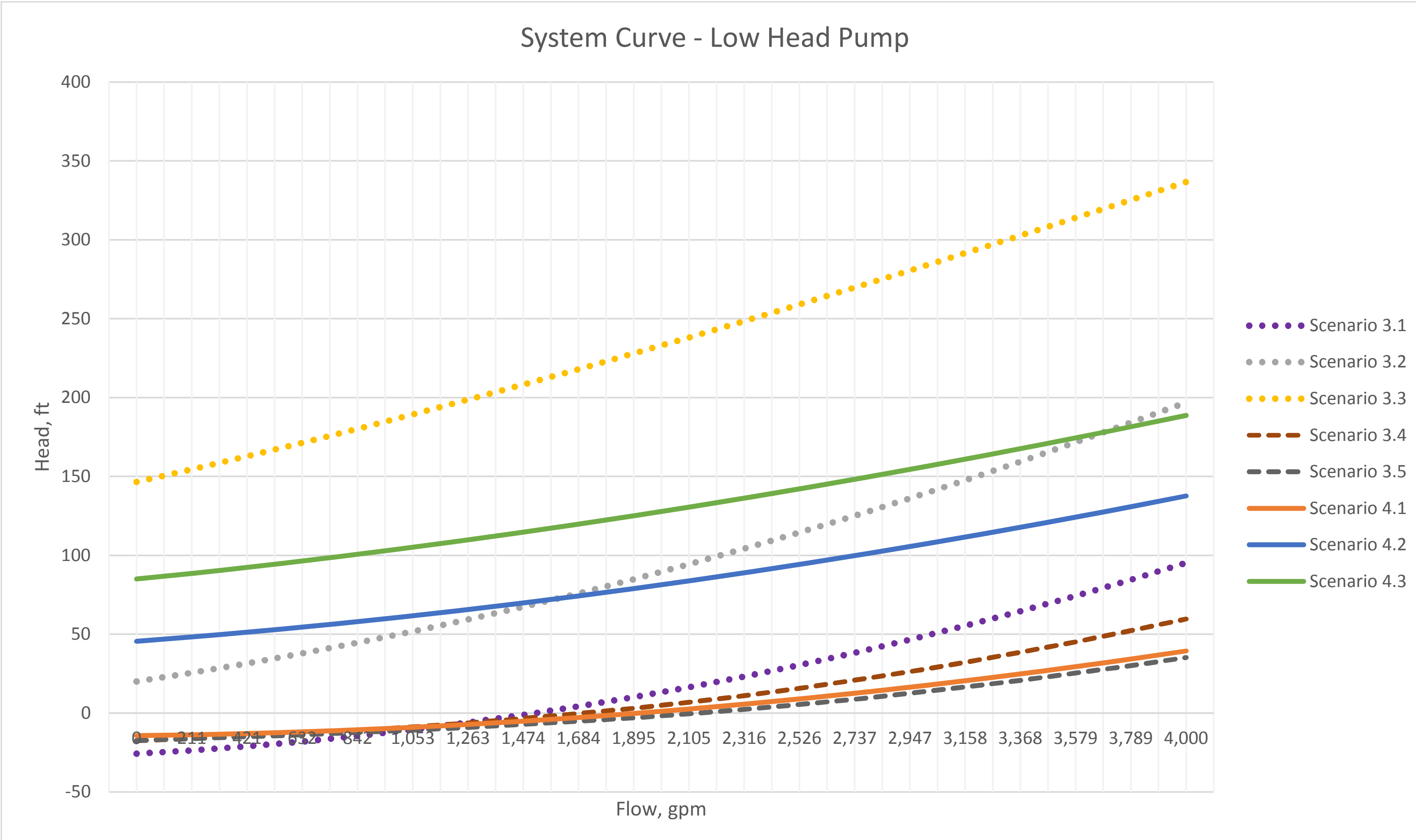
Notes:
(1) Representative wells chosen to simulate a range of conditions. Wells 203, 205, and 207 are assumed to be off in all scenarios.
(2) System curves do not account for station losses in the pump station, only losses in the suction and discharge transmission mains. Pump Designer will need to adjust pump or system curves to account for station losses
(3) Based on system capacity to accept flow or nominal design capacity of 4,000; not based on pump curve. To be verified by pump designer during pump selection
(4) Results from model with Estimated Booster Max Flow applied



Note: System curves do not account for station losses in the pump station, only losses in the suction and discharge transmission mains. Pump Designer will need to adjust pump or system curves to account for station losses

Low Head System Curve Summary													
				ID2 Wells Used in Scenario									
Scenario	**Description**	**Discharge Location**	**Pipe Upgrades Assumed to be Completed**	**Wells (1)**	**Total Well Flow, gpm**	**Estimated Booster Max Flow, gpm (3)**	**Total Supply with max from Booster, gpm (4)**	**R3 Tank Level**	**3485 Tank Levels**	**Demands**	**Notes**	**Frequency of Scenario Occurrence**	**Desired Booster Performance Under This Scenario**
3.1	Near Term Low Head Scenario	Blending Line	24" to Well 212	None	0	2000	2000	100%	50%	MDD	Low flows (~1,000 gpm) may be able to enter 3485 without the booster when R3 tank levels are high and wells are off; consider a check valve to bypass booster if this is expected to occur frequently	Seasonally; when R3 water is available and wells are not needed	For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
3.2	Near Term Mid Head Scenario	Blending Line	24" to Well 212	208, 212	2597	2000	4395	100%	50%	MDD			For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
3.3	Near Term High Head Scenario	Blending Line	24" to Well 212	201, 206, 208, 212, 229	4971	1900	6241	50%	100%	ADD	Max capacity of distribution system: 6,250 gpm		Design pump to operate nearest BEP at 2,000 gpm
3.4	Near Term to System Scenario	3485 System	None	None	0	2000	2000	50%	100%	ADD			For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
3.5	Long Term to System Scenario	3485 System	12" Line on Sycamore	None	0	2000	2000	50%	100%	ADD			For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
4.1	Long Term Low Head Scenario	Blending Line	30" Balancing Line	None	0	2000	2000	100%	50%	MDD	Low flows may be able to enter 3485 without the booster when R3 tank levels are high and wells are off; consider a check valve to bypass booster if this is expected to occur frequently	Seasonally; when R3 water is available and wells are not needed	For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
4.2	Long Term Mid Head Scenario	Blending Line	30" Balancing Line	206, 208, 212, 229	4541	2000	6384	50%	100%	ADD			For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range
4.3	Long Term High Head Scenario	Blending Line	30" Balancing Line	All	7304	2000	8969	50%	100%	ADD	Max capacity of distribution system is 10,000 gpm		For the proposed pump, identify max flow (& associated speed/efficiency) that can be pumped within allowable operating range

Notes:
(1) Representative wells chosen to simulate a range of conditions. Wells 203, 205, and 207 are assumed to be off in all scenarios.
(2) System curves do not account for station losses in the pump station or R3 turnout, only losses in the suction and discharge transmission mains. Pump Designer will need to adjust pump or system curves to account for station losses.
(3) Based on system capacity to accept flow or nominal design capacity of 2,000; not based on pump curve. To be verified by pump designer during pump selection
(4) Results from model with Estimated Booster Max Flow applied



Note: System curves do not account for station losses in the pump station, only losses in the suction and discharge transmission mains. Pump Designer will need to adjust pump or system curves to account for station losses