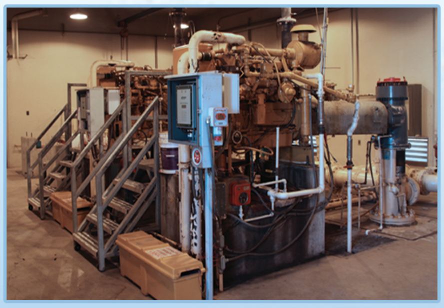
Appendix R –
Northeast Area Planning Study
Prepared by Carollo Engineers dated March 2013

Yorba Linda Water District



FINAL REPORT

Northeast Area Planning Study

Job No. 2010-11B

March 2013

carollo

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Yorba Linda Water District
Northeast Area Planning Study
2010-11B

REPORT

FINAL
March 2013

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YORBA LINDA WATER DISTRICT

Northeast Area Planning Study

FINAL REPORT

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EXECUTIVE SUMMARY

The purpose of the Northeast Area Planning Study is to evaluate the capacity of existing distribution system facilities and size new infrastructure required to provide water under anticipated operational conditions for future demands. The proposed Esperanza Hills Estates (EHE) and Sage (SG) developments are projected to add 542 acre-feet per year (afy) to the District's annual demands, resulting in an overall system annual demand of 25,388 afy, which equates to a 2 percent demand increase. The District's current maximum day demand is estimated to increase by 0.7 million gallons per day (mgd) to 33.6 mgd.

Storage Evaluation

Due to topology, the proposed EHE and SG developments will need to be divided into two pressure zones, with hydraulic grade lines at 1,200 feet above mean sea level (ft-msl) and 1,390 ft-msl. Based on updated storage criteria, these developments would require approximately 1.3 million gallons (MG) of storage. After evaluation of the following two alternatives, it is recommended that storage be accommodated as discussed in Option 1 below:

Option 1. The entire 1.3 MG storage would be located within both development areas. Each zone would need 0.18 MG of dedicated fire flow storage (0.36 MG), unless greater fire flow requirements are established by the Orange County Fire Authority. The remaining 0.94 MG storage would need to be prorated by the demands of each pressure zone. As detailed in Section 3.4.1, additional offsite improvements will be required.

Option 2. Utilizing the Hidden Hills Reservoir for additional storage is not a viable option as discussed in detail in Section 3.4.2.

Pump Station Evaluation

This project focused on the sizing of the District's Fairmont Pump Station (FPS) as the FPS is critical to serve the new developments and is planned for replacement due to aging. The FPS currently has a capacity of about 2,100 gallons per minute (gpm), and can be manually operated to alternate its suction and discharge pressure zones. Sizing of the proposed FPS was developed to include a variety of operating conditions to achieve a range of groundwater Basin Pumping Percentages (BPP). Twelve different operating scenarios for groundwater supplies ranging from 0 to 100 percent were developed. These scenarios were grouped in three categories based on the different suction and discharge conditions as listed in Section 4.5.1.

To accommodate these wide variety of pumping scenarios, four groups of pump units are required as summarized in Table ES.1. All seven pump units are recommended to be variable frequency drives (VFDs), but could be configured as constant speed pumps with the addition of one unit as described in Section 4.5.1.

In addition to the FPS improvements, Hidden Hills PS and Santiago PS would each need one additional pump unit if storage for the new development is partially provided from Hidden Hills Reservoir and the development is served from Zone 1,000-2 (Santiago Reservoir) or Zone 1,390 (Hidden Hills Reservoir). Details are provided in Section 4.5.2.

Table ES.1 Fairmont PS Sizing

Units	To Zone	From Zone	TDH (ft)	Design Capacity[1] (gpm)	Notes
1	920	675	237	800	No standby unit included since OC89 provides reliability.
2 - 3	1,000-1	675/780-3	388	2,800	1+1 configuration
4 - 6	780-3	675	120	5,500	2+1 configuration
7	1,000-1	920	212	2,800	No standby unit included since not assumed to be a typical operating condition.

Note:

1. Rounded up to nearest 100 gpm.

It is recommended that the District include either a portable diesel generator or on-site natural gas powered backup generator at FPS and that the PS include pressure reducing valves to supply Zone 675 from Zone 780-3 and supply Zone 920 from Zone 1,000-1 to increase operational flexibility.

Pipeline Evaluation

Based on hydraulic model analysis, two pipelines in the vicinity of FPS were also identified as deficient, resulting in high headloss and additional pumping head requirements for the new PS. To minimize the pump unit sizing and energy cost, it is recommended to increase the capacity of the following pipelines with large diameter pipeline replacements or parallel pipelines:

- The 12-inch diameter Zone 1,000-1 pipeline extending 3,500 feet along Fairmont Boulevard between FPS and Forest Avenue. This pipeline should be replaced by a 16-inch diameter pipeline or paralleled with a 12-inch diameter pipeline.

- The 12-inch diameter Zone 780-3 pipeline extending 670 feet along Fairmont Boulevard from Bastanchury Road onto the District’s FPS. Adding a dedicated pipeline to the Bryant Cross Feeder south of Bastanchury Road would require about 800 feet of 24-inch diameter pipeline.

Water Quality

The key steps the District can implement to limit nitrification and residual loss from occurring are reducing water age and improving mixing within the District's reservoirs. It is recommended that the District continue to follow its reservoir cycling practices, following the guidelines recommended in the nitrification study.

For new reservoirs, it is recommended that the District include within the design systems to increase cycling within the reservoirs, consisting of separate inlet and outlets (using multiple diffused inlets where possible), samplers to provide real-time automated monitoring of disinfection residual, and a mixing device within the reservoir. A reservoir management system could provide this functionality in a single system along with boosting disinfection residual.

For the Fairmont PS, it is recommended that the District incorporate a disinfection station into the design that can inject free chlorine. If this emergency approach is not sufficient, the next recommended step would be to install reservoir management systems (mixers, analyzers, and potentially injection of chloramines).

Other Recommendations

This Northeast Area Planning Study is primarily limited to the system evaluation surrounding the new Esperanza Hills/Sage developments and the FPS. It is recommended that a comprehensive system evaluation be conducted for all pump stations and the entire distribution system under the variety of operating scenarios. In addition, it is recommended that the updated hydraulic model be used to optimize the system operational controls of the system for the most common BPP target scenarios to make system operations more consistent year-around.

1.0 BACKGROUND

The Yorba Linda Water District (District) is an independent special district that provides water and sewer service to residents and businesses within its 27 square mile service area. Some of the last remaining developments within the District's service area are anticipated to be constructed in the near future. The District is undertaking this study to evaluate water service in the northeast area of the District. Specifically, this study is intended to evaluate the capacity of the system to supply the areas of new development and recommend sizing of infrastructure to provide water under anticipated operational conditions for future demands.

2.0 PROJECTED DEMANDS

2.1 Existing Demands

The District's fiscal year (FY) 2011/12 demands were 20,433 afy, averaging 18.2 mgd (including unaccounted for water). As has been observed throughout the region, demands for the District peaked in calendar year 2007 at 24,840 afy, falling by 25 percent to 18,654 afy in calendar year 2010. For conservative planning, existing demand distribution for this study was based on an Average Day Demand (ADD) of 21.7 mgd, equivalent to FY2007/08. Demands had been geospatially allocated within the hydraulic model during a previous project based on billing data. Based on the 2005 Water Master Plan (WMP), the District's seasonal peaking factor (MDD/ADD) is 1.48, resulting in a MDD of 32.2 mgd.

2.2 Planned Developments

Two developments are currently planned for the northeast area of the District's service area, the Esperanza Hills Estates development and the Sage development. The locations of these developments are shown on Figure 1. Demands were estimated for these developments based on the water demand factors developed in the 2005 WMP and an average density of one dwelling unit per acre. Resulting demands are shown in Table 1.

As shown in Table 1, projected ADD for both developments is 0.48 mgd, with a MDD of 0.72 mgd. While connection of the developments to the existing water distribution system will be discussed in greater detail in Section 3.4 and 4.5, the developments will most likely take supply from Zone 1,000-1 or a zone downstream of Zone 1,000-1.

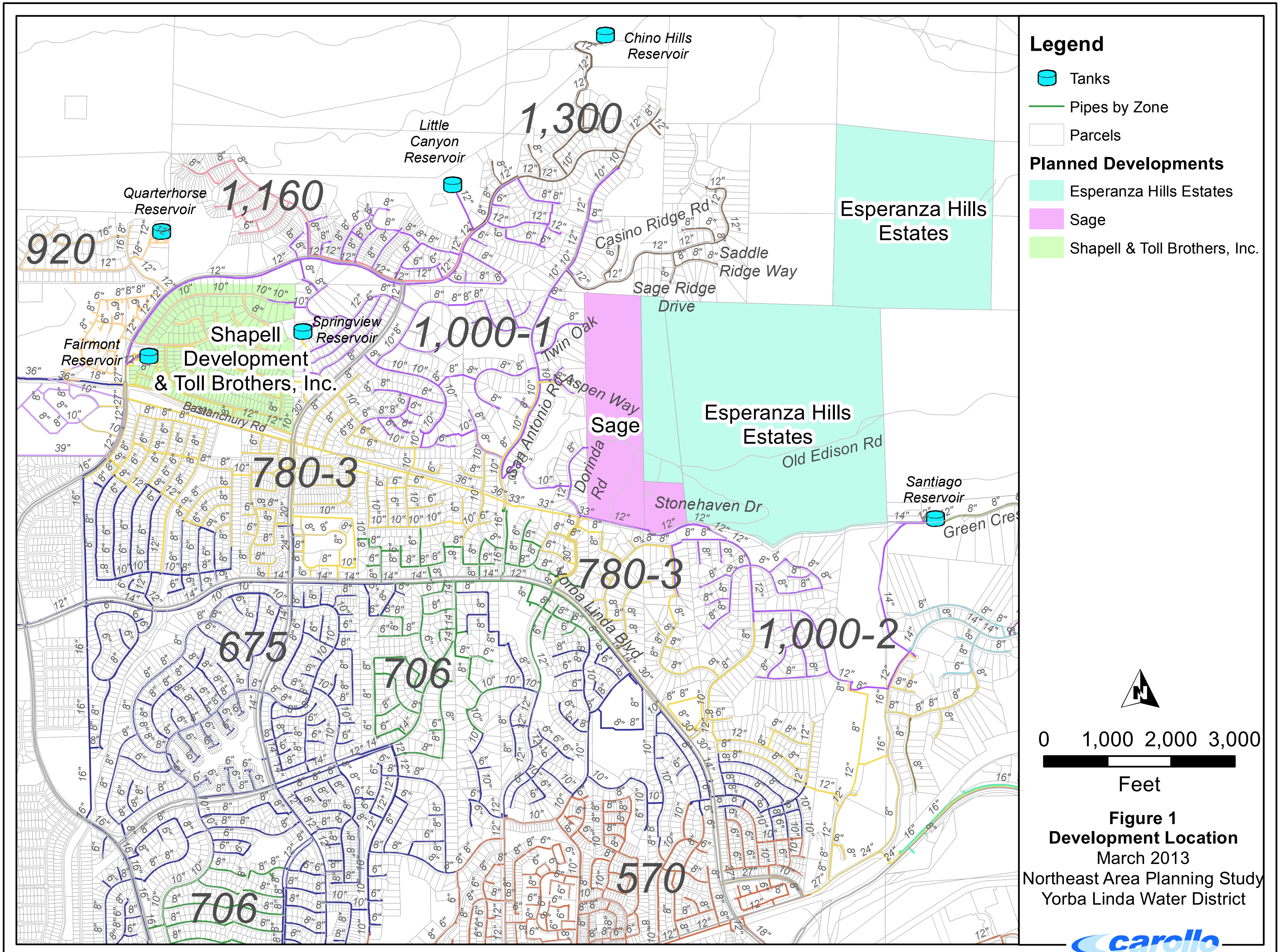

Figure 1
Development Location
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Table 1 Estimated Development Demand							
				Projected Water Demand		
Development	**Homes**	**Development Equivalent Acreage[1,2] (acres)**	**WDF (gpd/ac)**	**ADD (mgd)**	**AAD (afy)**	**MDD[3] (mgd)**
Esperanza Hills Estates	340	340	1,070	0.36	407.5	0.54
Sage	112	112	1,070	0.12	134.2	0.18
Total	**452**	**452**	**n/a**	**0.48**	**541.7**	**0.72**

Notes:

1. Based on discussions with developer's engineer, any disturbed area will be irrigated.
2. Using assumption of average density of 1 dwelling unit per acre with water demand factor (WDF) from 2005 WMP of 1,070 gpd/ac.
3. Based on seasonal peaking factor of 1.48.

In addition to the existing demands and planned development demands for the Esperanza Hills Estates and Sage developments, infrastructure has already been constructed for the Shapell & Toll Brothers, Inc. Development, but the houses have not yet been built. Thus, demands were added for this development based on the hydraulic analysis conducted for sizing its infrastructure. The Shapell & Toll Brothers, Inc. Development is served by three separate pressure zones – Zone 780-3, Zone 920, and Zone 1,000-1. Resulting demands are shown in Table 2.

As shown in Table 2, the Shapell & Toll Brothers, Inc. Development is anticipated to add approximately 0.65 mgd of demand under MDD conditions. The total projected future demand for the entire District's service area is summarized in Table 3.

As shown in Table 3, the District's future system ADD with the developments listed above is projected to increase from 21.7 mgd to 22.6 mgd. This equates to a 4 percent increase. Although this demand increase is fairly minimal system wide, the demand increase is substantial for a few pressure zones and the associated pump station and reservoir facilities.

Table 2 Assumed Demands for Shapell & Toll Brothers, Inc. Development			
Pressure Zone	**ADD (mgd)**	**AAD (afy)**	**MDD (mgd)**
780-3	0.27	306.3	0.40
920	0.16	175.1	0.23
1,000-1	0.01	7.9	0.01
Total	**0.44**	**489.2**	**0.65**

Notes:

1. Demand distribution within hydraulic model was based on equal distribution to all nodes within development, consistent with hydraulic analysis Shapell & Toll Brothers, Inc. Development, Yorba Linda Water System Calculations Addendum No. 1 (Hunsaker and Associates Irvine, Inc., 2005). Demand to each zone was based on percentage of demand in each zone in hydraulic junction report (since totals were slightly inconsistent).
2. Calculations within the study were completed for Peak Hour Demand conditions with a total Peak Hour Demand of 773.4 gpm; a seasonal peaking factor of 1.48 and a peak hour demand factor of 2.55 were assumed in order to calculate MDD and ADD based on the 2005 WMP.

Table 3 Future Demand Summary			
Component	**AAD (afy)**	**ADD (mgd)**	**MDD (mgd)**
Existing	24,357	21.7	32.2
Esperanza Hills Estates / Sage	542	0.5	0.7
Shapell & Toll Brothers, Inc. Development	489	0.4	0.7
Total	**25,388**	**22.6**	**33.6**

2.3 Projected Demands by Pressure Zone

As the capacity evaluation and sizing of pump stations and reservoir are dependent on the demand of each pressure zone, demands are presented by pressure zone in Table 4.

Table 4 Projected Demands by Pressure Zone

Pressure Zone	Reservoir	Existing Demand AAD (afy)	Existing Demand MDD (mgd)	Additional Development AAD (afy)	Additional Development MDD (mgd)	Total Demand AAD (afy)	Total Demand MDD (mgd)	Percentage of Existing Demand	Percentage of Total Demand
428	Highland	2,486	3.3			2,486	3.3	12%	12%
430		149	0.2			149	0.2	< 1%	< 1%
570	Lakeview	8,119	10.7			8,119	10.7	25%	24%
675	Valley View	1,413	1.9			1,413	1.9	6%	6%
675	Fairmont	3,119	4.1			3,119	4.1	18%	17%
680	Bryant Ranch	1,887	2.5			1,887	2.5	4%	4%
780-1	Gardenia	454	0.6			454	0.6	4%	4%
780-2		479	0.6			479	0.6	< 1%	< 1%
780-3	Springview	1,418	1.9	306	0.4	1,724	2.3	10%	10%
718		62	0.1			62	0.1	< 1%	< 1%
780-4	Elk Mountain	653	0.9			653	0.9	6%	6%
920	Quarterhorse	380	0.5	175	0.2	555	0.7	2%	2%
1,000-1	Little Canyon	881	1.2	550	0.7	1,430	1.9	5%	7%
1,000-2	Santiago	583	0.8			583	0.8	3%	3%
908		133	0.2			133	0.2	< 1%	< 1%
991		242	0.3			242	0.3	< 1%	< 1%
1,165	Camino de Bryant	452	0.6			452	0.6	3%	3%
1,160		128	0.2			128	0.2	< 1%	< 1%
1,300	Chino Hills	298	0.4			298	0.4	2%	2%
1,390	Hidden Hills	197	0.3			197	0.3	< 1%	< 1%
1,133		78	0.1			78	0.1	< 1%	< 1%
706		748	1.0			748	1.0	< 1%	< 1%
Total		**24,357**	**32.2**	**1,031**	**1.4**	**25,388**	**33.6**	**100%**	**100%**

As shown in Table 4, the 1,000 Zone is divided into Zone 1,000-1, served by Little Canyon Reservoir, and Zone 1,000-2, served by Santiago Reservoir. The zone is separated by an isolation valve, labeled on Figure 2 as SV-3. This valve needs to be closed to ensure proper cycling of Santiago Reservoir per discussions with the District's operations staff. If the pressure zone is operated as a single pressure zone, Santiago Reservoir fills such that cycling the reservoir becomes unfeasible.

While the demands shown in Table 4 are based on demands allocated in the hydraulic model, the percentages of demands used in this analysis are based on input from District operations staff, which was adjusted to account for the projected demands associated with future development. This demand distribution is deemed more reliable, as it eliminates the errors associated with geospatial allocation and scaling of billing data. As seen by comparing the existing percentage of demands by pressure zone to the total projected demand, Zone 1,000-1 is projected to increase from five percent of the total demand to seven percent, and increase for the pressure zone of about 40 percent. Note that the District is planning to implement some rezoning, affecting the boundary between Zones 920 and 1,000-1. By adjusting this boundary, the District will more fully utilize the excess storage in Quarterhorse Reservoir. Storage capacity will be discussed in Section 3.0.

3.0 STORAGE CRITERIA AND ANALYSIS

As a part of this study, the existing water system storage criteria as outlined in the District's 2005 WMP were reviewed and recommended for revision. Storage criteria are used in determining the required storage for the water system on a pressure zone basis and for the system as a whole. The criteria are used to compare existing storage volumes with the required volumes per the defined criteria to determine if the system has storage deficiencies that need to be address by constructing additional storage reservoirs or by sharing excess storage capacity between pressure zones. These criteria are also used to determine the storage needs for future developments seeking to connect to the District's distribution system.

3.1 Storage Components

Storage criteria are typically divided in to the following three components:

- Operational Storage
- Fire Flow Storage
- Emergency Storage

The typical factors used to size operational, fire flow, and emergency storage are described below.

Operational Storage

Operational storage is defined as the quantity of water that is required to balance daily fluctuations in demand and water production. It is necessary to coordinate water source

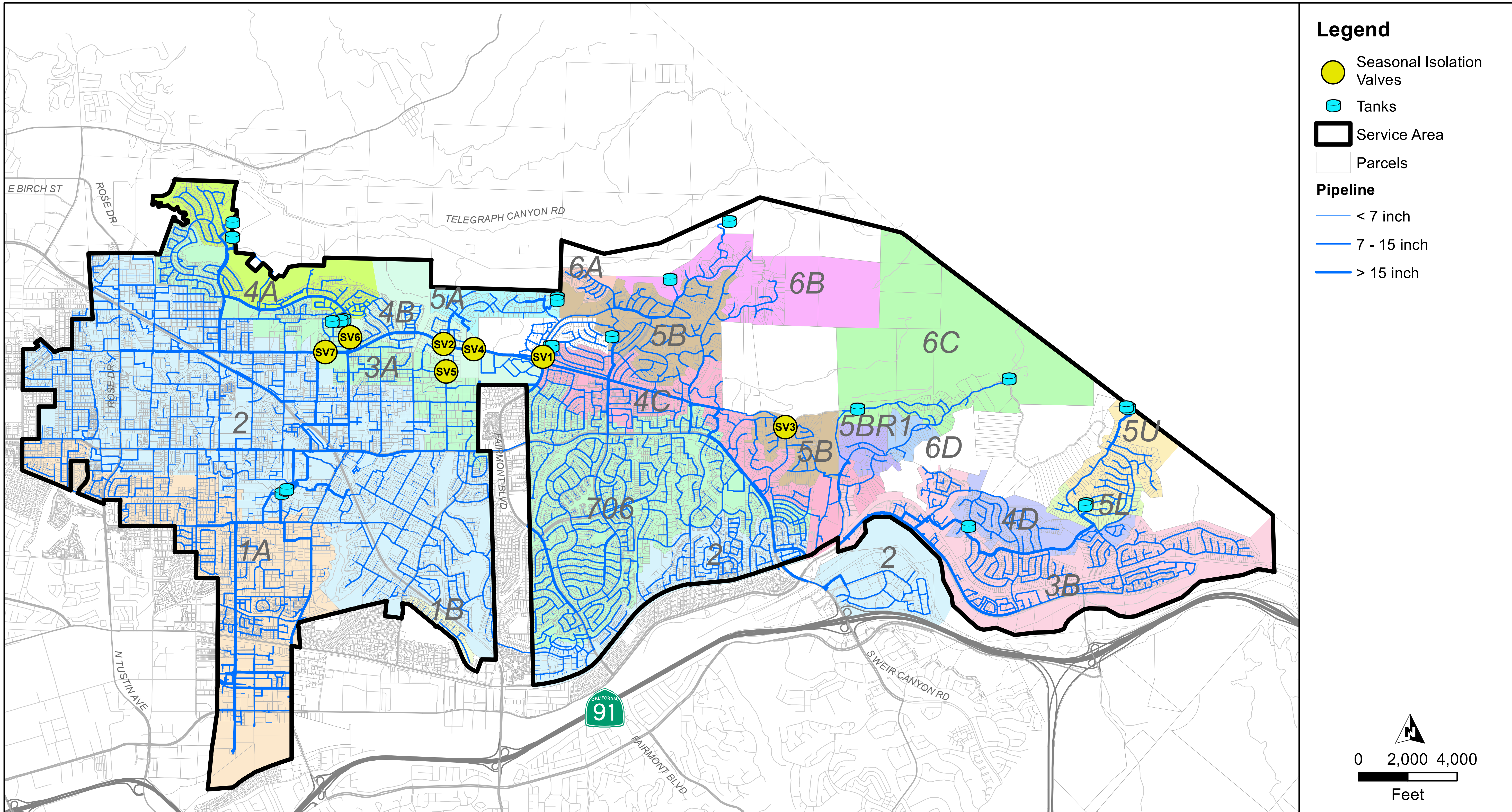

Figure 2
Seasonal Isolation Valves
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production rates and available storage capacity in a water system to provide a continuous treated water supply to the system. Water systems are often designed to supply the average of the MDD and use reservoir storage to supply water for peak hour flows that typically occur in mornings and late afternoons.

This operational storage is replenished during off-peak hours that typically occur during nighttime, when demand is less. The American Water Works Association (AWWA) recommends that operational storage be at least 25 percent of MDD (AWWA 1989).

Fire Flow Storage

Storage for fire flows is typically sized to be at least the volume equal to the maximum fire flow and its corresponding duration within each pressure zone (either directly or from a higher zone). This maximum fire flow is defined by land use category. For each zone, the land use category present with the highest fire flow requirement in each zone is selected and then multiplied with the corresponding duration to determine the minimum amount of designated fire flow storage in that particular zone. The District has historically assumed one fire per major pressure zone of its distribution system. The means, that subzones that are fed through pressure reducing valves (PRVs) from a major pressure zone will rely on the fire flow storage in that major pressure zone. In other words, only one fire per major pressure zone and associated subzones is assumed to take place at a particular time.

Emergency Storage

Storage is also required to meet system demands during emergencies. Emergencies cover a wide range of rare but probable events, such as water contamination, failure at water treatment plants (WTP), power outages, transmission pipeline ruptures, several simultaneous fires, and earthquakes. The volume of water that is needed during an emergency is usually based on the estimated amount of time expected to elapse before the disruptions caused by the emergency are corrected or additional supplies can be brought online. The occurrence and magnitude of emergencies is difficult to predict and therefore, emergency storage is typically set as a percentage of ADD or MDD rather than specifying an exact volume as a criteria.

3.2 Recommended Storage Criteria

The District has experienced water quality issues (i.e., loss of chlorine residual) related to high water age. The water quality concerns are particularly present in some of the pressure zones in the eastern part of the District’s service area where the water demand is very small compared to the available storage volume, resulting in high detention times.

To mitigate this issue, the District operates some of these reservoirs at lower levels and/or only utilizes one of two storage compartments, where reservoirs are divided into separate compartments. This strategy has resulted in a reduced usage of the reservoir capacity and prompted the question whether the storage criteria are too conservative to meet water quality objectives in the system.

For comparison, Carollo prepared a table of storage criteria used by other agencies and used in water master plans prepared by Carollo Engineers for other water utilities in Southern California. This comparison is summarized in Table 5.

Table 5 Storage Criteria for Various Southern California Purveyors

Agency	Supply Mix[1]	Operational Storage	Fireflow Storage[2] (MG)	Emergency Storage (MG)	Total Storage Requirement for YLWD[3]
City of Orange	GW + IW	30% MDD	3.7	100% MDD	49.5
City of Garden Grove	GW + IW	30% MDD	2.5	100% ADD	35.6
City of Upland	GW	30% MDD	2.9	100% MDD	49.5
City of Hesperia	GW	30% MDD	3.5	100% MDD	49.5
El Centro	IW	30% MDD	1.0	100% MDD	49.5
City of Pasadena	GW + IW	30% MDD	6.8	50% MDD	33.1
Victorville Water District	GW	25% MDD	8.0	50% MDD	31.4
YLWD	GW + IW	100% MDD	6.75	300-700% ADD	85.5
Existing Storage YLWD					**58.7**

Notes:
1. GW = Groundwater; IW = Imported Water
2. This is combined fire flow requirement for entire distribution system of the listed agency..
3. This is the total storage required if YLWD implements the same criteria as the listed agency using the operational and emergency storage criteria of the corresponding agency and 6.75 MG of fire flow storage (per the 2005 WMP).

As shown in Table 5, storage criteria varies from agency to agency but in general is substantially less than used by the District. Operational storage typically ranges from 25%-30% of MDD, compared to 100% of MDD used by the District. Emergency storage typically ranges from 50% to 100% of MDD. It should be noted that 50% of MDD is nearly typically (using a peaking factor of 1.7-2.0) the same as 100% of ADD.

Since the 2005 WMP, the District increased redundancy of its system supplies through upgrades to the distribution system and the purchase of three portable booster pumps and one portable electrical generator unit. In addition, Metropolitan Water District of Southern California (MWDSC) increased reliability of the Diemer WTP. Further, the District's groundwater supplies represent a point of redundancy to its water supply and storage system.

Based on this, it is recommended that the District revise its storage criteria to the same as the City of Orange, as the criteria are the most conservative of the listed agencies that has a similar water distribution system configuration (with multiple gravity pressure zones) and the same supply mix (both imported water and groundwater supplies). The ability to use groundwater wells to serve demands provides another form of (aquifer) storage and is therefore relevant for comparison. These recommended revised storage criteria compared to the District's 2005 WMP are therefore as follows:

- Operational Storage: 30 percent of MDD
- Fire Flow Storage: Consistent with criteria used in 2005 WMP, which was based on land use by pressure zone
- Emergency Storage: 100 percent of MDD.

3.3 Storage Evaluation

When the recommended storage criteria are adopted and applied, the District's total required storage volume would be approximately 49.5 MG, which is about 9.2 MG less than the District's existing volume of 56.7 MG as shown in Table 6.

Table 6 Storage Criteria

	Supply Mix[(1)]	Operational Storage	Fireflow Storage[(2)] (MG)	Emergency Storage (MG)	Total Storage Requirement for YLWD[(3)]
Previous Criteria	GW + IW	100% MDD	6.75	300-700% ADD	85.5
Updated Criteria	GW + IW	30% MDD	6.75	100% MDD	49.5
Existing Storage YLWD					**58.7**

Notes:
1. GW = Groundwater; IW = Imported Water
2. This is combined fire flow requirement for entire distribution system of the listed agency..
3. This is the total storage required if YLWD implements the same criteria as the listed agency using the operational and emergency storage criteria of the corresponding agency and 6.75 MG of fire flow storage (per the 2005 WMP).

While the total required storage volume of 49.5 MG is sufficient when the District's storage is considered a whole, storage capacity must be evaluated on a pressure zone by pressure zone basis, since storage must be available where it is needed. Table 7 and Table 8 present such an analysis for the existing and future systems, with reservoirs and pressure zones grouped based on whether storage would be available in an emergency. A figure showing this storage grouping is included in Appendix C.

Table 7	Existing Storage Analysis							
	Existing Demand				Reservoir Size			
Zone	AAD (afy)	MDD (mgd)	Operational (MG)	Emergency (MG)	Fire (MG)	Total (MG)	Existing (MG)	Balance (MG)
428	2,486	3.3	0.99	2.22	1.20	4.40	6.0	+1.6
Subtotal								***+1.6***
570	8,119	10.7	3.22	7.25	1.20	11.67	8.0	-3.7
430	149	0.2	0.06	0.13		0.19		-0.2
Subtotal								***-3.9***
675	4,532	6.0	1.80	4.05	0.45	6.29	9.5	+3.2
Subtotal								***+3.2***
780-1	454	0.6	0.18	0.41	0.18	0.77	2.0	+1.2
780-2	479	0.6	0.19	0.43		0.62		-0.6
Subtotal								***+0.6***
480-3	1,418	1.9	0.56	1.27	0.45	2.28	8.0	+5.7
706	748	1.0	0.30	0.67		0.96		-1.0
718	62	0.1	0.02	0.06		0.08		-0.1
Subtotal								***+4.7***
480-4	653	0.9	0.26	0.58		0.84	6.0	+5.2
680	1,887	2.5	0.75	1.68	1.20	3.63	2.3	-1.3
Subtotal								***+3.8***
920	380	0.5	0.15	0.34	0.18	0.67	7.3	+6.6
Subtotal								***+6.6***
1,000-1	1,463	1.9	0.58	1.31	0.18	2.07	2.0	-0.1
908	133	0.2	0.05	0.12		0.17		-0.2
Subtotal								***-0.3***
1,165	452	0.6	0.18	0.40	0.18	0.76	3.2	+2.4
991	242	0.3	0.10	0.22		0.31		-0.3
Subtotal								***+2.1***
1,300	298	0.4	0.12	0.27	0.18	0.56	0.5	-0.1
1,160	128	0.2	0.05	0.11		0.16		-0.2
Subtotal								***-0.2***
1,390	197	0.3	0.08	0.18	0.18	0.43	2.0	+1.6
1,133	78	0.1	0.03	0.07		0.10		-0.1
Subtotal								***+1.5***
Total	**24,357**	**32.2**	**9.7**	**21.7**	**5.6**	**37.0**	**56.7**	**+19.8**

Table 8 Future Storage Analysis												
	Existing Demand		Additional Development Demand		Total Demand		Reservoir Size					
Zone	AAD	MDD	AAD	MDD	AAD	MDD	Operational	Emergency	Fire	Total	Existing	Balance
	afy	mgd	afy	mgd	afy	mgd	MG	MG	MG	MG	MG	MG
428	2,486	3.3			2,486	3.3	0.99	2.22	1.20	4.40	6.0	+1.6
Subtotal												***+1.6***
570	8,119	10.7			8,119	10.7	3.22	7.25	1.20	11.67	8.0	-3.7
430	149	0.2			149	0.2	0.06	0.13		0.19		-0.2
Subtotal												***-3.9***
675	4,532	6.0			4,532	6.0	1.80	4.05	0.45	6.29	9.5	+3.2
Subtotal												***+3.2***
780-1	454	0.6			454	0.6	0.18	0.41	0.18	0.77	2.0	+1.2
780-2	479	0.6			479	0.6	0.19	0.43		0.62		-0.6
Subtotal												***+0.6***
480-3	1,418	1.9	306.3	0.4	1,724	2.3	0.56	1.27	0.45	2.28	8.0	+5.7
706	748	1.0			748	1.0	0.30	0.67		0.96		-1.0
718	62	0.1			62	0.1	0.02	0.06		0.08		-0.1
Subtotal												***+4.7***
480-4	653	0.9			653	0.9	0.26	0.58		0.84	6.0	+5.2
680	1,887	2.5			1,887	2.5	0.75	1.68	1.20	3.63	2.3	-1.3
Subtotal												***+3.8***
920	380	0.5	175.1	0.2	555	0.7	0.15	0.34	0.18	0.67	7.3	+6.6
Subtotal												***+6.6***
1,000-1	1,463	1.9	549.6	0.7	2,013	2.7	0.80	1.80	0.18	2.78	2.0	-0.8
908	133	0.2			133	0.2	0.05	0.12		0.17		-0.2
Subtotal												***-1.0***
1,165	452	0.6			452	0.6	0.18	0.40	0.18	0.76	3.2	+2.4
991	242	0.3			242	0.3	0.10	0.22		0.31		-0.3
Subtotal												***+2.1***
1,300	298	0.4			298	0.4	0.12	0.27	0.18	0.56	0.5	-0.1
1,160	128	0.2			128	0.2	0.05	0.11		0.16		-0.2
Subtotal												***-0.2***
1,390	197	0.3			197	0.3	0.08	0.18	0.18	0.43	2.0	+1.6
1,133	78	0.1			78	0.1	0.03	0.07		0.10		-0.1
Subtotal												***+1.5***
Total	**24,357**	**32.2**	**1,031.0**	**1.4**	**25,388**	**33.5**	**9.9**	**22.2**	**5.6**	**37.7**	**56.7**	**+19.1**

As shown in Table 7, the District's overall storage demand balance is positive with 19.8 MG more storage available than required. However, on a zone-by-zone basis, the storage balance shows a deficit for several pressure zone groups. This does not necessarily represent a deficiency, as in several cases, the storage deficits in lower zones can be accommodated through excess storage in upper zones. It should be noted that this storage analysis assumes full utilization of capacity of the reservoirs, a condition that is generally not present as most reservoirs are typically operated between 50 and 90 percent full.

For the future storage balance, the development demands for the Esperanza Hills Estates and Sage developments are assumed to be served from Zone 1,000-1. As shown in Table 8, the storage deficits for the zones described above are similar, with the exception of Zone 1,000-1, due to the new development demand. The storage balance deficit in this zone is predicted to be 1.0 MG, an increase of 0.8 MG over the existing 0.2 MG deficit.

There are three pressure zone groups that show a storage capacity deficit with the revised storage evaluation criteria, prior to adjustment for water transfer opportunities between pressure zone groups. These "deficiencies" can be resolved as follows:

570 Zone (with Subzone 430) – Lakeview Reservoir

While Lakeview Reservoir is only 8.0 MG, required storage for this pressure zone group is 11.86 MG based on the updated criteria. Excess storage in Springview, Fairmont, and Gardenia Reservoirs totals 8.5 MG, and can count for storage in Zone 570 given the number of pressure reducing stations connecting these zones. District operations staff have noted that, due to the potential for supply interruptions associated with MWD supplies, Springview Reservoir may need to be upgraded. Lakeview Reservoir is expandable, with the site accommodating a total of 12.0 MG.

Zone 1,300 (with Subzone 1,160) – Chino Hills Reservoir

The storage balance for Zone 1,300 shows a deficit of 0.2 MG. The Timber Ridge BPS does include an engine driven pump, which could allow use of water from Little Canyon Reservoir during power outages. However, the storage balance for Zone 1,000-1 also shows a deficit, which can be addressed as described below.

Zone 1,000-1 and Zone 1,000-2 – Little Canyon and Santiago Reservoirs

When considered as a whole, the storage balance for Zone 1,000-1 shows a deficit of 0.3 MG. The excess storage capacity in Hidden Hills Reservoir could be used for Zone 1,000-2, but currently there is no pressure reducing station from Zone 1,390 to Zone 1,000-2 to allow flow in this direction (such a pressure reducing station could be sited at Santiago BPS). Currently, only one of the two bays of Hidden Hills Reservoir is used, with the other bay being inactive. The District experiences water quality issues associated with the long residence times when the full capacity of Hidden Hills Reservoir is used.

3.4 Storage Recommendations for Development

Given the elevation differences of the proposed development parcels, the appropriate pressure zone hydraulic grade lines (HGLs) consistent with the YLWD zones are 1,200 ft-msl and 1,390 ft-msl. For redundancy, each proposed pressure zone will need to include at least a small storage tank to provide fire flow storage considering the risk of fires in the area. Based on the revised storage criteria and the projected development demands, the required storage for the new development is 1.3 MG as shown in Table 9.

Table 9 Required Storage for New Development

Zone	MDD (mgd)	Operational Storage (MG)	Fireflow Storage(2) (MG)	Emergency Storage (MG)	Total Storage Required (MG)
1,200	-	-	0.18	-	-
1,390	-	-	0.18	-	-
Total	**0.72**	**0.22**	**0.36**	**0.72**	**1.3**

Notes:

1. Breakdown of demand between zones is not known at this time; however, it is anticipated that each zone will require fire flow storage of 0.18 MG unless greater fire flow requirements are established by the Orange County Fire Authority, corresponding to an assumed 1,500 gpm fire flow requirement over a 2 hour period.

Two potential configurations for storage were investigated

- Construction of all new storage tanks for the development storage requirement; and
- Utilization of some of the excess storage capacity in Hidden Hills Reservoir

Following the investigation of these two alternatives, it was concluded that the dedicated storage for the new developments would be preferred due to reliability, water quality concerns, and reduced energy usage.

3.4.1 Alternative 1: Dedicated Storage for New Development

The initial configuration of infrastructure associated with the new developments would consist of entirely new storage and pumping facilities. Figure 3 depicts a hydraulic schematic of this configuration.

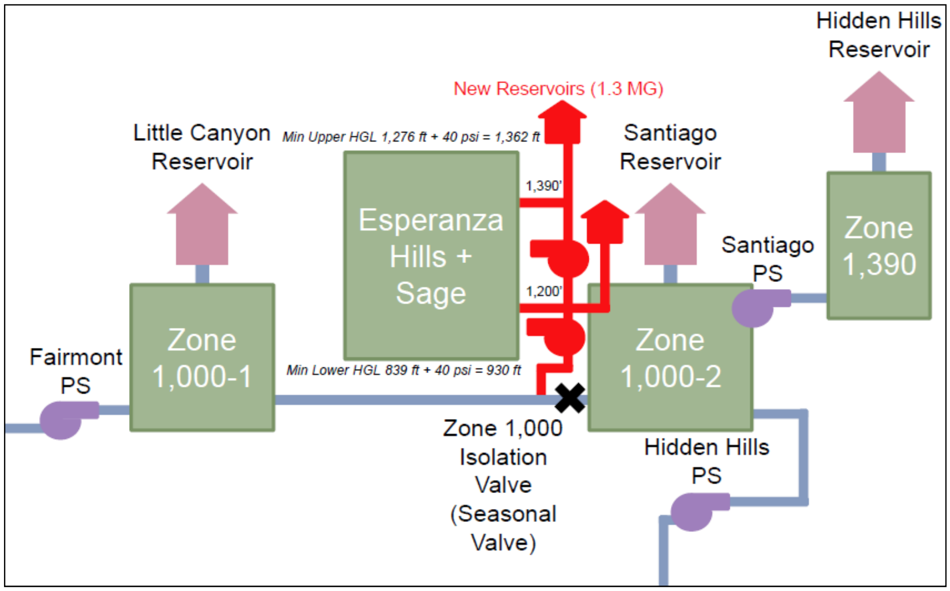


Figure 3 On-Site Storage Siting

As shown in Figure 3, the development is anticipated to take supply from Zone 1,000-1, served by Little Canyon Reservoir and fed by Fairmont PS. This configuration would require a pump station to supply the upper zone of the new development, while the lower zone could be supplied by the HGL of Little Canyon Reservoir. The elevation of the lower reservoir will need to account for headloss across the western portion of Zone 1,000-1.

Infrastructure required for this alternative includes:

- Two pump stations within development, one for each pressure zone
- Two tanks with a combined capacity of 1.3 MG (sizing depends on distribution of demands between zones)
- Pressure reducing station (if upper tank is sized to meet some demands in lower zone)
- In-tract development pipelines
- Increase to firm capacity of Fairmont PS (see Section 4.5.1)
- Additional offsite improvements including additional well capacity and pipeline upgrades (including zone reconfiguration improvements), to be determined by District staff.

3.4.2 Alternative 2: Utilization of Hidden Hills Reservoir Excess Storage

As previously discussed, this is not a viable option. While this alternative could potentially reduce the amount of storage within the development, the pipeline from Zone 1,390 represents a single point of failure that could leave the development without water supplies.

However, since emergency storage is not cycled, placing additional emergency storage in Hidden Hills will reduce cycling, exacerbating the existing water quality issues. In addition, pumping water through Santiago PS to an HGL of 1,390 ft-msl, and serving the 1,200 zone through a pressure reducing valve represents an ongoing energy loss. Based on these reasons, it is recommended that all storage be placed at the development site (Alternative 1).

3.4.3 Additional Esperanza Hills and Sage Requirements

In addition to new storage and conveyance infrastructure required to connect the new developments with the District's distribution system, additional offsite improvements are required. This includes additional groundwater well capacity and other distribution pipeline upgrades that will be determined by District staff.

4.0 PUMP STATION CRITERIA AND ANALYSIS

Since the District operates its distribution system under varying supply conditions, it is necessary that the District's distribution system can handle several different operational scenarios. Based on discussions with District staff, several operational supply scenarios were identified and the required capacity of the relevant pump stations were developed under each scenario.

4.1 Pump Station Sizing Criteria

Pump stations serving zones with gravity storage are typically sized such that the station can meet the zone MDD with the largest pump out of service. This allows the station to meet the average hourly demands, while peak demands are supplied from storage. Reservoir storage is then replenished in low demand hours. However, when a pump station operates on a time-of-use (TOU) schedule, the pump station needs to meet the zone MDD and replenish storage in less than 24 hours. TOU operations therefore also affect pump station capacity requirements.

The District currently operates the following pump stations on TOU:

- Hidden Hills PS
- Elk Mountain PS
- Springview PS
- Box Canyon PS

Time of use electricity rates incentivize reduced electricity usage during peak demand periods by slightly decreasing the rate of electricity during non-peak hours in exchange for a higher rate of electricity during peak hours. For this analysis, it is assumed the District's time of use peak hours are noon to 5 pm (SCE rate schedule TOU-PA-B), and that the District targets utilization of pump units during off-peak or super-off-peak hours where possible (11 pm to 8 am for SCE rate schedules TOU-PA-5, TOU-PA-B, TOU-PA-A, and 12 am to 6 am for TOU-PA-SOP).

Assuming that a pump station on this TOU schedule could not operate 6 hours a day (5 hours of peak rates with a 1-hour buffer), the pump station would need to be able to pump the entire MDD in 18 hours. Pump stations on a TOU schedule therefore need to be sized for 133% of MDD (24/18).

As a detailed energy cost analysis was beyond the scope of this study, it was assumed that PS sizing for operating under only off-peak hours (9 hours per day) or super-off-peak hours (6 hours per day) was not cost effective as this would result in significant stranded capacity during non-summer months while only providing marginal energy rate cost savings during a few summer months per year.

4.2 Pipeline Sizing Criteria

Where necessary, a pipeline velocity criteria of 7 fps was used to evaluate the capacity of existing pipelines and transmission mains per input from District staff. Where exceeded, headloss for the relevant pump station will be discussed.

4.3 Existing Pump Station Capacities

Each of the District's existing pump stations are listed in Table 10 with estimated total and firm capacities. The total capacity is based on the District's operations staff estimates of the amount of flow the pump station is able to handle, while the firm capacity is based on the sum of individual design capacities of the pump units (excluding the largest unit).

It should be noted that the Yorba Linda Boulevard Pump Station, listed in Table 10, is currently under construction, and anticipated to be online in early 2014.

Table 10 Existing Pump Station Capacity					
Pump Station	**Upstream Pressure Zone**	**Downstream Pressure Zone**	**Number of Units**	**Total Capacity(1) (gpm)**	**Firm Capacity(2) (gpm)**
Highland	428	570	5	18,000	13,500
Lakeview	570	675	4	5,000	3,400
Elk Mountain	780-4	1,165	3	2,500	1,200
Valley View	675	780-1	3	2,400	1,800
Yorba Linda	570	675	3	4,500	3,950
Springview	780-3	1,000-1	3	1,000	685
Hidden Hills	780-3	1,000-2	4	2,100	1,400
Paso Fino	OC89 / 780-2	920	3	2,400	1,700
Timber Ridge	1,000-1	1,300	4	1,700	645
Box Canyon	780-3	780-4	2	4,000	2,000
Santiago	1,000-2	1,390	3	1,300	800
Fairmont	675/780-3	780-3/1,000-1	2	2,100	1,500

Notes:
1. Total capacity (based on operations spreadsheet and hydraulic model)
2. With largest unit out of service.

4.4 Operating Conditions Based on Supply Mix Percentages

As the District adjusts its supply source mix (groundwater and imported water) seasonally, the District's transmission system must provide sufficient capability to accommodate a wide range of different supply conditions. Because of the water quality issues related to breakpoint chlorination, the District maintains supply separation between groundwater and imported water. Thus, the District adjusts to supply percentages by converting pressure zones from imported water to groundwater and vise-versa.

Based on discussions with District staff, target percentages of groundwater versus imported water were developed to determine the likely conditions for which the pump stations should be sized. Table 11 presents an overview of twelve different supply conditions, while a detailed list of the supply source mix by each pressure zone is listed in and graphically presented in Appendix B. It should be noted that the extreme supply mix conditions, such as 100 percent imported water or groundwater, should be considered emergency conditions because these are uncommon.

Table 11	Operating Conditions based on Supply Mix Percentages	
Operating Condition	**Percentage Imported Water**	**Percentage Groundwater**
Fully Imported Water	100%	0%
0	88%	12%
1	64%	36%
2	59%	41%
3	55%	45%
4	52%	48%
5	48%	52%
6	30%	70%
7	26%	74%
8	16%	84%
9	7%	93%
Fully Groundwater	0%	100%

As shown in Table 11, when moving down the table to conditions of greater supply from groundwater, less precision is available in selecting operating conditions (e.g., increasing to a groundwater condition above 74% requires moving all the way to 84%).

Historically, the District has worked around this difficulty by drastically changing supplies seasonally to higher percentages, and maintaining lower percentages of groundwater to make up the difference during the balance of the year. Figure 4 illustrates the District's supply percentage of groundwater over the past four years.

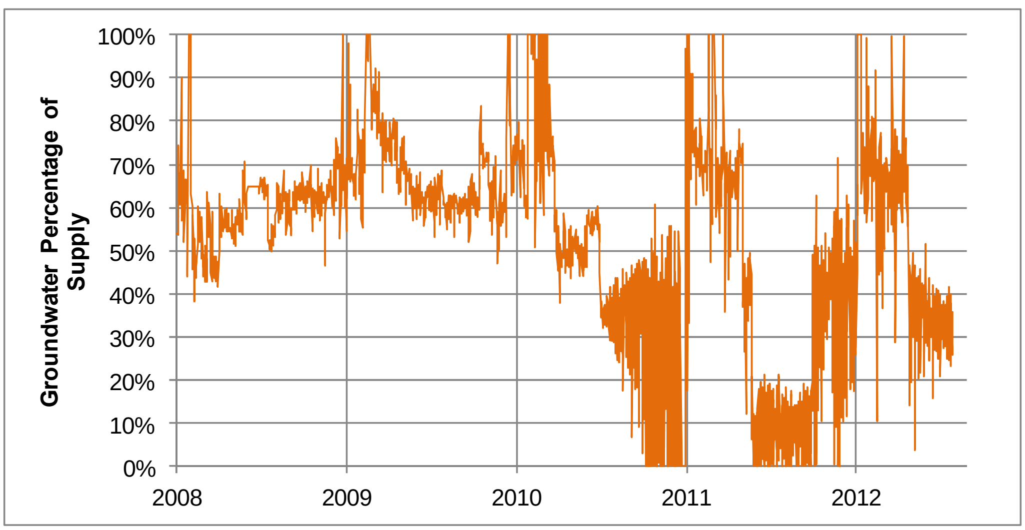


Figure 4 Percentage Groundwater of Total Supply

Table 12 Pressure Zone Supply by Operating Condition															
Zone	**MDD** mgd	**Reservoir**	**Fully IW**	**Condition 0**	**Condition 1**	**Condition 2**	**Condition 3**	**Condition 4**	**Condition 5**	**Condition 6**	**Condition 7**	**Condition 8**	**Condition 9**	**Fully GW**	**Percentage of System Demand**
428	3.3	Highland	IW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	12%
430	0.2		IW	IW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	< 1%
570	10.7	Lakeview	IW	IW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	24%
675	1.9	Valley View	IW	IW	IW	GW	GW	GW	GW	GW	GW	GW	GW	GW	6%
675	4.1	Fairmont	IW	IW	IW	IW	IW	IW	GW	GW	GW	GW	GW	GW	17%
680	2.5	Bryant Ranch	IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	4%
780-1	0.6	Gardenia	IW	IW	IW	IW	GW	GW	IW	IW	GW	IW	IW	GW	4%
780-2	0.6		IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	IW	GW	< 1%
780-3	2.3	Springview	IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	10%
718	0.1		IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	< 1%
780-4	0.9	Elk Mountain	IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	6%
920	0.7	Quarterhorse	IW	IW	IW	IW	IW	GW	IW	GW	GW	IW	IW	GW	2%
1,000-1	1.9	Little Canyon	IW	IW	IW	IW	IW	IW	IW	GW	GW	IW	GW	GW	7%
1,000-2	0.8	Santiago	IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	3%
908	0.2		IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	< 1%
991	0.3		IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	< 1%
1,165	0.6	Camino de Bryant	IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	3%
1,160	0.2		IW	IW	IW	IW	IW	IW	IW	GW	GW	IW	GW	GW	< 1%
1,300	0.4	Chino Hills	IW	IW	IW	IW	IW	IW	IW	GW	GW	IW	GW	GW	2%
1,390	0.3	Hidden Hills	IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	< 1%
1,133	0.1		IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	< 1%
706	1.0		IW	IW	IW	IW	IW	IW	IW	IW	IW	GW	GW	GW	< 1%
Total	**33.5**														**100%**
Percentage Imported Water			**100%**	**88%**	**64%**	**59%**	**55%**	**52%**	**42%**	**30%**	**26%**	**16%**	**7%**	**0%**	
Percentage Groundwater			**0%**	**12%**	**36%**	**41%**	**45%**	**48%**	**58%**	**70%**	**74%**	**84%**	**93%**	**100%**	

Notes:
IW = Imported Water
GW = Groundwater

It is anticipated that this problem will become worse in the future given the increased percentage of groundwater the District will be able to pump after annexation. In addition, several of the zones for which supply is being changed in the higher percentage groundwater conditions will be increasing in size given the developments discussed in Section 2.2. Recommendations to reduce the loss of residual decay will be discussed in Section 6.4.

4.5 Pump Station Sizing

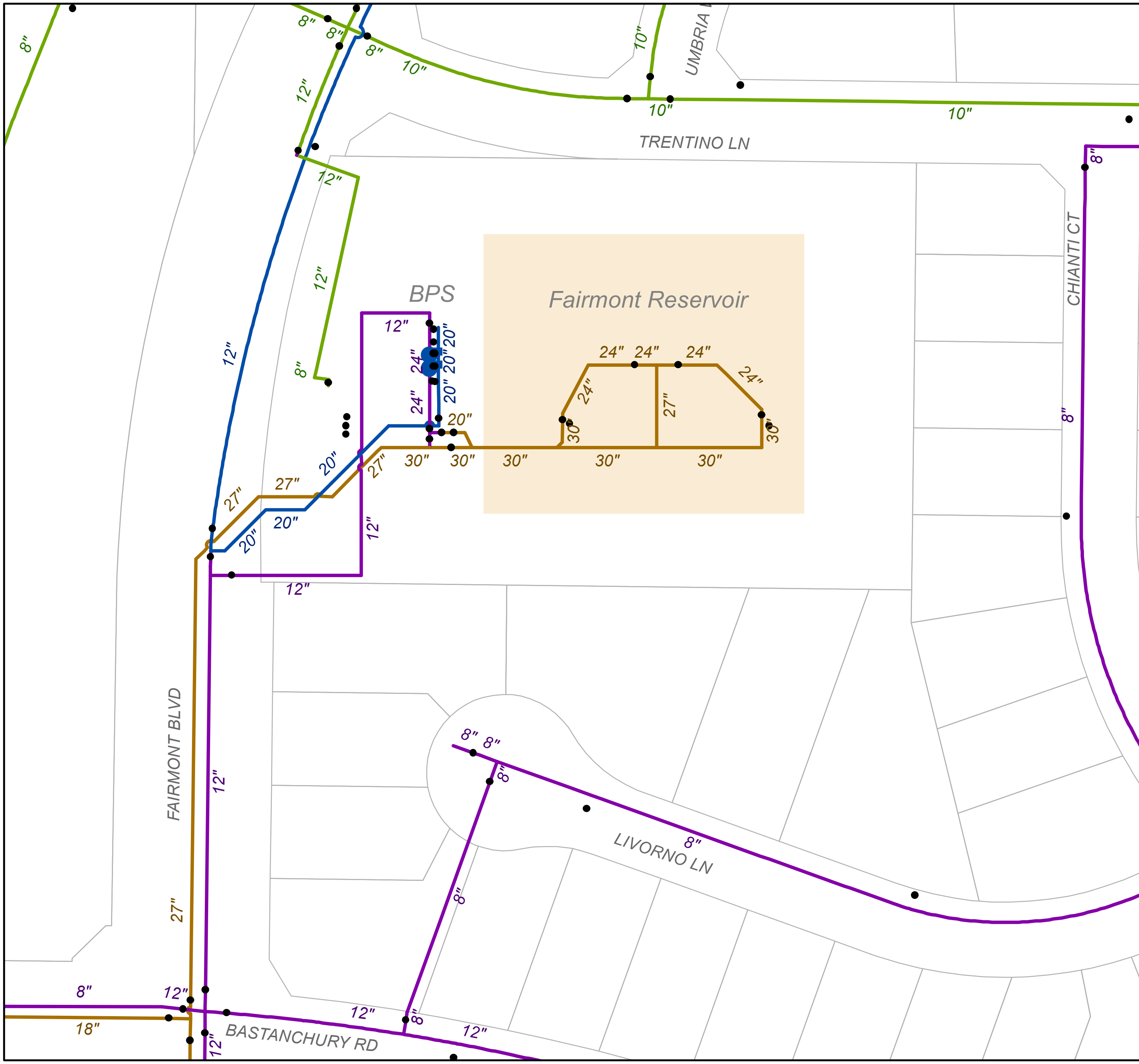
Based on the locations of the developments identified in Section 2.2, the Hidden Hills and Fairmont Pump Stations were identified for this project's scope of work as the primary pump stations that will be affected by the new development. Sizing of these pump stations under future demand conditions for various supply mix operating conditions are discussed in detail below. For this analysis, pump station capacity of upstream pump stations (located in lower pressure zones) were not evaluated, but increasing capacity of those pump stations may be necessary to achieve the targeted supply mix percentages.

4.5.1 Fairmont Pump Station

Currently, the FPS supplies Zone 1,000-1 from Zone 780-3. Figure 6 shows the layout of the Fairmont Reservoir and Pump Station site.

With manual reconfiguration of some isolation valves, the FPS can instead supply groundwater to Zone 780-3 from Zone 675. The large demand associated with Zone 780-3 and the limited capacity of the FPS limit the usefulness of this operating scenario. The District does maintain a portable engine driven pump at FPS to increase capacity under this operating scenario.

As described earlier, being able to switch supply sources for Zone 1,000-1 to groundwater would be useful to District operating staff for adjusting supply percentages. FPS is uniquely located within the District's distribution system to maximize this operational flexibility. Table 13 identifies the various pump station sizing groups required for FPS under the various operating conditions. It should be noted that the demands on the pump station were increased by 33 percent to account for the additional capacity requirements under TOU operations as discussed in Section 4.1.



Legend

- System Valves
- Pump Stations

Pipelines by Pressure Zone

- 675
- 780-1
- 920
- 1,000-1
- Fairmont Reservoir
- Parcels

0 50 100 Feet

Figure 5
Fairmont BPS Site Layout
March 2013
Northeast Area Planning Study
Yorba Linda Water District

carollo Engineers...Working Wonders With Water®

Table 13 Fairmont Pump Station Sizing

Condition	Supply Mix: Groundwater	Supply Mix: Imported Water	FPS Configuration: From Zone	FPS Configuration: To Zone	Demand on FPS: ADD (gpm)	Demand on FPS: MDD (gpm)	Demand on FPS: MinDD (gpm)	Recommended Sizing w/ PS Sizing Factor[1] (gpm)	Total Dynamic Head (ft)
1	36%	64%	780-3	1,000-1	1,420	2,102	653	2,795	330
2	41%	59%	780-3	1,000-1	1,420	2,102	653	2,795	330
3	45%	55%	780-3	1,000-1	1,420	2,102	653	2,795	330
4	48%	52%	780-3	1,000-1	1,420	2,102	653	2,795	330
5	52%	48%	780-3	1,000-1	1,420	2,102	653	2,795	330
6	70%	30%	675	*920/1,000-1*	*1,810*	*2,679*	*833*		
			675	920	390	577	179	768	237
			675	1,000-1	1,420	2,102	653	2,795	388
7	74%	26%	675	*920/1,000-1*	*1,810*	*2,679*	*833*		
			675	920	390	577	179	768	237
			675	1,000-1	1,420	2,102	653	2,795	388
8	84%	16%	675	780-3	4,131	6,114	1,900	5,495	120
9	93%	7%	675	*780-3/1,000-1*	*5,551*	*8,216*	*2,554*		
			675	780-3	4,131	6,114	1,900	5,495	120
			675	1,000-1	1,420	2,102	653	1,889	388

Note:

1. Includes factor to account for time-of-use operation (assuming 18 hours per day). Sized for MDD for Conditions 1 through 7 and ADD for Conditions 8 and 9.

As shown in Table 13, FPS would be operated similarly under Conditions 1 through 5, supplying imported water from Zone 780-3 to the west portion of Zone 1,000-1.

Conditions 6 and 7 are also identical for FPS, with the pump station supplying groundwater from Zone 675 to both Zone 1,000-1 and Zone 920.

Conditions 8 and 9 supply Zone 780-3 and the eastern portion of the District's service area with groundwater from Zone 675. In Condition 9, FPS also must supply the west half of Zone 1,000-1 with groundwater from Zone 675. (For FPS, Condition 9 is identical to operating fully with groundwater).

The governing flow and head conditions for the various operating conditions for FPS are depicted on Figure 6.

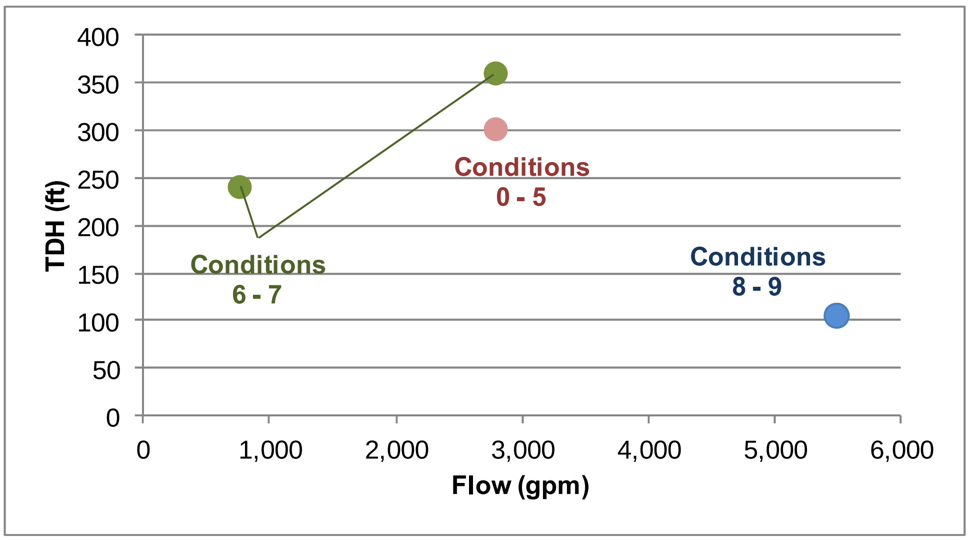


Figure 6 Fairmont PS Sizing

Based on the design points in Figure 6, it is recommended that the pump station include seven (7) pumps:

- A single pump unit to serve Zone 920 from Zone 675
- Two pump units to serve Zone 1,000-1 from Zone 675 or Zone 780-3 (1+1 PS configuration)
- Three pump units to serve Zone 780-3 from Zone 675 (2+1 PS configuration)
- A single pump unit to serve Zone 1,000-1 from Zone 920 (not included in operating conditions, but could be used to supply imported water from Zone 920 to Zone 1,000-1)

As listed, the pump station design points for serving Zone 1,000-1 from Zone 675 (under Conditions 6 and 7) and the design point for serving Zone 1,000-1 from Zone 780-3 (under

Conditions 1 through 5) are close enough to use the same set of pumps designed for the higher point, with a VFD reducing the head for the lower operating point. Given the range of flows needed for demand conditions other than MDD, it is recommended to use VFDs for all pump units for maximum operating flexibility.

Based on discussions with District operations staff, it is noted that the District does not currently utilize VFDs in the pump stations (to reduce operational complexity). The pump station could also be implemented without VFDs, with the addition of one unit (eight units instead of seven units). Separate units would need to be included for supplying Zone 1,000-1 under Conditions 0 through 5 and Condition 6.

Given the ability of Zone 920 to take imported water as a supply, it is recommended to only place a single unit (no standby) for the pump serving Zone 920. This backup supply would allow the District to serve all demands in Zone 920 with imported water in case of a pump failure or power outage, rather than providing additional backup capacity for this emergency at the FPS. It is not suggested to blend the two sources under typical operating conditions if possible, to avoid mixing of different disinfectant agents that can aversely affect water quality. Given the design head and flow, it may be possible to design the pump station to operate the standby unit for the second set of pumps as an emergency backup to the first unit.

Similarly, a single pump unit is included for supply of Zone 1,000-1 from Zone 920. While not addressed by any of the identified operating conditions, supply the MDD + TOU demand for Zone 1,000-1 of 2,795 gpm from Zone 920 is predicted to require a design head of 211 feet. If the pipeline downstream of this pump unit is increased in size (as will be discussed later), design head of 167 feet is predicted to be sufficient. It should be noted that the upstream Zone 920 pipeline is predicted to flow at a velocity of about 8 fps under this condition. If this configuration was used on a regular basis, increasing the diameter of the upstream pipeline could result in energy savings to the District over the long term.

It is recommended that the District include a natural gas powered backup generator at FPS. The existing pump station includes engine-driven pumps, which could operate during an electricity outage; the new pump station should also include this capability.

In addition, District operations staff indicated that capability for supplying lower pressure zones from upper pressure zones would increase operational flexibility. Thus, it is recommended that the pump station include pressure reducing valves to supply Zone 675 from Zone 780-3 and supply Zone 920 from Zone 1,000-1. These improvements should be coordinated with existing and planned off-site pressure reducing stations to most efficiently provide these flows given existing pipeline capacities.

The operation of the pump station for the various operating conditions are depicted in the following figures, with the active components of the pump station for the given operating conditions indicated in red (Figures 7 through 10).

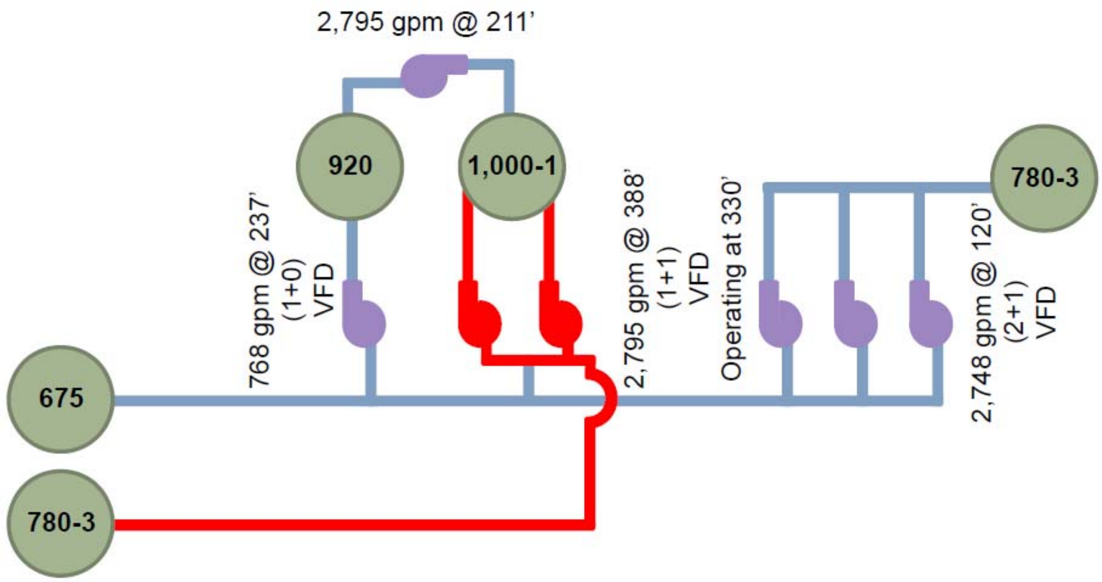


Figure 7 Fairmont PS Conditions 1 through 5 (Zone 780-3 to 1,000-1)

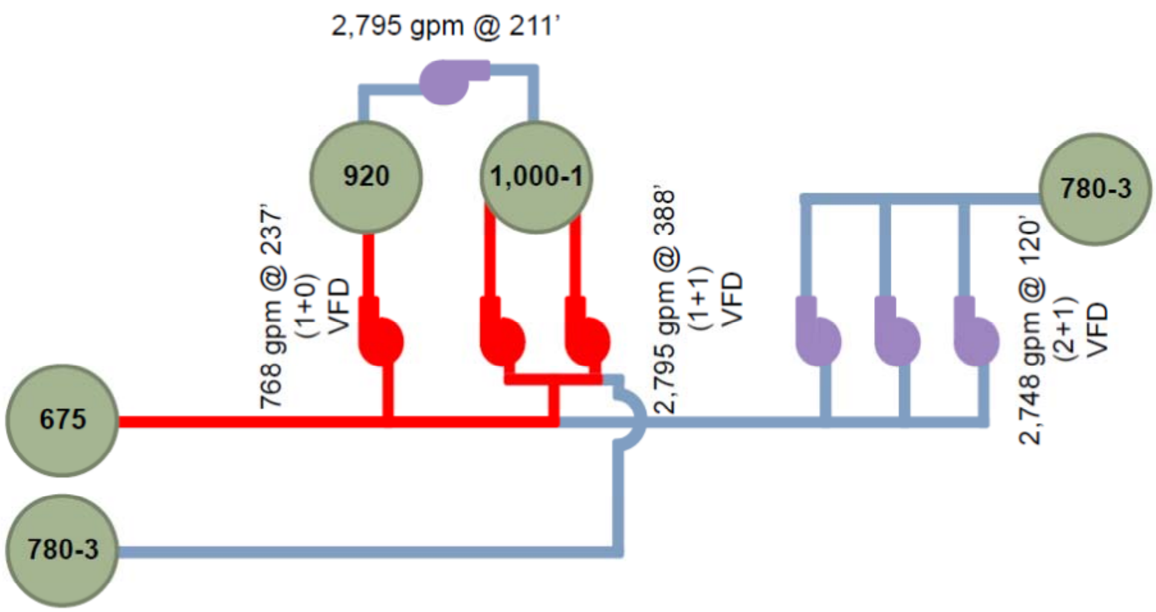


Figure 8 Fairmont PS Conditions 6 and 7 (Zone 675 to 920/1,000-1)

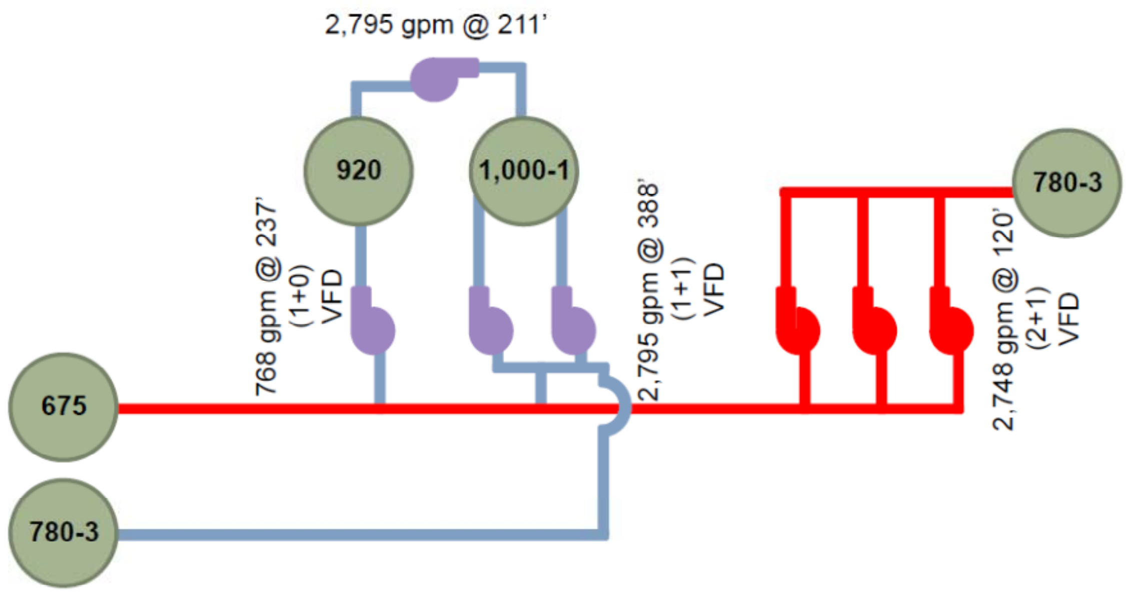


Figure 9 Fairmont PS Condition 8 (Zone 675 to 780-3)

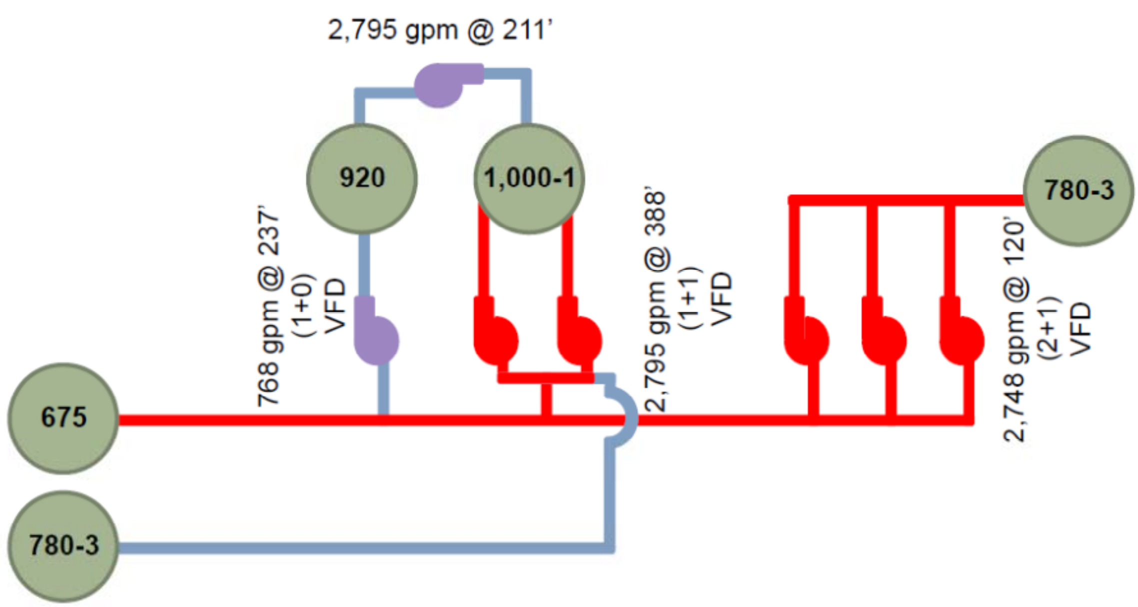


Figure 10 Fairmont PS Condition 9 (Zone 675 to 780-3/1,000-1)

Operation under Conditions 1, 6, and 9 were verified in the hydraulic model to check that tank cycling would occur regularly. Pipeline sizes of 16-inches diameter were assumed for the Zone 1,000-1 pump units, with roughness coefficients of 130. Development demands were assumed to use a unit diurnal pattern.

In addition to the identified pump station improvements, pipelines in the vicinity of FPS with velocities exceeding the sizing criteria of 7 fps were identified as potential hydraulic bottlenecks. These pipelines are as follows and shown on Figure 11:

- The existing 12-inch diameter Zone 1,000-1 pipeline installed in 1986 extending 3,500 feet along Fairmont Boulevard between FPS and Forest Avenue is predicted to experience velocities of about 7.6 fps under future system conditions (Conditions 1 – 5, 6, 7, and 9). If this segment of pipeline is upgraded to a 16-inch diameter pipeline, the pump station head could be reduced from approximately 388 feet to 364 feet. In addition, it is predicted that the design head of the seventh pump unit could be reduced in head from 211 feet to 167 feet. Based on discussions with District staff, given the age of the pipeline, paralleling with a 16-inch diameter pipeline and abandoning in the future may be a preferred phasing approach.

- The 12-inch diameter Zone 780-3 pipeline extending 670 feet along Fairmont Boulevard from Bastanchury Road onto the District's FPS site is predicted to experience velocities of about 8.2 fps under future system conditions (Conditions 1 – 5). Adding a dedicated pipeline north of the Bryant Cross Feeder to the FPS site would require about 800 feet of 24-inch diameter pipeline.

4.5.2 Hidden Hills and Santiago Pump Stations

If the new Esperanza Hills/Sage development is supplied from Zone 1,000-1, Hidden Hills and Santiago pump stations would not experience any increased demands. Both pump stations would operate under existing conditions for all operating conditions. However, if the Esperanza Hills Estates development connects to Zone 1,390 to utilize storage capacity in Hidden Hills Reservoir as described in Section 3.4.2, the capacity of each pump station needs to be increased. However, the demands would be consistent under all operating conditions. shows the capacity analysis with the development demands.

Table 14 Hidden Hills and Santiago PS Sizing

Pump Station	Pressure Zone	Existing MDD (gpm)	Development MDD (gpm)	Additional TOU Demand (gpm)	Total Demand (gpm)	Existing Firm Capacity (gpm)	Additional Firm Capacity Needed (gpm)
Hidden Hills PS	1,000-2 (Santiago), 908, 1,390, 1,133	909	500	465	1,874	1,400	474
Santiago PS	1,390, 1,133	252	500	417	1,169	800	369

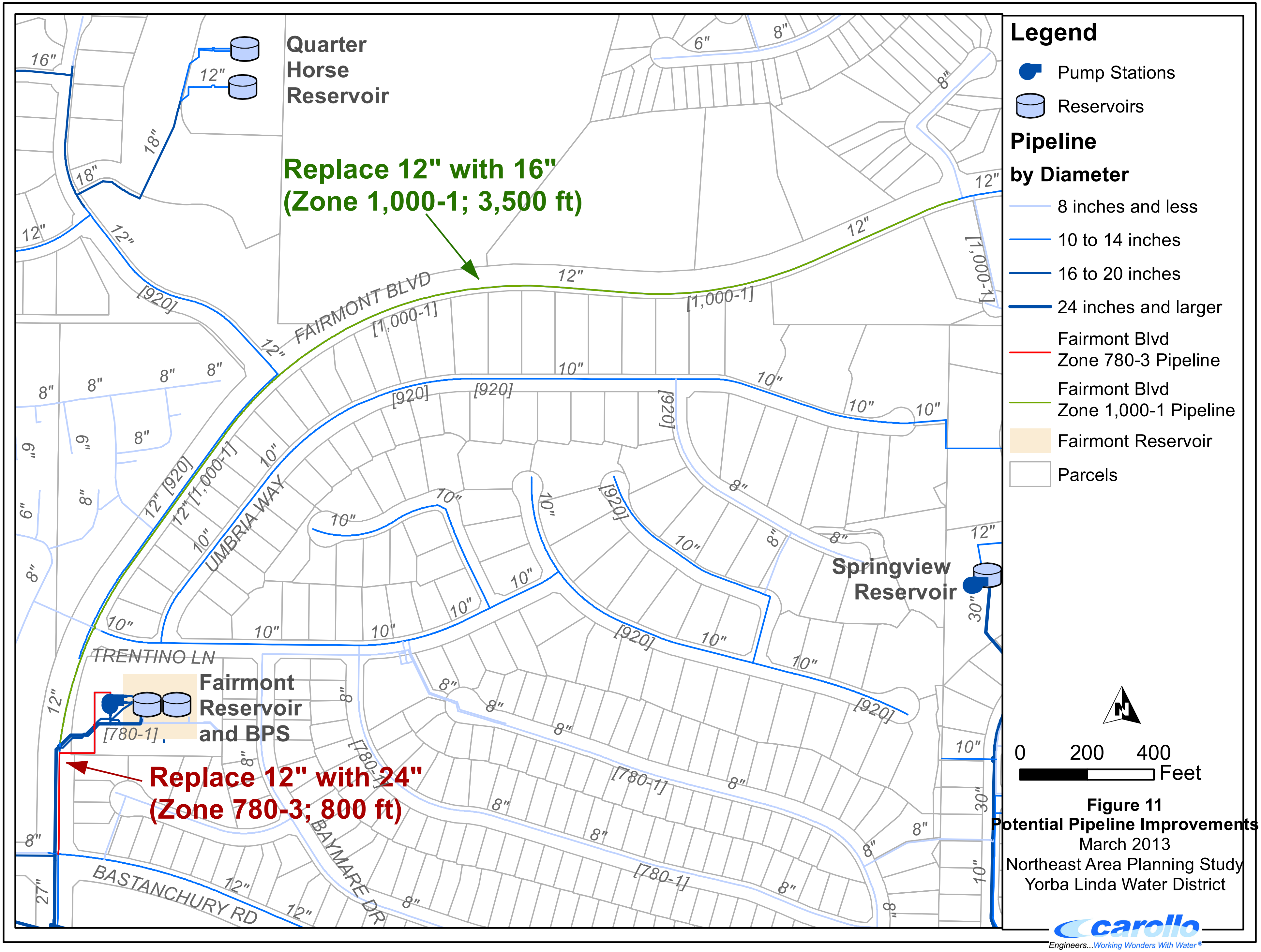


Figure 11
Potential Pipeline Improvements
March 2013
Northeast Area Planning Study
Yorba Linda Water District

As shown in Table 14, the firm capacity of the existing pump stations would be insufficient to meet MDD and the additional TOU demand after connection of the new development. The Hidden Hills PS would require a 500-gpm increase in firm capacity, while the Santiago PS would require a 400-gpm increase in firm capacity.

The current sizing of each pump station and the recommended additional units (shown in bold) are shown in Table 15.

Table 15 Existing Pump Station Hydraulics

Pump Station	Unit	Type	Size (hp)	Design Flow (gpm)	Design Head (ft)
Hidden Hills PS					
	1(1)	Electric	20	600	200
	2	Electric	40	650	290
	3	Electric	40	650	290
	4(1)	Electric	40	650	290
	new	**Electric**	**40**	**650**	**290**
Santiago PS					
	1	Electric	75	300	450
	2	Electric	25	100	425
	3	Electric	100	500	430
	4	Engine	240	1,520	385
	new	**Electric**	**100**	**500**	**430**

Note:

1. Manufacturer pump curves note that Units 2, 3, and 4 have a design point of 650 gpm at 290 feet of head. 2005 WMP describes Unit 4 as 20 hp, with 200 gpm capacity, with Units 1, 2, and 3 having a capacity of 400 gpm. Within hydraulic model, curves for Units 1, 2, and 3 are similar, with Unit 4 providing a much lower head. To maintain consistency with the manufacturer curve sheets, Units 2, 3, and 4 are assumed identical here, with Unit 1 being the lower flow pump.

As shown, it is recommended that an additional unit be added to both pump stations (identical to Unit 3 in each case).

5.0 HYDRAULIC MODELING

As a part of this study, the District's hydraulic model was updated and calibrated for fireflow, extended period simulation (EPS) capabilities, and water quality conditions. A screenshot of the updated hydraulic model is shown on Figure 12. Details on the hydraulic model user's manual and calibration process are included in Appendix D and E, respectively.

Water quality analysis was conducted using the multi-species extension (MSX) capabilities included in InfoWater MSX, as described in Appendix E.

In addition, the various operating conditions discussed in Section 4.4 were modeled within the hydraulic model. In addition, the improvement pipelines discussed in Section 4.2, were sized using the updated hydraulic model.

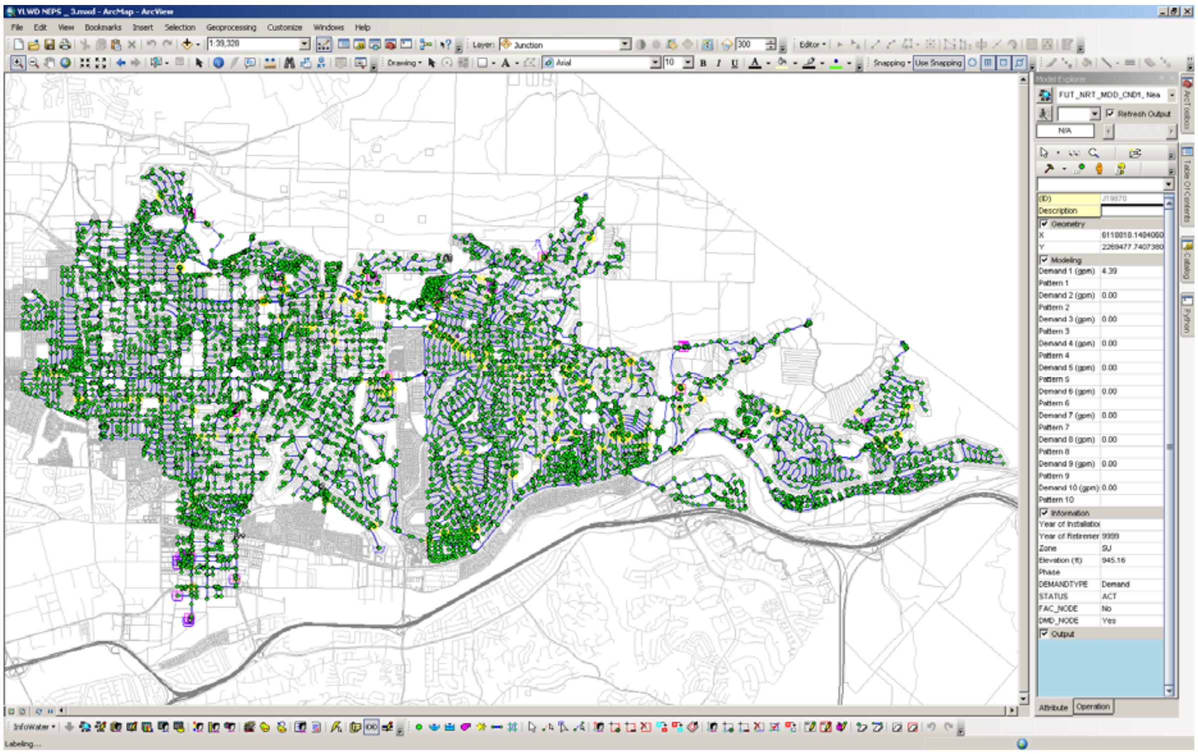


Figure 12 Hydraulic Model Screenshot

5.1 Updates to Hydraulic Model

Prior to the calibration process, the hydraulic model was updated to reflect existing conditions of the District's distribution system. This included interpolating elevations to all model junctions, closing pipe segments or inserting closed valves to enforce pressure zone boundaries, updating pump units, revising groundwater wells to utilize pump elements rather than flow control valves, incorporating seasonal valves based on operating condition, and more fully modeling pressure regulating stations.

Pipelines constructed since the development of the previous hydraulic model were added to the hydraulic model from the District's GIS layers, provided on 9 August 2012. In addition, the following projects were added to the hydraulic model based on record drawings or construction plans provided by District staff:

- Lakeview Grade Separation Project, which included an 18-inch diameter transmission main relocation (dated June 2011)

- 2010 Waterline Replacement Project, including replacement of two PRS and five pipeline segments (July 2012)
- Pressure Reducing Station Upgrades, including replacement of four PRS (dated August 2011)
- Well 20

During the calibration process, controls and pressure reducing station settings were added to the hydraulic model based on discussions with District staff.

5.2 Near-Term Facilities Included in Hydraulic Model

In addition to the model updates discussed previously, several facilities that are currently in planning or design stages were incorporated into the hydraulic model as near-term facilities. These near-term facilities are:

- Yorba Linda Boulevard Pipeline, including installation of a 20-inch diameter pipeline (dated January 2012)
- Yorba Linda Boulevard Booster Pumping Station (dated August 2012)
- Yorba Linda High School Bryant Cross Feeder Replacement – 90 percent drawings (dated December 2012)
- Well 21

While model management practices are discussed in greater detail in Appendix D, these facilities are identified separately from existing facilities in the hydraulic model by use of the Status field. Prior to changing these facilities from near-term (Status of “NRT”) to existing (Status of “ACT”), the facility details should be reviewed as they may have changed during the design and construction process.

6.0 WATER QUALITY ANALYSIS

6.1 Nitrification Action Plan and Current Operating Practices

In 2002, the District conducted a nitrification study, which concluded nitrification was occurring in some of the District’s reservoirs during certain operating conditions (YLWD, 2002). Nitrification refers to the biological conversion of free ammonia (from chloramines decay or interaction with free chlorine) to nitrite and sometimes nitrate, leading to high microbial counts and further degradation of chloramines residual by the nitrite.

The study recommended a Nitrification Action Plan, consisting of the following steps:

- Alert Level – increased sampling frequency, dependent upon the severity of water quality degradation
- Action Level 1 – cycling the reservoir or reducing the reservoir operating level
- Action Level 2 – super-chlorination, reservoir flushing, or sediment cleaning

The steps are triggered based on sampled levels of chlorine, nitrite, heterotrophic plate counts (HPC), and ammonia. The plan also recommended some possible capital improvements to increase mixing in some reservoirs.

Within chloraminated systems, nitrification occurs under high water age or conditions of mixing free chlorine with combined chlorine, which leads to loss of residual, release of free ammonia, and microbial growth.

Low chlorine residuals are particularly a concern to the District in the District's upper pressure zones, where large storage volumes and low demands lead to long retention times. District operations staff operate some of the reservoirs in the upper pressure zones at reduced levels or reduced capacity to reduce retention times and aid in cycling.

Based on discussions with District staff, the District follows the procedures in its Nitrification Action Plan when nitrification is occurring as indicated by the key water quality parameters levels (e.g. total chlorine, nitrite, HPC, and total and free ammonia). Based on review of SCADA data of reservoir levels (as a part of the hydraulic model calibration), District operations staff are diligent about cycling reservoirs on a consistent schedule and maintaining separation of source waters (i.e., free chlorine groundwater and combined chlorine imported water) where possible.

6.2 Sampled Chlorine Levels in Distribution System

As a part of this project, the District provided water quality sampling data from its Total Chlorine Residual (TCR) sampling sites. These data were analyzed to determine what typical fluctuations in chlorine residual occur in the distribution system, and whether breakpoint chlorination is generally occurring. Table 16 presents a summary of these data by sampling site and hydraulic zone, with sampling sites including some low residual levels in both free and combined chlorine (Total chlorine < 0.1 mg/L) highlighted in green.

As discussed in Section 4.4, the District changes supply sources for pressure zones to achieve targeted supply balances (related to BPP and groundwater percentage of overall supply). Since this analysis is covering samples taken over an entire year, some of the identified breakpoint chlorination could be occurring during the periodic cycling of water sources. Several sample sites are served with combined chlorine between May and October, and free chlorine during the balance of the year.

However, within Zone 2 breakpoint chlorination is occurring due to physical mixing of the groundwater and imported water. This is due to the hydraulics of the east side of Zone 2 requiring additional pressure from Zone 3 via several PRS. The District's operations staff is aware of this situation.

Table 16 Chlorine Residual by Sample Site and Zone

Sample Site	Zone	Source Water(1)	Average Combined Chlorine(2) (mg/L)	Minimum Combined Chlorine(2) (mg/L)	Average Free Chlorine(2) (mg/L)	Minimum Free Chlorine(2) (mg/L)
13	1A	GW			1.09	0.65
31	1A	GW			1.09	0.77
35	1A	GW			1.23	0.76
34	1A	GW			0.94	0.61
32	1A	GW			1.13	0.76
24	2	VAR	1.86	0.02	0.78	0.02
27	2	VAR	1.67	0.02	0.47	0.02
22	2	VAR	1.69	0.01	0.51	0.02
25	2	VAR	1.69	0.05	0.66	0.05
14	2	GW			1.09	0.76
28	2	GW			1.11	0.75
30	2	GW			1.11	0.72
23	2	VAR	1.82	0.08	0.80	0.00
21	2	GW			1.11	0.71
29	2	GW			1.08	0.72
19	3A	VAR	1.55	0.07	0.93	0.28
26	3A	VAR	1.61	0.05	0.83	0.02
20	3A	VAR	1.53	0.09	0.75	0.03
16	3B	IW	1.89	1.39		
17	3B	IW	2.00	1.32		
36	3A	VAR	1.20	0.05	1.01	0.02
11	3A	VAR	1.19	0.05	1.06	0.06
33	3A	VAR	1.23	0.05	1.01	0.02
8	3A	VAR	1.27	0.06	1.01	0.79
6	4C	IW	2.07	1.23		

Table 16	Chlorine Residual by Sample Site and Zone					
Sample Site	Zone	Source Water[1]	Average Combined Chlorine[2] (mg/L)	Minimum Combined Chlorine[2] (mg/L)	Average Free Chlorine[2] (mg/L)	Minimum Free Chlorine[2] (mg/L)
9	4C	IW	2.24	1.14		
7	4C	IW	2.02	1.17		
10	4C	IW	2.24	1.40		
12	4D	IW	2.00	1.63		
37	4A	VAR	1.29	0.08	0.91	0.05
2	5B	IW	2.02	0.30		
5	5B	VAR	1.97	0.08	0.03	0.02
18	5U	IW	1.64	0.78		
15	5A	VAR	1.35	0.03	0.37	0.03
3	6B	IW	1.80	0.03		
4	6D	IW	1.23	0.25		
1	6A	IW	1.80	0.06		

Notes:

1. IW = Imported Water; GW = Groundwater; VAR = Varies, depending on operating condition or mixing is occurring (likely through pressure reducing stations). Several sites covert to imported water between May and October, such as those located within Zones 3, 4, and 5.
2. Water quality sampled weekly from January through October of 2012.
3. Since free and total chlorine are not sampled at each sampling site, judgment was used based on source water to determine the likely state of the total chlorine.

As shown in Table 16, chlorination type is generally separated by pressure zone. As discussed previously, supply sources to some pressure zones are adjusted seasonally to achieve production targets. Some water quality sampling sites show signs that mixing is occurring of free chlorinated water and water disinfected with chloramines (specifically in Zone 2). At some sites, breakpoint chlorination is likely occurring under certain operating conditions.

Figure 13 shows the sampled chlorine residual at each of the District's sampling sites over the course of the year. This chart illustrates the difference in total chlorine residual for the chloraminated and free chlorine disinfected supply water by sampling site. Free chlorine disinfected sampling sites are shown in orange, with chloraminated sites shown in green. Sites which appear to switch sources from groundwater during January through May to imported water from May through October are shown in blue. Note that only a few sites are shown to simplify the graphic.

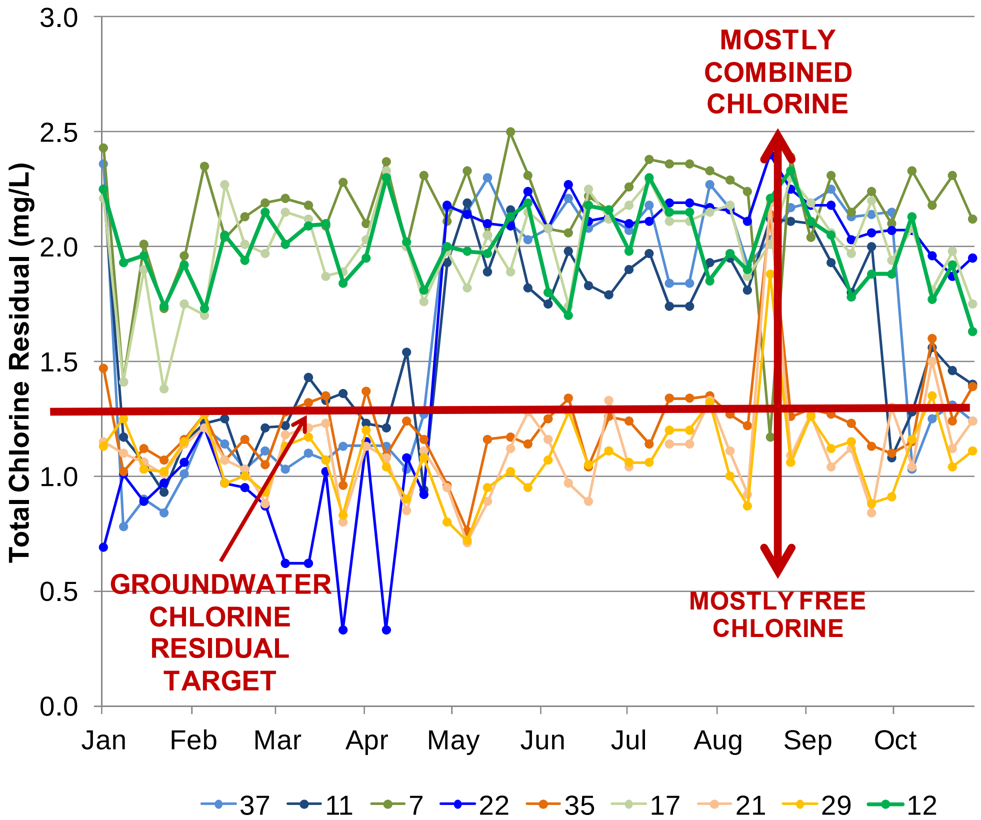


Figure 13 Sampled Chlorine Residuals by Sampling Site

The District also provided sampling data for each of the District's reservoirs. A summary of this data is shown in Table 17 along with the calculated total chlorine to ammonia (as N) ratios, which are used to determine whether free chlorine is present within the reservoir. Notes are included to describe some of the analysis of the data shown.

Table 17 Sampled Water Quality Data at Reservoirs

Reservoir	Total Chlorine (mg/L)		Chlorine:Ammonia (as N) Ratio		Notes
	Average	Range	Average	Range	
Bryant Ranch	1.74	1.34 - 2.05	4.9	1.3 - 19.1	Almost entirely combined, some dichloramine
Camino de Bryant	0.84	0.25 - 2.03	3.1	0.3 - 29.7	Low residual in July, likely due to breakpoint
Chino Hills	1.34	0.07 - 2.17	4.2	0.8 - 11.7	Low residuals in February and November
Elk Mountain	1.51	0.06 - 2.04	4.6	0.3 - 11.6	Low residuals in October and November
Fairmont	0.89	0.13 - 2.08	6.5	0.1 - 136.0	Supply switched to IW in May through October
Gardenia	1.79	0.88 - 2.44	12.7	0.9 - 126.0	Supply switched to IW in May through October
Hidden Hills	1.35	0.07 - 2.14	4.4	0.1 - 20.5	Low residual in July, likely due to breakpoint
Lakeview	0.87	0.76 - 0.98	38.6	0.8 - 93.0	Groundwater supply
Little Canyon	1.73	0.17 - 2.37	5.0	0.2 - 21.3	Low residual on occasion, excess ammonia in October
Quarter Horse	0.99	0.05 - 2.21	7.0	0.1 - 70.0	Low residual on occasion, periods of free chlorine
Santiago	1.83	1.08 - 2.14	4.6	1.1 - 18.7	Entirely combined
Spring View	1.85	0.47 - 2.28	5.2	0.5 - 23.5	Low residual in March, potentially due to breakpoint
Valley View	1.67	0.45 - 2.42	11.9	0.5 - 60.5	Supply switched to IW in May through October

6.3 Impact of Proposed Improvements on Water Quality

Since the proposed developments are anticipated to increase demand in the upper pressure zones, connecting the developments would likely lead to decreased retention times and simpler cycling practices.

Following water quality calibration, the hydraulic model was used to predict the effect of connecting the developments on chlorine levels in the distribution system. Figure 15 presents predicted total chlorine residuals across the distribution system along with sampled total chlorine residuals at the District's water quality sampling sites. It should be noted that a comparison of the sampled residuals and predicted residuals is included in Appendix E along with a discussion of the calibration and results. Figure 16 presents predicted total chlorine levels under near-term conditions, assuming operating Condition 1 and summer demand conditions. Each of these maps shows the predicted residual levels at 12:00 noon. It should be noted that the simulation run time for the existing system was longer (5 days), thus the lower residual levels in portions of the free chlorine area of the distribution system.

As is discussed in Appendix E, a number of assumptions are made in preparing the water quality analysis shown here; as the conditions affecting these assumptions may vary, the District should use the results as an anticipated range rather than counting on the specific levels shown in this analysis.

In addition, the predicted total chlorine residual within the Little Canyon reservoir is shown under existing conditions and with the development demand connected to the distribution system Figure 14.

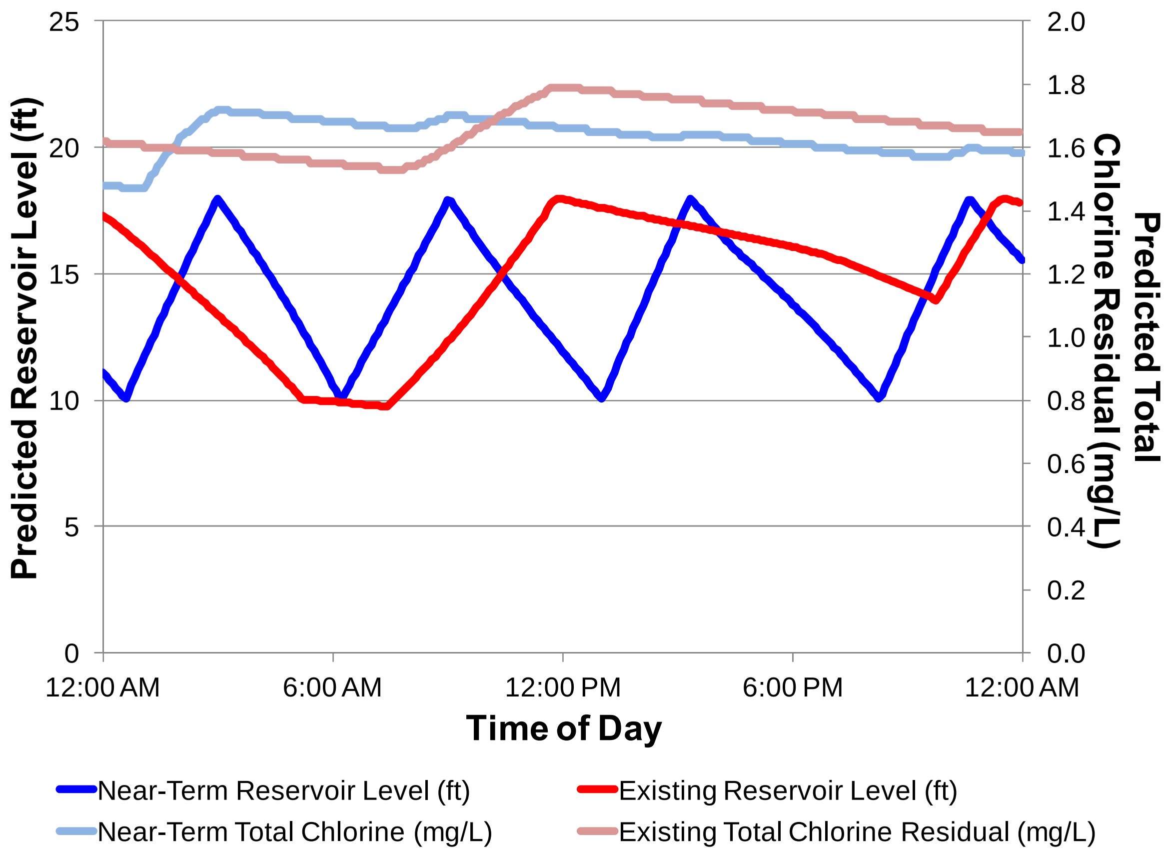


Figure 14 Predicted Effect of Development on Little Canyon Reservoir

As shown in Figure 14, the cycling is predicted to be slightly improved after the development has been connected, with the added demands increasing the pull of demands during the take portion of the reservoir cycling and the increased capacity of the Fairmont PS filling the reservoir more rapidly. As shown, chlorine levels are not predicted to change substantially.

It should be noted that, within the hydraulic model, reservoirs are treated as fully mixed at all times, a condition that is not realistic for most reservoirs. Thus, this prediction assumes fully mixed reservoirs. The key steps the District can implement to limit nitrification from occurring are reducing water age and improving mixing within the District's reservoirs. Thus, implementing measures to more fully replicate the fully mixed condition should reduce the loss of residual from decay and microbial reactions.

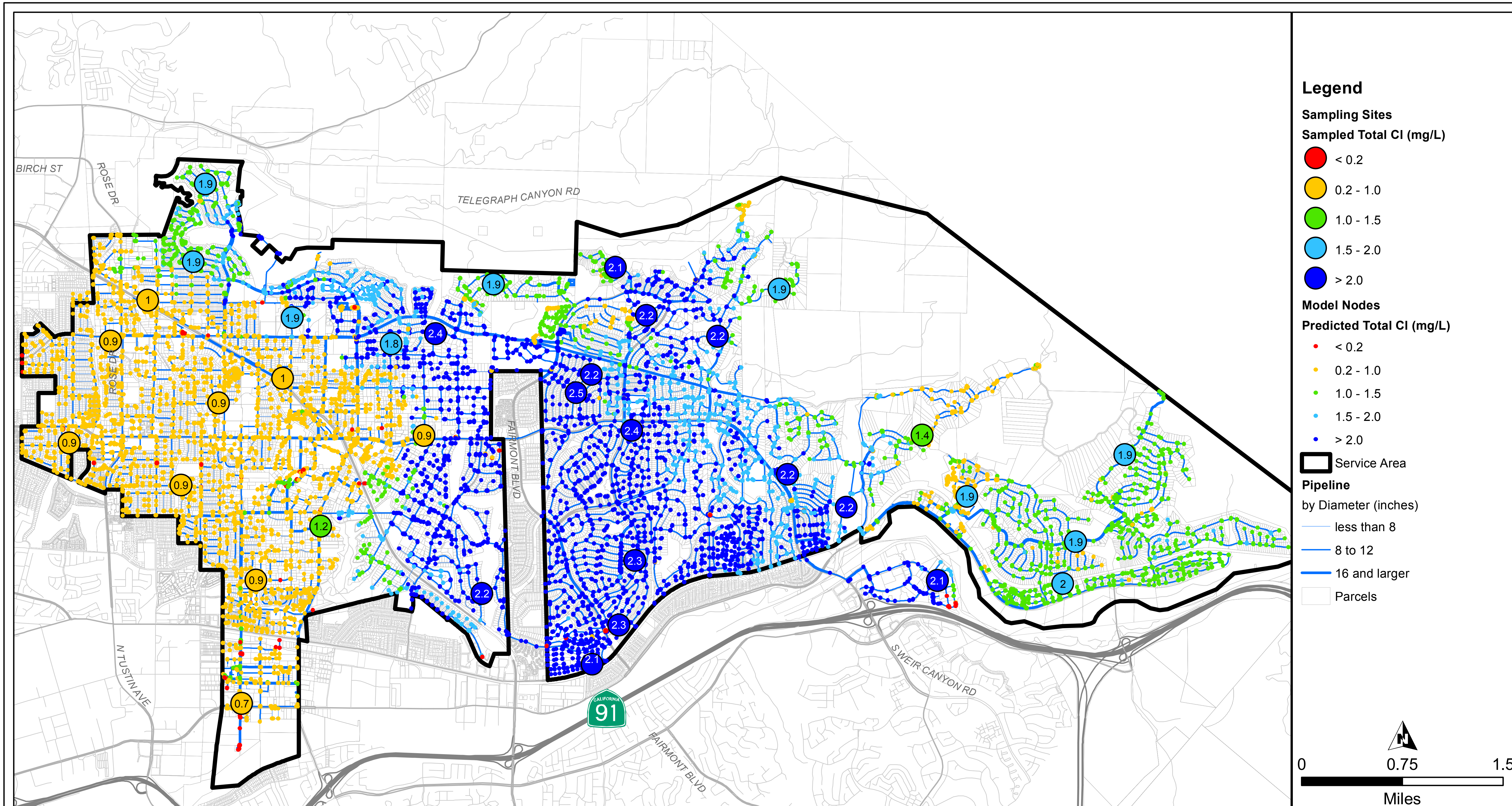


Figure 15
Sampled and Predicted
Existing Residuals
February 2013
Northeast Area Planning Study
Yorba Linda Water District

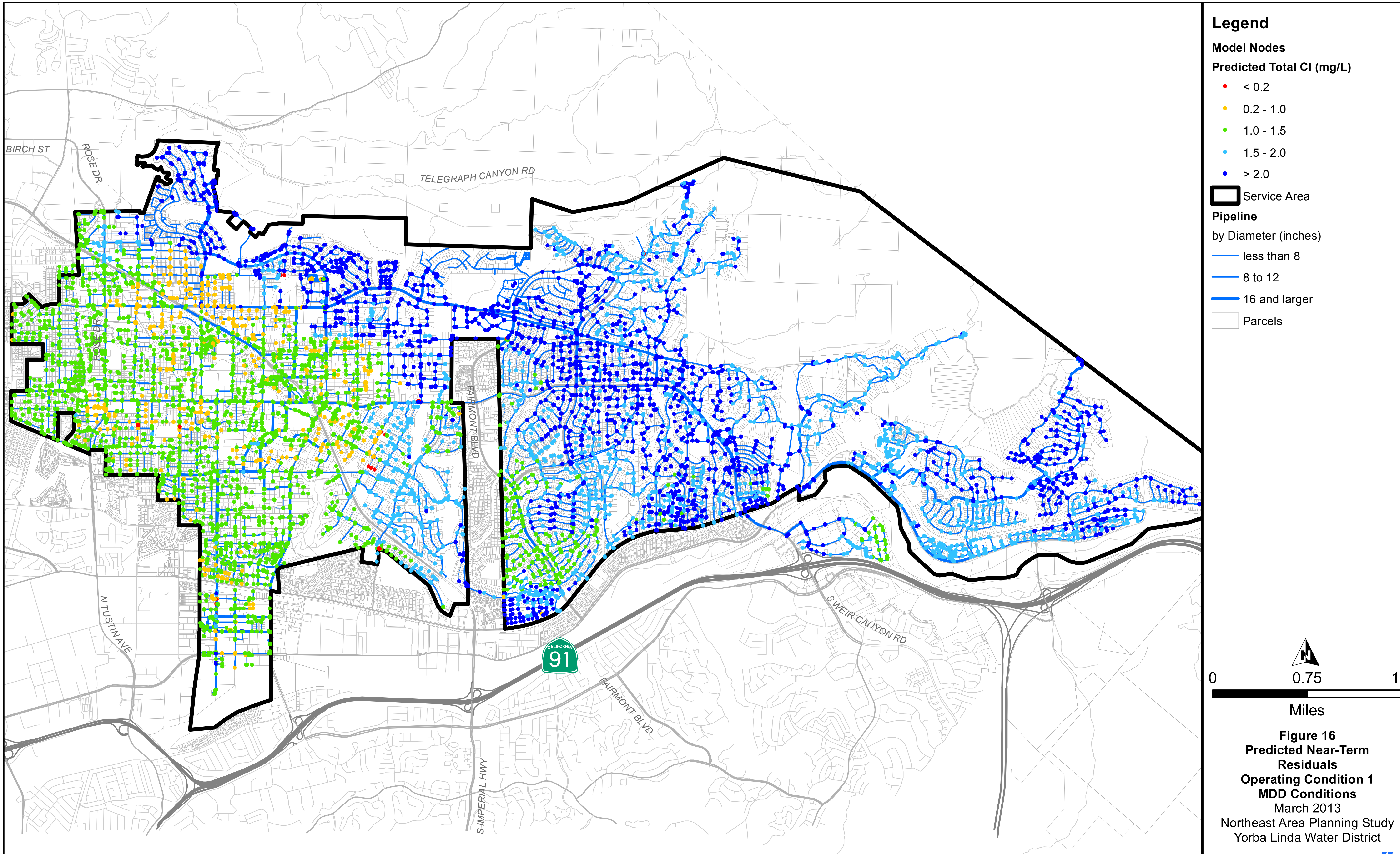


Figure 16
Predicted Near-Term Residuals
Operating Condition 1
MDD Conditions
March 2013
Northeast Area Planning Study
Yorba Linda Water District

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6.4 Recommendations

Based on the modeling predictions, the District may anticipate similar residual levels in the future as currently experienced. It is anticipated that the connection of the developments will improve cycling of the Little Canyon reservoir as shown in Figure 14. As noted previously, the key steps the District can implement to limit nitrification from occurring are reducing water age and improving mixing within the District's reservoirs. Increased cycling will help to improve mixing, but new reservoirs in the upper pressure zones will also increase water age.

In order to limit chlorine residual loss from decay and microbial reactions, it is recommended that the District decrease water age and improve mixing in reservoirs, induce breakpoint chlorination to eliminate microbial populations under a free chlorine residual shock dose when nitrification occurs, and implement a system providing real-time automated monitoring of disinfection residual to improve reaction time to nitrification episodes. Several of these steps are included in the District's existing nitrification action plan; it is recommended that the District continue to follow its reservoir cycling practices, following the guidelines recommended in the nitrification study.

Based on this study, additional recommendations are included for future new reservoirs, chlorine residual booster stations, and to improve future water quality analyses.

6.4.1 New Reservoirs

For future new reservoirs, it is recommended that the District include the following elements in the design phase:

- separate inlet and outlets
- mixing device within the reservoir
- samplers to provide real-time automated monitoring of disinfection residual

Reviewing record drawings of recently completed reservoirs, the District has implemented separate inlet and outlets at several of its most recently completed reservoirs, and has added SCADA connected total chlorine residual monitors at reservoirs where loss of chlorine residual is of particular concern, including Hidden Hills and Camino de Bryant reservoirs. Including multiple diffused inlets should further improve mixing with the reservoirs.

Reservoir management systems currently on the market incorporate real-time automated monitoring of disinfection residual and a mixing device. Models are also available with disinfection capabilities through free chlorine injection or an automated booster chloramination system. The District should consider the implementation of such a device in the design of new reservoirs. Such a system could also benefit existing reservoirs, such as Camino de Byrant reservoir.

6.4.2 Chlorine Booster Station

In addition to efforts associated with reductions in water age and increasing reservoir mixing, addition of a disinfection point at a strategic location in the distribution system to increase chlorine residual would be beneficial. The benefit would be maximized where a switch of disinfection type is in place seasonally or where mixing of residual types physically occur within the distribution system, under which conditions chlorine residual loss is more likely to take place.

As discussed in Section 4.5.1, Fairmont PS would be a centralized location for the future distribution system. Incorporating a disinfection point at Fairmont PS would allow the ability of increasing the chlorine residual for the following zones:

- Zones 1,000-1, 1,160, and 1,300 under Operating Conditions 1 through 7 as wells as Operating Condition 9
- Zone 920 under Operating Conditions 6 and 7
- Zones 680, 718, 780-3, 780-4, 908, 991, 1,000-2, 1,133, 1,165, and 1,390 under Operating Conditions 8 and 9. (As discussed previously, supplying this Operating Condition is only feasible under lower demand conditions given the District's current pump station capacities and groundwater supplies. This condition is also not anticipated to occur frequently in the future when the District intends to achieve a more consistent BPP target throughout the year.)

The District currently only disinfects with free chlorine. Disinfection generally occurs at disinfection stations near the wellfield. In addition, the District maintains a disinfection station at Lakeview PS, which is run when breakpoint chlorination is required when supplying Zone 675 from 570.

Since Fairmont PS would convey both free-chlorine disinfected water and chloraminated water, ideally a disinfection station that could inject both free chlorine and chloramines would provide the most operational flexibility. However, this would be the District's first chloramination facility, requiring the District's operational staff to begin handling chloramines.

If a free-chlorine disinfection station is incorporated into Fairmont PS, the intended operation would change based on the supply water (thus based on the Operating Condition). When supplying groundwater (Operating Conditions 6, 8, and 9), the disinfection station would simply increase free chlorine residual to the targeted residual level. When supplying imported water, the disinfection station would need to induce breakpoint chlorination, under an as-needed basis (e.g., when nitrification or residual loss is occurring). Based on the District's water quality sampling records discussed in Section 6.2, residual loss has occurred at the Little Canyon reservoir. Disinfection with free chlorine would result in the formation of disinfection byproducts.

It should be noted that boosting disinfectant residuals for Zones 680, 718, 780-3, 780-4, 908, 991, 1,000-2, 1,133, 1,165, and 1,390 under Operating Conditions 1 through 7 (the District's typical operating conditions), would not be possible at Fairmont PS. Boosting chlorine in the at a facility along the Bryant Cross Feeder would increase the chlorine residual to some of these pressure zones.

Based on these advantages and disadvantages, it is recommended that the District installs disinfection station into the design of the Fairmont PS that can inject free chlorine during emergencies. It should be noted that this would not allow boosting disinfectant residuals in the eastern pressure zones during Operating Conditions 1-7, but avoids the needs of operating staff to work with chloramines. If the District continues to experience loss of residual in the future in the eastern pressure zones, or if this emergency approach is not sufficient, the next recommended step would be to install reservoir management systems (mixers, analyzers, and potentially injection of chloramines).

6.4.3 Improving Water Quality Analysis

Some recommendations that could increase the potential accuracy of future water quality modeling include sampling for TOC at reservoir sites, sampling for both free and total chlorine at TCR sites, sampling for pH in the reservoirs as wells as distribution system sites, and conducting jar testing on samples of the groundwater to approximate a bulk coefficient of decay for the free chlorine component. The nitrification study recommended increased sampling of some of these constituents, specifically free chlorine, pH, and free ammonia.

7.0 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Based on the analysis completed as a part of this study, the estimated storage requirements for the new potential developments is 1.3 MG, including fire flow storage.

Based on the identified operating conditions for supplies, the recommended configuration and sizing of pumps for the FPS is detailed in Table 18. All pump units are recommended to be controlled by variable frequency drives (VFDs). If the District elects to install constant speed pumps rather than VFDs, an eighth unit would be recommended at the pump station to pump from Zone 675 to Zone 780-3 to provide additional flexibility in the range of flows the pump station could accommodate between Zones 675 and 780-3.

Table 18 Fairmont PS Sizing					
Units	**To Zone**	**From Zone**	**TDH (ft)**	**Total Design Capacity[(1)] (gpm)**	**Notes**
1	920	675	237	800	No standby unit included since OC89 provides reliability.
2 - 3	1,000-1	675/780-3	388	2,800	1+1 configuration
4 - 6	780-3	675	120	5,500	2+1 configuration
7	1,000-1	920	211	2,800	No standby unit included since not assumed to be a typical operating condition.

Notes:
1. Rounded up to nearest 100 gpm.

If the development connects to Zone 1,000-2 or Zone 1,390, Hidden Hills PS and Santiago PS would need to be increased in size. This is discussed in Section 4.5.2.

In addition, a natural gas powered generator or portable generator trailer connection at the FPS site is recommended for emergency backup in case of an electricity outage.

Based on hydraulic model analysis, the following two pipelines were also identified as deficient (as hydraulic bottlenecks):

- The 12-inch diameter Zone 1,000-1 pipeline extending 3,500 feet along Fairmont Boulevard between FPS and Forest Avenue. This pipeline should be replaced by a 16-inch diameter pipeline or paralleled with a 12-inch diameter pipeline.

- The 12-inch diameter Zone 780-3 pipeline extending 670 feet along Fairmont Boulevard from Bastanchury Road onto the District's FPS. Adding a dedicated pipeline north of the Bryant Cross Feeder would require about 800 feet of 24-inch diameter pipeline.

These pipelines are recommended for increased diameter replacement or additional parallel pipelines to be constructed as a part of upgrading the FPS.

For water quality, the key steps the District can implement to limit nitrification and residual loss from occurring are reducing water age and improving mixing within the District's reservoirs. It is recommended that the District continue to follow its reservoir cycling practices, following the guidelines recommended in the nitrification study.

For new reservoirs, it is recommended that the District include within the design systems to increase cycling within the reservoirs, consisting of separate inlet and outlets (using multiple diffused inlets where possible), samplers to provide real-time automated monitoring of disinfection residual, and a mixing device within the reservoir. A reservoir management system could provide this functionality in a single system along with boosting disinfection residual.

For the Fairmont PS, it is recommended that the District incorporate a disinfection station into the design that can inject free chlorine during emergencies. If this emergency approach is not sufficient, the next recommended step would be to install reservoir management systems (mixers, analyzers, and potentially injection of chloramines).

To improve future water quality analyses, it is recommended that the District include sampling for TOC at reservoir sites, sampling for both free and total chlorine at TCR sites, sampling for pH in the reservoirs as wells as distribution system sites, and conducting jar testing on samples of the groundwater to approximate a bulk coefficient of decay for the free chlorine component.

REFERENCES

(KWC, 2012) KWC Engineers, Yorba Linda Estates Conceptual Layout, March 2012.

(SMP, 2012) Summers/Murphy and Partners, Inc., "Esperanza Hills Conceptual Trails Plan Stonehaven Drive Option 1", 30 October 2012.

(YLWD, 2002) Water Reservoir Nitrification Prevention and Control Study, September 2002.

(YLWD, 2005) Domestic Water System Master Plan, May 2005.

References: GIS Layers			
Layer Name [Original Filename]	**Description**	**Date Modified (or Received)**	**Source**
YLWD_GIS_082012.mdb	Water System GIS	20 August 2012	YLWD
Elevation Contours [breakline.shp, bridge.shp, Depression Index Contour Hidden Segment.shp, Depression Index Contour.shp, Depression Intermediate Contour.shp, Index Contour Hidden Segment.shp, Index Contour.shp, Intermediate Contour.shp]	Elevation Contours	September 2012	YLWD

References: Water Distribution System Data			
File Name [Original Filename]	**Format**	**Date Range, Modified (or Received)**	**Resolution**
Demands - Daily Consumption and Production - 2008 to June 2012.xlsm	XLS	January 2008 – June 2012	Daily
Demands - Monthly Demand - 2001 to 2012.xlsx	XLS	January 2001 – July 2012	Monthly
Supply Data - Production Zone Percentages from Operations.xlsx	XLS	December 2012	Not Applicable
Pump Tests - SCE - Valley View and Lakeview BPS (June 2011).pdf	PDF	June 2011	Not Applicable
Pump Tests - SCE - Groundwater Wells (2011).pdf	PDF	2011	Not Applicable
Pump Curve - Well 19 VFD Affinity Curve Operating Zone.pdf	PDF	June 2007	Not Applicable
Pump Curve – Well 19 Email Correction.pdf	PDF	January 2007	Not Applicable
Pump Curve - Well 20 (December 2011).pdf	PDF	June 2011	Not Applicable
Pump Curve – BPS (June 2011).pdf	PDF	June 2011	Not Applicable

Appendix B

SUPPLY OPERATING CONDITIONS

Figure B.1 - Condition 1

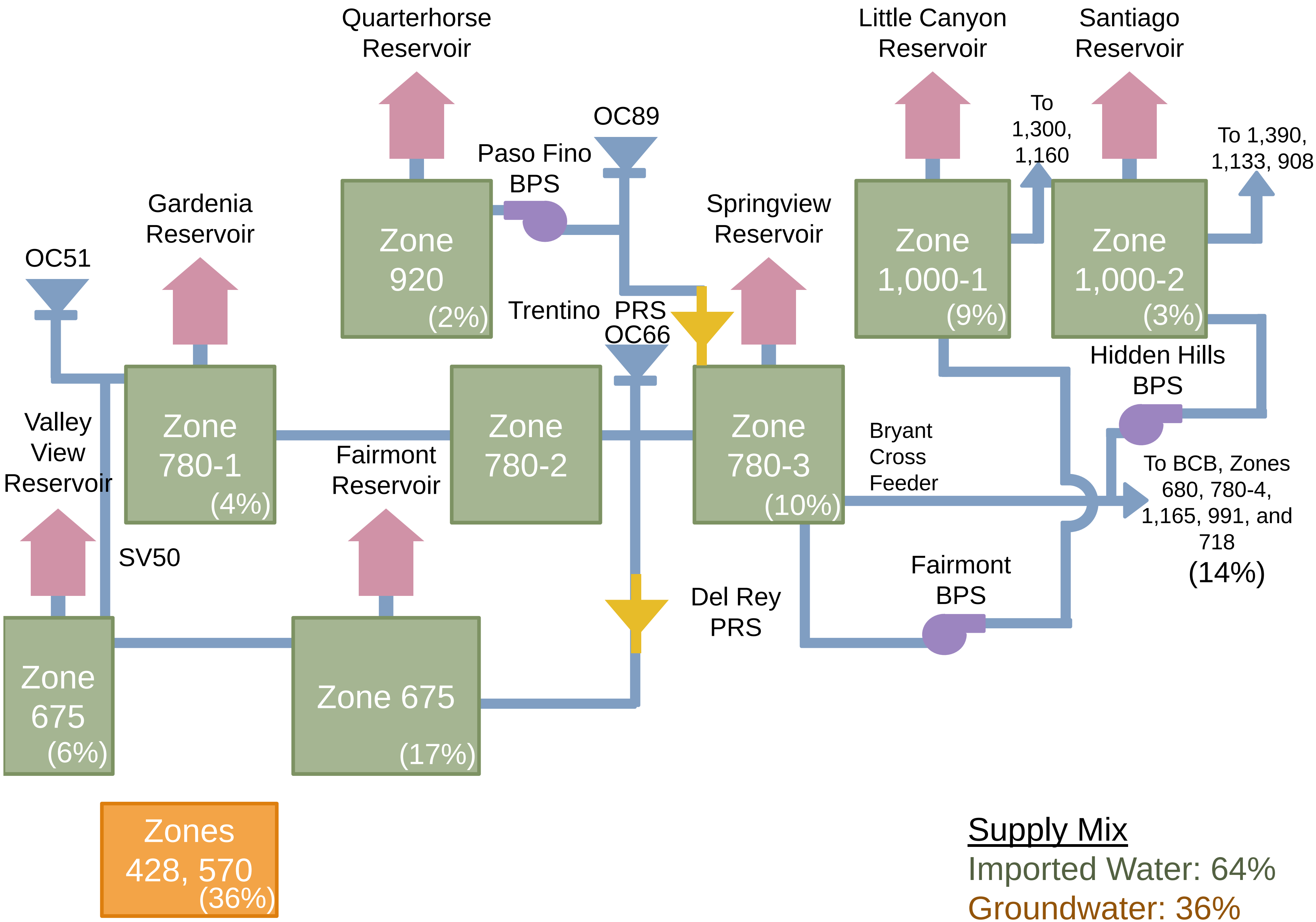
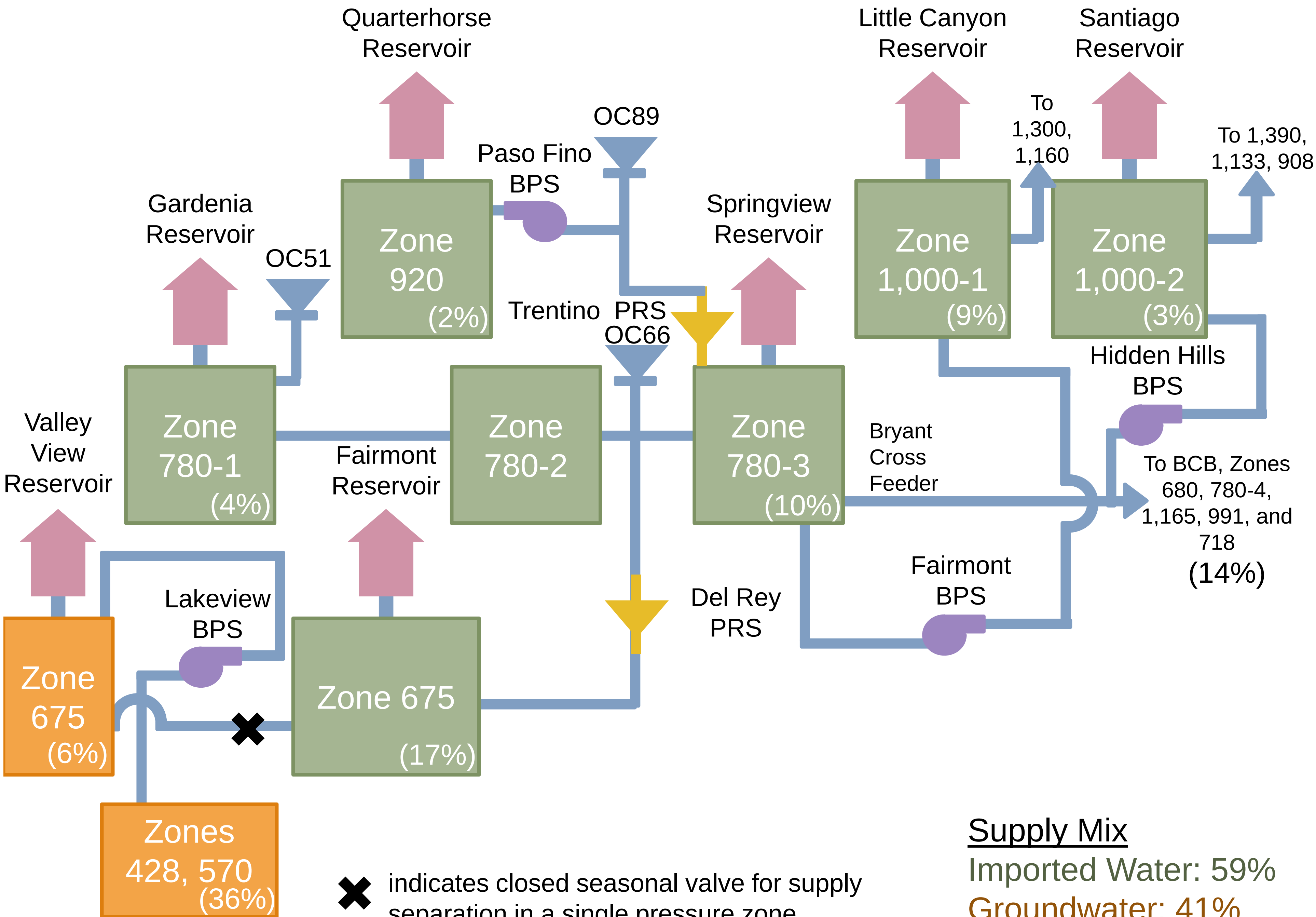


Figure B.2 - Condition 2



✖ indicates closed seasonal valve for supply separation in a single pressure zone

Supply Mix
Imported Water: 59%
Groundwater: 41%

Figure B.3 - Condition 3

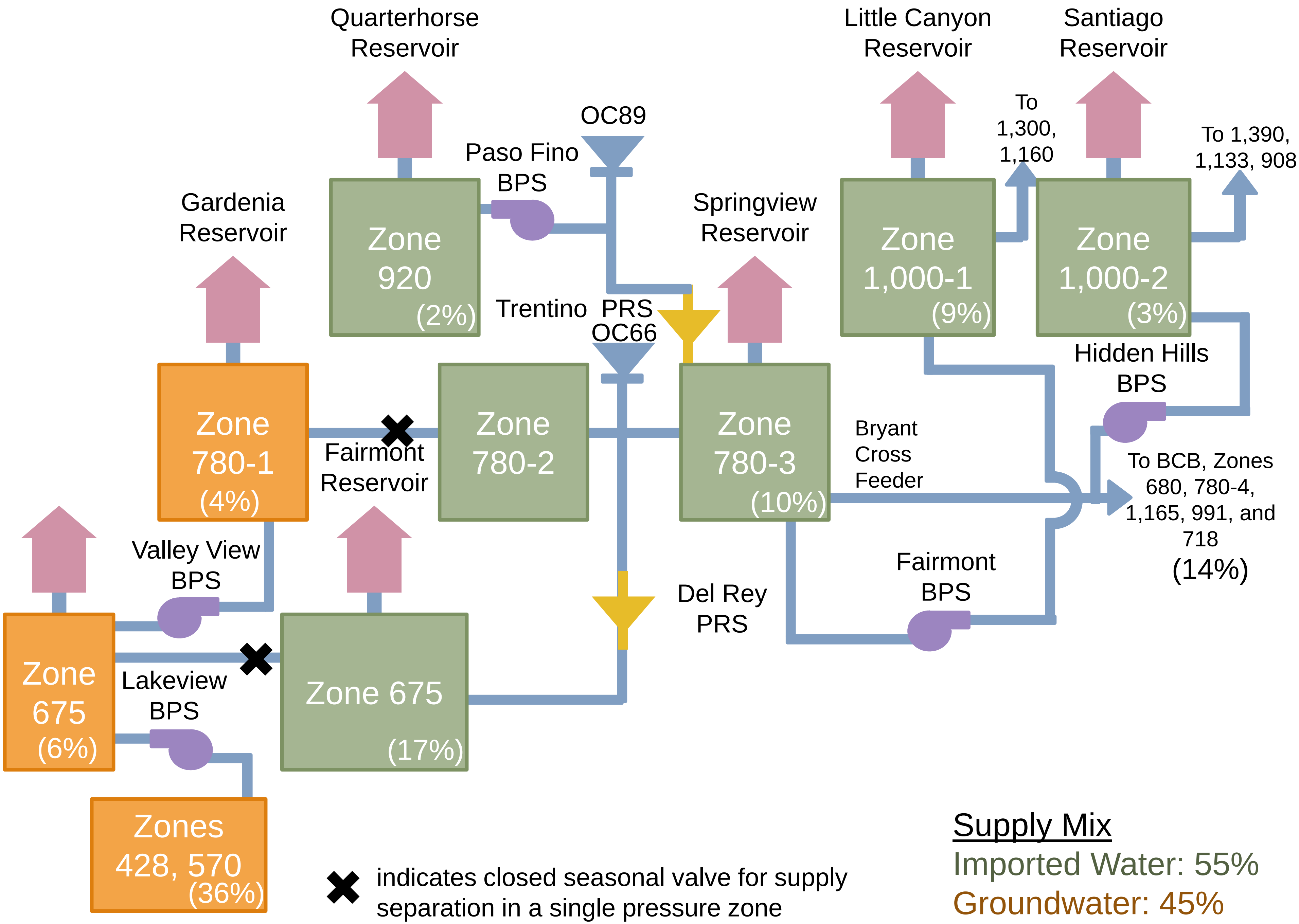


Figure B.4 - Condition 4

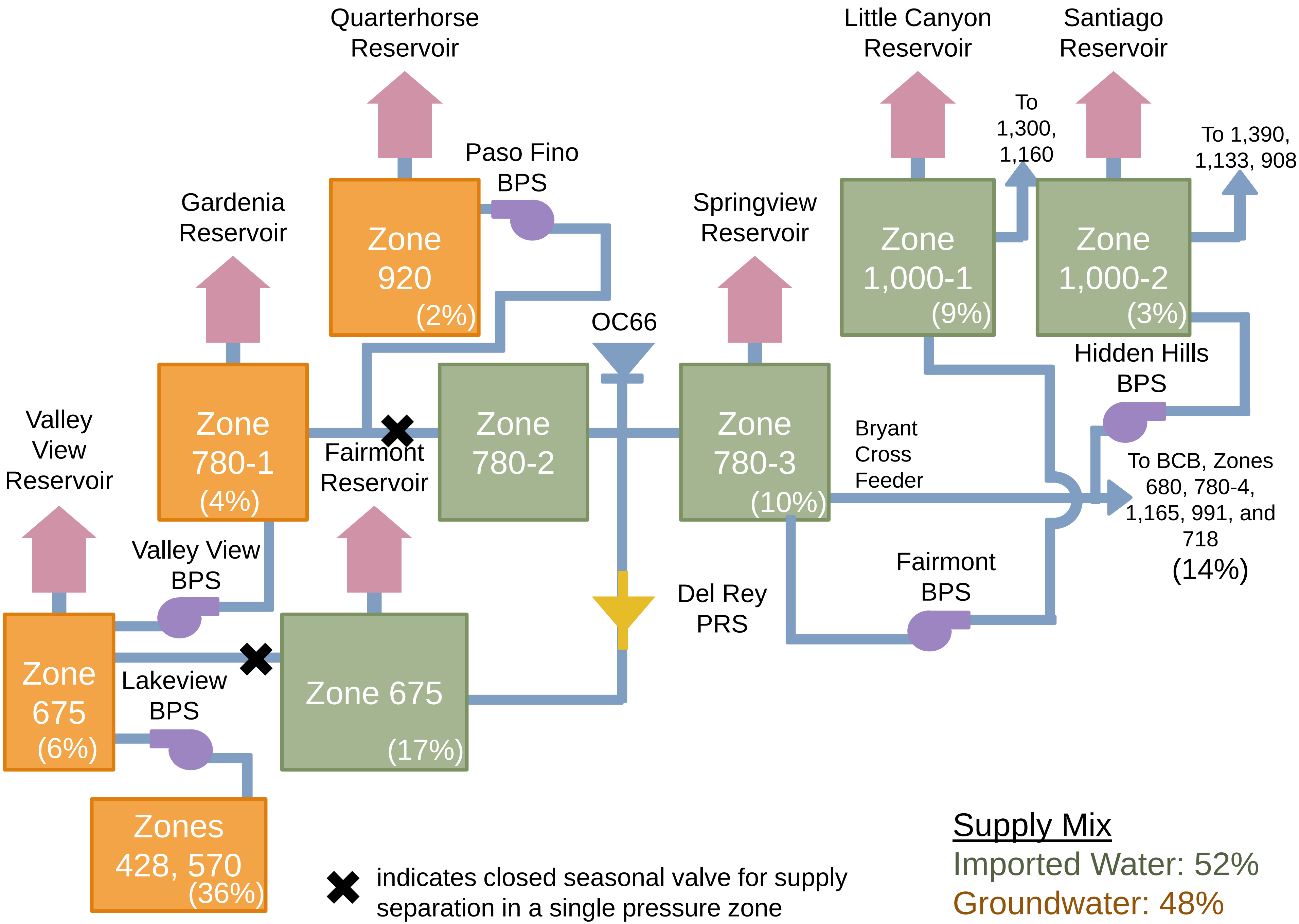
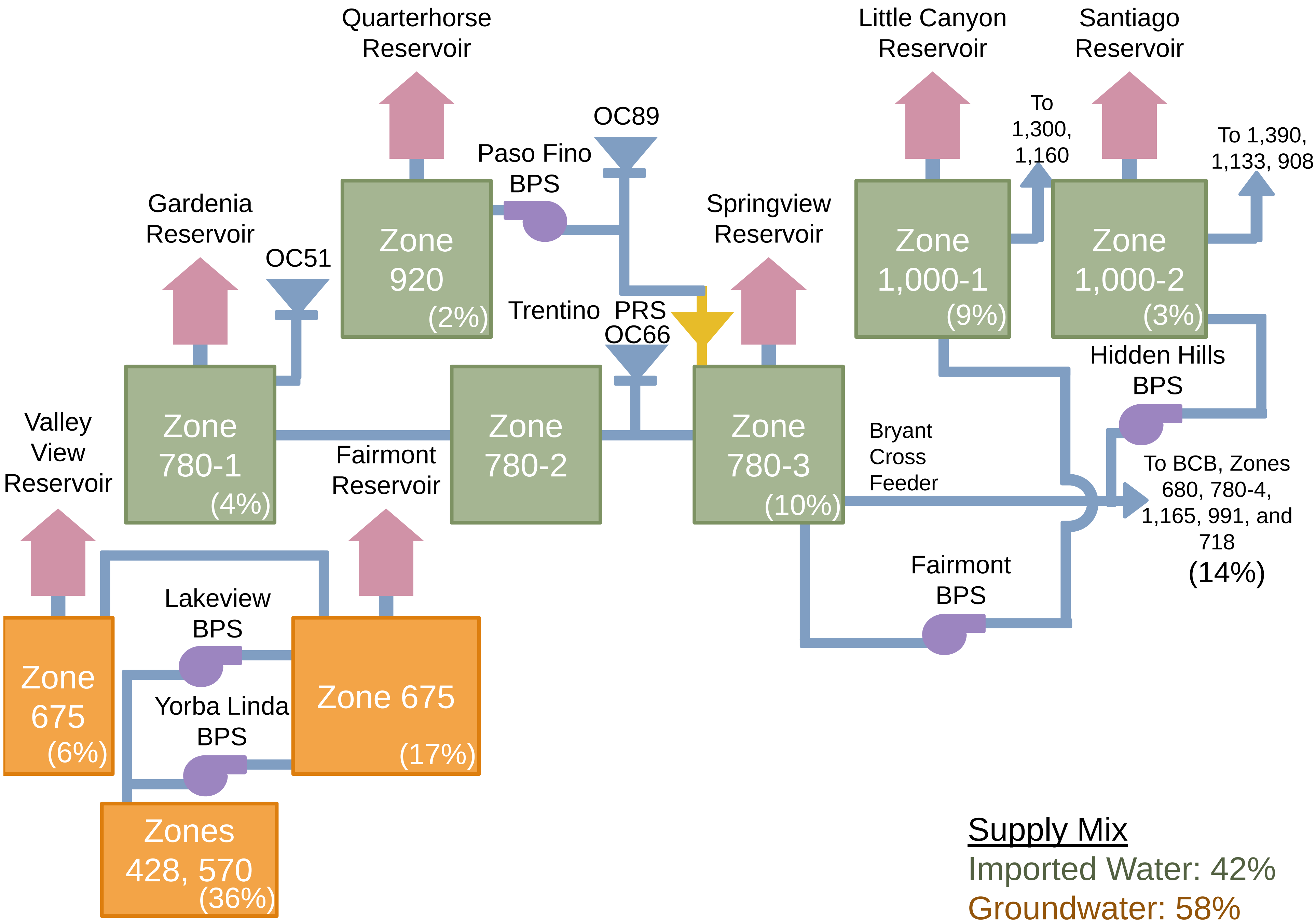
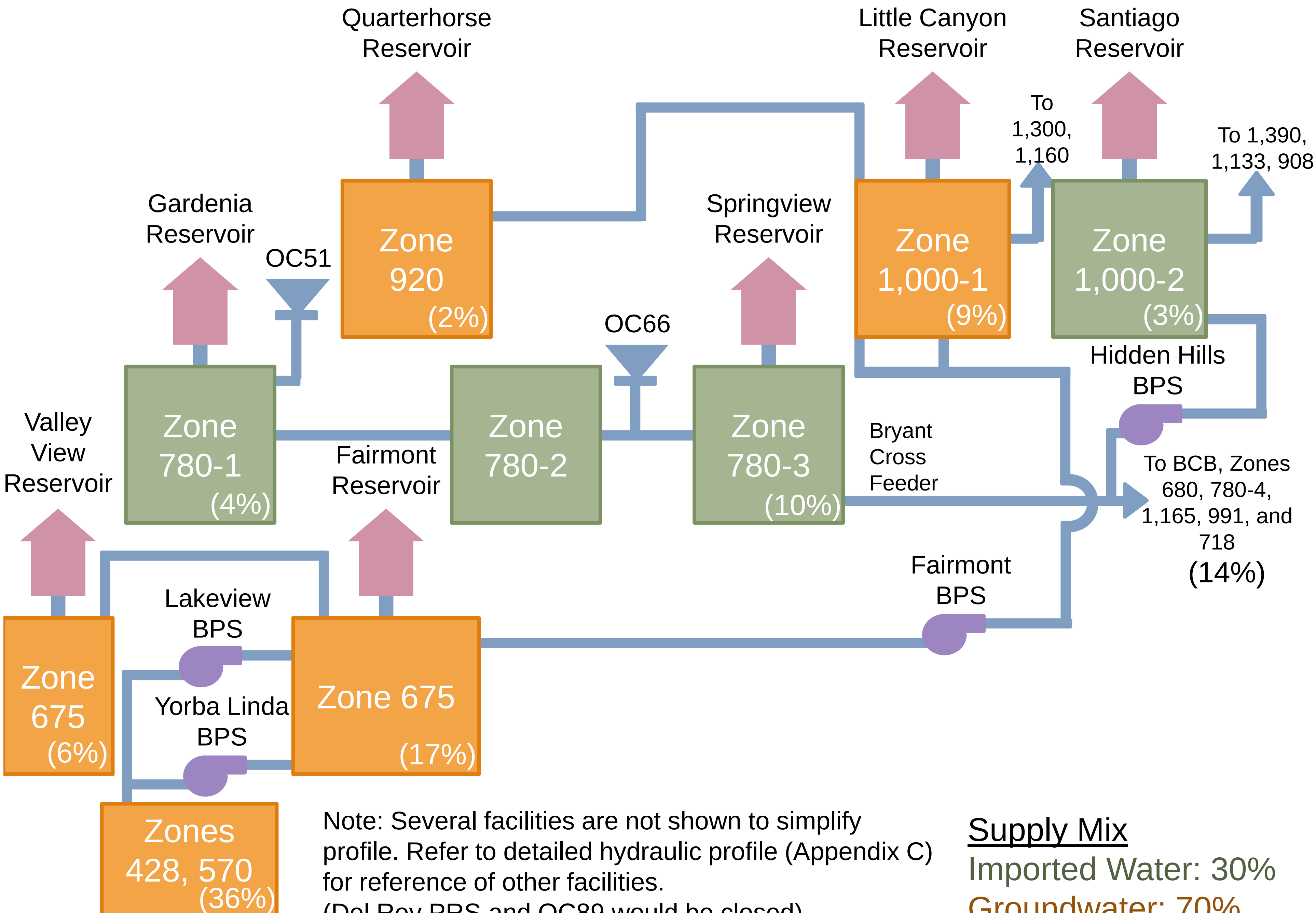


Figure B.5 - Condition 5



Supply Mix
Imported Water: 42%
Groundwater: 58%

Figure B.6 - Condition 6



Note: Several facilities are not shown to simplify profile. Refer to detailed hydraulic profile (Appendix C) for reference of other facilities.
(Del Rey PRS and OC89 would be closed)

Supply Mix
Imported Water: 30%
Groundwater: 70%

Figure B.7 - Condition 7

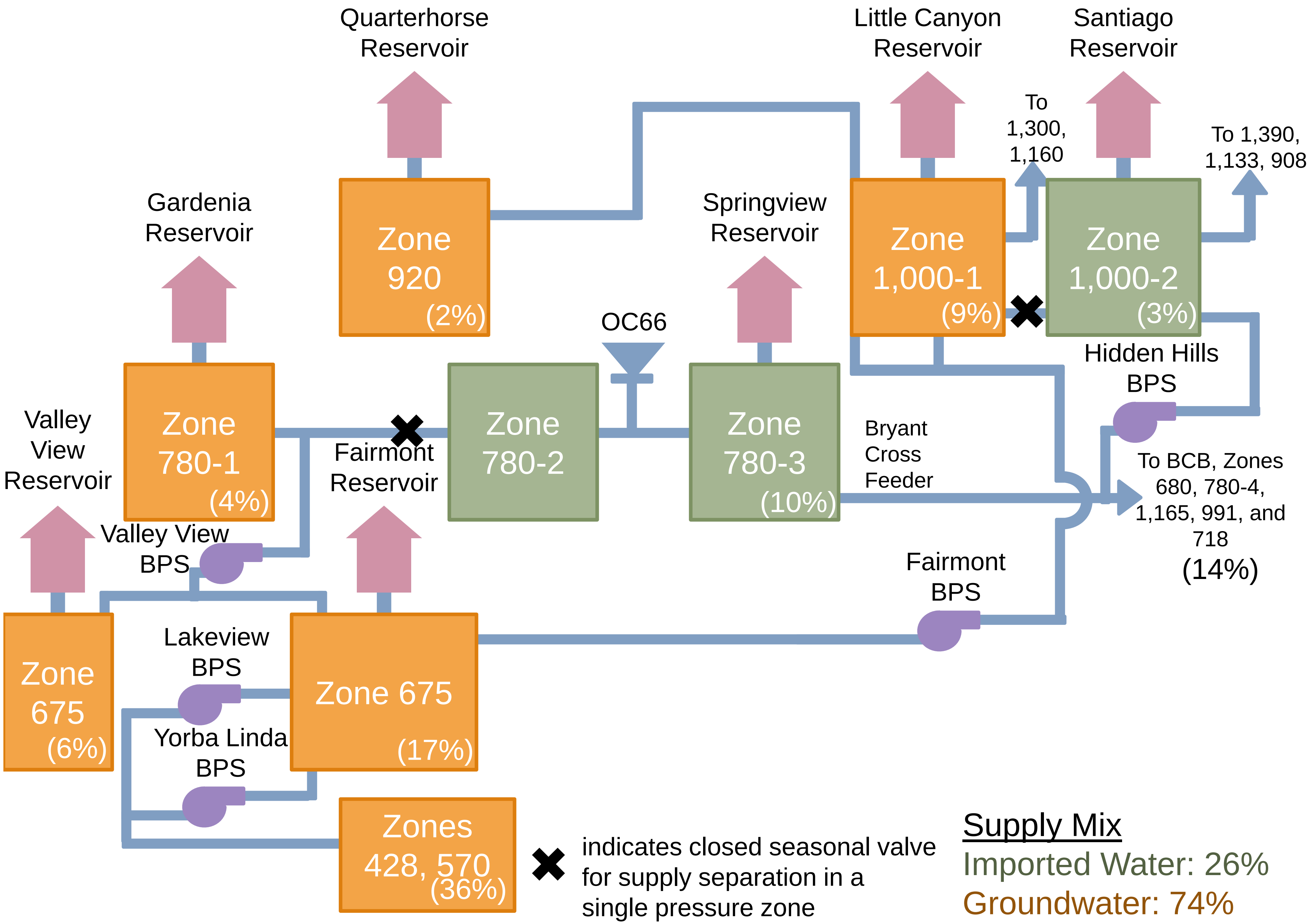


Figure B.8 - Condition 8

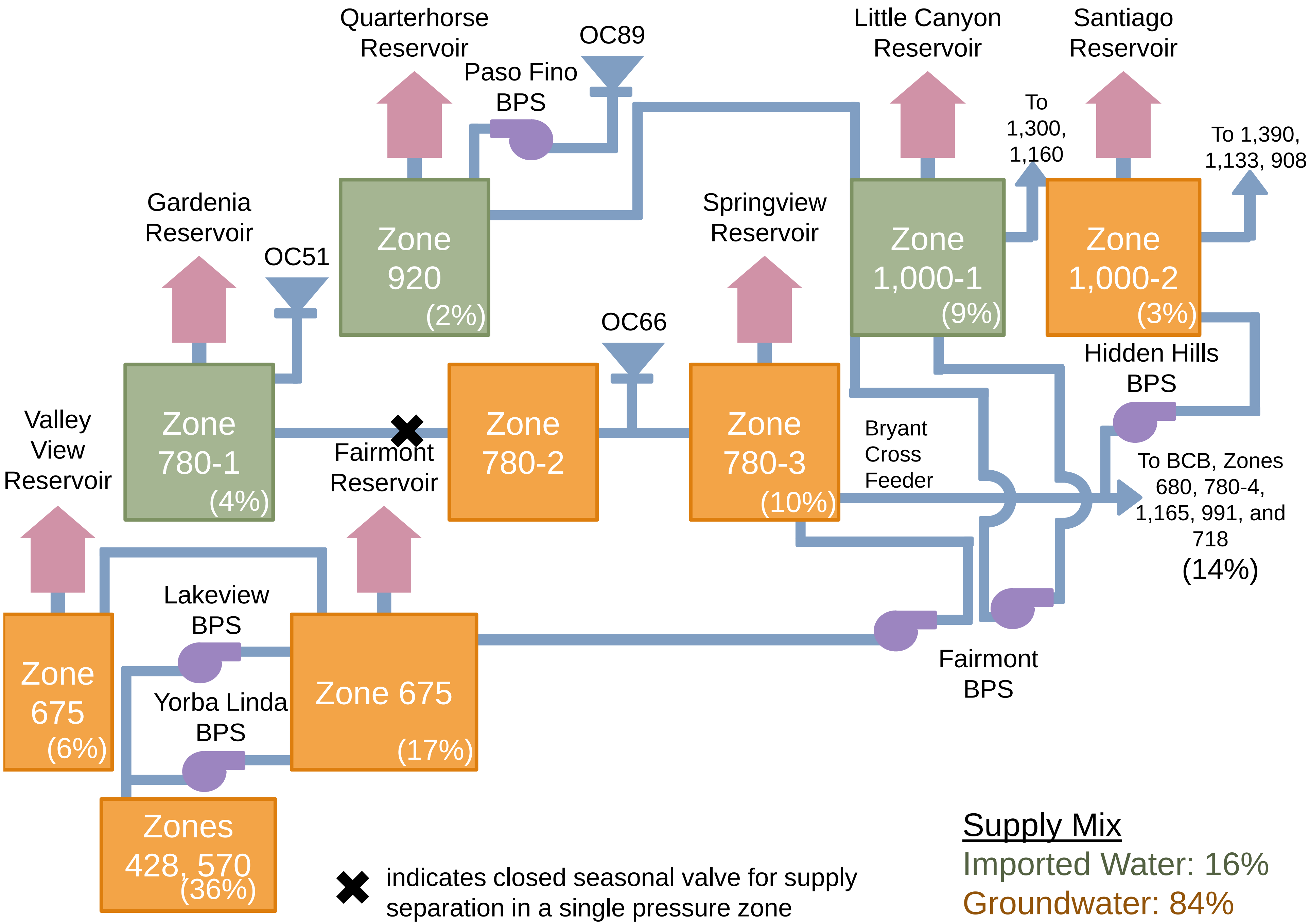
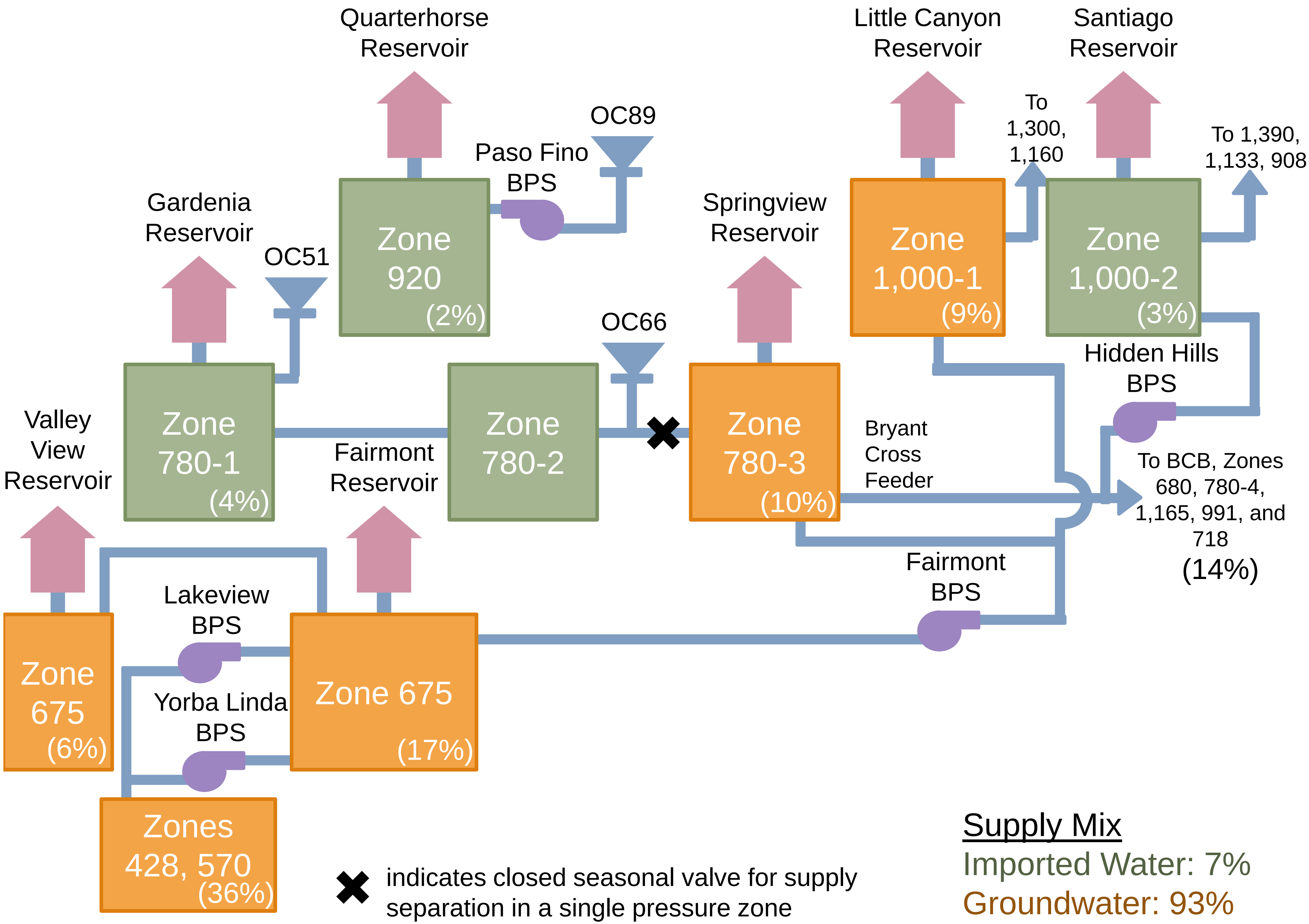


Figure B.9 - Condition 9



<u>Supply Mix</u>
Imported Water: 7%
Groundwater: 93%

Appendix C

RESERVOIR STORAGE GROUPS

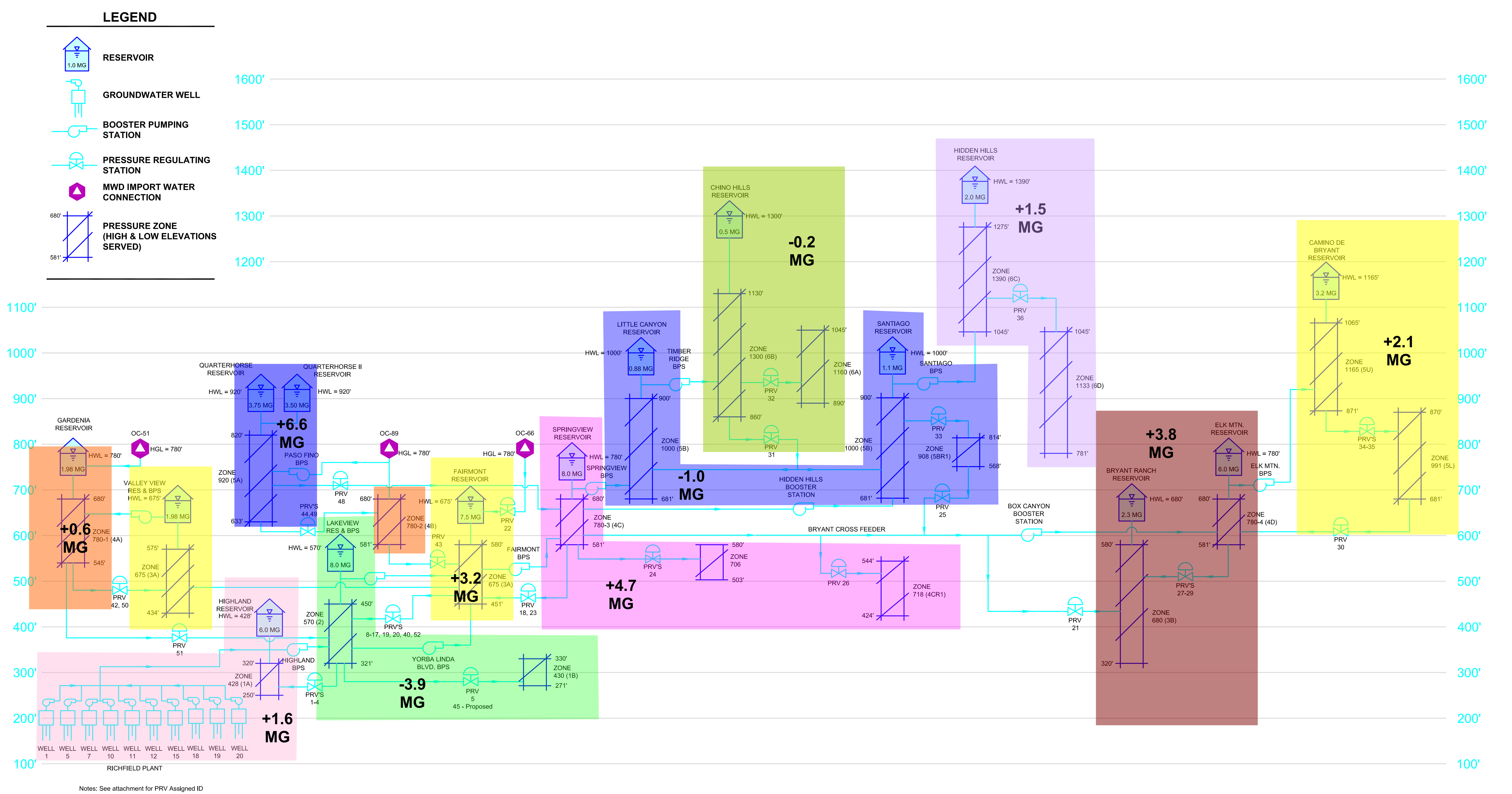


FIGURE C.1

HYDRAULIC PROFILE SCHEMATIC

YORBA LINDA WATER DISTRICT

March 2013

Yorba Linda Water District

Appendix D

HYDRAULIC MODEL MANUAL

This manual is intended as a reference for the District in utilization of the hydraulic model prepared as a part of the Northeast Area Planning Study. For further details on the calibration efforts, refer to Appendix E of the Northeast Area Planning Study report. An electronic copy of the facilities model data will be included with this report.

D.1 HYDRAULIC MODEL OVERVIEW

Rapid innovations in personal computing and the large selection of software have made network analysis modeling efficient and practical for virtually any water system. Hydraulic modeling is an important tool for analyzing a water system. Hydraulic models can simulate existing and future water systems, identify system deficiencies, analyze impacts from increased demands, and evaluate the effectiveness of proposed system improvements, including those within capital improvement plans. In addition, a hydraulic model provides both the engineer and water system operator with a better understanding of the water system. Hydraulic models are typically composed of three main parts:

- The data file that stores the geographic location of facilities. The geographic data file provides water system facility locations and is typically represented as an AutoCAD or geographic information systems (GIS) file. Elements used in this file to model system facilities include pipes, junction nodes (connection points for pipes and location of demands), control valves, pumps, tanks, and reservoirs.
- A database that defines the physical system. The database for the District's model is linked to the geographic data file. The database includes water system facility information such as facility size and geometry, operational characteristics, and production/consumption data.
- A computer program "calculator". This calculator solves a series of hydraulic equations based on information in the database file to define and generate the performance of the water system in terms of pressure, flow and operation status.

The key to maximizing benefits from the hydraulic model is correctly interpreting the results so the user understands how the water distribution system is affected by the various components of the model. This understanding enables the engineer to be proactive in developing solutions to existing and future water system goals and objectives. With this approach, the hydraulic model is not only used to identify the adequacy of system performance, but is also used to find solutions for operating the water system according to established performance criteria.

Developing an accurate and reliable hydraulic model begins with entering the best available information into the database and calibrating the model to match existing conditions in the field. Once the model has been calibrated, it becomes a valuable tool to evaluate operational problems and to plan distribution system improvement projects.

D.2 HYDRAULIC MODEL DEVELOPMENT

D.2.1 Hydraulic Model Selection

Several software programs are widely used to model distribution systems. The variety of program capabilities and features makes the selection of a particular software program generally dependent upon three factors: user preference, the requirements of the particular water distribution system, and the cost associated with the software.

The District has selected InfoWater®, developed by Innovyze, Inc., for the hydraulic modeling of its water distribution system.

D.2.2 Previous Hydraulic Model

The District provided its previous model, also developed in InfoWater®, converted as a part of a previous hydraulic model development and calibration effort. The previous hydraulic model was based on the District's GIS layers. As provided, the hydraulic model did not include junction elevations, zone delineations (through initial status set on pipeline segments or valve elements). Groundwater wells were modeled as fixed-head reservoir elements with flow control valves.

The District previously completed a hydraulic model update in 2005 as a part of the Water Master Plan Update. The hydraulic model at that time was developed in H_2ONET® and was not based on the District's GIS layers. Where possible, initial controls and facility information was adapted from the 2005 hydraulic model to provide the basis for discussions with District operations staff in support of updating the controls.

D.2.3 Model Pipelines

Hydraulic models consist of links and nodes to model representations of physical system components of a distribution system. Links are used to represent pipes, pumps, and control valves. Pipeline segments represent the actual transmission or distribution water pipelines. In the attribute table for each pipe, data typically includes diameter, length, roughness coefficient, and pressure zone. The model calculator uses the attribute data to determine increases or decreases in energy levels across the link. Some of the reported output data that the model calculates for links include flows, velocities, head loss, and changes in hydraulic grade line.

As the previous hydraulic model was based on the District's GIS layers, only pipelines constructed since the completion of the District's previous hydraulic model were imported from the District's GIS layers. As will be discussed later, pipeline improvements planned for near-term implementation were also imported into the hydraulic model in a separate near-term scenario.

D.2.4 Model Nodes

Nodes represent the connections between links and may act as either a supply source, such as a reservoir or tank, or a customer demand. Nodes also define the boundaries of each link and separate links that may contain different attributes. Each node also has an elevation. Attribute data associated with each node typically includes elevation, water demand, and pressure zone. The model calculates system pressures, hydraulic grade lines, demands, and water quality parameters at each node.

For pipelines added to the hydraulic model, junctions were automatically generated. Elevations were interpolated for all junctions within the hydraulic model from elevation contours provided by the District, except where more detailed information was available for individual facilities (e.g., reservoir floor elevation was provided by District staff in a separate spreadsheet).

D.2.5 Demand Allocation

The previous hydraulic model included demands allocated based on historical billing records. The total model demands were compared with updated consumption data provided by the District's operations staff and judged sufficiently consistent for use in the hydraulic model through global adjustment to updated demand levels on a District-wide basis.

Where boundary conditions allowed for direct calculation of demands by pressure zone, demands by pressure zone were adjusted slightly as a part of the calibration efforts.

Since the model demands were adjusted globally based on consumption levels calculated from production data, unaccounted for water is implicitly accounted for and was not incorporated separately.

Near-term and future demands (developed as discussed in Section 2.2 of the report) were allocated based on the parcel areas and allocated to the Demand2 field within applicable future scenarios.

D.3 HYDRAULIC MODEL UPDATE

The primary source for the development of the hydraulic model was the District's GIS layers and former hydraulic model. The District provided details on the District's water distribution system facilities as well as updated pump tests and utilization data.

D.3.1 Pipes

Pipe segment information consists of length, location, connectivity, diameter, and where possible, material and installation year. Pipeline connectivity in the model needs to be correct so that flow through the distribution system can be represented correctly. An estimate of initial pipe roughness or friction factor can be derived from the parameters such as material, age, and diameter.

Pipe segment data for the District's hydraulic model was imported from the District's previous model, including information on the material, diameter, connectivity, and location. This information previously had been added to the model based on the District's GIS layers. Length was calculated based on the digitized spatial alignment. The roughness coefficients in the hydraulic model were estimated for various pipeline materials and pressure zones.

Pipelines constructed since the development of the previous hydraulic model were added to the hydraulic model from the District's GIS layers, provided on 9 August 2012. In addition, the following projects were added to the hydraulic model based on record drawings or construction plans provided by District staff:

- Lakeview Grade Separation Project, which included an 18-inch diameter transmission main relocation (dated June 2011)
- 2010 Waterline Replacement Project, including replacement of two PRS and five pipeline segments (July 2012)

Additional pipelines were imported from the District's GIS database based on a spatial overlay and attribute information. It was assumed that pipelines not represented in the previous model, as well as accompanied by a status of "ACT" and owned by "YLWD," should be imported from the GIS database.

A total of 16,983 pipe segments are included in the model (compared with 16,551 pipe segments in the previous hydraulic model; note that many of these are related to future pipe segments and inserted nodes).

In addition to the existing pipelines, several pipelines that are currently in planning or design stages were incorporated into the hydraulic model as near-term facilities. These near-term facilities are:

- Yorba Linda Boulevard Pipeline, including installation of a 20-inch diameter pipeline (dated January 2012)
- Yorba Linda High School Bryant Cross Feeder Replacement – 90 percent drawings (dated December 2012)

As will be discussed later, these pipelines are identified separately from existing facilities in the hydraulic model by use of the Status field. Prior to changing these facilities from near-term (Status of "NRT") to existing (Status of "ACT"), the facility details should be reviewed as they may have changed during the design and construction process.

D.3.2 Elevations

Elevations were interpolated from 3-foot contours provided by District GIS staff. This contour information was used to determine junction and facility elevations throughout the system. Where more detailed information was available (such as the previous hydraulic model for reservoirs or facility details from District staff), these elevations were used instead of interpolating from the contour layer.

D.3.3 Groundwater Wells

Well data includes well production capacity, pump total dynamic head, elevation, groundwater levels, and control scheme to determine the conditions under which the wells operate.

The District's well locations were included in the previous version of the hydraulic model and verified with the District's GIS layers where discrepancies were identified. All groundwater wells were converted from fixed-grade reservoir elements (with head representing maximum head capacity of the pump station) and a flow-control valve to pump elements with the aquifer modeled as a fixed-grade reservoir element representing the groundwater level. As the groundwater level changes, it will need to be updated within the hydraulic model. The description field of the reservoir elements was used to indicate the date of the groundwater level used in the modeling.

Where possible, full pump curves were used (to increase model flexibility). Well number 19 was modeled using the variable-speed pump capabilities of InfoWater. After discussions with District operations staff regarding the control of engine-driven pumps, the engine-driven pumps were modeled using pump settings rather than variable-speed pump capabilities.

District staff provided hydraulic details, including groundwater levels and pump test data from Southern California Edison (SCE) pump tests conducted in 2011.

Two additional wells were added to the model, listed as follows:

- Well 20 (added to active scenario, with controls disabling the well)
- Well 21 (added to near term scenario)

D.3.4 Reservoirs

Reservoir data includes base elevation, overflow elevation, effective diameter and height. The locations of the system's storage facilities were obtained from the previous hydraulic model. Reservoir volumes were reconciled with volume-depth curves provided by District staff.

During the calibration process, it was noted that Quarterhorse and Hidden Hills reservoirs were currently operated with only one bay active. For Quarterhorse, the previous hydraulic model had modeled the reservoir as two separate tank elements, one with a volume equivalent to about half of the total operating capacity and one with a volume equivalent to the full operating capacity. The volume-depth curves were updated so that each tank element corresponds to the volume of an individual bay (i.e., the North Bay with a volume of 3.7 MG and the South Bay with a volume of 3.5 MG). The North Bay was inactivated by setting the status of the relevant model elements to “INA”. To reactivate the elements temporarily, the facility manager can be used. To reactivate the elements within the existing scenario, the status should be set to “ACT”.

For Hidden Hills, a volume-depth curve was added to the model representing the volume of a single bay. This volume-depth curve is named “RESVOL_HH_INDBAY”. To change the tank to use the full reservoir volume, change the curve to “RESVOL_HH_TOTAL”.

D.3.5 Pressure Reducing Stations

Pressure Reducing Station (PRS) information includes number of valves, valve type, valve diameter, location, elevation, and pressure set points. District staff provided two lists of updated hydraulic details and pressure setpoints for the District’s PRSs. Previous versions of the hydraulic model included only the larger pressure reducing valve for each PRS (40 valves in 40 PRS). This is generally sufficient for fire flow analysis, but given the water quality modeling capabilities associated with this project, all pressure reducing valves should be modeled within each PRS. Carollo included 48 additional valves in the model accordingly for a total of 88 valves in 44 PRS. Pressure relief valves, which operate only under emergency or atypical conditions, were not modeled.

PRS constructed as a part of the following projects were added since the development of the previous hydraulic model were added to the hydraulic model from the District’s GIS layers, provided on 9 August 2012. In addition, the following projects were added to the hydraulic model based on record drawings or construction plans provided by District staff:

- 2010 Waterline Replacement Project, including replacement of two PRS and five pipeline segments (July 2012)
- Pressure Reducing Station Upgrades, including replacement of four PRS (dated August 2011)

D.3.6 Booster Pumping Stations

Data for booster pumping stations includes pump capacity, hydraulic performance curve, number of pumps, and pump control scheme.

District staff provided updated pump test information and manufacturer pump curves, as available. Where applicable, the individual pump units were updated within the hydraulic model. In addition, the Yorba Linda Boulevard Booster Pumping Station (dated August 2012) project was added to the hydraulic model in the near-term scenario.

D.3.7 Operational Information

Operational information includes pump and well control schemes, PRV and PSV setpoints, and general operating strategy. The general operating strategy includes items such as managing blending of supplies to meet water quality objectives, water turnover in reservoirs, and determining which water sources to use run based on water resources or other constraints.

The District's control schemes and operating strategy is adjusted to respond to changing demands and operational conditions. The District's control strategy relies on human operators with detailed knowledge of the distribution system making the key decisions about the overall control of the system. Typically, the operator adjusts controls of wells, booster pumping stations, and imported water connections based on several priorities:

- Reservoir cycling to reduce water quality issues
- Sufficient reservoir volume in case of emergency
- Annual supply ratios/percentages of imported water versus groundwater supply
- Time of use electricity rates, only for the following sites:
  - Springview BPS
  - Hidden Hills BPS
  - Box Canyon BPS
  - Elk Mountain BPS

Based on discussions with District operations staff, most operators control the booster pump stations to achieve cycling of each tank based on the levels shown in Table D.1. District staff noted that the operational controls include a low-level cutoff point, generally between 6 and 8 feet, in which an escalating series of alarms are provided to the operator and, if not responded to, the applicable BPS units are shutoff.

It should be noted that operational controls are adjusted periodically, and thus are intended to represent typical behavior of the water distribution system. During the calibration, adjustments were made based on the recorded SCADA data.

D.3.8 SCADA Data

Based on discussions with District staff and initial review of the SCADA data, it was decided to use a 7-day period for the EPS calibration, selected between August 9th through 16th,

2012. During the selected EPS calibration period, District operations staff were targeting a supply mix of 60 percent imported water and 40 percent groundwater.

Table D.1 Operational Controls

Name	Contributing BPS / Facility	Cycled Between Lower (ft)	Cycled Between Upper (ft)	Notes
Reservoirs				
Camino de Bryant	Elk Mountain	6/8	10/12	
Elk Mountain	Box Canyon	10	16/20	Increased level when additional storage needed.
Fairmont	Palm Avenue	12	20	
Gardenia	Valley View	18	28	
Hidden Hills	Santiago	3	8	
Highland	wellfield	12	20	
Lakeview	Highland	13	28	
Little Canyon	Springview	8	18	
Quarter Horse	Paso Fino	7/8	15/16	
Santiago	Hidden Hills	10	18	
Springview	Fairmont	10	20	Requires call to MWDSC in order to adjust.
Chino Hills	Timber Ridge	8	18	
Valley View	Lakeview	12	20	Floats based on hydraulics in the system.
Pressure Reducing Stations				
OC51	Gardenia			
OC66	Springview			
OC89	Paso Fino PS			Paso Fino PS boosts pressure of OC89, so control for the two are intertied; within the hydraulic model, this is accomplished using a clearwell
Pressure Reducing Stations				
Copper Canyon	Bryant Ranch	10	20	
Del Rey	Fairmont	14	20	

The SCADA data was used to develop the diurnal patterns and establish controls for model facilities. Further details on the calibration process are discussed in Appendix E.

D.3.1 Seasonal Valves

The District adjusts supplies to some of its pressure zones through the operation of seasonal valves. Based on discussions with District staff seasonal valves were identified along with the general reasons that the valves may be adjusted. The state of the seasonal valves in August 2012 along with the details regarding their purpose are described in Table D.2. Locations for each of the seasonal valves are included in Figure 2 of the report.

Table D.2 Assumed Status of Seasonal Valves

ID	Zone	Number	Location	Status (August 2012)	Use	Description
SV1	3A	O-13/ 147	Fairmont Bl. & Lariat Dr.	Open	isolates Fairmont Reservoir from Distribution System	Zone 3 Fairmont Reservoir isolation on Bastanchury/Fairmont
SV2	3A	O-12/30	Bastanchury Rd. & Clydesdale Dr. (on 18”)	Open	separates Valley View and Fairmont Portions of Zone 3A	Valley View/Fairmont Clydesdale isolation west Clydesdale
SV3	5B/5B R1	M-16/12	Stonehaven Dr. & Rockhampton Ct./ Heatheridge Dr.	Closed	separates Santiago and Little Canyon portions of Zone 5B	San Antonio/Little Canyon
SV4	4B	O-12/65	Lariat Dr./Bastanchury Rd., 1,200’ e/o Clydesdale Dr. (on 36”)	Open	separates Gardenia and middle portions of Zone 4B (alternatively could also be looked at as moving some of Zone 4B into 4C)	Gardenia/SV zone 4 Gardenia/SV after school
SV5	4B/3A	O-12/58	Maple Leaf Ln. 300’ w/o Cedar Creek Dr.	Closed		Mapleleaf
SV6	3A	O-10/67	Lakeview Av. 600’ n/o Bastanchury Rd. (on 16”)	Closed	w/ SV7, separates Valley View and Fairmont Portions of Zone 3A	Lakeview zone 3 Valley View/Fairmont Shutoff Lakeview
SV7	3A	O-10/95	Bastanchury Rd. 900’ w/o Lakeview Av. (on 16”)	Closed	w/ SV6, separates Valley View and Fairmont Portions of Zone 3A (Lakeview BPS can supply Valley View)	Plumosa Between airvacs zone 3

Notes:
1.For all valves except SV3, state is assumed based on SCADA data and effect on model.

D.4 SCENARIOS

Scenarios were setup in the hydraulic model to simulate different demand conditions, operating conditions, and active facilities. To simplify organization, hierarchical scenarios were used, as shown in the list of scenarios in Table D.3, along with a description of the intended operating condition the scenario simulates.

Table D.3 Scenarios

Scenario Name	Description	Intent
BASE	Base Data Scenario	Not for Use (Folder)
CALIB	Calibration Scenarios	Not for Use (Folder)
CALIB_EPS_10DY	EPS Calibration (168 hour simulation)	Validates Controls
CALIB_EPS_ALLWELLS	All Groundwater Wells Active	Validates Roughness Coefficients Between Wellfield and Highland Reservoir
CALIB_EPS_WATERQUAL	Water Quality Scenarios	Not for Use (Folder)
CALIB_EPS_AGE	Water Age Analysis	Establish Hydraulic Retention Time
CALIB_EPS_MSX	Multi-Species Water Quality Analysis	Model Chlorine Residuals
CALIB_FF_2011		Not for Use (Folder)
CALIB_FF_2011_##	Fireflow Test ## Dynamic Condition	Validates Roughness Coefficients
CALIB_FF_2011_ST_##	Fireflow Test ## Static Condition	Validates HGL
EXISTING	Existing System Scenarios	Not for Use (Folder)
EXIST_ADD	Existing System ADD Conditions	Typical Operation of System
EXIST_MDD	Existing System MDD Conditions	Peak Demand Conditions
EXIST_MINDD	Existing System MinDD Conditions	Minimum Demand Conditions
FUTURE	Future System Scenarios	Not for Use (Folder)
FUTURE_NEARTERM	Future System Scenarios	Not for Use (Folder)
FUR_NRT_MDD	Future System MDD Conditions	Not for Use (Folder)

Table D.3 Scenarios		
Scenario Name	**Description**	**Intent**
FUR_NRT_MDD_CND1	Future System MDD – Supply Operating Condition 1	Near-term System Maximizing Imported Water
FUR_NRT_MDD_CND6	Future System MDD – Supply Operating Condition 6	Near-term System Zones 5A and 5B Groundwater
FUR_NRT_MDD_CND9	Future System MDD – Supply Operating Condition 9	Near-term System Maximizing Groundwater

Notes:

refers to each specific calibration test, numbered 01 through 21, and represents several scenarios. Note that each fireflow test is setup as a steady-state analysis using a start clock-time to establish the time of the test.

D.5 DEMANDS

D.5.1 Demand Conditions and Demand Sets

Demand sets are used to model different scenarios for the distribution system. Within InfoWater®, scenarios are assigned a Demand Set, corresponding to a specific demand condition. For example, showing the system under average day demand conditions by selecting the “EXIST_ADD” demand set.

The model is set up to utilize the demand sets to represent average day demand conditions. For demand conditions other than ADD, the seasonal peaking factor can be adjusted using the global multiplier in simulation options. This is intended to reduce the complexity of adding demands to the model, as when adding a new demand to the existing system it will not need to be manually included in the demand sets for Maximum Day Demands, Average Day Demands, etc.

The main demand sets to be used are EXIST_ADD, representing existing demand conditions, and NRT_ADD, representing near-term demand conditions with development demands incorporated. The model demand sets, are shown in Table D.4.

Table D.4 Demand Sets		
Demand Set ID	**Description**	**Intended Use**
BASE	Base Demand Set	Not for Use
CALIB_FF_2011	-	Not for Use
CALIB_FF_2011_##	Demand for Fireflow Test ## Dynamic Condition	Verifying Calibration
EXIST_PREVMODEL	Demand Table from Previous Hydraulic Model	Backup
EXIST_ADD	Existing Average Day Demand	Analysis of Existing System
NRT_ADD	Near-Term Future Demand	Analysis of Future System
Notes:		
## refers to each specific calibration test, numbered 01 through 21, and represents several scenarios.		

The above demand sets are assigned to the appropriate scenarios, such that when a scenario is selected, the demand set will become active.

D.5.2 Demand Tables

Within InfoWater®, each Demand Set consists of a demand table containing ten fields of demands assigned to each junction, named Demand1 through Demand10. Each field can represent a component of demand. For this model, the demand tables use only the Demand1 and Demand2 fields.

Table D.5 Demand Table Fields		
Field Name	**Scenarios**	**Demand Source**
Demand1	All	Existing System Demands
Demand2	Calibration	Fireflow Demand (based on Fireflow Test)
Demand2	Future	Development Demadns

It is recommended that when testing alternatives in the existing system Demand3 through Demand10 are used to avoid unintentionally adding demands into the existing system database.

D.6 DATABASE FIELDS

D.6.1 Attribute Data Information

For junction elements, attribute data was added for the fields DEMAND, FACILITY, and STATUS. Descriptions for the junction fields added to the model as well as sources are shown in Table D.6.

Table D.6 Junction Attribute Data Fields

Field Name	Description	Valid Entries	Source
YR_INST	Indicates year facility was installed.	Integer, blank used for unknown years.	Added, where facilities were added as a part of this project
YR_RETIRE	Indicates year facility is anticipated to be retired.	Integer, 9999 used for unknown years.	Fully populated (used in facility management to indicate an element to be retired in future scenarios)
ZONE	Pressure zone which junction is a part of.	Zone name (uses number-letter designation)	Fully populated from pipelines
ELEVATION	Elevation (for pressure calculations)	Elevation, in ft-msl	Interpolated from ground elevation contours provided by District
FAC_NODE	Indicates if the junction is a part of a facility (use for output relates with pressure criteria)	Boolean (Yes or No)	Generated by Consultant
DMD_NODE	Indicates if the junction has demands allocated (use for output relates with pressure criteria)	Boolean (Yes or No)	Generated by Consultant, based on previous DemandType field
STATUS	Indicates whether a facility is active in the existing system.	ACT, INA, RET, NRT, OTH, ABN	Generated by Consultant

The Junction Description field was also populated where relevant. The Junction Zone field was fully populated and made consistent for use in Database Queries.

The DEMAND and FACILITY fields can be useful in restricting analysis to specific conditions (e.g., does this improvement cause pressure at any demand nodes to fall below

40 psi or are velocities in any pipe segments over 10 fps). Database queries using output relates were generated and included in the domain manager for this purpose.

For pipeline elements, attribute data was used from the previous hydraulic model and imported from the District's GIS layers for facilities that were updated. Descriptions for all the fields added to the pipeline elements in the model as well as sources are shown in Table D.7.

Table D.7 Pipeline Attribute Data Fields

Field Name	Description	Valid Entries	Source
YR_INST	Year pipeline installed. Adapted from year of "ASBUILT" field. For pipelines with unknown "ASBUILT" field, used "SIGNDATE" field.	Integer (1925 – 2013), 9999 used for unknown years.	Previous model or GIS database
YR_RETIRE	Indicates year facility is anticipated to be retired.	Integer, 9999 used for unknown years.	Fully populated (used in facility management to indicate an element to be retired in future scenarios)
ZONE	Pressure zone which pipeline is a part of.	Zone name (uses number-letter designation)	Previous model or GIS database (fully populated and made consistent)
MATERIAL	Pipeline material	ACP, CIL, CIN, CIP, CML, CMLCS, CO, DIP, DW, PVC, STL, WS, blank for unknown	Previous model or GIS database
ATLAS	Number corresponding to atlas map on which pipe segment appears.	X - #	Previous model or GIS database, populated for all added elements
OWNER	Indicates pipeline owner	YLWD, ANAHEIM, MWDSC	Previous model or GIS database
DWGNO	Drawing number	Alpha numeric ID	Previous model or GIS database
ASBUILTNO	As build number	Alpha numeric ID	Previous model or GIS database
STATUS	Indicates whether a facility is active in the existing system.	ACT, INA, RET, NRT, OTH, ABN	Previous model or GIS database

The Pipe Description field was also populated where relevant. The STATUS fields are used as part of facility management in switching between scenarios. For example, using the value NRT (meaning Near Term) for a pipe segment being evaluated will prevent the segment from being active in the Existing Scenarios.

D.7 DATA SETS

D.7.1 Pipe Sets

Pipe sets are not used in the hydraulic model; care should be taken when using pipe sets to prevent unintended inconsistencies between hydraulic model scenarios.

D.7.2 Control Sets

32 control sets are used in the hydraulic model, listed as follows:

- EXIST_TYP_ADDExisting System Typical Controls Average Day Demand
- EXIST_TYP_MDDExisting System Typical Controls Maximum Day Demand
- EXIST_TYP_MINDDExisting System Typical Controls Minimum Day Demand
- CALIB_10D_EPSCalibration Controls
- CALIB_MISC_ALLWELLSInitial Status Set for 11 July 2012 Test of All Wells
- CALIB_WQ_EPSStable Convergence Controls (for longer duration simulations)
- CALIB_FF_01 through CALIB_FF_21
- EXIST_CND06_MDDExisting System MDD - Supply Condition 6 (Zone 5A/5B GW)
- EXIST_CND01_MDDExisting System MDD - Supply Condition 1 (Zone 3A IW)
- EXIST_CND09_MDD

The CALIB_ control sets are used to establish the specific and detailed controls from the calibration period. These control sets should only be used to replicate calibration conditions. The CALIB_FF_01 through CALIB_FF_21 control sets are static representations of the state of the distribution system, intended for steady state runs only.

The EXIST_TYP_MDD control set represents the typical operations of the system as determined from discussions with District operations staff. Changes to the District's typical control strategies should be made in this control set.

If more specific controls are needed to evaluate system performance under different conditions (e.g., proposed new level setpoints), it is recommended to copy the EXIST_TYP_MDD control set and assign it to the specific scenario. Alternatively, when modeling entirely new facilities, adding controls to the EXIST_TYP_MDD control set will not impact existing facilities once the new facilities have been inactivated (i.e., using control sets across scenarios can be a good idea).

D.8 WATER QUALITY CAPABILITIES

Two sets of Simulation Options were setup for water quality analysis, a traditional water age simulation and a multi-species chlorine residual analysis simulation.

D.8.1 Age Analysis

Age analysis is used for predicting hydraulic retention times and water age. The Scenario CALIB_EPS_AGE is setup to perform age analysis. Age analysis can be performed in other scenarios by changing the simulation options to MDD_SPF_AGE.

Age analysis requires significant simulation times so that times within the reservoirs converge. Age analysis should be used with some of the longer duration Simulation Time options for this reason. Computational performance can be increased by disabling reporting of the bulk of the long simulation times; this is included in the EPS_30DY time options (the EPS_30DY_DEBUG includes the full reporting for troubleshooting). It is recommended to utilize more stable control settings for this type of analysis (as used in CALIB_WQ_EPS).

Initial values are included in the EXIST_AGE quality set that simplify this process.

D.8.2 Chlorine Residual Analysis

As discussed in detail in Appendix E, InfoWater’s Multi-Species Extension (MSX) was used to model chlorine residuals. A first-order decay equation was adapted into the built-in chloramine decomposition model to model free chlorine decay for the groundwater supplied zones within the District’s distribution system.

To utilize the MSX capabilities, use the simulation options MDD_SPF_MSXCR. Calculated concentrations for chlorine residual will be output in the following fields in units of mg/L:

- CCOMBCL – Combined Chlorine from the chloramines decay model, representing the summation of monochloramine and dichloramine
- CFREECL – Free Chlorine from the first-order decay model
- CTOTALCL – Total Chlorine, the summation of the combined chlorine from the chloramine decay model and the free chlorine from the first-order decay model

To adjust initial chlorine concentrations, select the relevant element in the Model Explorer and click the Multi-Species Water Quality button and adjust the relevant parameters (although injection occurs downstream of the pump units, the Reservoir elements were used to establish initial conditions for simplicity). Global initial values can be adjusted in the

Run Manager > Simulation Options > Quality tab > MSX Model (ChlorChl) > Species tab > Global Init. (Note that some species are in units of mols per liter).

Note that the MSX extension dramatically increases the computational load, with a 7-day simulation requiring about 20 hours to simulate (on an Intel Core 2 Duo processor).

D.9 MODEL MAINTENANCE PROCEDURES

The hydraulic model is setup to use Query Sets for switching the active facility set within each scenario. If new elements are added to the model, they will behave as active until the model scenario is changed unless the STATUS field is properly populated. If the STATUS field is not populated, the new element will become inactive after switching scenarios. Ordinarily, this should cause the model to be resilient towards unintended modifications due to temporary analysis or “what if” scenarios, but this may create some unexpected errors if, for instance, junctions are inserted into an existing pipeline segment without the STATUS field of the junction set to match the pipeline.

To maintain consistency with the District’s GIS layers, the values in the status field of the District’s GIS layer (LIFECYCLES) was used as the STATUS field.

Two query sets are included for switching between scenarios:

- FAC_EXIST: Existing system and Calibration scenarios. Includes elements with the STATUS field of “ACT”
- FAC_FUT_NEARTERM: Facilities planned in the near-term. Includes elements with the STATUS field of “NRT” and elements with a STATUS field of “ACT” that also have a retirement year greater than 2013.

To create elements within the existing system scenario (that are intended to remain in the existing system scenario), populate the STATUS field of all the elements with “ACT” (without quotes) and the YR_RETIRE field of 9999. It would be of benefit to the District to ensure that the installation year, pressure zone, DMD_NODE, FAC_NODE, elevation, and hydraulic data are fully populated when adding elements to the model.

No retirement year is incorporated for the existing scenario, to avoid retiring facilities unintentionally. Instead, the STATUS field of facilities that are to be retired should be set to RET, INA, OTH, or ABN (all values currently in the model used for this purpose).

Since the calibration scenarios are based on the existing facility set at the time of delivery of this model, changes to the existing facilities will change the functionality of the calibration scenarios in the future. It is recommended that checking of the original calibration be conducted based on the delivered hydraulic model (thus, the calibration scenarios and datasets could be deleted from other updated versions of the hydraulic model).

Appendix E

HYDRAULIC MODEL CALIBRATION

This appendix provides an overview of the hydraulic model calibration efforts undertaken as a part of the Northeast Area Planning Study.

E.1 INTRODUCTION

Calibration is a necessary element in developing an accurate hydraulic model. Calibration is attained by comparing model results with field measurements and adjusting the model components, such as pipe roughness coefficients and model controls, until the model produces results that agree with the field measurements.

Following the update of the District's hydraulic model, it was calibrated so that a level of confidence in the simulation of pressures and flows could be achieved. Calibration is complicated by the fact that some data are static and known, some data are variable, and others are estimated.

Data related to pipe diameter, length, roughness coefficient, and locations are known with a great deal of certainty. Data related to the District's SCADA systems vary with time, day, season, and the number of customers. Pump rates and discharge pressures vary accordingly based on the demands and controls.

Hydraulic models are calibrated by comparing field data with model results to accomplish the following purposes:

- Establish a degree of confidence in the model, allowing for use in system planning and/or facility sizing
- Identify data errors or identify missing data parameters
- Discover anomalies in the field

This chapter discusses the field-testing used to gather data for the model calibration, the calibration methodology, and the calibration results.

E.2 CALIBRATION METHODOLOGY

The model calibration consists of four parts:

- Macro calibration
- Fire flow test calibration
- Extended period simulation (EPS) calibration
- Water quality calibration

This section discusses the methodology for each part of the calibration.

It should be noted that the model is a simulation of the behavior of the water distribution system. The actual water distribution system is affected by many more detailed events than can be simulated in the model and the intention of the calibration of the hydraulic model is to predict the general behavior of the water distribution system. Thus, the focus of the calibration was on preparing the model to predict general behavior of the system in a variety of conditions rather than explicitly replicating the field conditions observed during the calibration.

The methodology and results of each of these four calibration steps is described below.

E.3 MACRO CALIBRATION

This initial calibration process is a macro calibration. The purpose of macro calibration is to make the model run under calibration day demand conditions and produce reasonable system pressures and cycling reservoirs. Adjustments to the model made in this first step included modifications of pipeline connectivity, operational controls, ground elevations, and facility characteristics, as well as the facility control schemes.

The macro calibration process involved three specific focus areas to improve the accuracy of model results. These are connectivity, system pressures, and pump stations.

The connectivity features of the hydraulic modeling software were used to verify the connectivity of the transmission mains within the distribution system. Problems found using the connectivity checking tools were reviewed on a case-by-case basis to determine whether adjustments needed to be made to the connectivity. Very few pipelines needed modifications of network connectivity.

Typical pressures were compared with the model output. This process was used to find errors in the model, such as elevations, or pipe connectivity, as well as changes required in how operational controls were to be implemented in the model.

Pressures and flows predicted by the model for each pump station in the system were compared to pump tests provided by the District to verify that the pump attributes entered into the model, such as pump power, groundwater depth and the pump curves, produce results comparable to collected data.

E.4 FIRE FLOW CALIBRATION

Fire flow calibration is intended to stress the District’s distribution system by creating a differential between the hydraulic grade line (HGL) at the point of hydrant flow and the system HGL at neighboring hydrants. In general, fire flow tests consist of using flowing hydrants and test or pressure residual hydrants. The field tests are then simulated within the hydraulic model to calibrate the model under steady state conditions.

Hazen-Williams roughness coefficients, or C-factors, have industry accepted value ranges based on pipeline material, diameter, and age. Characteristics specific to the District's distribution system such as water quality (e.g. Langelier index, pH, TDS, etc.), temperature, construction methodologies, material suppliers, and other factors may result in roughness coefficients that differ from the typical coefficients used the industry.

Fire flow calibration refines the initial estimation of the value of roughness coefficients that best indicate the conditions of the District's distribution system. During average day demand conditions, roughness coefficients have a relatively small effect on the operation of the distribution system. As the demands increase in the system during warm weather days, velocity within pipelines increase and roughness coefficients contribute more to overall system head loss. The hydraulic grade line (HGL) differential caused by the fire flow test increased the effect of the roughness coefficients on system losses. Fire flow tests artificially create high demand events to generate more head loss, allowing a better estimation of the pipeline roughness coefficients.

Roughness coefficients were adjusted only within a tolerance of industry accepted roughness coefficient ranges to match measured system pressures. When the model was unable to match the calibration results without leaving the acceptable range of roughness coefficient values for a given pipeline material and age, further investigation of was conducted to identify to cause of the difference between model and field results. This investigation included the identification of closed pipelines, partially closed or malfunctioning valves, extreme corrosion within pipelines, connectivity and diameter errors in GIS/as-builds, and/or diurnal patterns of large water users.

The calibration of fire flow tests is intended to develop a steady state (single time step) calibrated hydraulic model by closely matching its water model pressures to field pressures under similar demand and system boundary conditions. The primary varied parameter for this calibration was the pipeline roughness coefficient, although some other parameters were adjusted during the calibration process as appropriate.

E.4.1 Field Testing

Fire flow calibration was completed using historical fire flow tests. Field testing for those tests was conducted in September 2011, prior to this study.

Boundary conditions for the hydraulic model were developed based on production data provided by District staff. For calibration purposes, the hydraulic model demands were adjusted to match the demands experienced during the fire flow testing.

Table E.1	Demands During Calibration				
			Demand		Peaking Factor[1] (Compared to ADD)
Date	Day	General Temperature	Production (mgd)	Consumption (mgd)	
September 22, 2011	Thursday	85° F	20.5	22.2	1.02
September 26, 2011	Monday	79° F	19.5	23.1	1.06
September 27, 2011	Tuesday	90° F	23.3	21.2	0.98

Notes:
(1) Based on ADD for 2011.

As shown in Table E.1, the demand during the calibration testing was fairly even with average annual demand for the District's water distribution system. It is desirable to have higher than average demands during the fire flow calibration, so that system is tested in a stressed state, where roughness coefficients have a greater impact on the measured pressures in the distribution system. However, the segmented nature of the District's water distribution system (given the number of pressure zones) limits this effect on the locations of individual fire flow tests. Sites for each of the 21 tests are presented on Figure E.1.

E.4.2 Fire Flow Calibration Methodology

Simulation options were developed for each calibration day (listed in Table E.1) to establish global multipliers for the demands. Flow and static scenarios were then setup for each fire flow test, with time settings developed to create a steady state scenario at the approximate time of the test (rounded to the nearest 5-minute increment).

For each test, the nearest junction to the flowing and residual hydrants was identified. If necessary, pipelines were split to add a new junction for each hydrant. The fire flow demand was established on the junction representing the flowing hydrant for the flow scenario. These demands were scaled to account for the demand multiplier and added to the Demand2 field. Predicted pressure at the junction representing the residual hydrant was then recorded for the static and flowing scenarios. Initial calibration results were presented to District staff and further investigation was conducted to identify potential unknown field issues associated with the predicted residual pressures that did not correlate well with field test results.

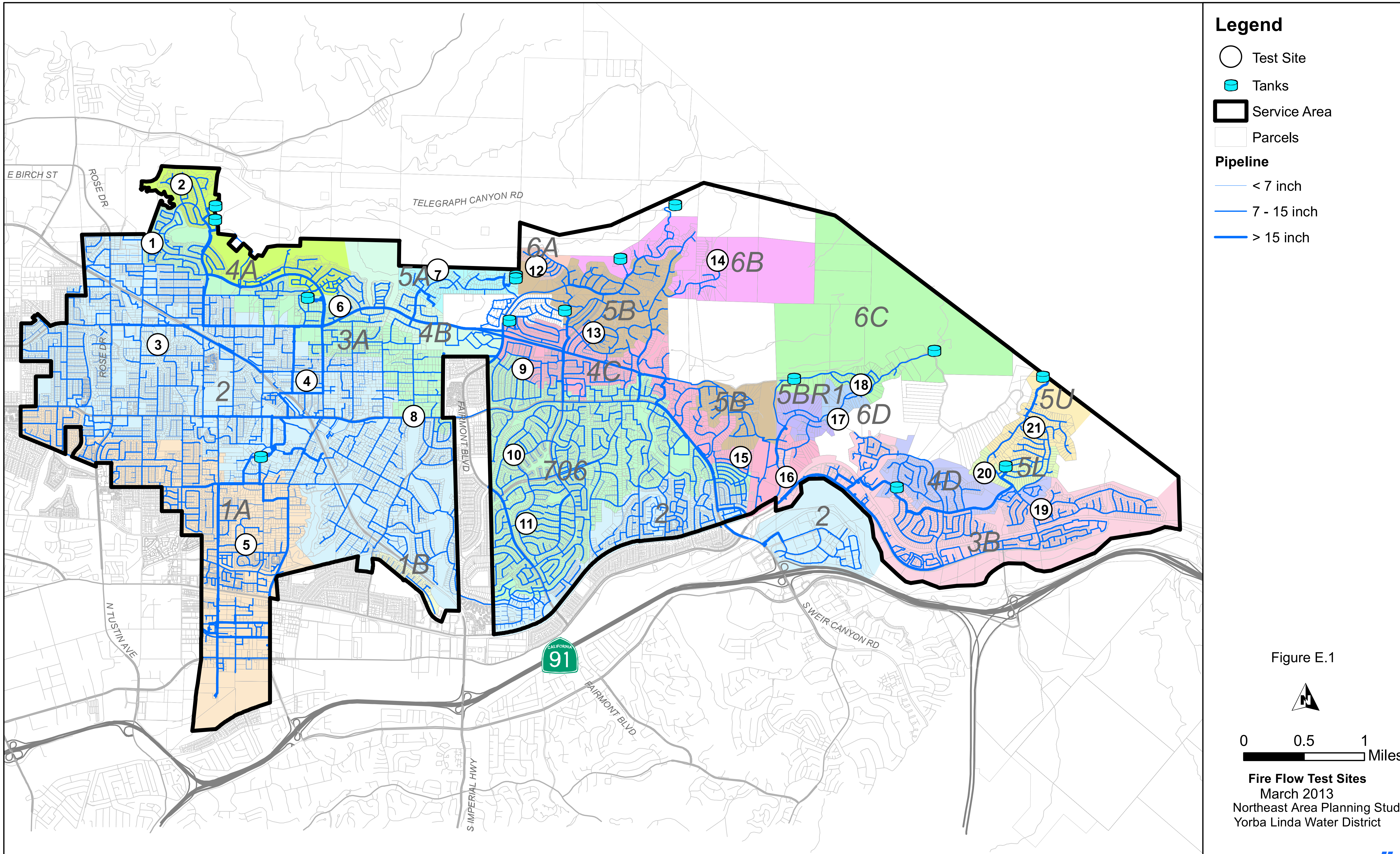


Figure E.1

Fire Flow Test Sites
March 2013
Northeast Area Planning Study
Yorba Linda Water District

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Table E.2 Fire Flow Test Calibration Results

Test	Model ID	Flow (gpm)	Date	Time	Field Static Pressure (psi)	Model Static Pressure (psi)	Field Residual Pressure (psi)	Model Residual Pressure (psi)	Static Difference (psi)	Residual Difference (psi)	Static Difference	Residual Difference
1	J4254	1,301	9/27	13:00	78	77	70	71	+1	-1	-1%	+1%
2	J9816	1,632	9/22	10:40	74	72	56	58	+2	-2	-3%	+3%
3	J9356	1,698	9/22	9:00	85	85	73	74	+0	-1	-1%	+2%
4	J27980	1,447	9/27	14:15	60	58	48	49	+2	-1	-4%	+2%
5	J494	1,632	9/22	11:20	65	63	55	55	+2	-0	-4%	+0%
6	J15756	1,662	9/22	13:15	95	92	85	85	+3	-0	-3%	+0%
7	J22598	1,496	9/22	13:40	95	91	65	64	+4	+1	-4%	-2%
8	J19200	1,870	9/22	14:50	96	97	87	90	-1	-3	+1%	+3%
9	J22318	1,585	9/27	11:20	84	82	74	77	+2	-3	-2%	+4%
10	J24512	1,571	9/26	8:40	58	72	48	68	-14	-20	+25%	+42%
11	J22738	1,294	9/26	9:25	70	67	40	42	+3	-2	-5%	+4%
12	J20000	1,578	9/26	10:00	95	94	70	70	+1	+0	-1%	-1%
13	J22426	1,763	9/26	10:25	123	121	90	90	+2	+0	-1%	-0%
14	J26146	1,161	9/26	10:55	97	97	60	74	-0	-14	+0%	+24%
15	J15388	2,334	9/26	13:10	111	112	105	106	-1	-1	+1%	+1%
16	J16148	630	9/26	13:45	70	71	55	57	-1	-2	+1%	+4%
17	J15610	1,264	9/26	15:05	125	125	100	101	-0	-1	+0%	+1%
18	J13356	1,883	9/27	9:05	125	125	98	97	+0	+1	-0%	-1%
19	J19468	1,675	9/27	9:40	102	100	82	84	+2	-2	-2%	+3%
20	J15220	1,739	9/27	10:00	88	88	65	65	-0	+0	+0%	-0%
21	J18204	1,611	9/27	10:27	74	72	64	64	+2	+0	-2%	-0%
Average									0	-2	-0%	+4%

Notes:

1. Colors based on percentage difference, with green indicating correlation between model prediction and field testing of 5% or less, yellow indication 5% to 10%, and red indicating greater than 10%.

E.4.3 Fire Flow Calibration Results

Calibration results are presented in Table E.2, showing both the field test results and model predictions for static and residual pressures. As shown, model predictions were within five percent of field-testing results for 19 of the 21 tests.

For Test 10, model predictions of both static and residual pressures are higher than that observed in the field.

For Test 14, model predictions of static pressures correspond to the field results. However, after applying the fire flow demand of 1,161 gpm, the model predicts less headloss than observed in the field results, with the model prediction for residual pressure about 14 psi above that observed in the field.

In summary, the calibration results indicate the model generally predicts conditions similar to those observed in the field. Within a few areas of the model, there may be unknown local conditions, but the overall distribution system is adequately represented by the model.

Based on the results of the calibration and discussions with District staff, it was concluded that the fireflow calibration was satisfactory.

E.5 EXTENDED PERIOD SIMULATION CALIBRATION

The EPS calibration is intended to calibrate the EPS capabilities of the hydraulic model by closely matching the model pressures, flows, and tank levels to field conditions over a 24-hour period of similar demand and system boundary conditions. The primary parameters varied for this calibration were operational controls and operational control strategies; although other parameters may also be adjusted as calibration results are generated. The EPS calibration is considered the most important part of the model calibration, as it allows comparison of the overall behavior of the model to the behavior of the water distribution system during a prolonged period of time, and therefore also allows simulation of reservoir levels which cannot be evaluated in steady state model runs.

As a part of the EPS calibration, model predictions for parameters such as tank levels and booster pump station flows were compared against recorded SCADA data. The week of August 9th through 16th, 2012, was selected for the EPS calibration due to the higher demands on the system during that period.

As discussed in the Hydraulic Model Manual included in Appendix D, controls for the hydraulic model were developed based on discussions with District operations staff based on the operators typical operating philosophy. Because control of the District's distribution system relies on human decision making rather than computer-controlled hydraulic parameters, several simulation time controls or pattern-based controls were used for the

EPS calibration. For instances where simulation time controls were used, equivalent hydraulic parameter-based controls were developed and added to the model as disabled controls for use in scenarios evaluating alternate demand conditions.

A comparison of model predictions to observed field conditions following calibration for tank levels, booster pump station flows, imported water connection flows, and groundwater well flows, and discharge pressures is included at the end of this appendix. The SCADA data is shown as a point cloud on each chart with one-minute intervals, while model results are represented by a solid line with a five-minute report time step. In summary, the calibration results indicate the model generally predicts conditions similar to those observed in the field. Within a few areas of the model, there may be unknown local conditions, but the overall distribution system is adequately represented by the model.

Based on the results of the calibration, it can be concluded that the model is calibrated to steady state and extended period conditions. The model provides an accurate representation of the District's distribution system and system operations to a level suitable for the purposes of identifying system deficiencies and evaluating capital improvements to the District's water distribution system.

E.6 WATER QUALITY CALIBRATION

The water quality calibration is intended to calibrate the water quality results of the hydraulic model by matching its predicted total chlorine residuals to laboratory-measured chlorine residuals taken from sampling sites in the distribution system.

The intended functionality for this water quality calibration is prediction of disinfectant residual in the District's water distribution system.

Traditional water quality modeling within InfoWater uses a first-order reaction rate to predict the decay of a single constituent. Model development for this project was conducted using InfoWater MSX, which expands this capability to model interactions between constituents.

Predicting total chlorine residuals in the distribution system requires the model to accurately calculate flows and velocities, since the model calculates residual decay and interaction of various water quality constituents by predicting water age from transit time. Once the hydraulic conditions have been adequately established, water quality modeling parameters will be adjusted. Due to the many variables that affect the decay of chlorine residuals, water quality calibration is not an exact science, and there is greater variability in a water quality calibration than a hydraulic calibration.

The key challenge is the fact that the District obtains chloraminated water from MWDOC and uses sodium hypochlorite (free chlorine) to disinfect supplies from groundwater wells. The chemical reactions between these two different types of disinfectants (i.e. free versus combined chlorine) are fairly complex and depend upon several varying parameters. The

District strives to maintain separation of these sources by pressure zone. However, when these two disinfectant types mix, the reaction of free chlorine with combined chlorine can result under certain conditions in localized break-point chlorination. During break-point chlorination, excess free chlorine in chloraminated water consumes the available ammonia so that the remaining disinfectant residual exists as free chlorine. As the free chlorine to ammonia-nitrogen ratio increases, the combined chlorine breaks down to nitrogen gas, resulting in loss of residual, unless excess free chlorine is applied. Break-point chlorination will impact and complicate the free chlorine residual measurements during sampling. The chloraminated water is not detectable as free chlorine, but can be measured as part of the total chlorine samples (i.e. total chlorine residual minus free chlorine residual = chloramines residual).

Free chlorine is a strong oxidant, readily reacting with both organics and inorganics, leading to a gradual decay of free chlorine due to different reactivities of a variety of parameters. Within a water distribution system, the half-life of free chlorine can range from several hours to several days. Unlike chloramines, free chlorine reaction with natural organic matter can lead to trace amounts of hundreds of disinfection byproducts. Since modeling the individual reactions with organic matter would not be feasible, it is important to find modeling parameters that can reflect changes in the various organic content, such as total organic carbon (TOC), dissolved organic carbon (DOC), and UV-254 (a standard measure of absorbance of ultraviolet light). In addition, free chlorine also reacts with inorganics including iron, manganese, and ammonia. As a part of this study, attempts were made to include wall reactions between free chlorine and inorganics commonly occurring in pipeline material; however, given the number of pipe segments within the District's distribution system model, runtimes were found to be unfeasibly long.

Chloramines are less reactive than free chlorine, but, separate from reactions with organics and inorganics, tend to be more unstable due to autodecomposition and reaction with inorganics and natural organic matter. Chloramine decay was modeled in this study based on the model of chloramine decomposition included in AWWARF's *Optimizing Chloramine Treatment*. This model (Valentine, Ozekin, and Vikesland, 1998) was intended to model autodecomposition of chloramines in a distribution system rather than chlorine and chloramines interactions, and includes thirteen rate coefficients. Using this model for chlorine and chloramine interaction would require establishing the rate coefficients for the mixed system through similar experimental sampling as used to develop the model. Since the District strives to maintain separation of water by supply source in different pressure zones, and since the intended functionality for this water quality calibration is prediction of disinfectant residual in the District's water distribution system, free chlorine was modeled as a separate constituent, modeled using first-order decay.

In addition, the total chlorine samples were collected at different times during the day, under different hydraulic conditions, thus "following the water" in the distribution system from the source is challenging. The EPS calibration of the model must give a good representation of flows through the distribution system. With only one sample at each location per day, the temporal variation in chlorine level at each location is not well captured. The District maintains four chlorine analyzers and provided total chlorine samples from SCADA data at these sites to capture some chlorine variation in the system.

The water distribution model is not designed to predict the hydraulics of mixing within the reservoirs. A computational fluid dynamic (CFD) model would need to be created for each reservoir in order to determine how water quality (e.g. water age, temperature gradient, chlorine residuals) changes within each reservoir.

Due to these and other unknown conditions, the water quality calibration results are typically not as accurate as hydraulic calibration, and can be used only to estimate general trends of chlorine decay within the distribution system.

E.6.1 Chlorine Sampling

The sampling sites for the calibration consist of the 37 total chlorine residual (TCR) sampling sites and the 13 sampled reservoir sites. Locations of the 37 TCR sampling sites are presented on Figure E.2 along with five SCADA analyzer locations. The sampling sites are representative of several hydraulic zones and subzones in the distribution system (Zones 1A through 6D), and include both free chlorinated and chloraminated sites, and some mixed disinfectant sites. As the District normally collects its TCR samples every Monday or Tuesday and reservoir samples on Wednesday and Thursday, the water quality calibration date was selected to be Monday, August 13, 2012, and reservoir sampling data from August 8th and 9th, as well as August 15th, was used for the reservoir boundary conditions. This day (August 13, 2012) was selected to fall within the EPS calibration, thus all hydraulic boundary conditions were recorded as part of that effort.

Table E.3 presents reservoir sampling data for August 8 and 15, 2012. The total chlorine to ammonia ratio is included for each sample to give an indication on what reservoirs are under free or combined chlorine conditions. It should be noted that demands were at their highest this week; sampling data for other months of the year include samples of total chlorine residuals at much lower levels. The presented data is for calibration purposes rather than analysis.

Table E.3 Water Quality Reservoir Sampling Data

Reservoir	August 8th and 9th, 2012					August 15th, 2012					Primary Supply[2]
	Temp (°F)	Total Chlorine (mg/L)	Total Ammonia as N (mg/L)	Nitrite as N (mg/L)	Cl_2: NH_3-N Ratio	Temp (°F)	Total Chlorine (mg/L)	Total Ammonia as N (mg/L)	Nitrite as N (mg/L)	Cl_2: NH_3-N Ratio	
Bryant Ranch	79.1	2.04	0.28	0.011	7.3	80.4	1.98	0.43	0.016	4.6	IW
Elk Mountain	81.3	1.95	0.46	0.022	4.2	81.5	2.01	0.45	0.017	4.5	IW
Camino de Bryant[1]											IW
Santiago	80.0	1.88	0.44	0.017	4.3	81.1	2.08	0.42	0.023	5.0	IW
Hidden Hills	79.8	2.14	0.48	0.013	4.5	80.4	1.58	0.26	0.025	6.1	IW
Chino Hills	81.1	1.87	0.44	0.014	4.3	82.5	2.05	0.46	0.014		IW
Little Canyon	80.2	1.48	0.39	0.031	3.8	81.6	2.04	0.45	0.014	4.5	IW
Quarter Horse	81.3	1.81	0.44	0.014	4.1	80.9	2.28	0.47	0.015	4.5	IW
Spring View[1]						81.3	1.95	0.45	0.013	4.9	IW
Fairmont	80.7	1.93	0.46	0.008	4.2	81.1	2.33	0.46	0.015	4.3	IW
Lakeview	71.6	0.93	0.01	0.011	93.0	80.9	2.07	0.47	0.018		GW
Gardenia	79.3	2.35	0.38	0.014	6.2	80.4	1.98	0.43	0.016	5.1	IW
Valley View	82.5	2.13	0.35	0.010	6.1	81.5	2.01	0.45	0.017	4.4	IW

Notes:

1. Sample not conducted due to low water level.
2. The District does not separately sample free chlorine residual; thus, for pressure zones/reservoirs supplied by Imported Water (IW), total chlorine residual is assumed to be entirely combined chlorine, while for pressure zones/reservoirs supplied by Groundwater (GW), total chlorine residual is assumed to be entirely free chlorine.

Table E.4 Water Quality Analyzer SCADA Data				
	Total Chlorine Residual (mg/L)			
Site	**Initial Condition**	**Average (8/9 – 8/15)**	**Minimum (8/9 – 8/15)**	**Maximum (8/9 – 8/15)**
Camino de Bryant Reservoir	2.26	1.87	1.56	2.31
Hidden Hills Reservoir – Outlet	1.79	1.73	1.44	2.22
Highland BPS	1.24	1.09	0.72	1.33
Paso Fino BPS	2.10	2.00	1.75	2.25
Lakeview Reservoir Inlet (Zone 2)	1.24	1.04	0.77	1.35
Lakeview BPS (Zone 3; after Chlorine Injector)	1.27	1.00	0.65	1.41

Notes:

1. In addition, Valley View has an analyzer connected to SCADA, but it reported 1.15 mg/L for the entire calibration period with no variation. Reservoir sampling data will be used instead to establish boundary conditions within the hydraulic model.

Table E.5 Water Quality TCR Sampling Data												
		August 7th, 2012					August 13th, 2012					
Sample Site	Zone	Time	Temp (°F)	Total Chlorine (mg/L)	Assumed Supply	pH	Time	Temp (°F)	Total Chlorine (mg/L)	Assumed Supply	pH	
1	6	11:01	82.9	2.06	IW	7.93			2.08	IW		
2	5	11:07	81.3	2.22	IW	7.99			2.24	IW		
3	6	11:40	83.3	1.89	IW	7.98			1.92	IW		
4	6	12:26	83.1	1.80	IW	8.02			1.40	IW		
5	5	11:49	82.0	2.00	IW	7.99			2.20	IW		
6	4	12:12	83.6	2.09	IW	7.94			2.19	IW		
7	4	12:36	80.6	2.29	IW	8.06			2.24	IW		
8	3W	10:45	80.7	2.34	IW	8.08			2.44	IW		
9	4	10:32	80.9	2.36	IW	8.08			2.23	IW		
10	4			2.39	IW		12:07	81.1	2.51	IW	7.89	
11	3W			1.95	IW		10:01	82.0	1.81	IW	7.94	
12	4			1.97	IW		13:28	83.6	1.90	IW	7.98	
13	1			1.14	GW		08:30	74.1	0.92	GW	7.44	
14	2			1.12	GW		09:10	74.1	0.89	GW	7.43	
15	5			1.99	IW		10:45	82.0	1.87	IW	8.00	
16	3			2.25	IW		13:52	83.1	1.95	IW	7.93	
17	3			2.18	IW		13:15	84.2	1.87	IW	7.94	
18	5			1.34	IW		13:36	81.3	1.91	IW	7.91	
19	3ID1			2.36	IW				2.40	IW		
20	3ID1			2.29	IW				2.27	IW		
21	2W			1.11	GW				0.92	GW		
22	2ID1			2.16	GW				2.11	GW		

Table E.5 Water Quality TCR Sampling Data												
		August 7th, 2012					August 13th, 2012					
Sample Site	Zone	Time	Temp (°F)	Total Chlorine (mg/L)	Assumed Supply	pH	Time	Temp (°F)	Total Chlorine (mg/L)	Assumed Supply	pH
23	2W			2.07	IW				2.15	IW	
24	2ID1			2.27	GW				2.31	GW	
25	2ID2			2.06	GW				2.10	GW	
26	3ID1			2.47	IW				2.48	IW	
27	2ID1			2.22	GW				2.24	GW	
28	2W			0.99	GW				0.95	GW	
29	2W			1.00	GW				0.87	GW	
30	2W			1.12	GW				0.95	GW	
31	1			1.14	GW				0.86	GW	
32	1			1.28	GW				0.92	GW	
33	3W			1.88	IW				1.90	IW	
34	1			0.86	GW				0.72	GW	
35	1			1.27	GW				1.22	GW	
36	3W			2.03	IW				1.90	IW	
37	4W			2.17	IW				1.92	IW	

Notes:

1. The District does not separately sample free chlorine residual; thus, for pressure zones supplied by Imported Water (IW), total chlorine residual is assumed to be entirely combined chlorine, while for pressure zones supplied by Groundwater (GW), total chlorine residual is assumed to be entirely free chlorine.

E.6.2 Establish Boundary Conditions

To establish boundary conditions for the water quality model, the chlorine dosage at each point of entry into the distribution system was input into the hydraulic model. The boundary conditions assumed are listed in Table E.6. It should be noted that this is a targeted dosage rather than sampled data.

Table E.6 Assumed Supply Water Quality

Source	Total Chlorine (mg/L)	Total Organic Carbon (mg/L)	pH
Imported Water Connections	2.5	0.93	8.00
Groundwater Wells (after injection)	1.4	2.4	7.76

For the groundwater wells, the chlorine residual was assumed at the reservoir model elements for simplicity even though the chlorine injectors are actually located further downstream for some of the groundwater wells. Note that the TOC and pH are not required for the single-order decay model used for water in the free chlorine zones, but were included for consistency.

In addition, the District maintains a chlorine injection station at the Lakeview BPS site. Within the model, this is assumed to be located at Junction J5358. During the calibration this site was not operating as the Lakeview BPS did not flow since upper/downstream zones were being supplied with imported water.

For the imported water connections, all water quality parameters listed in Table E.6 were assigned to the reservoir elements. Based on MWDOC’s standard operations, it was assumed that the chlorine residual was entirely monochloramine and that no dichloramine is present in the source water. For reference, MWDOC’s target total chlorine to ammonia (as N) ratio is 5 to 1.

The District does not collect samples of TOC at its reservoirs during routine sampling. To approximate initial TOC conditions within each reservoir, the TOC concentrations at the sources were used based on whether a reservoir was primarily supplied by groundwater or imported water. However, based on analysis of some of the sampling site data, moving further into the distribution system TOC levels decrease slightly through reaction with chlorine to form disinfection byproducts; thus, TOC levels should be slightly lower at the reservoir sites than in the source water. With TOC data unavailable, the effect of reduced TOC concentration on the decay rate was assumed to be negligible within the hydraulic model.

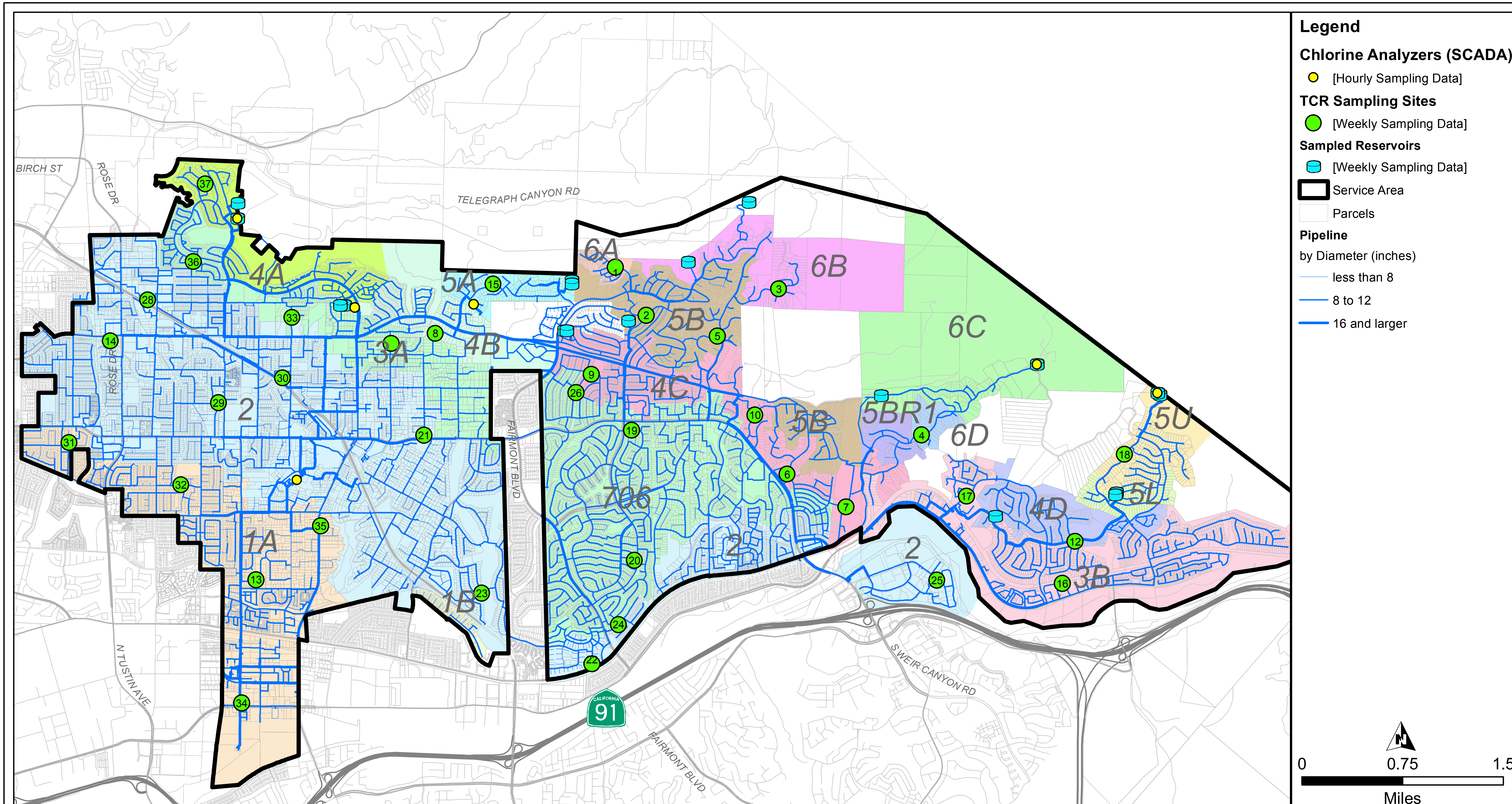

Figure E.2
Water Quality
Sampling Sites

Northeast Area Planning Study
Yorba Linda Water District

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E.6.3 Establish Initial Conditions

To determine the initial chlorine residual across the distribution system (for the start, or hour 0, of the modeling scenario), the residual levels shown in Table E.7 were used for an initial global residual. Initial water quality at reservoirs were taken from sampling data shown in Table E.3.

Table E.7 Assumed Initial Water Quality

Source	Total Chlorine (mg/L)
Imported Water Supplied Zones	2.2
Groundwater Supplied Zones	1.4

The hydraulic model was then run under an EPS until the water quality levels throughout the distribution system stabilized. Since the chlorine residuals at each reservoir were known (via the sampling), this stabilization occurs fairly quickly within the hydraulic model, during the period of the calibration.

E.6.4 Decay Rates

While the reaction rates are included in the chloramine decay model based on published literature, the decay of free chlorine and chloramines in the District's distribution system is dependent upon a large number of factors, including but not limited to temperature, pH, Total Chlorine: Ammonia-N ratio, TOC concentration, source water quality makeup, interactions with pipe wall materials, hydraulic retention time, and interactions within the Districts reservoirs.

For the chloramine model used in this analysis, decay in chlorine residual is included in four components of the chloramines model – autodecomposition of monochloramine, monochloramine interaction with organic matter, monochloramine decay through conversion to hypochlorous acid and interaction with organic matter, and dichloramine decay through interaction with a reactive intermediate. The interactions with organic matter assume dual-phase kinetics of NOM oxidation by chloramines - an initial rapid loss of chloramines residual followed by a slow decrease in residual. In order to adapt this chloramines decay model to the District's specific water quality, the fast reactive fraction of the direct monochloramine interaction with TOC was adjusted iteratively based on SCADA results.

Following the calibration process, the resultant reactive fractions used for the model were:

- Fast Reactive Fraction: 0.0025 (decay through monochloramine-TOC interaction)
- Slow Reactive Fraction: 0.3 (decay through HOCl-TOC Interaction)

For free chlorine, the assumed first order decay includes two components, a bulk rate of decay and a wall rate of decay. In absence of jar test data, these rates were iteratively adjusted based on available SCADA data for known groundwater supplied portions of the model. Following the calibration process, the resultant decay coefficients used for the model were:

- Bulk Decay Coefficient: 0.02
- Wall Decay Coefficient: 0.05

For reference, a 1996 AWWARF study evaluating several water distribution systems reported a range of bulk first-order decay coefficients between 0.01 and 0.74 (AWWARF, 1996). It should be noted that first-order decay will vary with TOC concentrations, which were assumed from average annual TOC levels within the source water from the District's 2012 annual water quality report.

E.6.5 Water Quality Calibration

Calibration is conducted by comparing the actual chlorine residual levels recorded at the sampling sites to the predicted values in the hydraulic model. This comparison is shown in Table E.8. As listed in Table E.5, sampling times were only available for a few of the sites; for sites without sampling time data available, residuals for the entire 24-hour period of the sampling day were averaged for this comparison.

Table E.8 Comparison of Sampled Residuals to Model Predictions

Sample Site	Zone	Assumed Supply(1)	Sampled Residual(2) (mg/L)	Model Prediction (mg/L)	Difference [Sample - Prediction] (mg/L)
1	6	IW	2.1	1.4	+0.7
2	5	IW	2.2	2.1	+0.1
3	6	IW	1.9	1.4	+0.6
4	6	IW	1.4	1.0	+0.4
5	5	IW	2.2	2.0	+0.2
6	4	IW	2.2	2.1	+0.1
7	4	IW	2.2	1.8	+0.5
8	3W	IW	2.4	2.0	+0.5
9	4	IW	2.2	2.4	-0.2
10	4	IW	2.5	1.9	+0.6
11	3W	IW	1.8	2.4	-0.6
12	4	IW	1.9	1.4	+0.5

Table E.8 Comparison of Sampled Residuals to Model Predictions					
Sample Site	Zone	Assumed Supply[(1)]	Sampled Residual[(2)] (mg/L)	Model Prediction (mg/L)	Difference [Sample - Prediction] (mg/L)
13	1	GW	0.9	0.7	+0.2
14	2	GW	0.9	0.4	+0.5
15	5	IW	1.9	1.1	+0.7
16	3	IW	2.0	1.3	+0.6
17	3	IW	1.9	1.0	+0.9
18	5	IW	1.9	1.4	+0.6
19	3ID1	IW	2.4	2.2	+0.2
20	3ID1	IW	2.3	2.1	+0.1
21	2W	GW	0.9	1.1	-0.1
22	2ID1	GW	2.1	2.1	-0.0
23	2W	IW	2.2	2.0	+0.1
24	2ID1	GW	2.3	2.1	+0.2
25	2ID2	GW	2.1	2.0	+0.1
26	3ID1	IW	2.5	2.3	+0.2
27	2ID1	GW	2.2	2.2	+0.1
28	2W	GW	1.0	0.3	+0.6
29	2W	GW	0.9	0.6	+0.3
30	2W	GW	1.0	0.6	+0.3
31	1	GW	0.9	0.5	+0.4
32	1	GW	0.9	0.5	+0.4
33	3W	IW	1.9	2.0	-0.1
34	1	GW	0.7	0.6	+0.1
35	1	GW	1.2	0.9	+0.4
36	3W	IW	1.9	1.7	+0.2
37	4W	IW	1.9	1.6	+0.3

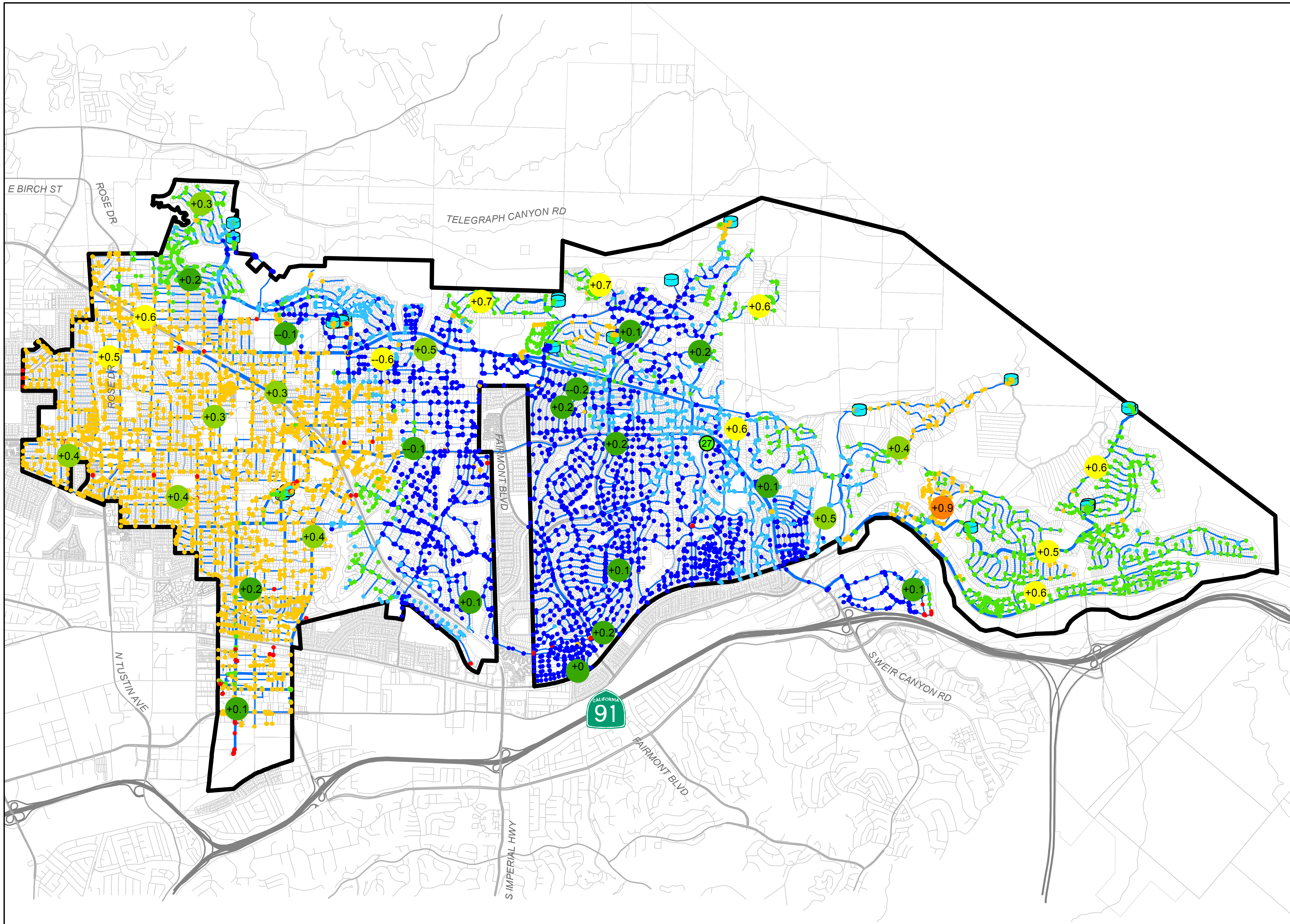
Notes:

1. Based on hydraulic model prediction of supply water.
2. Sampling times were only available for sites at which physical constituents were also sampled (which are adjusted biweekly). For unknown sampling times, average water quality levels for the 24-hr period on the sampling day were used for model predictions.

As seen in Table E.8, overall the model is predicting residuals slightly below or equivalent to the sampled residuals, indicating the model is conservative. Overall, the calibration results show that the model predicts lower residuals in areas where lower residuals were sampled, and higher residuals in areas where higher residuals were sampled. However, the District should not expect that the model predictions to accurately predict exact chlorine residuals, likely due to the number of assumptions made in setting the boundary conditions for this model, and the theoretical nature of the modeled reactions and limitations thereof.

The differences between sampled and predicted residual are shown by location in Figure E.3. As shown on Figure E.3, the hydraulic model predicts results consistent with the District's sampling results in much of Zones 1, 2, and 3. The model predicts lower residuals than seen in the sampling results in several of the upper pressure zones.

Based on the results of the calibration, water quality results should be used for general trends, but not detailed analysis. The model provides an accurate representation of the District's distribution system and system operations to a level suitable for the purposes of identifying system deficiencies and evaluating capital improvements to the District's water distribution system.



Legend

by Difference (mg/L)

- < 0.25
- 0.25 - 0.50
- 0.50 - 0.75
- 0.75 - 1.0
- > 1.0

Predicted Residual

Total Cl (mg/L)

- < 0.2
- 0.2 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

Tanks

Service Area

Parcels

Pipeline

- 6 inch and less
- 8 to 12 inch
- 16 inch and larger

0 0.5 1 Miles

Predicted Water Quality Correlation with Field Results

Northeast Area Planning Study
Yorba Linda Water District

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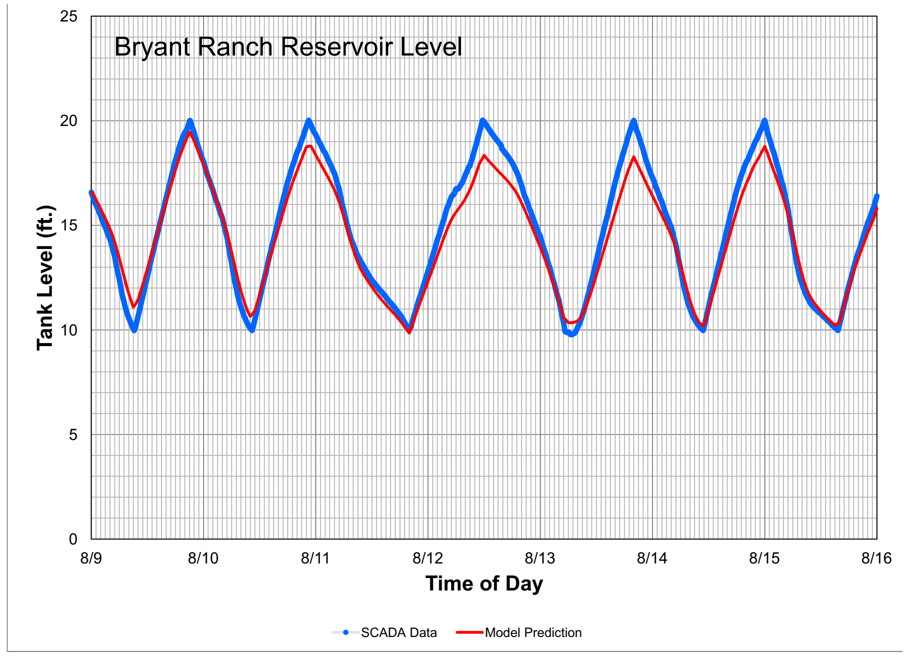
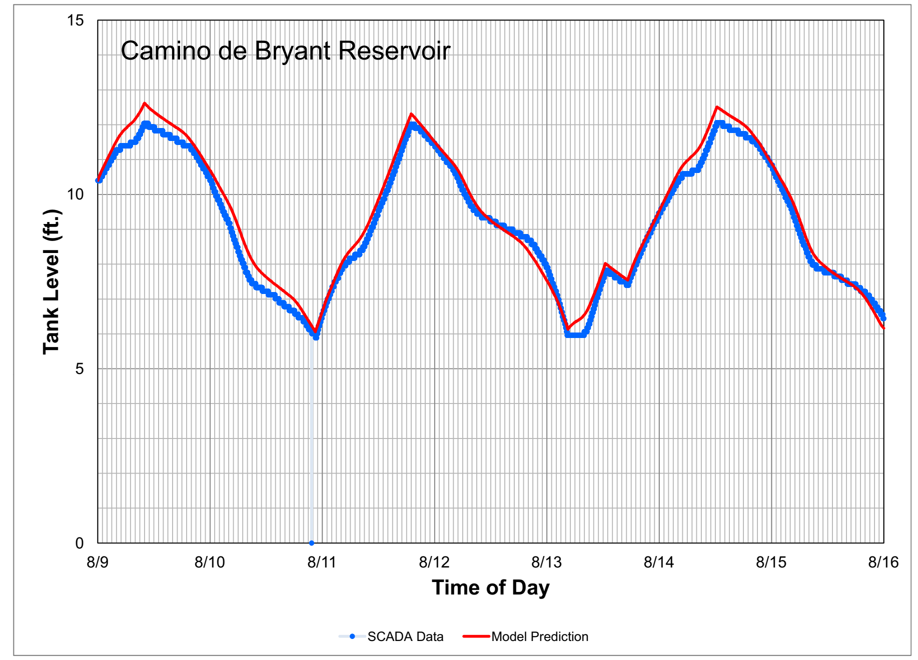
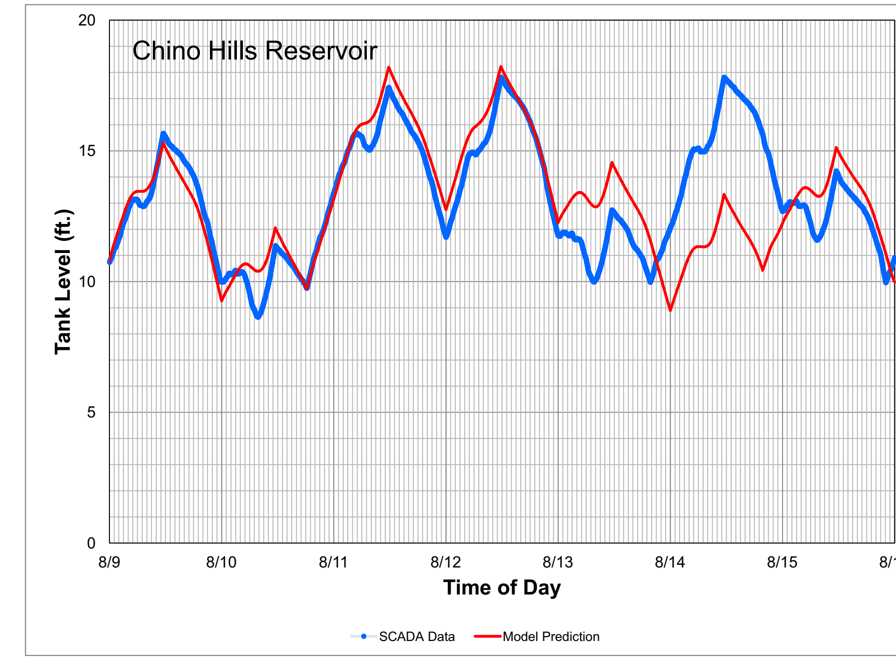
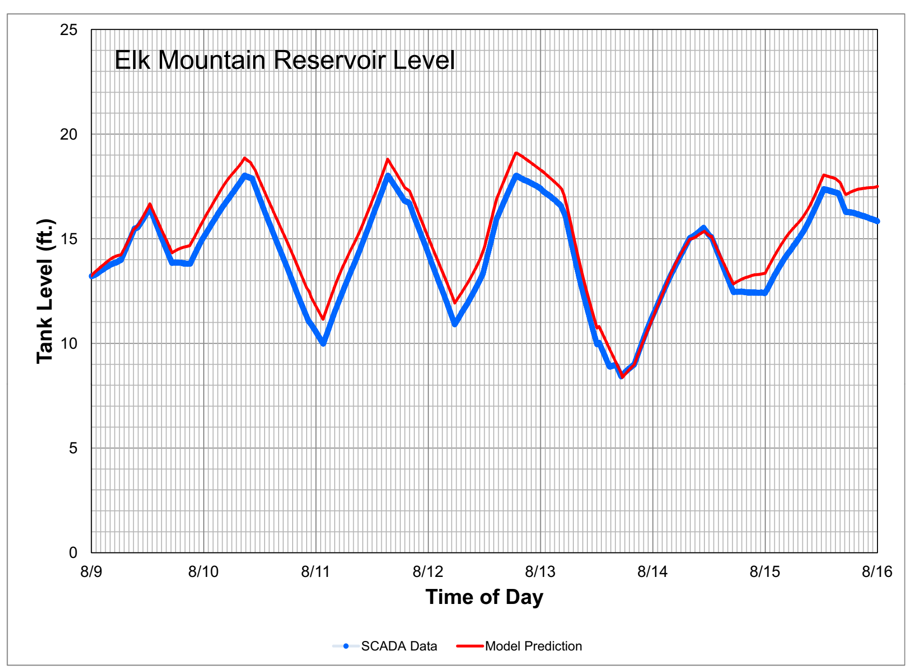
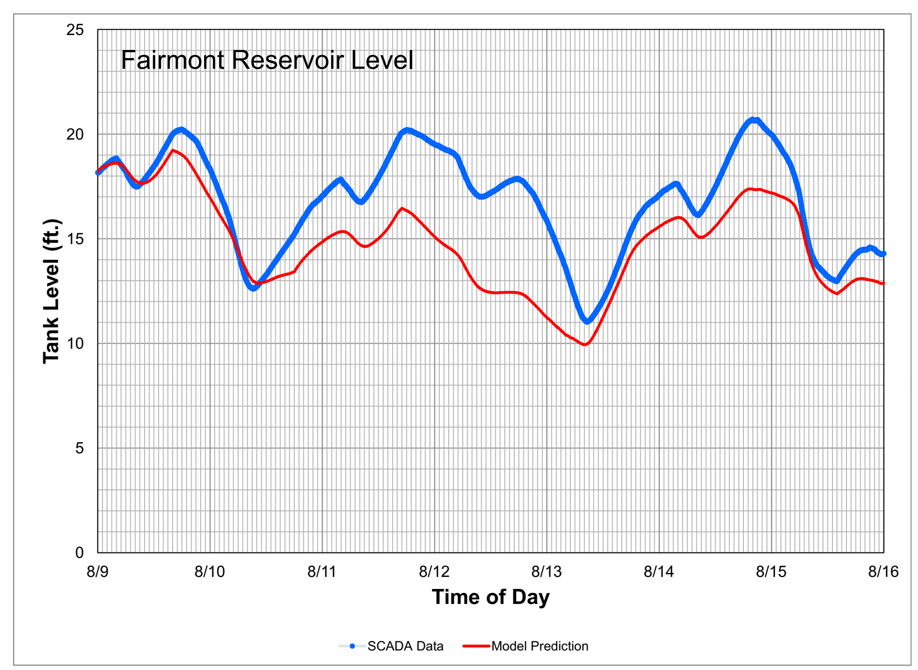
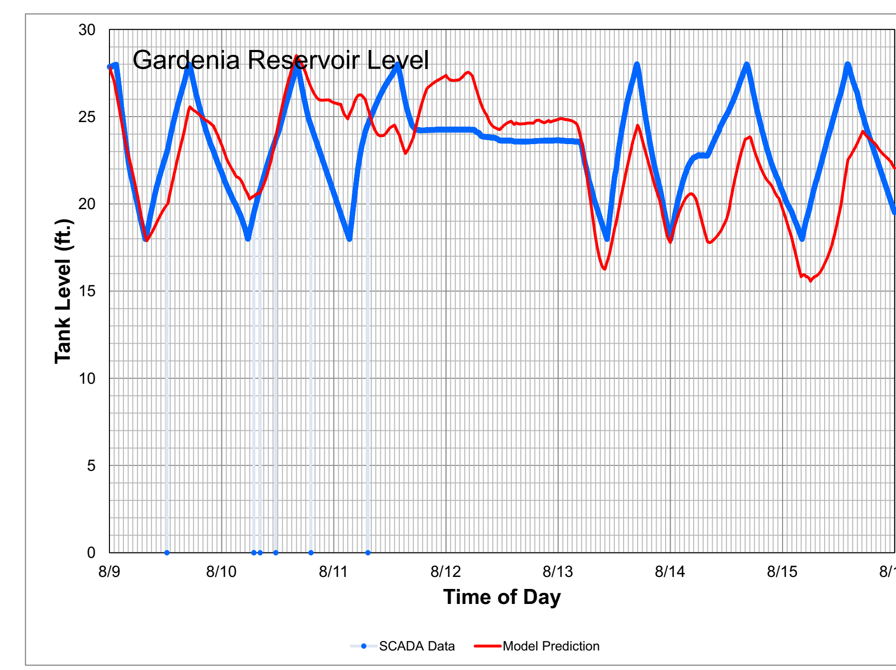

Bryant Ranch Reservoir Level
Tank Level (ft.)
Time of Day
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
0
5
10
15
20
25
SCADA Data
Model Prediction

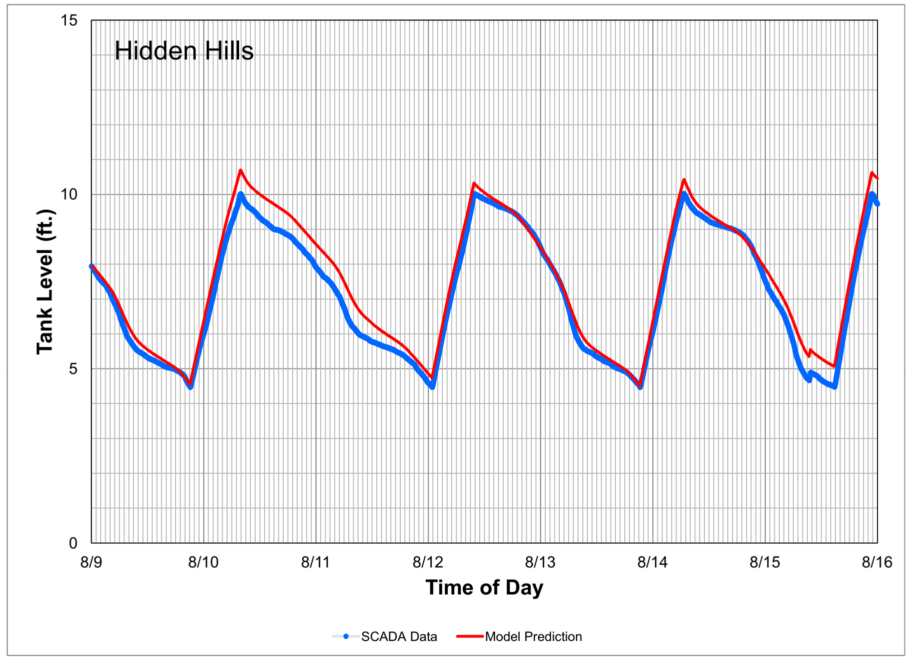

Camino de Bryant Reservoir
Tank Level (ft.)
Time of Day
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
0
5
10
15
SCADA Data
Model Prediction

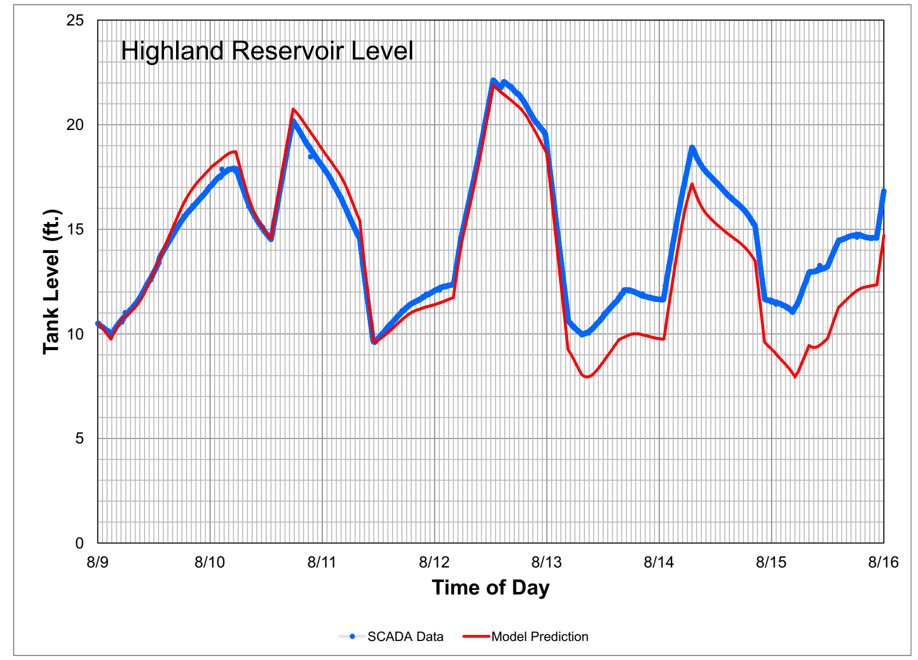

Chino Hills Reservoir
Tank Level (ft.)
Time of Day
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
0
5
10
15
20
SCADA Data
Model Prediction

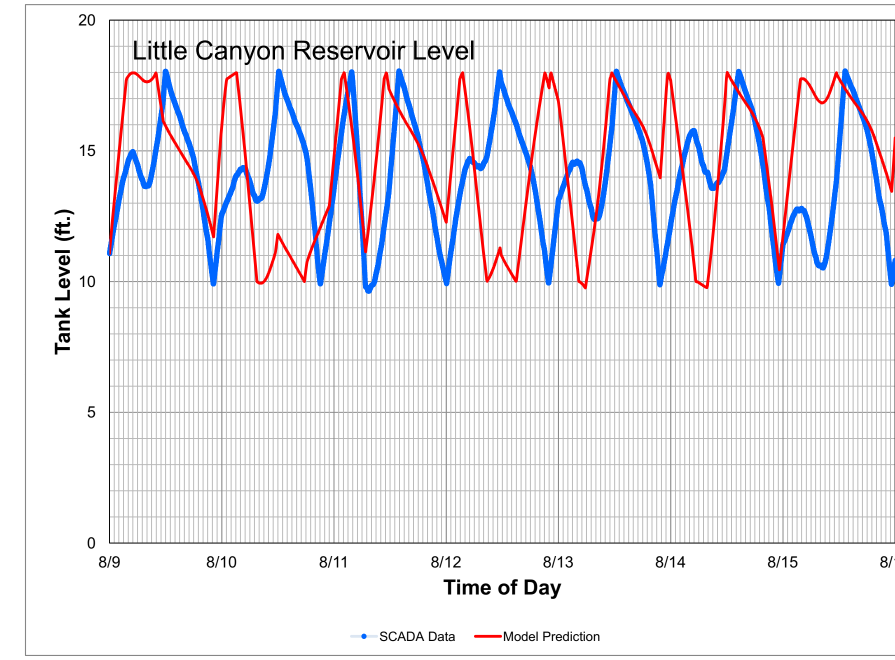

Elk Mountain Reservoir Level
Tank Level (ft.)
Time of Day
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
0
5
10
15
20
25
SCADA Data
Model Prediction

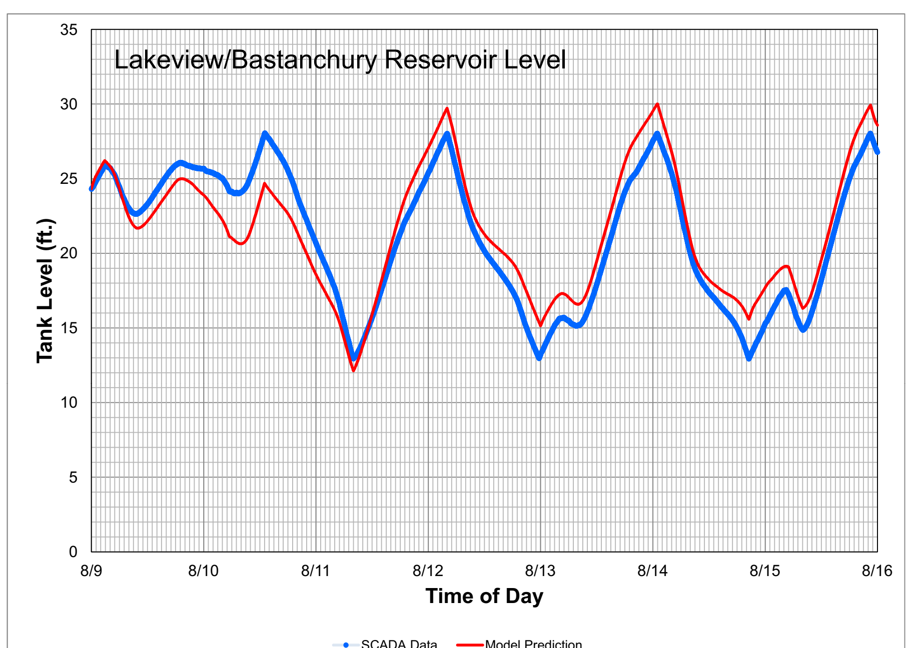

Fairmont Reservoir Level
Tank Level (ft.)
Time of Day
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
0
5
10
15
20
25
SCADA Data
Model Prediction

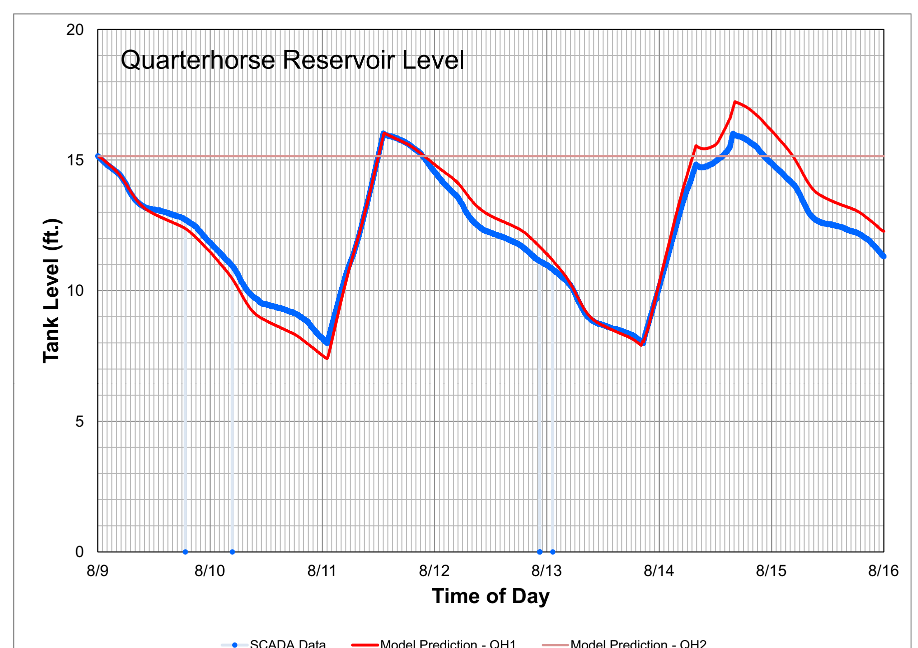

Gardenia Reservoir Level
Tank Level (ft.)
Time of Day
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
0
5
10
15
20
25
30
SCADA Data
Model Prediction

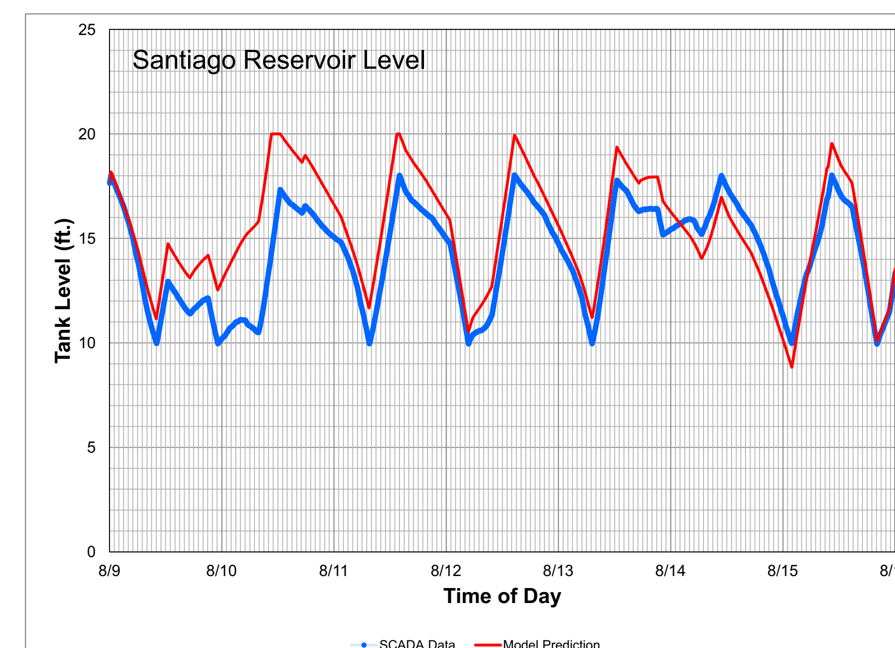

Hidden Hills
Tank Level (ft.)
Time of Day
0
5
10
15
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
SCADA Data
Model Prediction

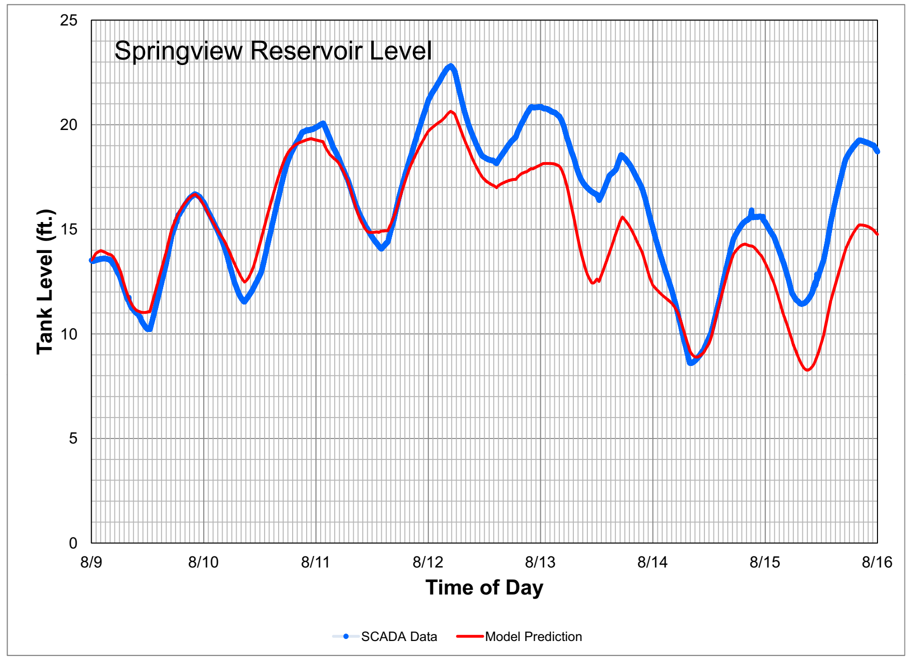

Highland Reservoir Level
Tank Level (ft.)
Time of Day
0
5
10
15
20
25
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
SCADA Data
Model Prediction

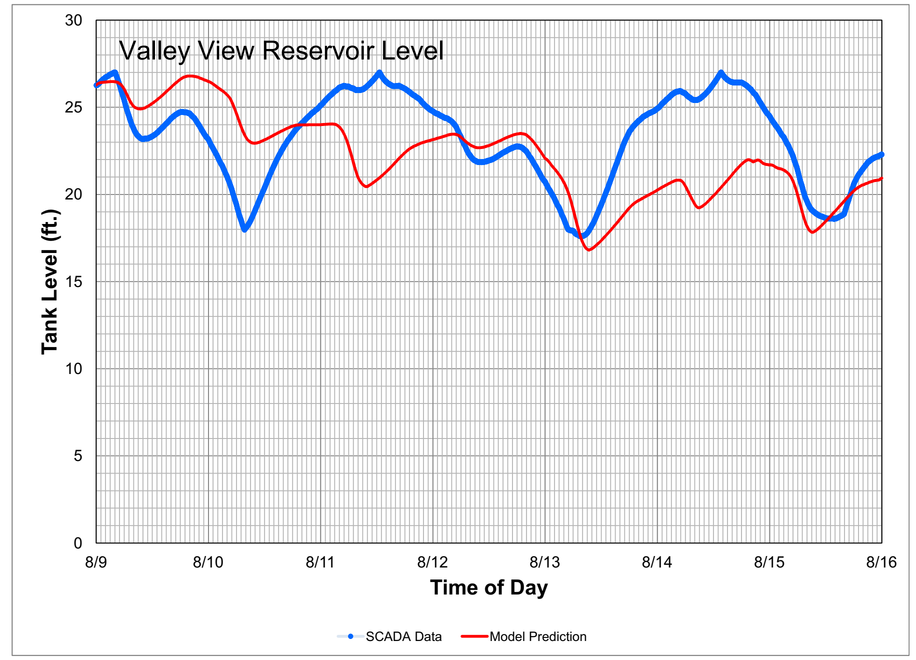

Little Canyon Reservoir Level
Tank Level (ft.)
Time of Day
0
5
10
15
20
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
SCADA Data
Model Prediction

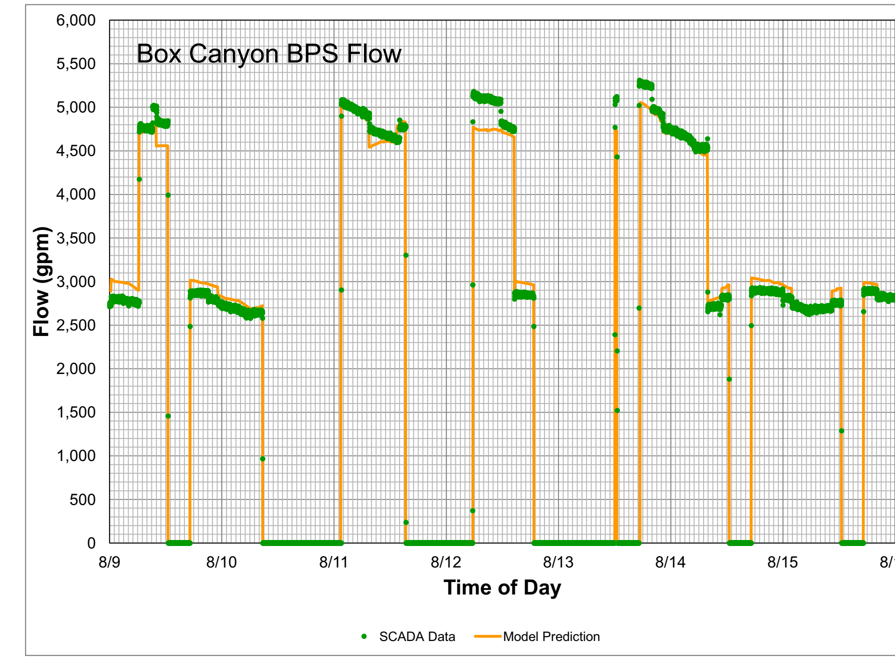

Lakeview/Bastanchury Reservoir Level
Tank Level (ft.)
Time of Day
0
5
10
15
20
25
30
35
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
SCADA Data
Model Prediction

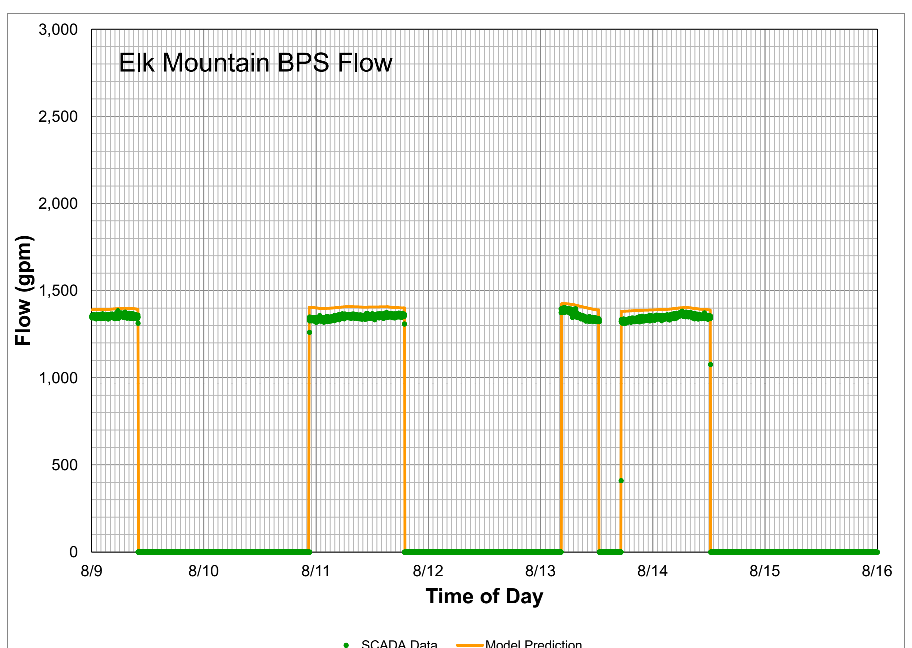

Quarterhorse Reservoir Level
Tank Level (ft.)
Time of Day
0
5
10
15
20
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
SCADA Data
Model Prediction - QH1
Model Prediction - QH2

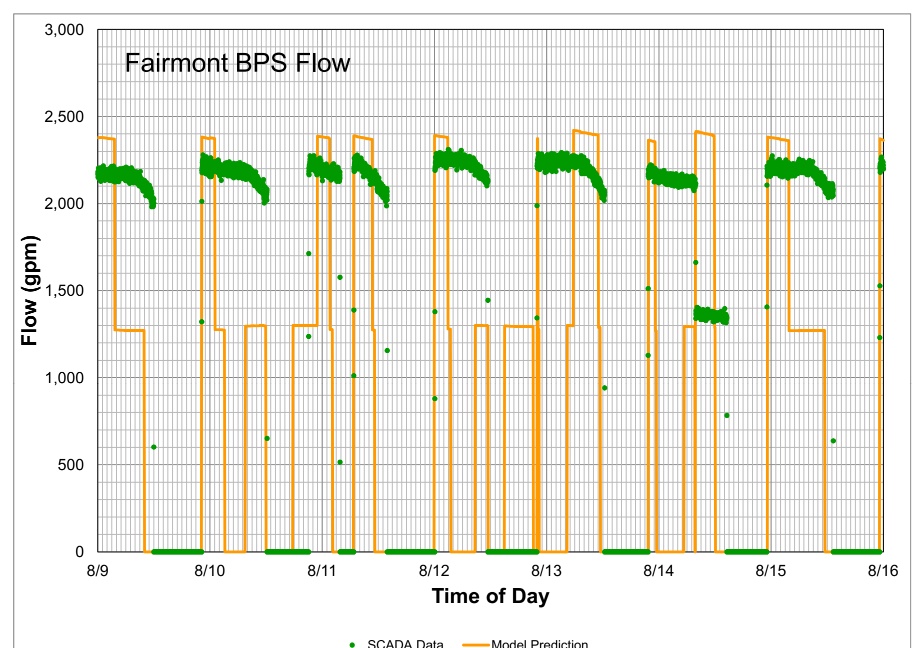

Santiago Reservoir Level
Tank Level (ft.)
Time of Day
0
5
10
15
20
25
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
SCADA Data
Model Prediction

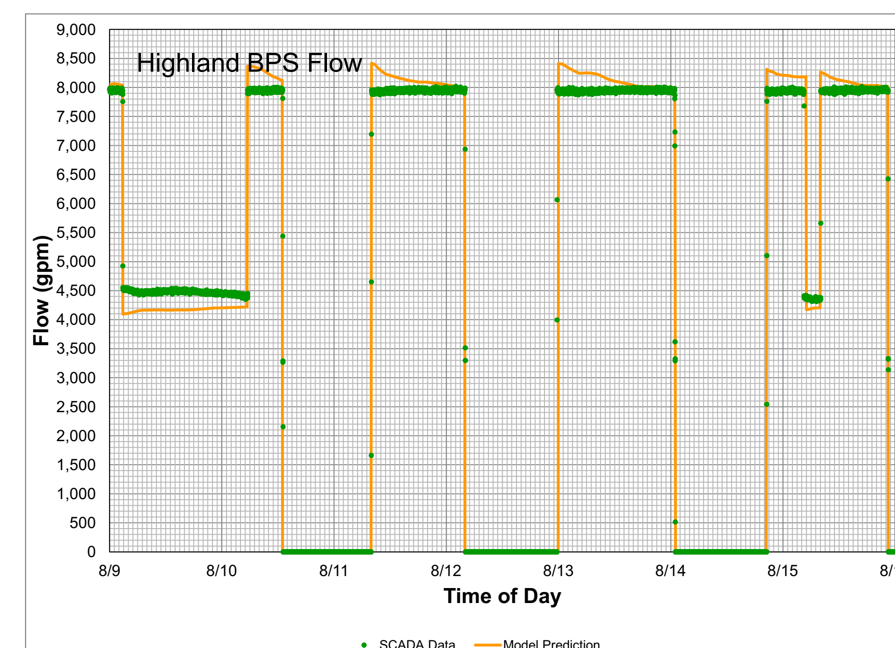

Springview Reservoir Level
Tank Level (ft.)
0
5
10
15
20
25
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

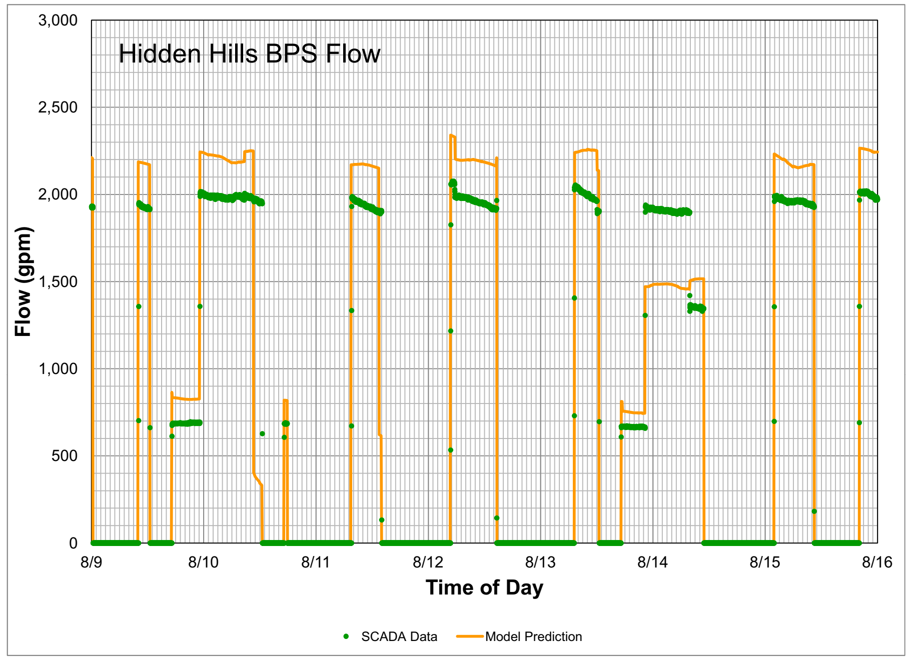

Valley View Reservoir Level
Tank Level (ft.)
0
5
10
15
20
25
30
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

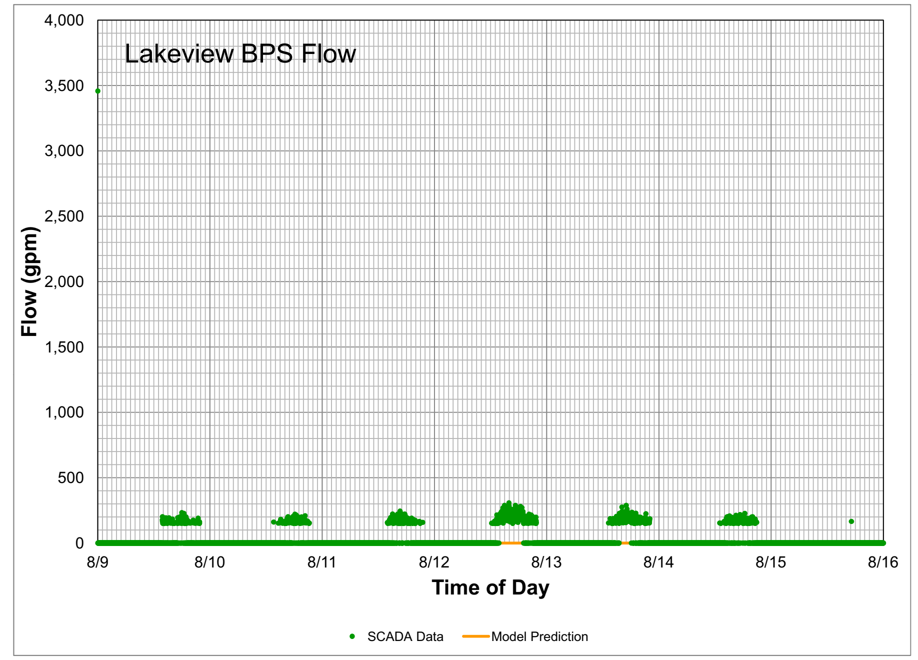

Box Canyon BPS Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

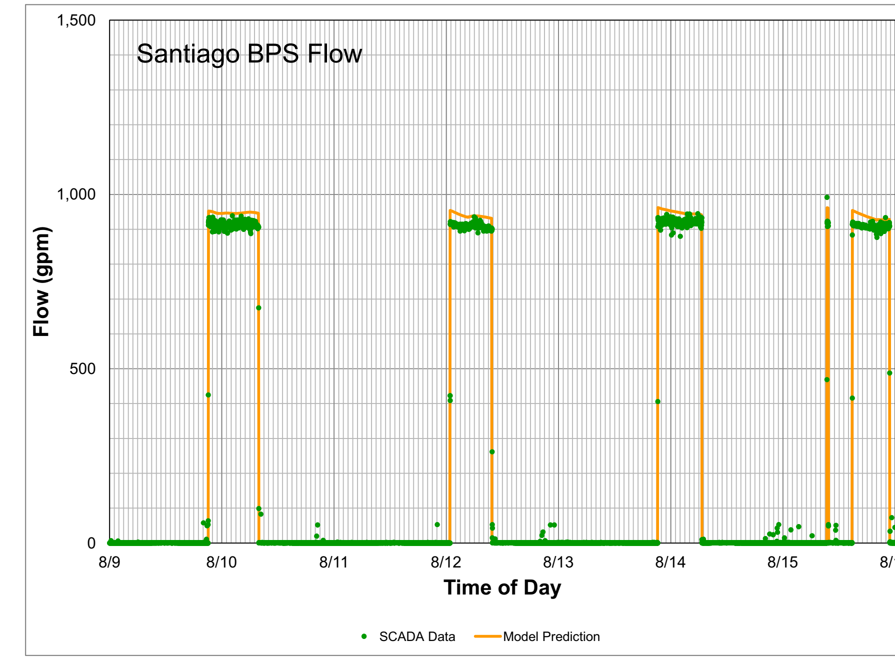

Elk Mountain BPS Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

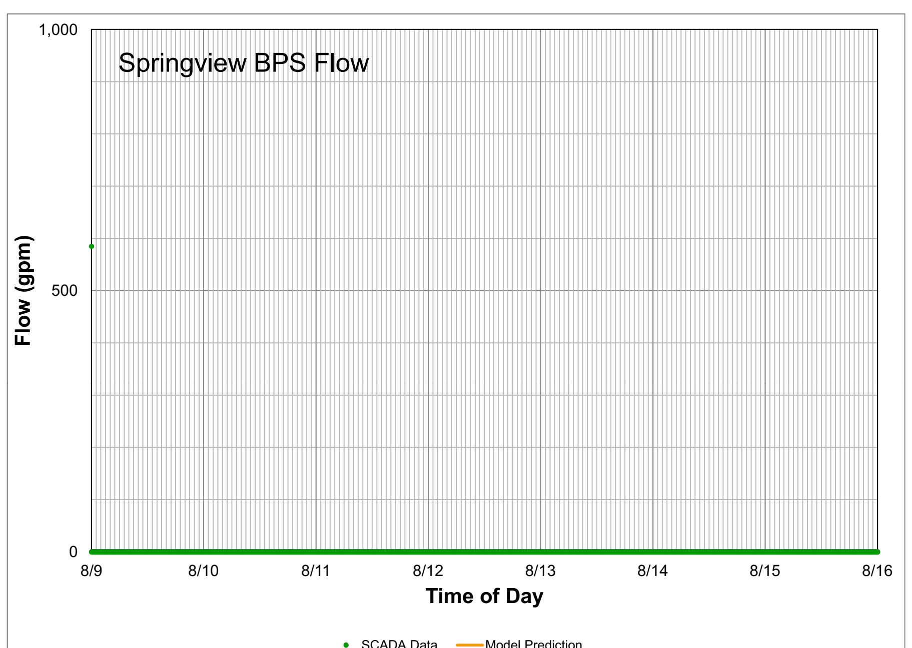

Fairmont BPS Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

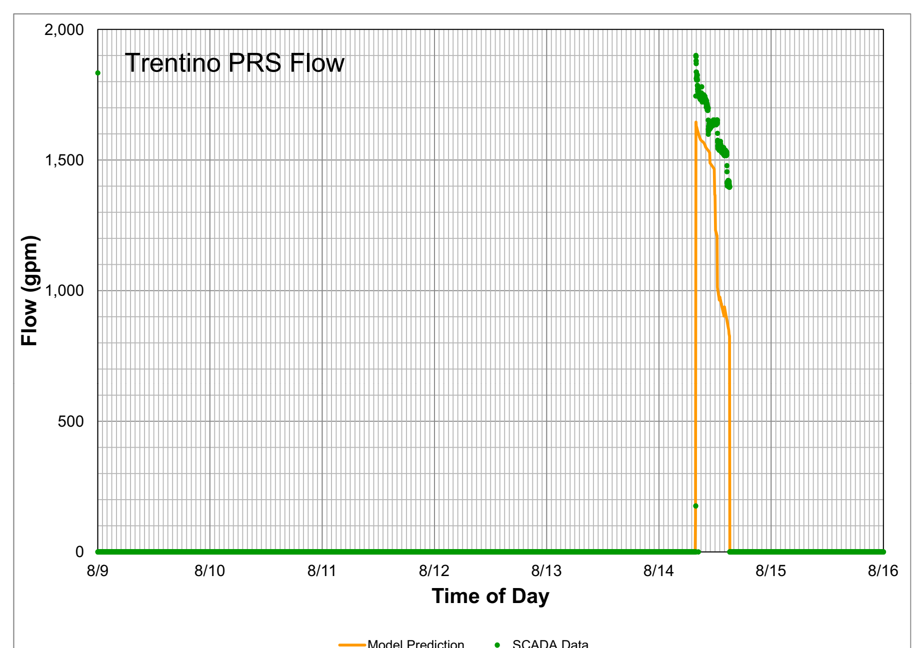

Highland BPS Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
6,500
7,000
7,500
8,000
8,500
9,000
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

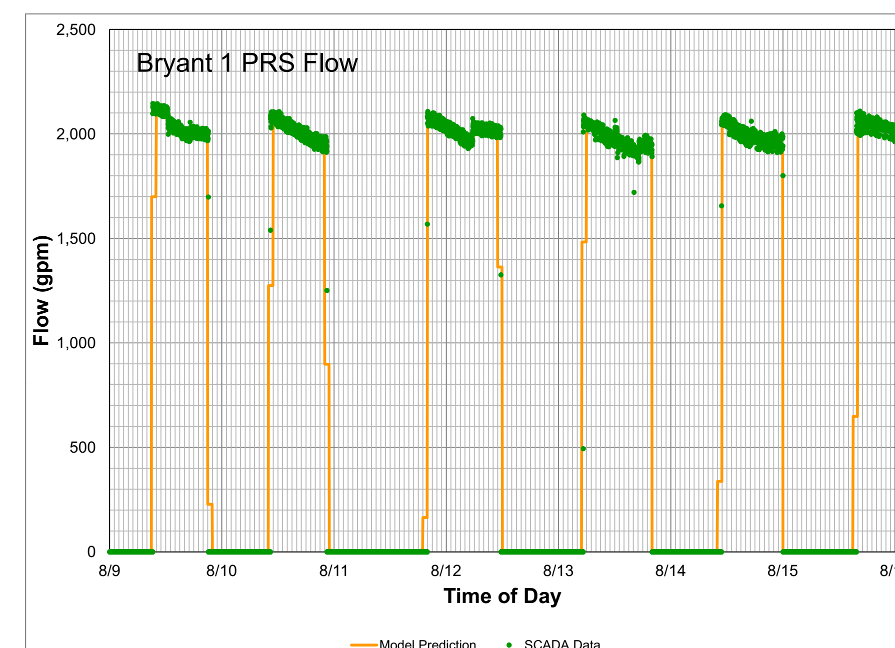

Hidden Hills BPS Flow
Flow (gpm)
3,000
2,500
2,000
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

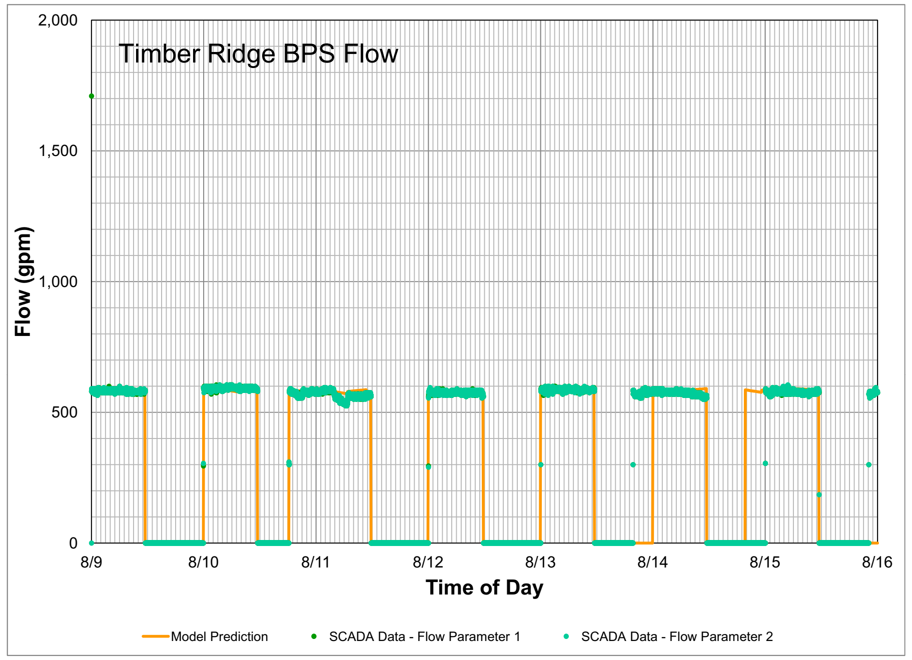

Lakeview BPS Flow
Flow (gpm)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

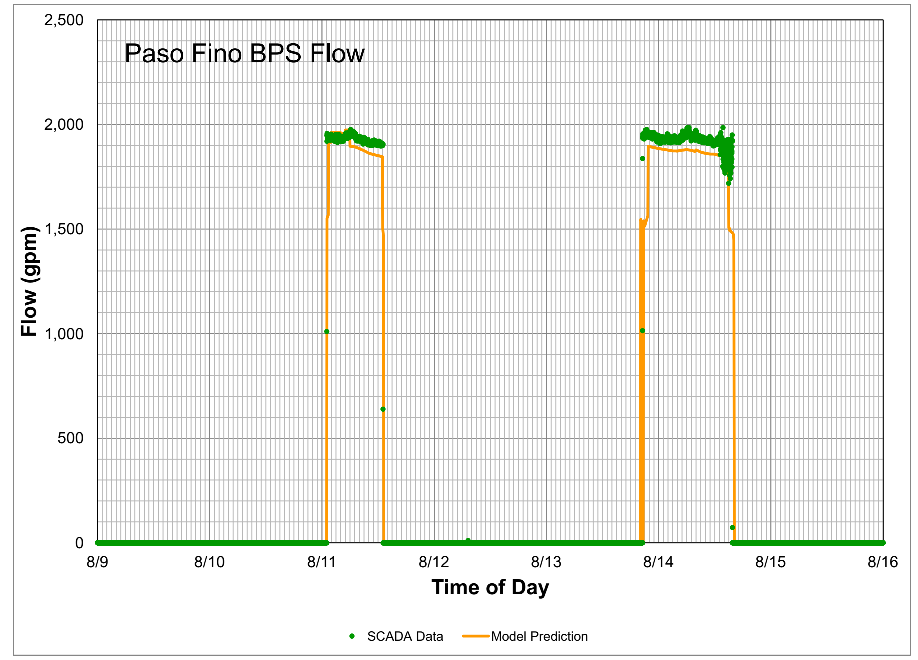

Santiago BPS Flow
Flow (gpm)
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

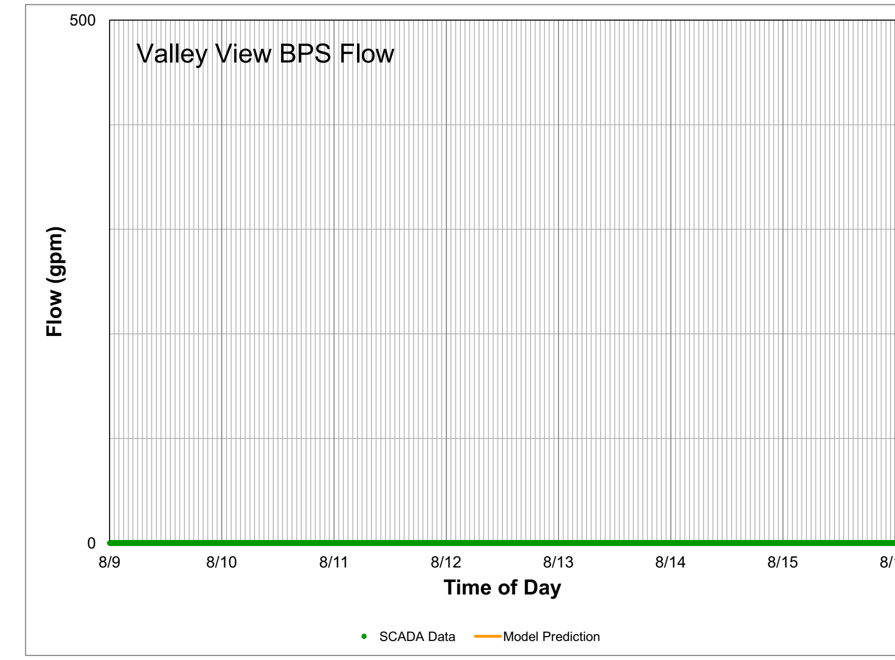

Springview BPS Flow
Flow (gpm)
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

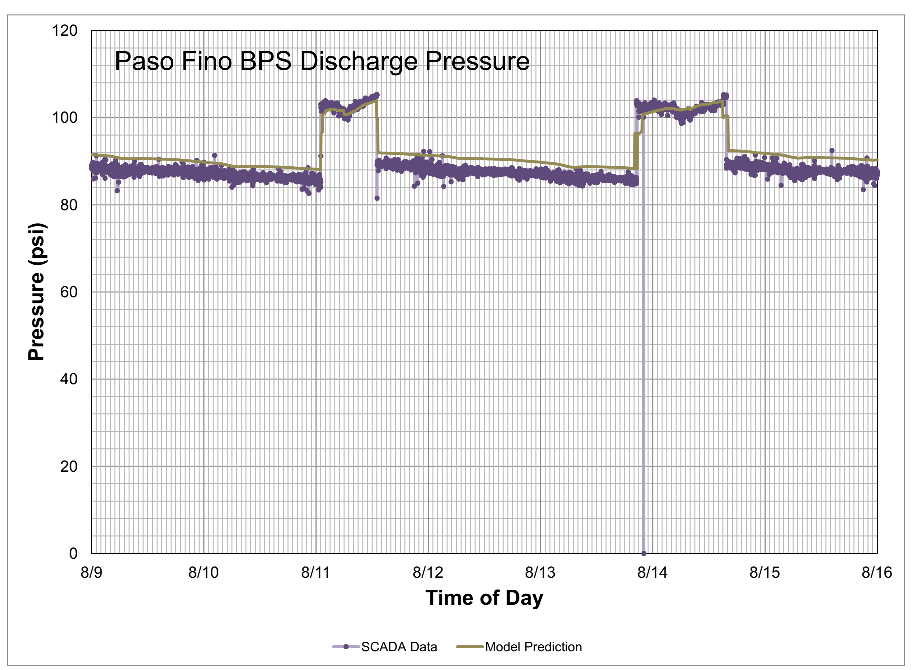

Trentino PRS Flow
Flow (gpm)
2,000
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

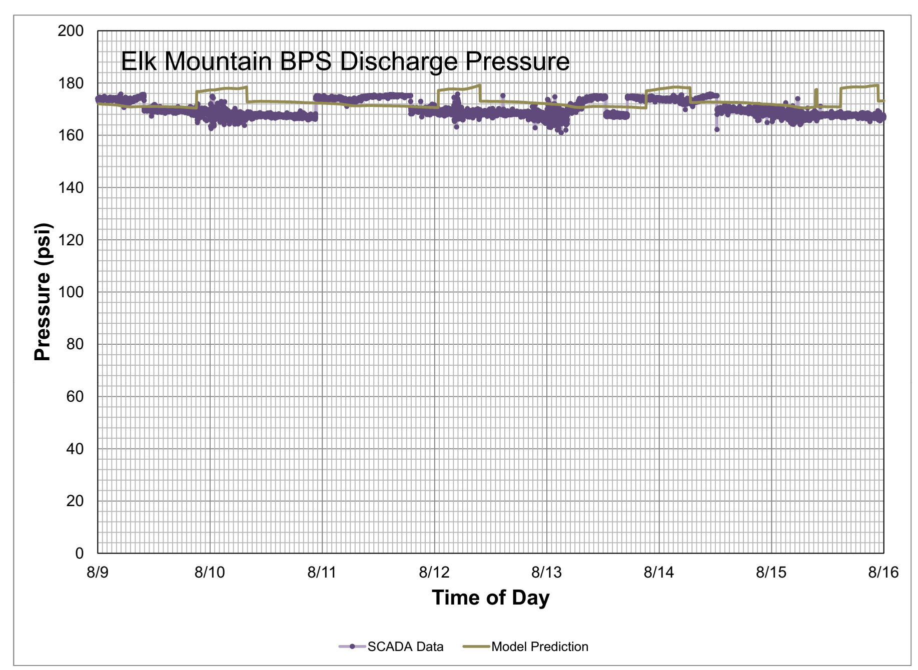

Bryant 1 PRS Flow
Flow (gpm)
2,500
2,000
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

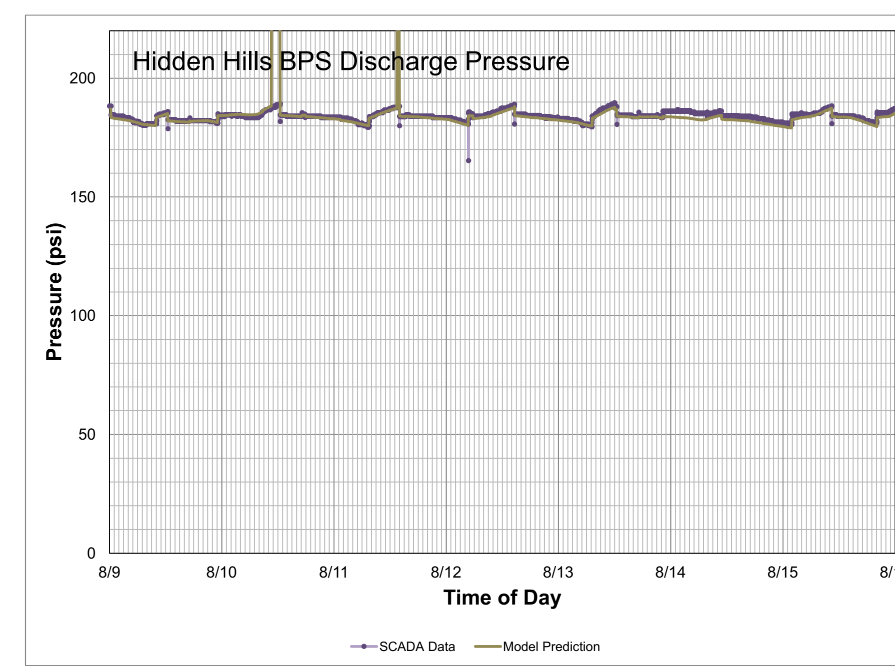

Timber Ridge BPS Flow
Flow (gpm)
2,000
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data - Flow Parameter 1
SCADA Data - Flow Parameter 2

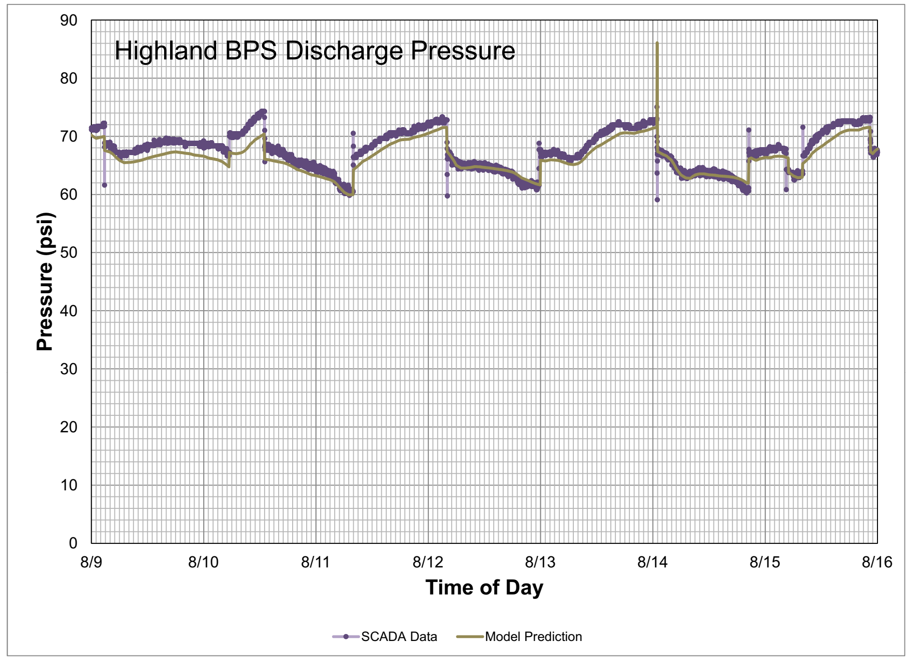

Paso Fino BPS Flow
Flow (gpm)
2,500
2,000
1,500
1,000
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

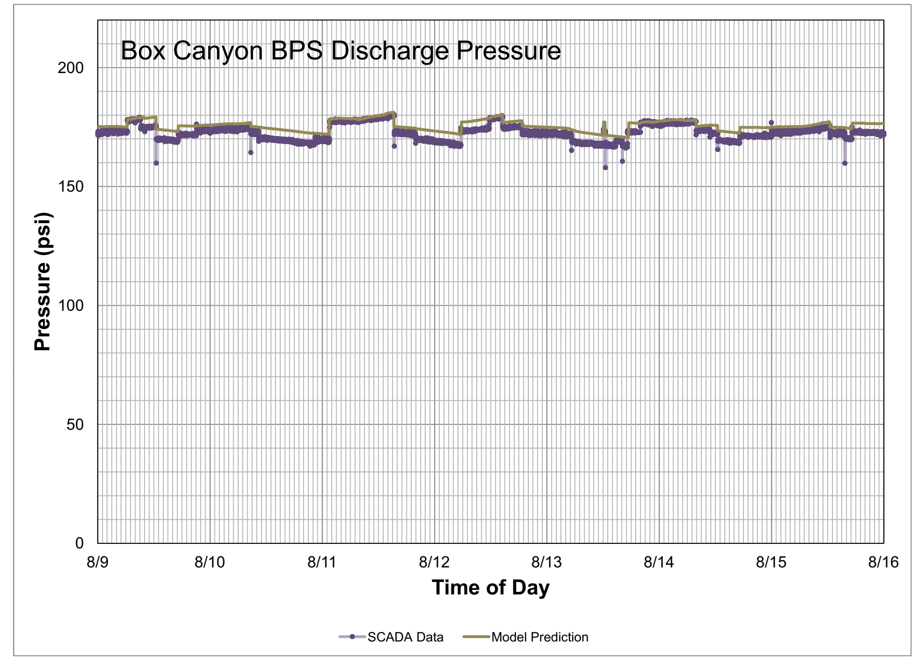

Valley View BPS Flow
Flow (gpm)
500
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

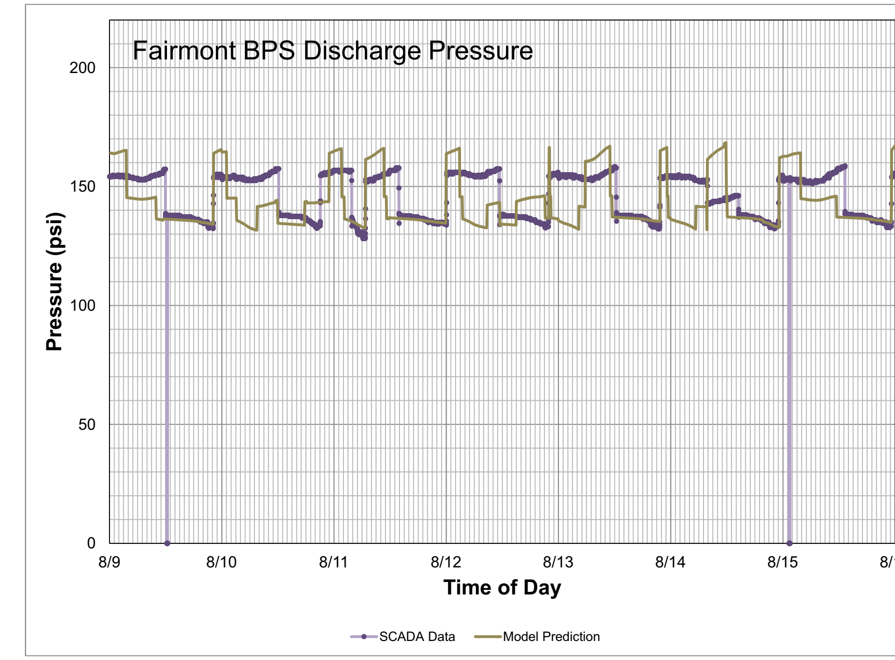

Paso Fino BPS Discharge Pressure
Pressure (psi)
120
100
80
60
40
20
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

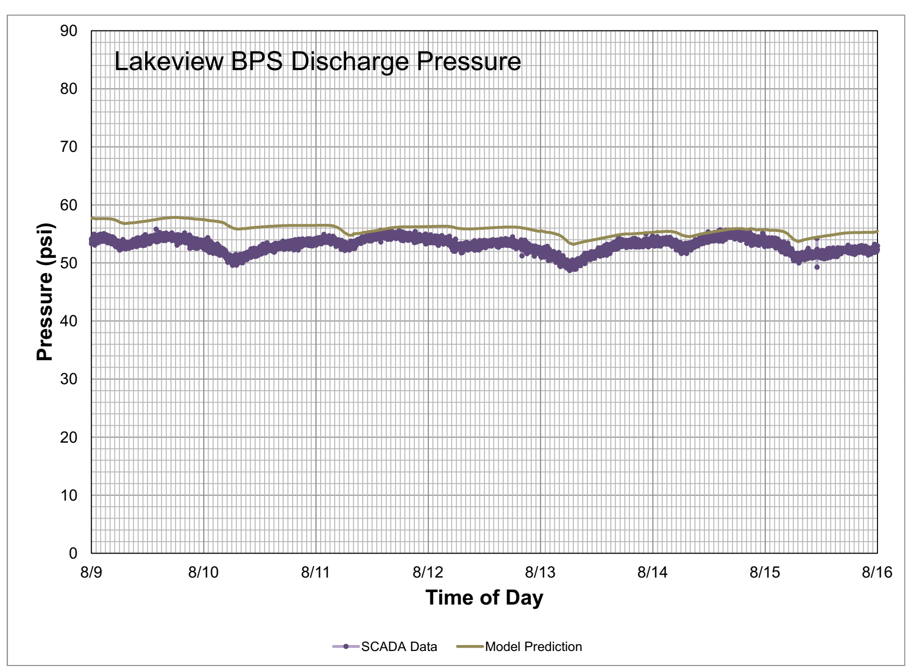

Elk Mountain BPS Discharge Pressure
Pressure (psi)
200
180
160
140
120
100
80
60
40
20
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

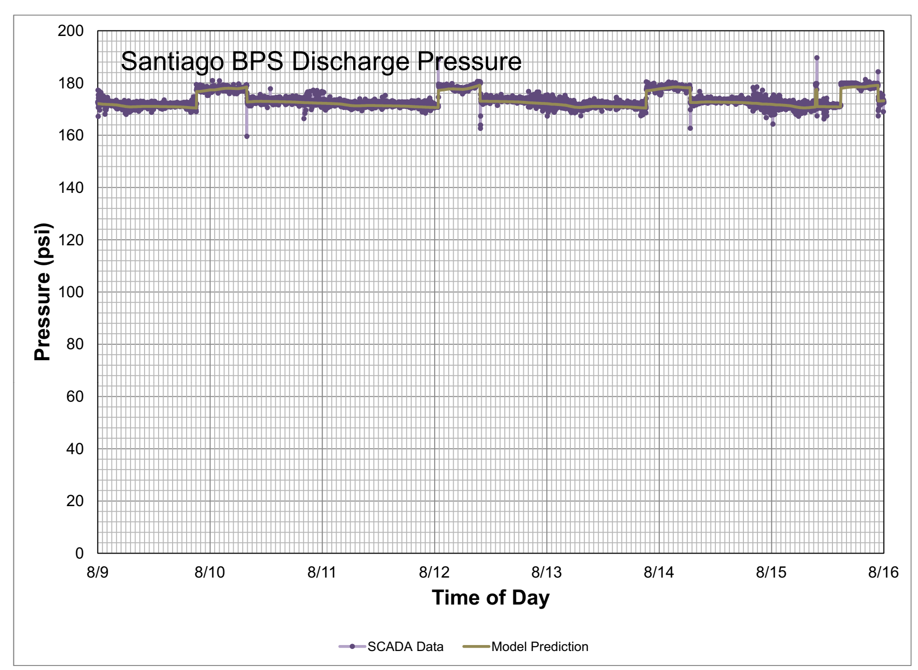

Hidden Hills BPS Discharge Pressure
Pressure (psi)
200
150
100
50
0
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

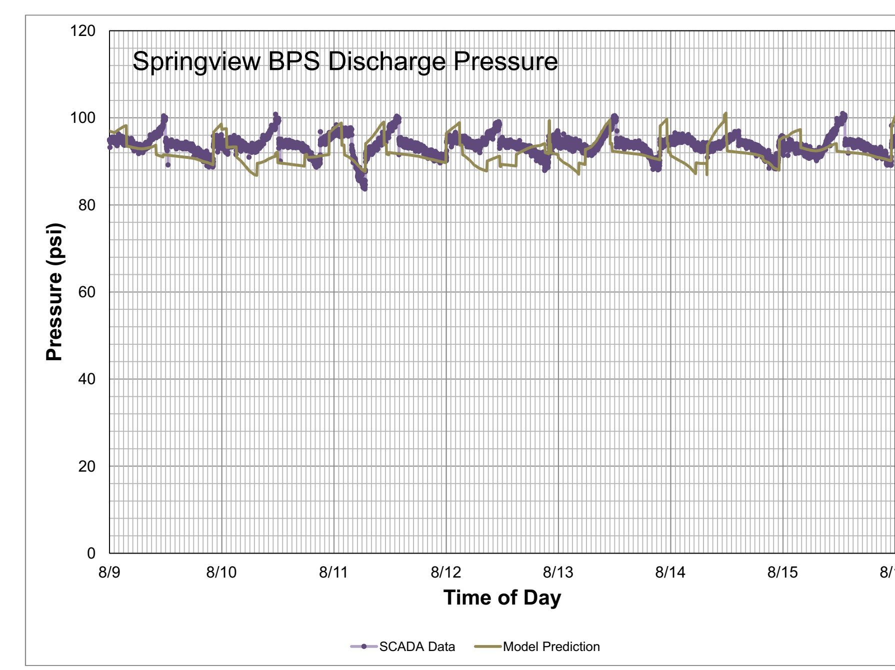

Highland BPS Discharge Pressure
Pressure (psi)
Time of Day
SCADA Data
Model Prediction

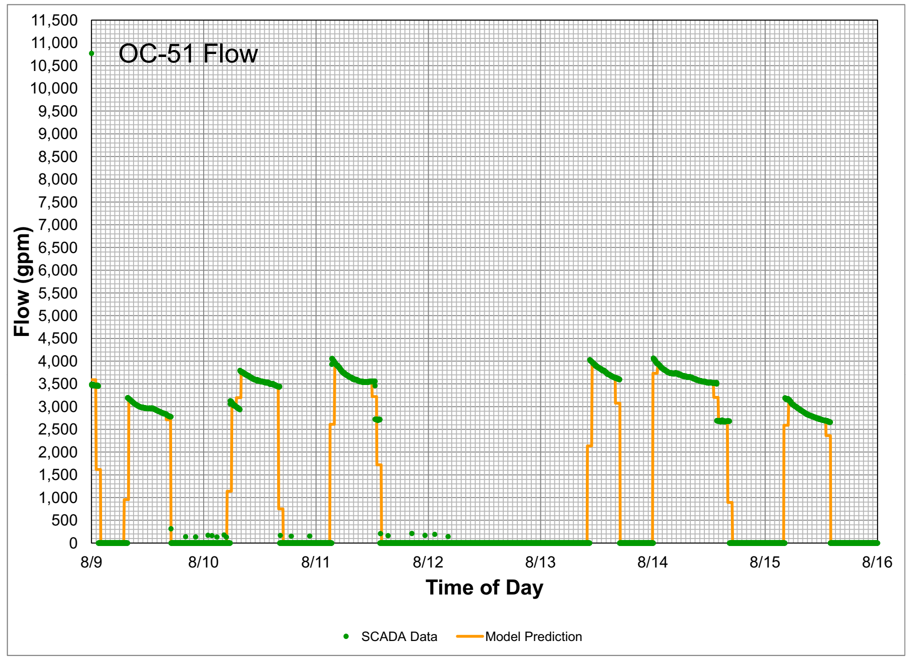

Box Canyon BPS Discharge Pressure
Pressure (psi)
Time of Day
SCADA Data
Model Prediction

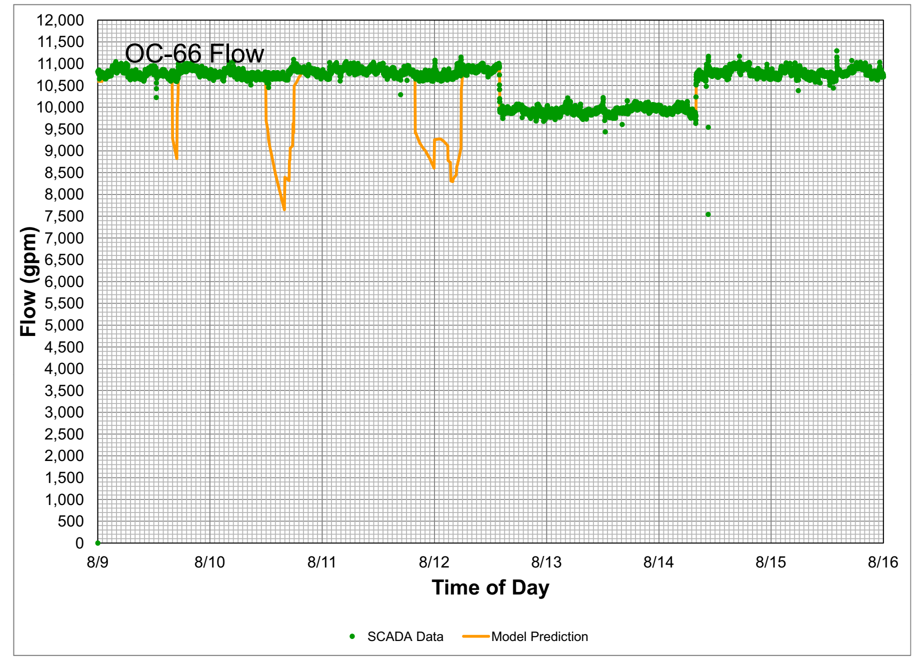

Fairmont BPS Discharge Pressure
Pressure (psi)
Time of Day
SCADA Data
Model Prediction

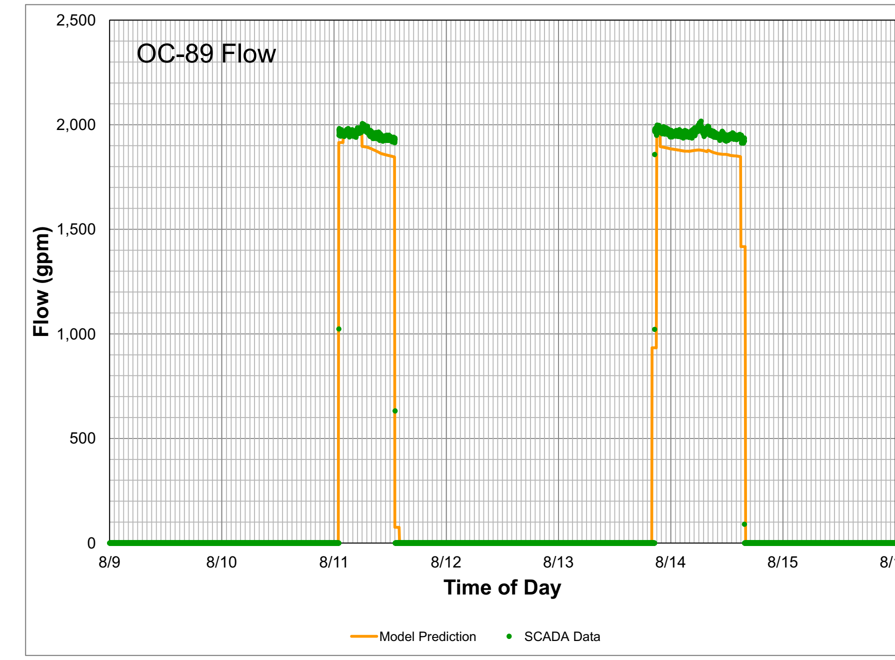

Lakeview BPS Discharge Pressure
Pressure (psi)
Time of Day
SCADA Data
Model Prediction

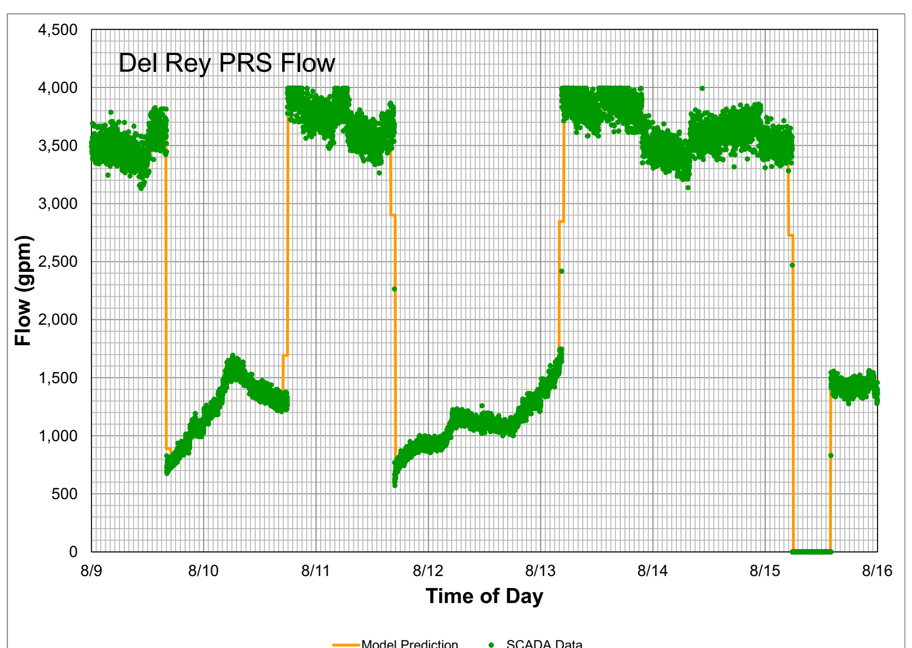

Santiago BPS Discharge Pressure
Pressure (psi)
Time of Day
SCADA Data
Model Prediction

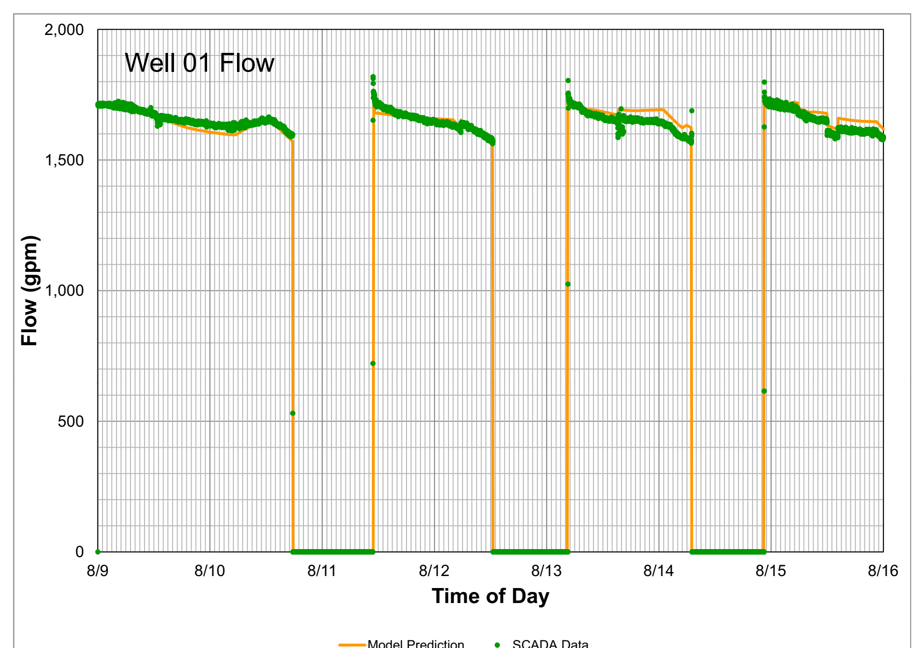

Springview BPS Discharge Pressure
Pressure (psi)
Time of Day
SCADA Data
Model Prediction

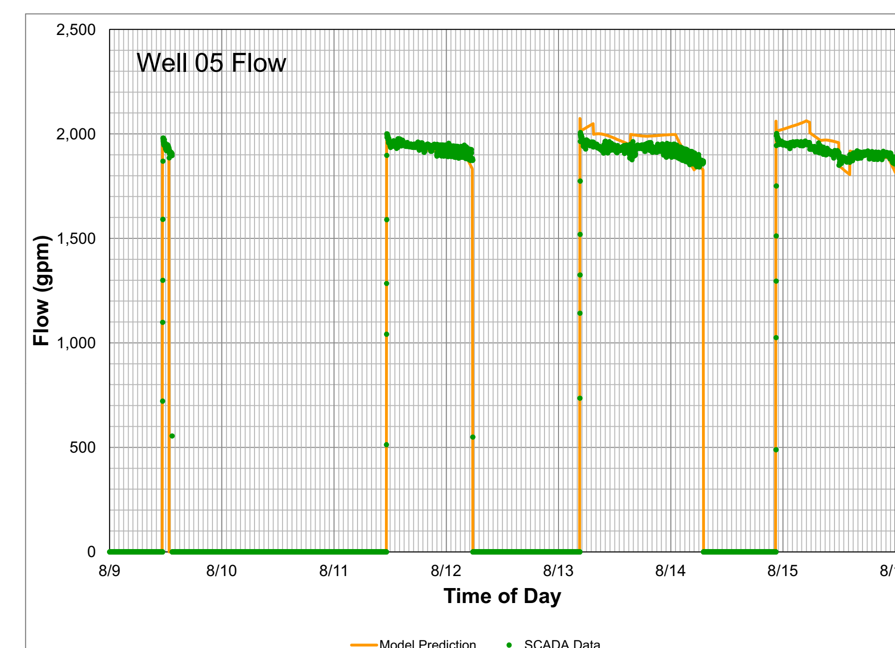

OC-51 Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
6,500
7,000
7,500
8,000
8,500
9,000
9,500
10,000
10,500
11,000
11,500
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

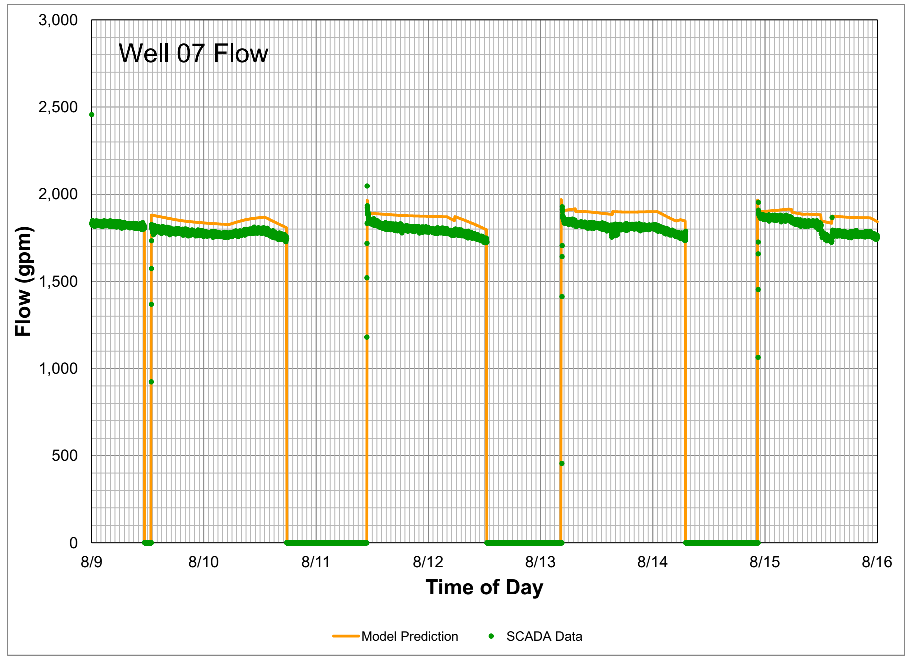

OC-66 Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
6,500
7,000
7,500
8,000
8,500
9,000
9,500
10,000
10,500
11,000
11,500
12,000
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction

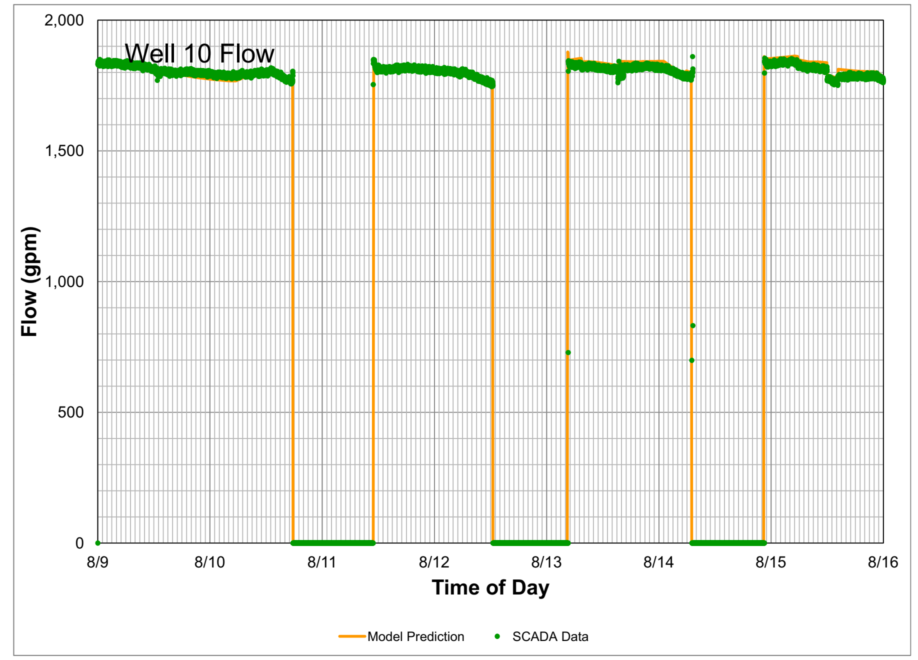

OC-89 Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

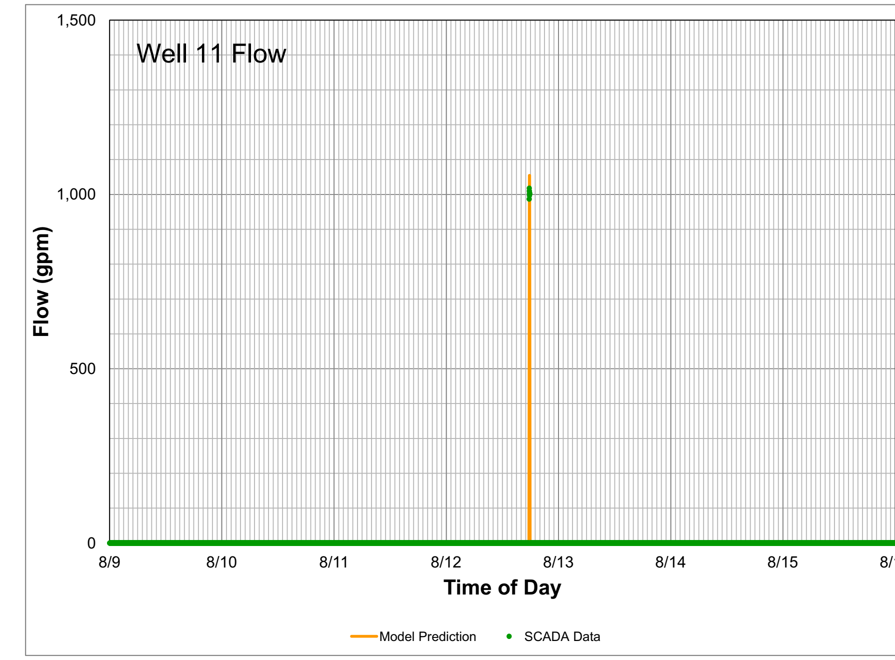

Del Rey PRS Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

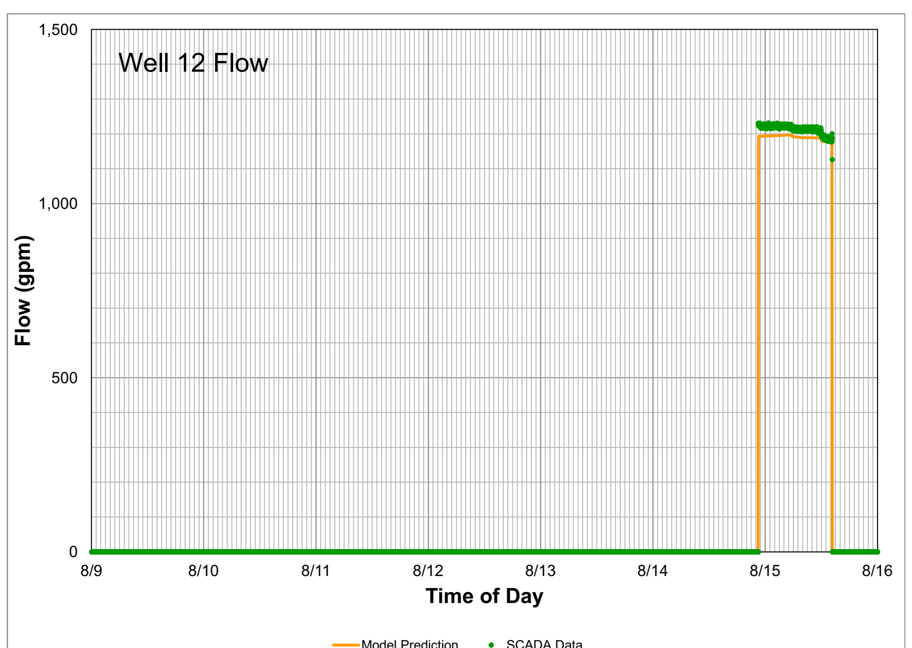

Well 01 Flow
Flow (gpm)
0
500
1,000
1,500
2,000
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

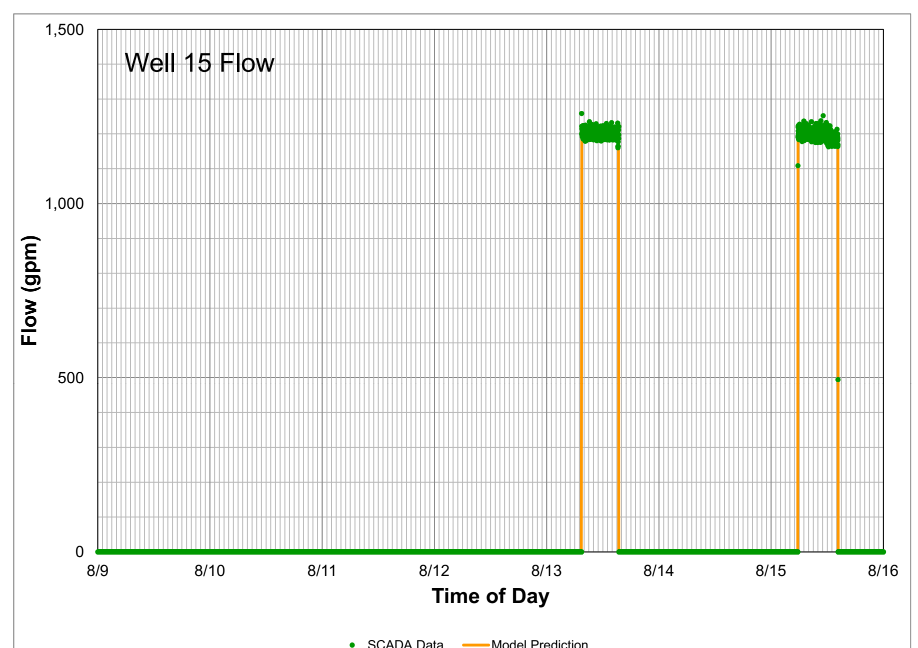

Well 05 Flow
Flow (gpm)
0
500
1,000
1,500
2,000
2,500
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

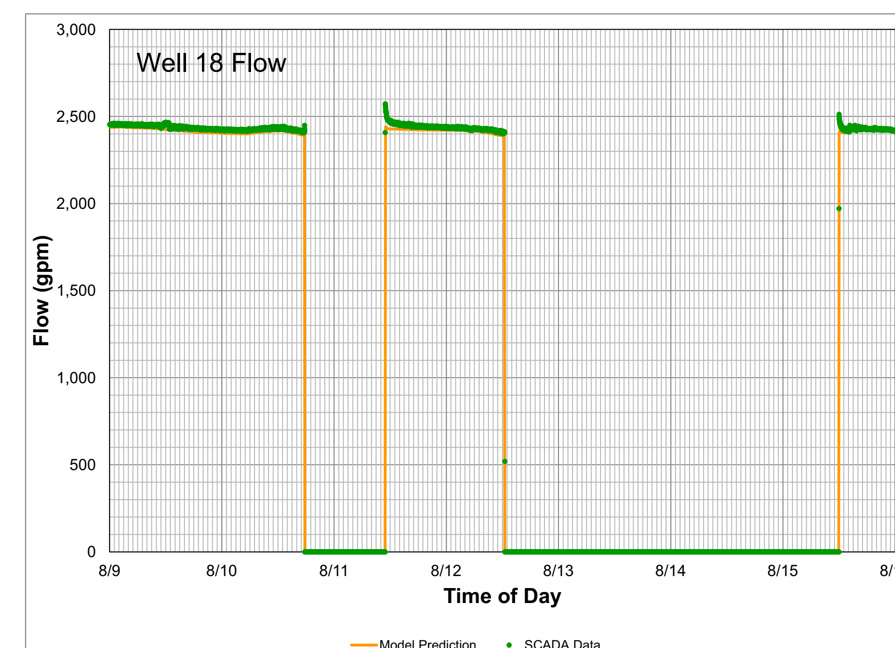

Well 07 Flow
3,000
2,500
2,000
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data

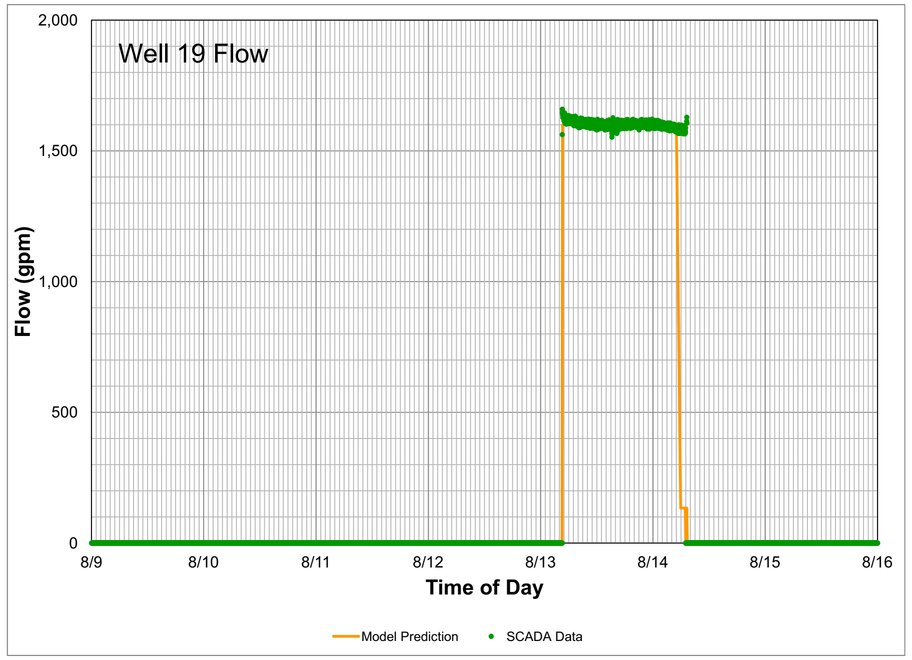

Well 10 Flow
2,000
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data


Well 11 Flow
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data


Well 12 Flow
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data


Well 15 Flow
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
SCADA Data
Model Prediction


Well 18 Flow
3,000
2,500
2,000
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data


Well 19 Flow
2,000
1,500
1,000
500
0
Flow (gpm)
8/9
8/10
8/11
8/12
8/13
8/14
8/15
8/16
Time of Day
Model Prediction
SCADA Data