San Juan Water District
Retail Water Master Plan Update
March 2006

Chapter 6: Hydraulic Model Development

Chapter Contents:

Chapter Highlights:

Using the methodology described in this chapter, WYA developed an updated and enhanced hydraulic network analysis model of the District's retail water distribution system using H_2ONET.

Assignment and reallocation of water demands included:

- Assigning water demands based on actual meter records to specific nodal locations in the model,
- Allocating five different demand conditions which included average day, summer, winter, fall and spring demand conditions, and
- Allocating wholesale demand at each assigned node are provided by the District.

For model calibration of C-factors, twenty-four locations were chosen for hydrant flow testing in the District's Upper and Lower Granite Bay, American River Canyon, Gravity and Sierra Pressure Zones.

For the model verification, nineteen hydrant pressure recorders (HPR) were placed in 108 different locations within the District's distribution system. Each HPR collected field pressure data at a particular location for about a week from June 29, 2004 to September 8, 2004.

The results of the hydraulic model calibration/verification efforts produced:

- An accurate representation of District's retail water supply and distribution system
- An average pressure differential between those pressures observed in the field and those predicted by the model within ±5 psi. However, there are areas where results indicate the possibility of closed or partially closed valves and/or a different pipeline configuration.
- Accurate pressure and flow rate comparisons at each of the District's water facilities for both SCADA and field readings

WEST YOST
ASSOCIATES
Consulting Engineers

CHAPTER 6. HYDRAULIC MODEL DEVELOPMENT

To refine and enhance the District's hydraulic network model, WYA completed the following steps:

- Used the District's existing retail water distribution system maps (exported from the District's GIS) and existing digital water distribution maps in AutoCAD to create and update the hydraulic model.
- Verified that the converted hydraulic model system configuration (pipeline sizes, alignments, connections, and other facility sizes and locations) was representative of the District's current retail water system.
- Allocated existing water demands by using the District's geocoded meter information to properly distribute demands within the hydraulic model.
- Updated, enhanced and calibrated the District's water system hydraulic model to simulate pressures and flows observed in the field.

To accomplish these tasks, WYA worked closely with the District's Engineering and Operations staff to obtain and review:

- Available information regarding existing transmission mains, reservoirs, treatment facilities and other water facilities.
- As-built drawings and maps detailing older sections of the retail system to confirm pipeline sizes, material type, age, locations and alignments.
- Land use and available meter data.

The updated retail water distribution model was then calibrated and verified using pressure and flow data observed in the field between July and September 2004. The model update and development are described below.

HYDRAULIC MODEL UPDATE

In previous work for the District, WYA created a calibrated and verified hydraulic model for the District's Sierra and Bacon Pressure Zones. As part of this Retail Water Master Plan Update, the District requested that WYA update the remaining pressure zones which include: Upper and Lower Granite Bay, American River Canyon (North and South), Crown Point, and Gravity. In addition to updating the model, WYA also evaluated whether the existing, skeletonized hydraulic model simulated the District's water system in sufficient detail to allow hydraulic analysis at a level consistent with the District's desired planning criteria.

During the model update process, WYA compared the previously developed hydraulic model to the District's water distribution maps. Any discrepancies with the system configuration and pipeline size, material type and age were provided to the District for review and comment. The District's responses were then incorporated into the hydraulic model to further refine system configuration and the hydraulic performance prior to calibration and verification.

Hydraulic Model Element Naming Scheme

H_2ONET was the hydraulic modeling software used to create a mathematical representation of the retail water system. The model includes a network of nodes and node-connecting elements. The model was constructed by assigning nodes at each junction of two or more pipes at locations where pipeline diameters changed, and at locations where there was a significant water demand or supply. Setting up a model with specific element numbers representing key hydraulic facilities was necessary because it allows the modeler to easily locate specific nodes or pipelines while modeling. Water distribution system models have many types of nodal elements, including junction nodes where pipes connect, storage tank and reservoir nodes, pump nodes and control valve nodes. Hydraulic models use link elements to describe the pipes connecting these nodes. Table 6-1 lists the naming scheme for each model network element, the type of element used to represent it in the District's model, the primary modeling purpose and a prefix, corresponding to the node or link type.

Table 6-1. Prefix Designations for Network Elements

Element	Type	Description	Prefix
Junction	Node	Removes (demand) or adds (inflow) water from/to the system	J
Node	Node	Represents transition in pipeline characteristic or point where pressure or water quality is monitored	N
Tank	Node	Represents storage facility	T
Reservoir	Node	Represents an infinite external source (e.g., Hinkle Reservoir)	R
Pump	Node	Raises the hydraulic grade line to overcome elevation differences and friction losses	PMP
Control Valves	Node	Controls flow or pressure in the system based on specified criteria	CV
Pipelines	Link	Conveys water from one node to another	P

As each facility was created in the model, pipes, nodes, pumps, tanks, and valves were numbered sequentially. Table 6-2 summarizes the numbering scheme used in the development of the District's hydraulic model.

Table 6-2. Numbering Scheme for Nodes and Pipelines

Description	Node/Pipeline Number
Source Nodes: Nodes which represent a source to the distribution system (i.e. water treatment plant, groundwater, water purveyor)	0-99
Pump Facilities	100-199
Valves (meters, gate, butterfly, etc.)	200-299
Check Valves	300-399
Control Valves (i.e. pressure reducing valves, flow control valves, etc.)	400-499
Chemical Booster Stations	500-599
Water Quality Sampling Stations	600-699
Inter-ties/Emergency Connections	700-799
Reservoirs/Tanks	900-999
Wholesale Customers	1000-1999
Sierra Pressure Zone Nodes	2000-2999
Gravity Pressure Zone Nodes	3000-3999
Bacon Pressure Zone Nodes	4000-4999
Lower Granite Bay Pressure Zone Nodes	5000-5999
Upper Granite Bay Pressure Zone Nodes	6000-6999
Crown Point Pressure Zone Nodes	7000-7999
ARC-North Pressure Zone Nodes	8000-8999
ARC-South Pressure Zone Nodes	9000-9999

Modeling Assumptions and Criteria

Establishing computer modeling assumptions and criteria was important for updating, enhancing, calibrating, verifying and running the model, and for interpreting the results of the computer simulations. The assumptions and criteria used for the District's water distribution system hydraulic model included:

- A minimum pipe size of 4-inches was modeled, except in critical areas of the system where including smaller diameter pipes was required to complete a loop or to provide service to an isolated area.
- Information on pipe length, diameter, material type and age was extracted from the District's existing GIS, and was compared for accuracy to information on the District's hard-copy maps.

- Pipe roughness coefficient (C-factor) values were assigned based on age and pipe material, then subsequently adjusted during calibration based on the results of the hydrant flow testing.
- Information on pump station piping configurations, performance curves, and motor size were acquired from site visits, “as-built” plans and the District’s operational staff.
- Pipe length accuracy was assumed to be ±25 feet.
- Ground surface elevations were estimated using available, digital topographic maps and surveyed benchmark elevations. Elevations were estimated to the nearest foot where spot elevations were not available.
- Pressure set points for PRVs were obtained from the District.
- Recorded field data were received from the District’s facilities.
- Diurnal curves for the District were established using SCADA information.
- The water demands in the model were expressed in gpm.
- The District’s wholesale customer demands were obtained from the District, and incorporated into the hydraulic model based on the wholesale average demand from year 2000 to 2003.

Model Input Data

The model input data is described below.

Junctions. Input data for each junction in the District’s water system model included elevation and either a constant pressure or flow (demand). The elevation of each node was determined by using the *Smart Topography* feature in the H_2OMAP software. Digital topography provided by the District, in shapefile format, was brought into the model as a GIS theme and then, using the *Smart Topography* feature, the elevations were automatically computed and allocated to junction nodes. A shapefile was generated from H_2OMAP and imported into the District’s H_2ONET model.

Pipelines. The input data for the pipelines includes length, diameter, material, age and pipeline C-factor. The pipeline lengths, diameters, material type and age were determined from the GIS database provided by the District. Pipelines in the water distribution system vary in size from 4-inches to 72-inches in diameter. Recently installed pipelines are PVC while older pipeline materials within the District include cast iron, asbestos cement, welded steel, ductile iron and reinforced concrete. C-factors for these pipelines depend on the age of the pipeline, and can range from 80 (old cast iron) to 150 (newest, PVC). Appropriate C-factors were used to calculate head loss in the distribution system.

Storage Reservoirs. Reservoirs remain at a constant water level irrespective of the flow unless they are specified as variable-head reservoirs. Reservoirs have unlimited volume and are generally used to represent a lake or other inexhaustible supply source. The District’s Hinkle Reservoir is currently represented in the model as a storage reservoir.

Storage Tanks. Storage tanks are distinguished from reservoirs as having a known finite volume. Water surface levels in storage tanks change with time as water flows into or out of them. Storage tanks were used to simulate the District's existing retail tanks. Each of the storage tanks was input into the model as a tank with a minimum level, maximum level and diameter.

Pump Stations. The District operates eight booster pump stations in its retail system. Original pump curves were available and input into the model. Data for the pumps were previously described in Chapter 2. Each pump was modeled using a multi-point curve within the model.

ASSIGNMENT AND RE-ALLOCATION OF WATER DEMANDS

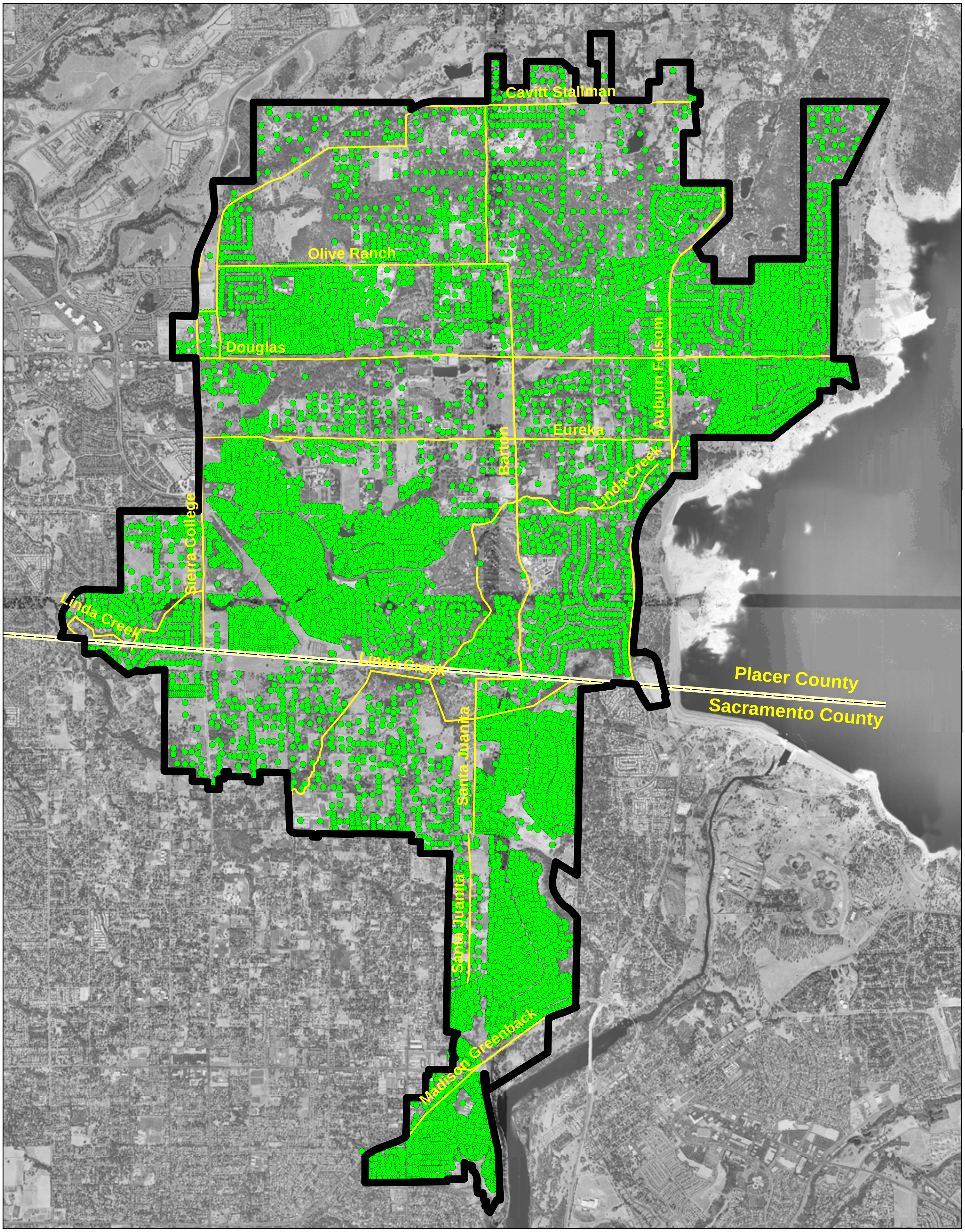
The focus of the assignment and re-allocation of average day water demands was to confirm the location and quantity of existing large water user demands. These large user demands were allocated in the hydraulic model based on geocoded meter data. The methodology used to assign and allocate water demands in the hydraulic model is summarized below:

1. Assign water demands based on actual meter records to specific nodal locations in the model.
2. Allocate five different demand conditions which include average day, and summer, winter, fall and spring.
3. Allocate wholesale demand at each assigned node provided by the District.

These steps are discussed in further detail below.

Demand Allocation Based on Metered Data

Customer/meter billing data (each with distinct X and Y coordinates) provides an accurate measure of localized demands imposed on the water distribution system. H_2OMAP *Demand Allocator*^{TM} uses GIS technology to geocode consumption data to designated junction nodes. This method provides a means to assign demands to the junctions closest to the water meter. For each of the junction nodes, the demands are then summed to establish localized demands imposed on each of the nodes. Figure 6-1 illustrates the retail meter locations used for this purpose.



LEGEND

● LOCATION OF WATER METERS
▭ RETAIL SERVICE AREA BOUNDARY
— MAJOR STREETS
- - - COUNTY LINE

FIGURE 6-1

San Juan Water District
Retail Water Master Plan

GEOCODED METER DATA

WEST YOST
ASSOCIATES
Consulting Engineers

i:\414\0302\WMP Figures\Chapter 5\Fig5-2_Meters.mxd

HYDRAULIC MODEL CALIBRATION

To verify that the model correctly represented the District's water system, and could produce hydraulic results consistent with those observed in the field, the District, under WYA's direction, collected data to calibrate/verify the hydraulic model. The description of the hydraulic model calibration and verification process, and the results, are described below.

Hydraulic Model Calibration

The hydraulic model was calibrated to confirm that the computer simulation model accurately represented the operation of the water distribution system under varying conditions. After refining/enhancing the District's hydraulic model, twenty-four locations were chosen for possible hydrant flow testing for the Upper and Lower Granite Bay, American River Canyon, Gravity and Sierra Pressure Zones (see Figure 6-2). Associated pipeline C-factor evaluations were initially performed in the field on August 11, 18, and 25, 2004. Selection of these hydrant test sites was based on the size, material type and age of the pipelines involved in the tests. These tests were used to evaluate pipeline friction factors (C-factors), which in turn were used to calibrate the model and ensure that the model closely represented the observed pressure conditions in the field.

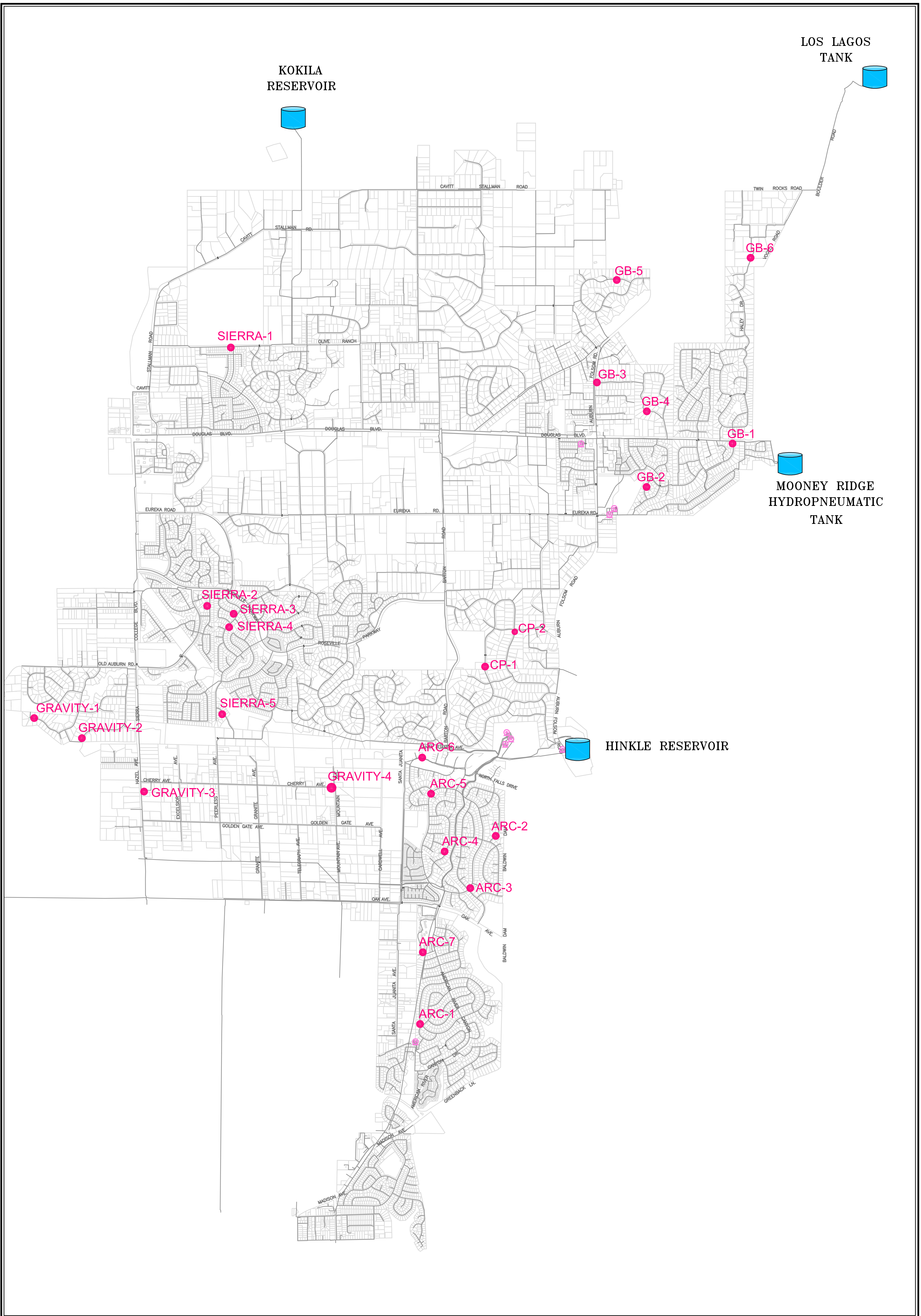
Each test involved flowing water through pipelines of a particular size and material type, and measuring the pressure drops along the pipelines to determine friction losses. The test procedure consisted of monitoring discharge and pressure at the key flowing hydrant, and pressures at other hydrants along the supply routes to that key hydrant. Static pressures were measured while the key hydrant was closed, and residual pressures were measured while the key hydrant was flowing.

Calibration Results

Using the hydraulic model of the District's retail water system, each hydrant flow test was simulated. Results were compared to the collected field data to determine the accuracy of the model. The differences between observed static and residual pressures for the field hydrant test, compared to readings predicted by the model, were calculated. The goal of the calibration effort was to achieve no greater than a 5 psi differential between the field hydrant test data and predicted model results.

Pipelines in the District's retail water system date from the 1950s and range in size from 4-inches to 72-inches in diameter. Pipeline materials include cast iron, welded steel, asbestos cement, ductile iron, reinforced concrete cylinder pipe (RCCP), and PVC. C-factors ranging from 100 to 150 were used in the model after calibration.

Prior to any model runs, each pipeline was assigned a preliminary C-factor based on the pipeline age and material type. Table 6-3 summarizes the preliminary C-factors that were used in the model development. During the calibration step, these C-factors were adjusted to better reflect observed field conditions.



LEGEND

- ● FIRE HYDRANT LOCATION (PRESSURE ZONE-TEST NO.)
- ◎ PUMP STATION
- ▮ RESERVOIR/TANK

Figure 6-2

San Juan Water District
Retail Water Master Plan
HYDRANT FLOW TESTING LOCATIONS

WEST YOST ASSOCIATES
Consulting Engineers

Table 6-3. Preliminary Pipeline C-Factors[(a)]

Year	Age	Asbestos Cement[(b)]	Cast Iron (Unlined)	Steel (Unlined)	Cement Lined Pipes (Cast Iron and Steel)	Concrete	Ductile Iron	PVC
1950	54	120-130	80					
1954	50	120-130	80					
1964	40	120-130	85					
1974	30	120-130	90	85	125	100	100	
1984	20	120-130	90	100	130	130	100	135
1994	10	135-145	NA	130	130	130	110	140
2004	0	NA[(c)]	NA	140	140	135	130	150

[(a)] Sources: Previous WYA master planning efforts, AWWA design manuals, and pipe manufacturers' recommendations.
[(b)] Depends on pipeline diameter.
[(c)] NA – Not Applicable, material was not installed during these years.

The results of this initial hydraulic model calibration generally validated the system pipeline configuration and assumed C-factors. The calibration procedure produced a few modifications to some pipeline friction coefficients and corrections in the ground surface elevations at several locations that were found to be inaccurate in the original data collection effort. However, the average differentials between those pressures observed in the field and those predicted by the model were within ±5 psi.

Based on comparison of collected hydrant flow testing data and model simulation results, the following tests required further evaluation conducted by the District to verify the actual system configuration (e.g. pipeline sizes, connection points and looping) to be consistent with the District's system maps:

- American River Canyon: Test 3, Test 5, and Test 6

The number and spatially distributed hydrant flow test locations provided varied conditions to test the accuracy of the hydraulic model to simulate the operation of existing water facilities. The results of the calibration runs from the remaining hydrant tests indicated that the model simulated the District's retail water system with a high level of accuracy and was able to match field-observed pressures and flows.

The detailed results of individual calibration tests are provided in Appendix A.

HYDRAULIC MODEL VERIFICATION

Verifying that a model replicates field conditions requires thorough knowledge of how the system performs over a wide range of operating conditions. To ensure that the retail hydraulic model was correctly configured and capable of producing results consistent with those observed in the field, a verification process was carried out. Hydrant pressure recorders (HPRs) were used to record pressures in the field. The data were then compared with model-predicted pressures at the same system locations during extended period simulations (EPS). Other pressure points monitored by the District were also used in the verification process. The description of the verification process and the results are described below.

Developing System-Wide Diurnal Curves

WYA collected SCADA data from the District on the flows out of the Hinkle Reservoir, storage tank levels and pump discharge pressures on the following dates:

- July 14 to July 31, 2004;
- August 12 to August 31, 2004; and
- September 1 to September 5, 2004.

To add the time variable to the District's retail water system model and create a true EPS model to compare to the collected SCADA data, a realistic diurnal pattern of the District's demand was developed. To create this diurnal pattern, production data from all of the District's pump stations, reservoirs and tanks were summed using individual SCADA flow recordings to represent total demand in the District system at each hour of July 20 to July 21, August 16 to August 17, August 20 to August 21, August 27 to August 28, and September 2 to September 3, 2004. The resulting diurnal pattern over 48-consecutive hours is shown in Figures 6-3 and 6-4. By using this pattern, the model can more accurately represent fluctuations in demand over the specified time period.

Figure 6-3: 48 Hour Demand Diurnal

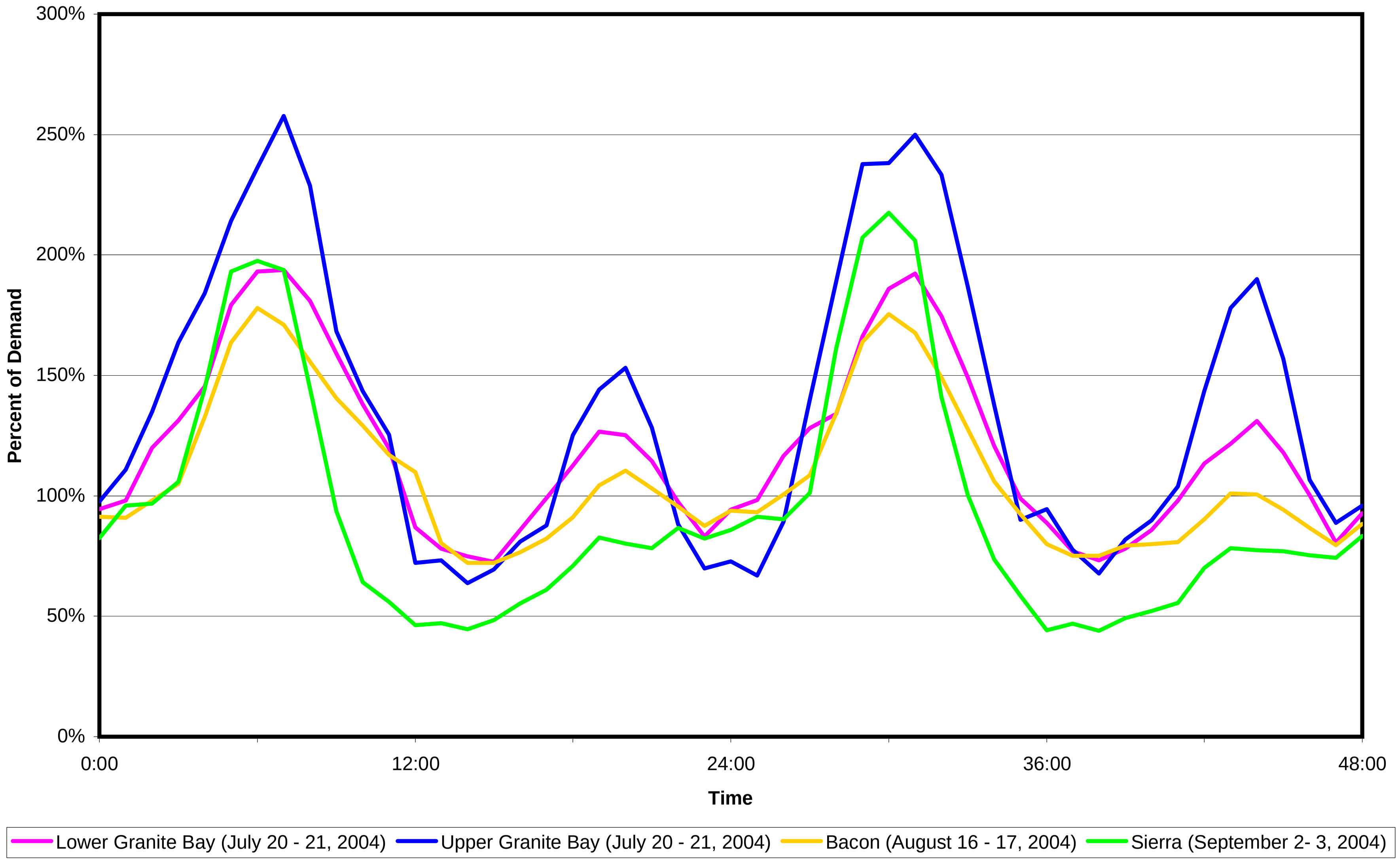
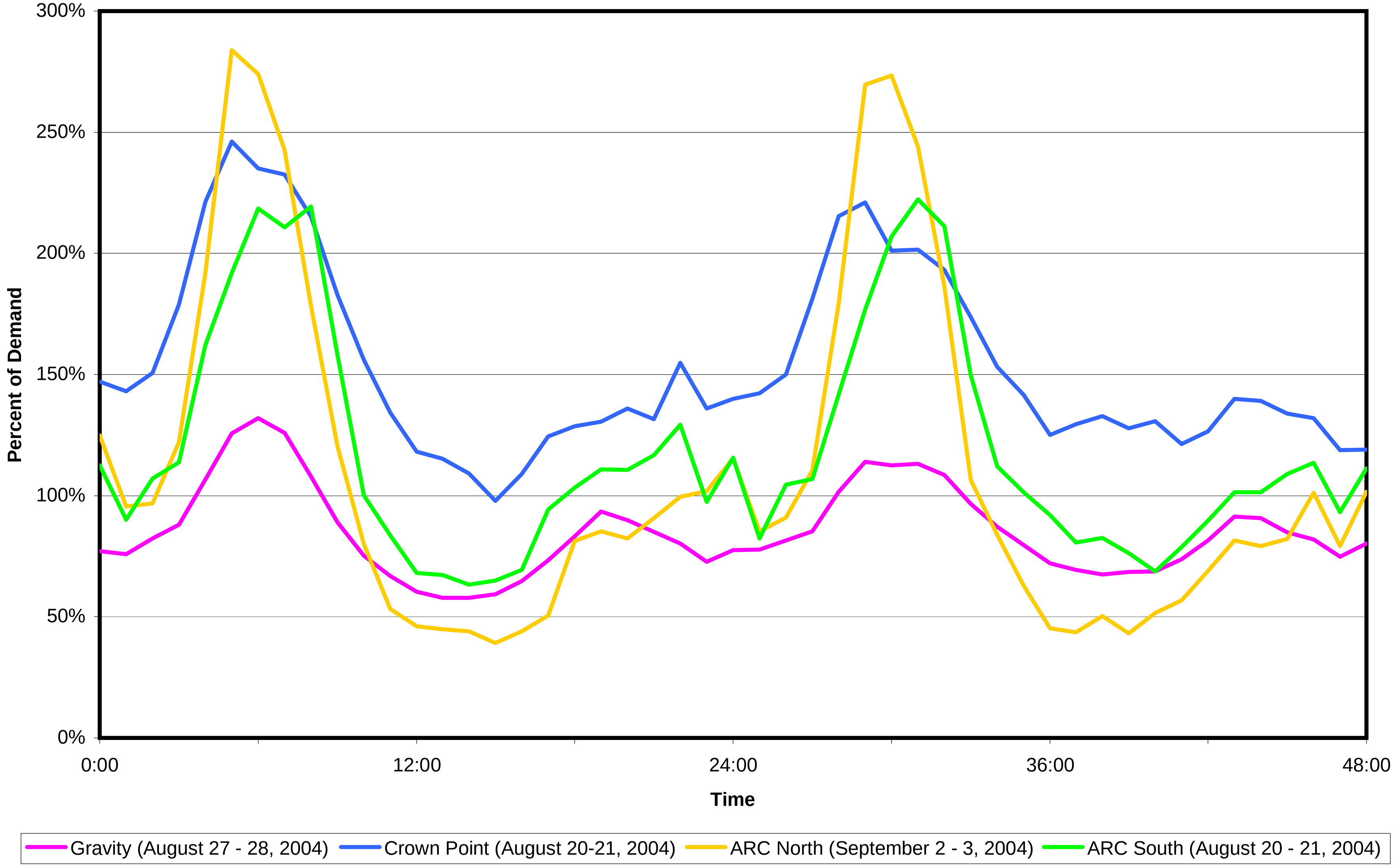


Figure 6-4: 48 Hour Demand Diurnal



Pressure Verification

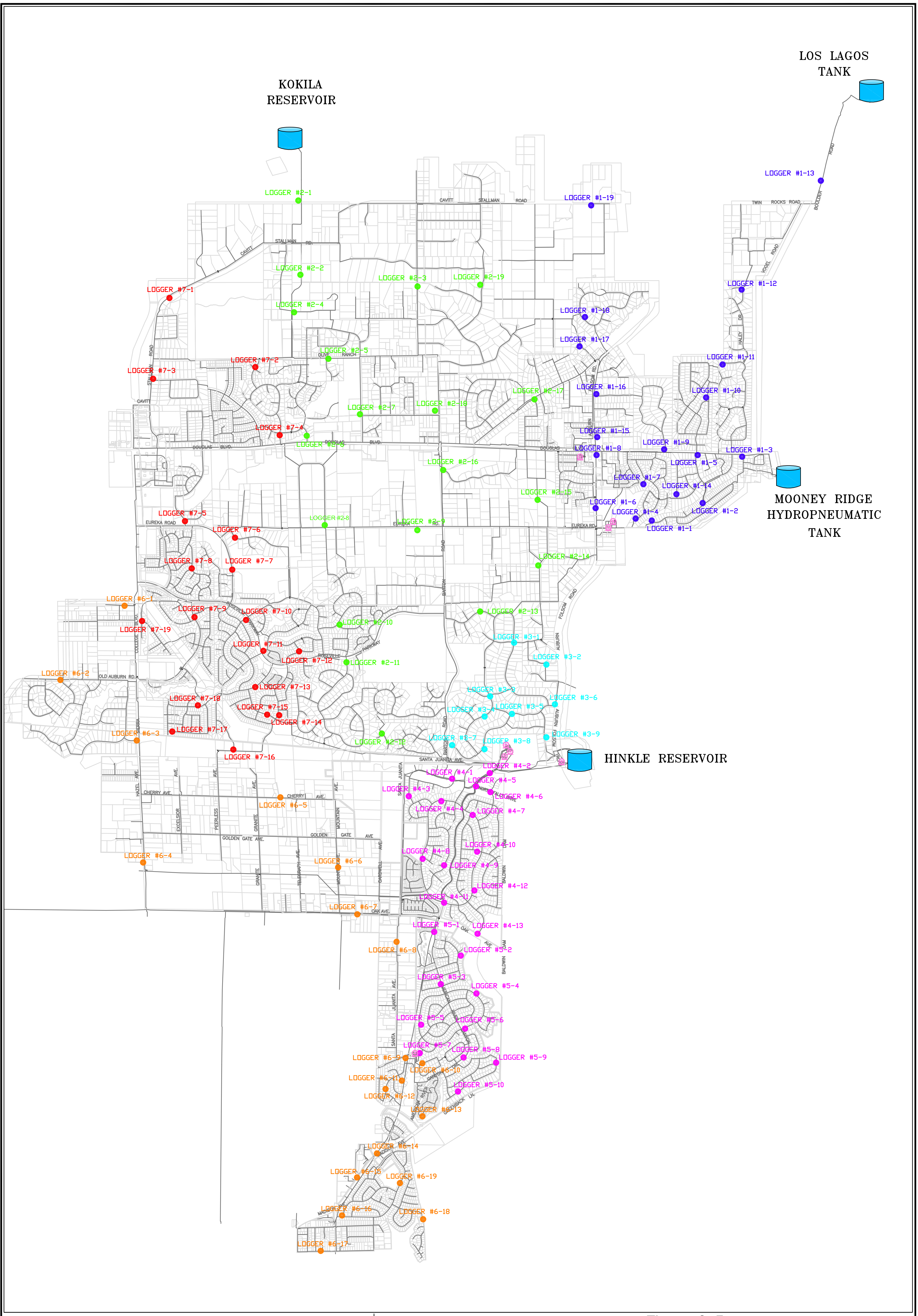
Nineteen HPRs were placed in 108 different locations within the District's distribution system. Each HPR collected field pressure data at a particular location for about a week from June 29, 2004 to September 8, 2004. The locations were selected based on their proximity to the transmission mains and at extreme elevations (low and high) in each of the District's pressure zones.

A monitoring program was developed to collect pressure data in each of these areas over at least a one-week period. Figure 6-5 shows the locations where hydrant pressure recorders were installed and pressures monitored. In total, 19 HPRs were set up and moved weekly from one pressure zone to the other, except for the first group which was set to monitor pressure for the entire month of July 2004. The HPRs were grouped into the following 5 rotation cycles:

- The first rotation cycle covered the Upper and Lower Granite Bay Pressure Zones,
- The second rotation covered the Bacon Pressure Zone,
- The third rotation covered the southeast portion of the ARC-South and Crown Point Pressure Zones,
- The fourth rotation covered the Gravity Pressure Zone, and
- The last rotation cycle covered the Sierra and ARC-North Pressure Zones.

Figure 6-5 shows overall locations of each HPR by monitoring group.

Following the integration of the diurnal patterns into the hydraulic model, an EPS was performed and the resulting pressures at each of the HPRs, and the suction and discharge side of pump stations, were graphed. To verify whether the District's hydraulic model was accurately predicting flow, model-predicted pressures and tank levels were compared to actual field data.



LEGEND

- ● UPPER AND LOWER GRANITE BAY LOCATION
- ● BACON LOCATION
- ● CROWN POINT LOCATION
- ● ARC NORTH AND ARC SOUTH LOCATION
- ● GRAVITY LOCATION
- ● SIERRA LOCATION
- ◎ PUMP STATION
- ▬ RESERVOIR/TANK

N

0 1500 3000
SCALE IN FEET

Figure 6-5

San Juan Water District
Retail Water Master Plan
HYDRANT PRESSURE RECORDING LOCATIONS

WEST YOST
ASSOCIATES
Consulting Engineers

Verification Result

Due to the complexity of the District's distribution system, the verification process was grouped into eight service areas based on the retail area's pressure zones. These eight service areas are Lower Granite Bay, Upper Granite Bay, Bacon, Crown Point, ARC-North, ARC-South, Sierra and Gravity Pressure Zones.

Graphs of representative comparisons between model-predicted and field-observed pressures and flows are provided following each pressure zone discussion. Individual graphs of facility comparisons between model-predicted and field-observed pressures and levels are provided in Appendix A.

The results of each of the retail service areas are further described below.

Lower Granite Bay

The supply to the Lower Granite Bay Pressure Zone is from the Lower Granite Bay and Douglas Pump Stations which are supplied by the Bacon Pump Station and the Los Lagos Tank. In the verification process, the Lower Granite Bay Pump Station was the main supply to the Lower Granite Bay Pressure Zone.

The verification results in this area indicate that model-simulated flow rate comparison are similar to the recorded SCADA flow rates (see Figure 6-6). The modeled trend follows closely with the recorded SCADA reading. The pressure trend comparisons for simulated pressure and recorded field pressure readings are extremely close as shown in Figure 6-7.

Upper Granite Bay

The Upper Granite Bay Pressure Zone is directly supplied by the District's Upper Granite Bay Pump Station and Mooney Ridge hydropneumatic tank. Due to the complexity of hydropneumatic tanks, this pressure zone was verified by using the Upper Granite Bay Pump Station SCADA information. The simulated trend of the Upper Granite Bay Pump Station flow rate follows closely with the recorded SCADA reading. The verification results shown in Figure 6-7 indicate that the Upper Granite Bay Pressure Zone is configured correctly and demands have been allocated correctly.

Figure 6-6: Upper and Lower Granite Bay Pump Stations Verification

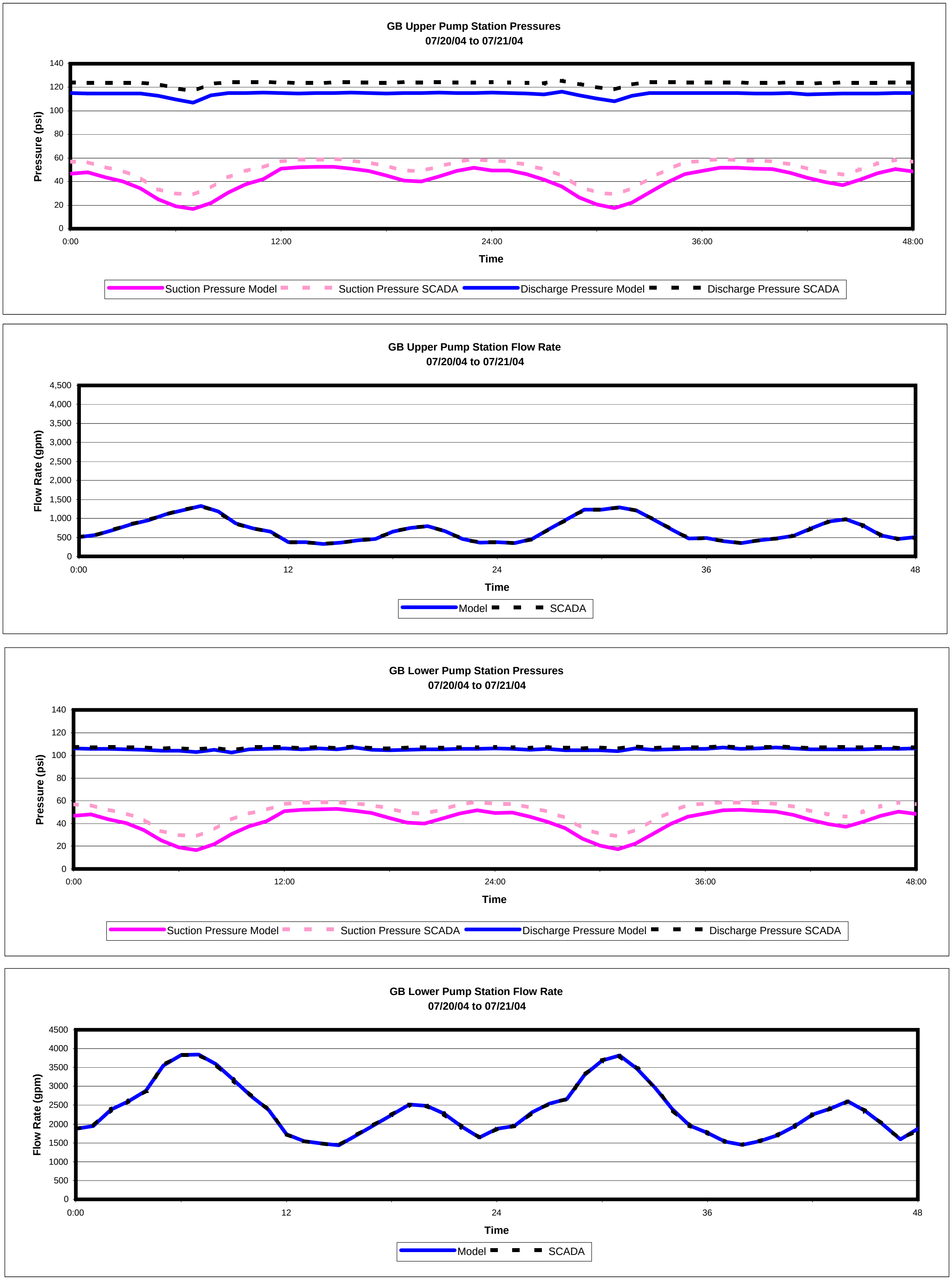
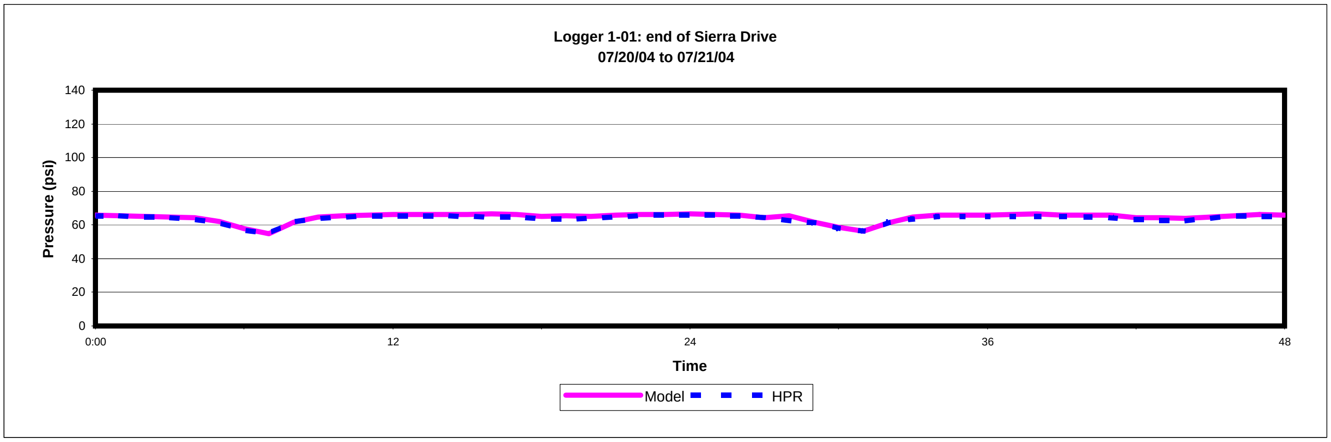
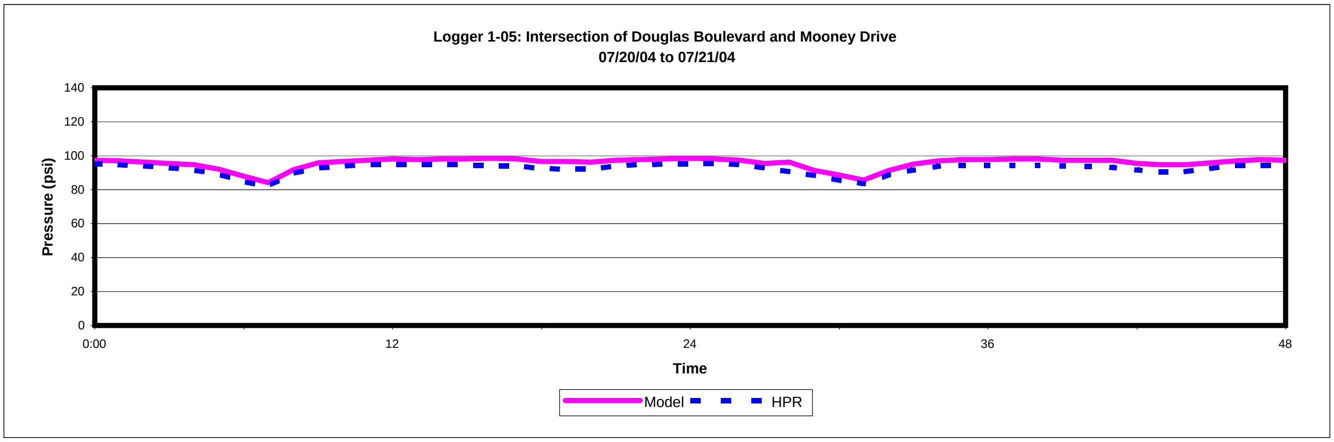
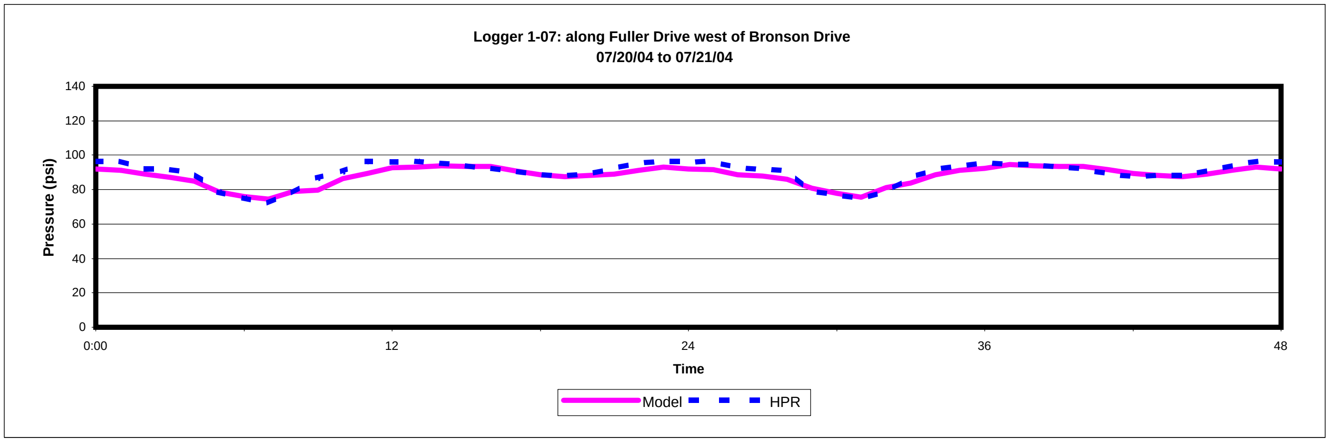
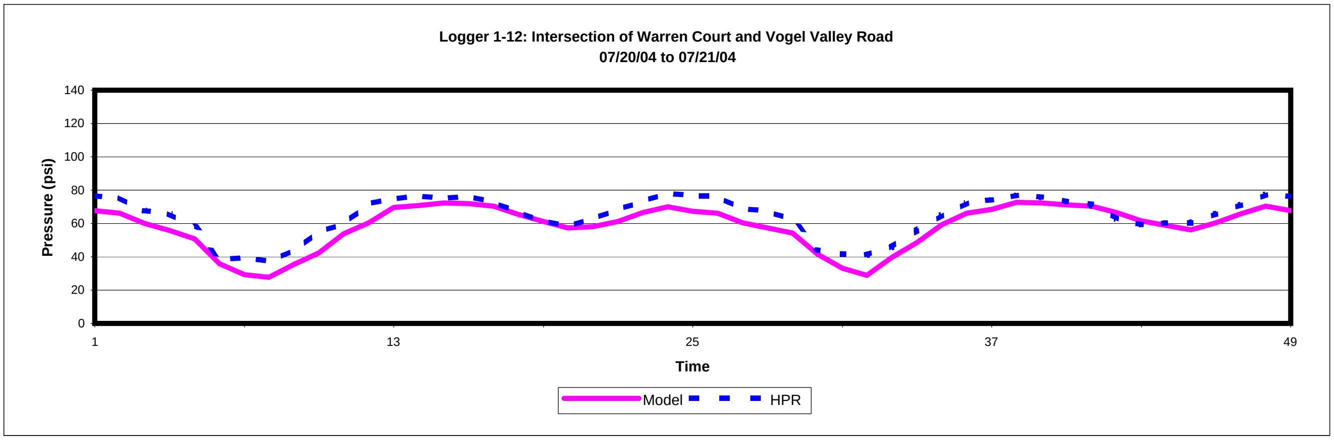


Figure 6-7: Pressure Comparison Between Field Recording and Model Simulation in Upper and Lower Granite Bay Pressure Zones


Logger 1-01: end of Sierra Drive
07/20/04 to 07/21/04


Logger 1-05: Intersection of Douglas Boulevard and Mooney Drive
07/20/04 to 07/21/04


Logger 1-07: along Fuller Drive west of Bronson Drive
07/20/04 to 07/21/04

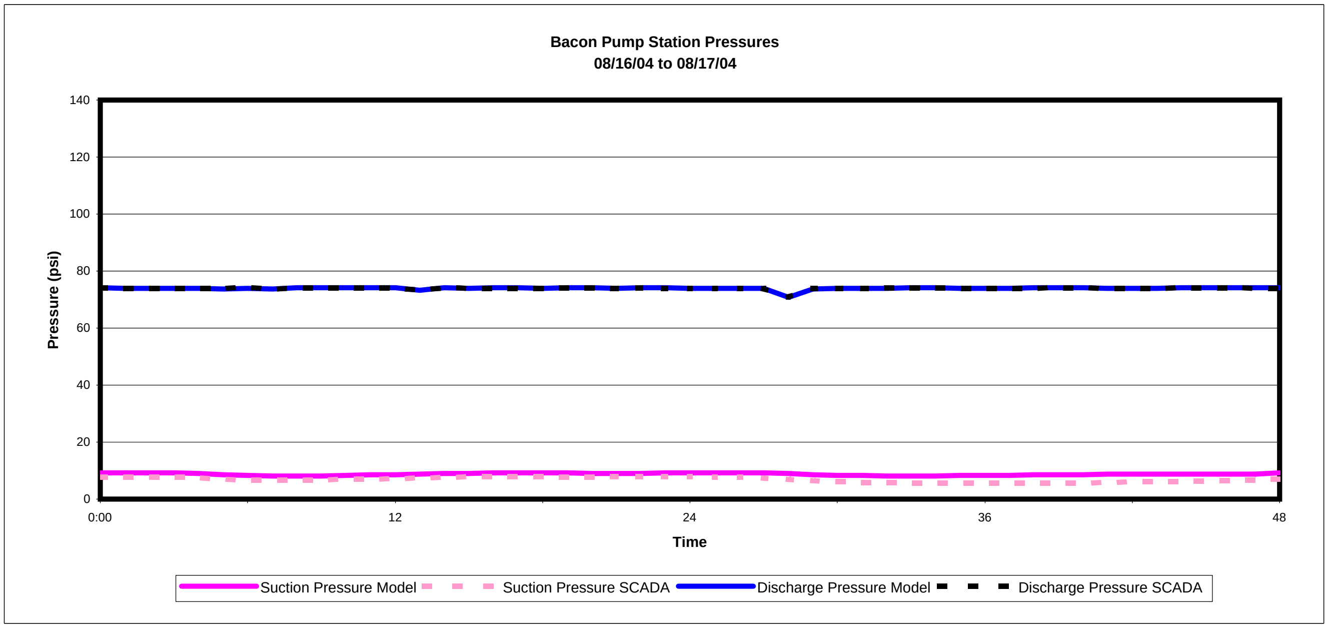

Logger 1-12: Intersection of Warren Court and Vogel Valley Road
07/20/04 to 07/21/04

Bacon

The Bacon Pressure Zone is supplied by the Bacon Pump Station and the Kokila Reservoir. The comparisons of SCADA recorded field data to hydraulic model simulation results are shown on Figure 6-8. The excellent match between field-observed and model-predicted pump station flow and pressure indicates that the Bacon Pressure Zone is correctly configured, and the demands have been allocated correctly.

Nineteen pressure recorders were placed in Bacon Pressure Zone, and results indicate that the comparison of pressure recorders and the field-recorded data is trending closely, if not exactly. Figure 6-9 illustrates a graphical comparison of field-recorded versus hydraulic model-predicted pressures. The close trending of these data sets further indicates that the hydraulic model accurately mimics the District’s water system configuration in the Bacon Pressure Zone.

Figure 6-8: Bacon Pump Station Verification



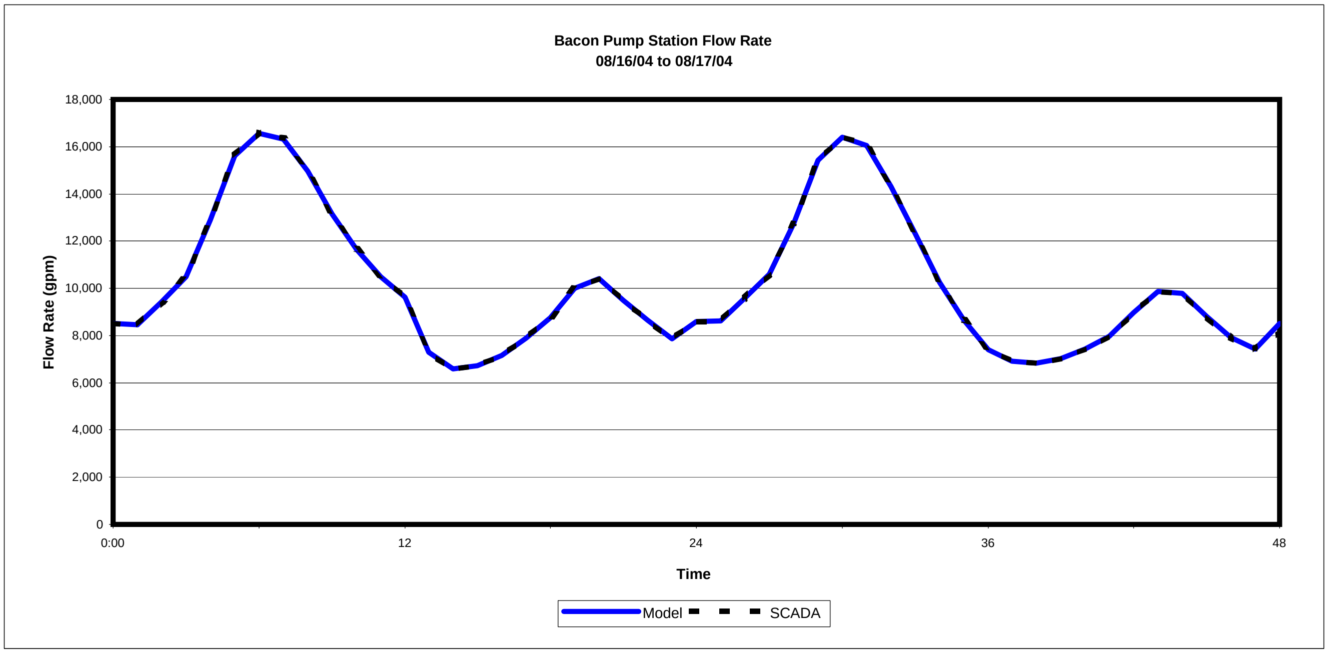
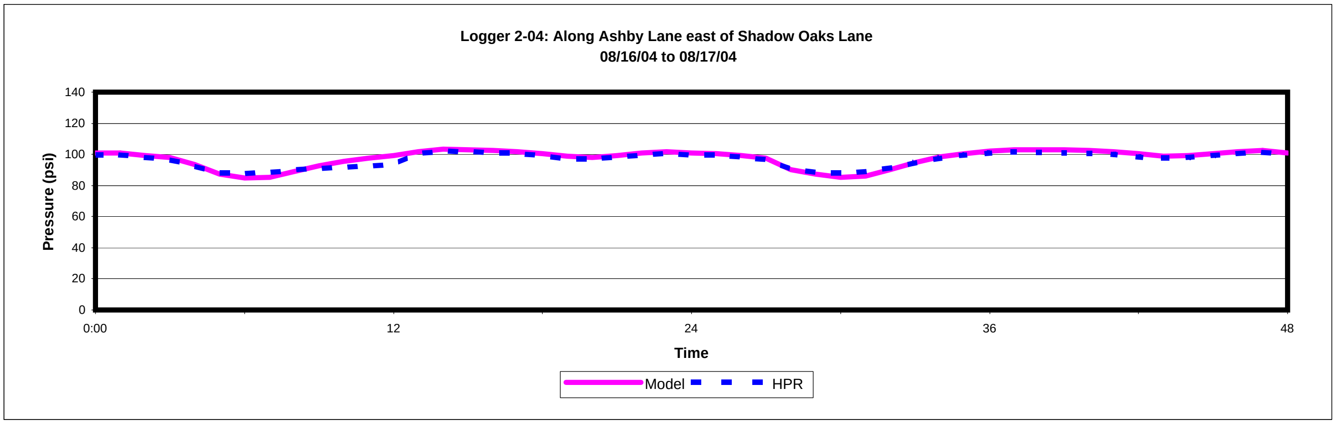
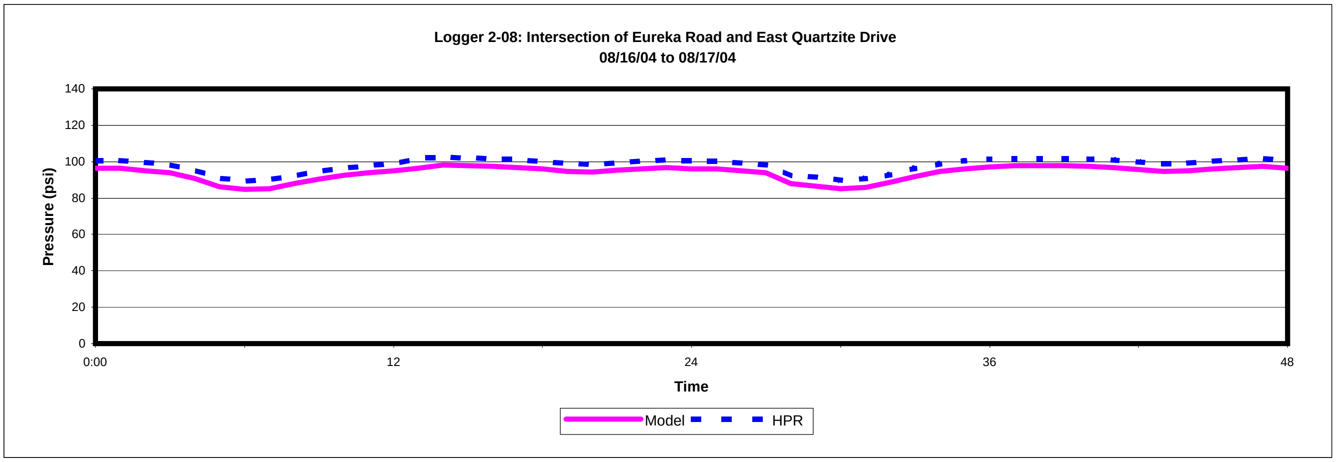
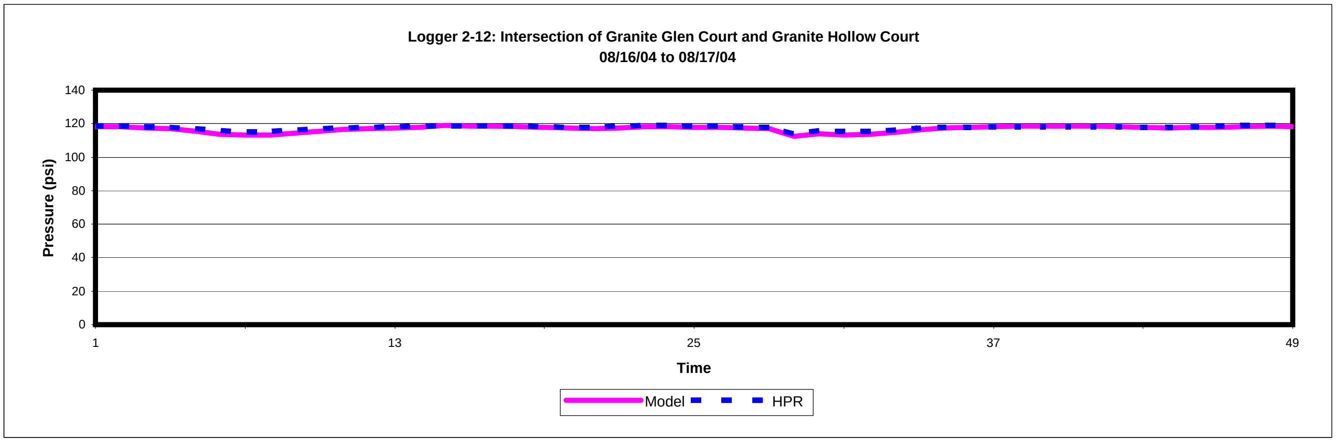
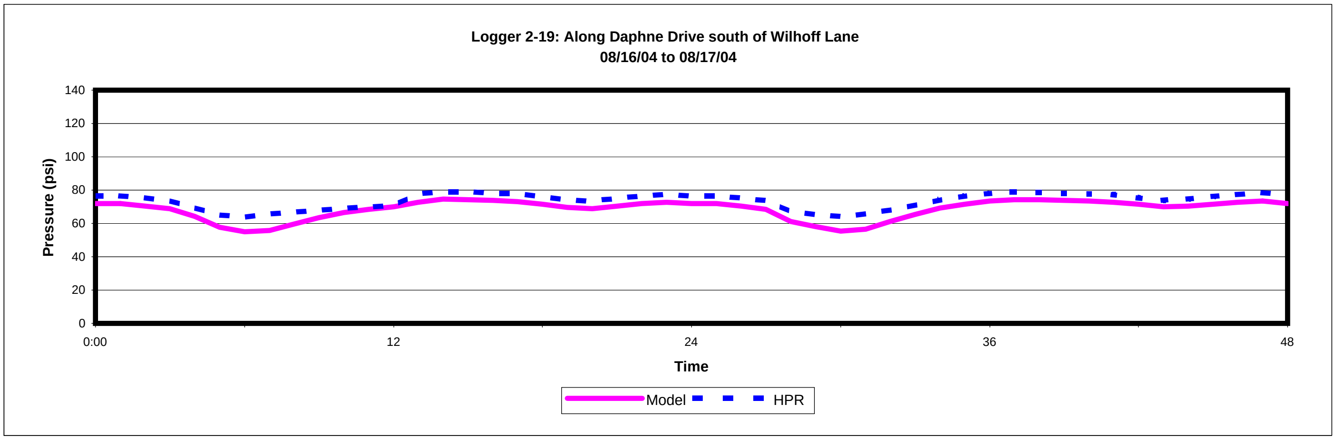


Figure 6-9: Pressure Comparison Between Field Recording and Model Simulation in Bacon Pressure Zone









ARC-South

The American River Canyon South Pump Station directly supplies water to the ARC-South Pressure Zone in the American River Canyon area. Results indicate that the simulated flow trends closely with the recorded SCADA information (see Figure 6-10).

The comparison of simulated pressure trends very closely with the recorded pressures which indicates that the model is correctly configured (see Figure 6-11).

Crown Point

The Crown Point Pressure Zone is served directly by Crown Point Pump Station which is located next to the Hinkle Reservoir. The Crown Point Pump Station was included in the verification. Flow rate and pressure comparisons for the Crown Point Pump Station showed similar trends in comparison to SCADA trends, as presented in Figure 6-10.

Comparisons of the pressure recorder and simulated data trended well. Results are shown in Figure 6-11. Most of the trends, though not exact, follow closely with the recorded pressures. This trending indicates that the model can accurately mimic the water system in this area, and that the demand has been allocated correctly.

Figure 6-10: ARC-South and Crown Point Pump Stations Verification

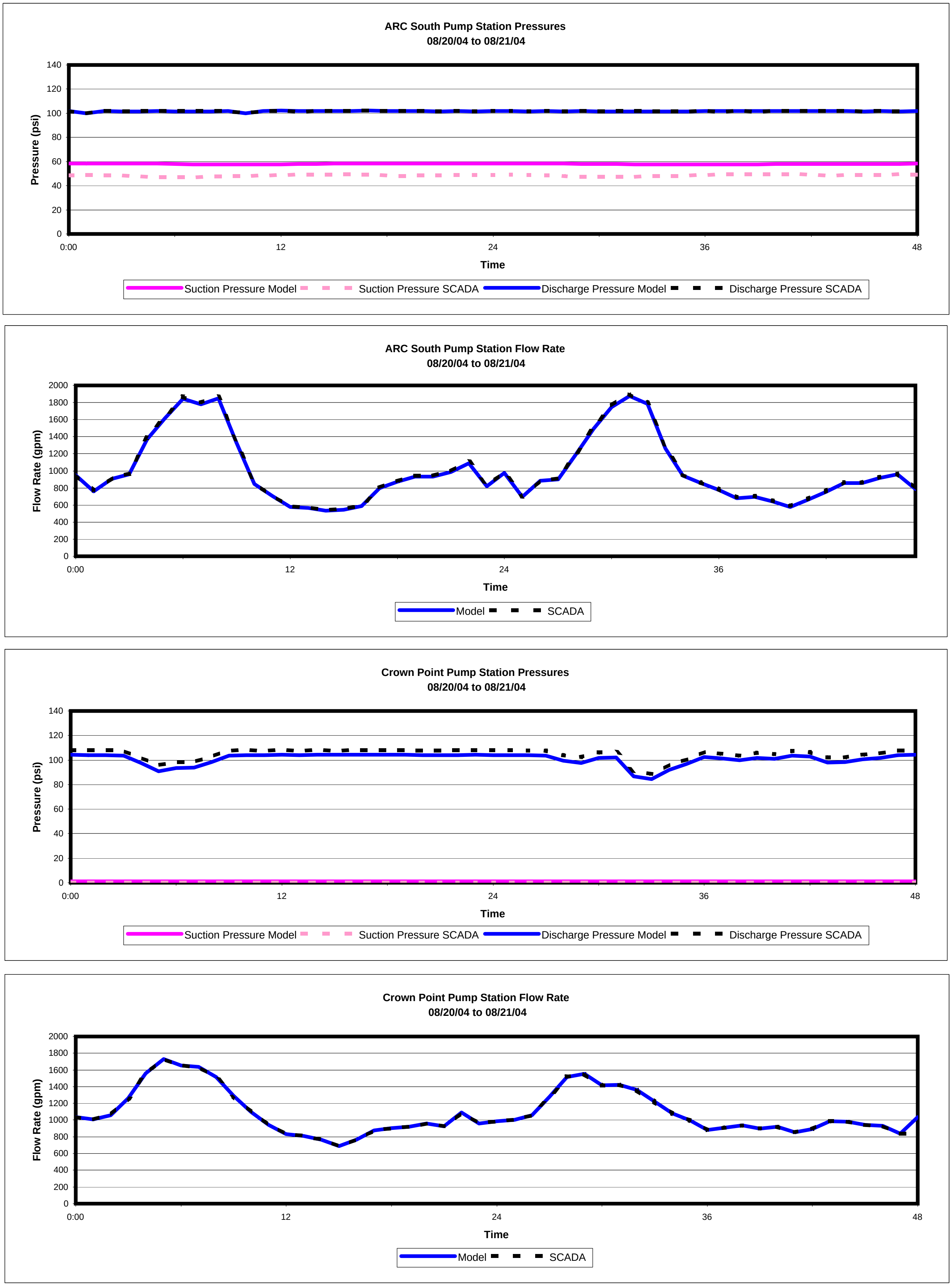
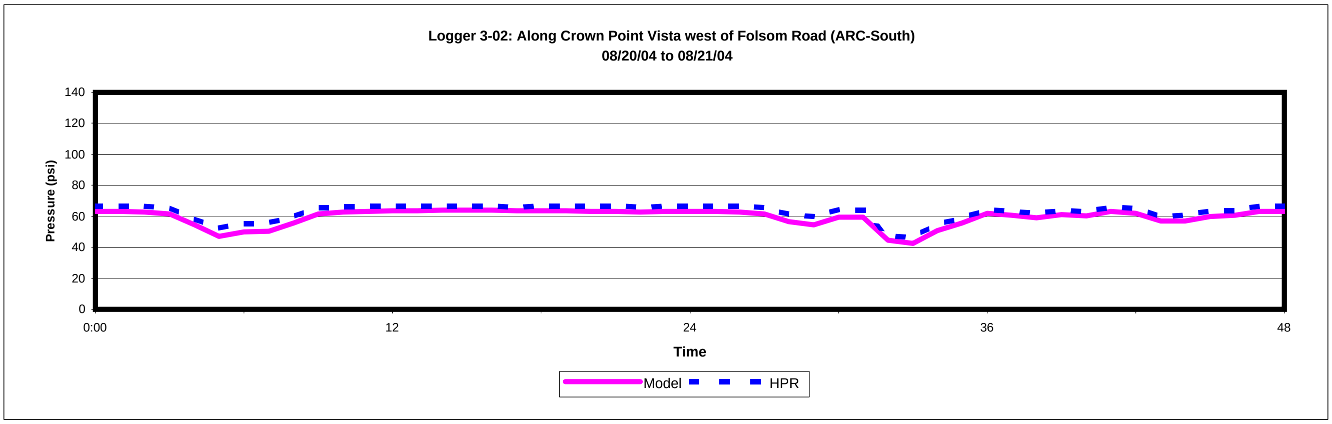
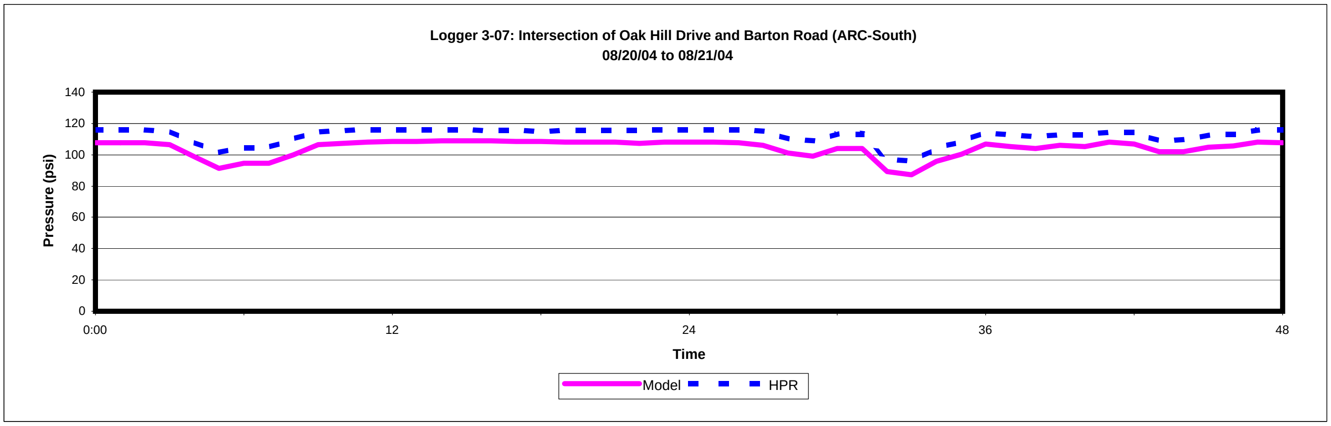
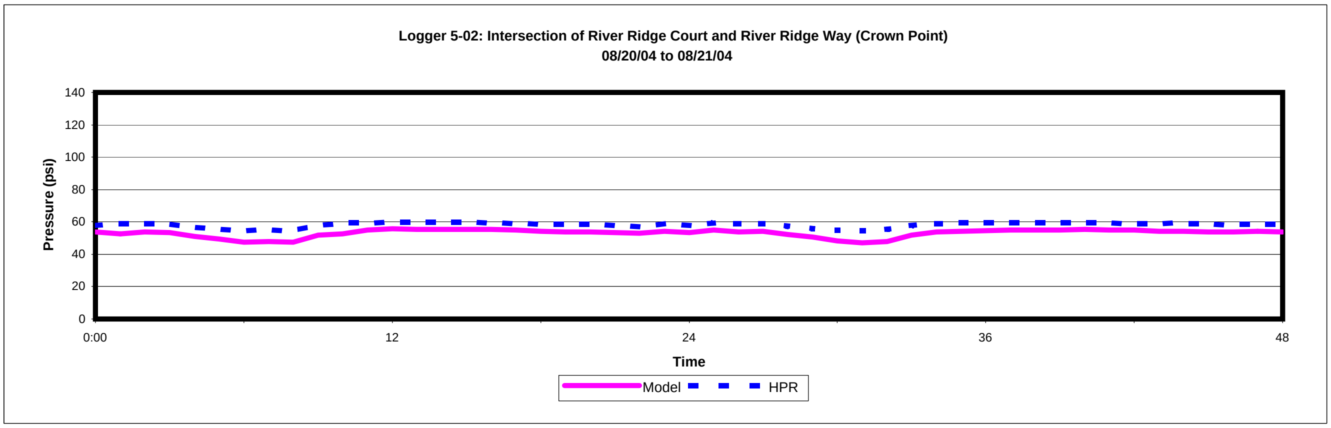
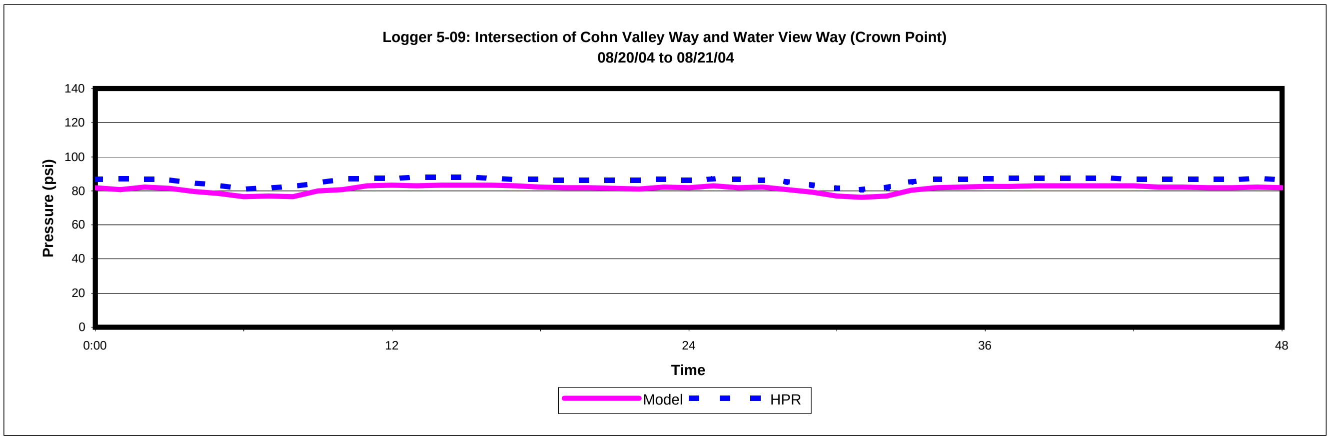


Figure 6-11: Pressure Comparison Between Field Recording and Model Simulation in ARC-South and Crown Point Pressure Zones







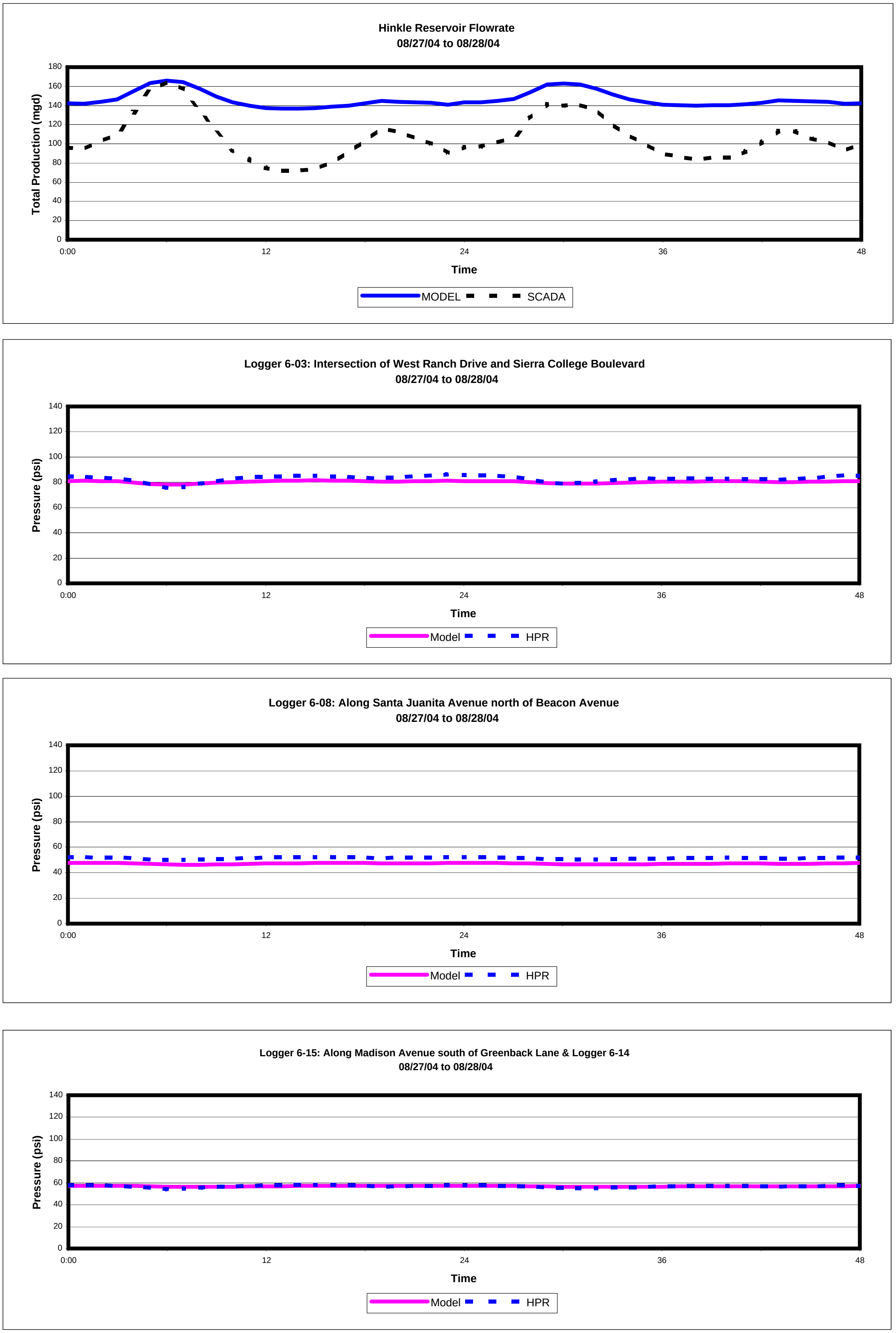


Gravity

Located in the southwest portion of the District's retail water system, the Gravity Pressure Zone is directly served by the Hinkle Reservoir. As shown in Figure 6-12, the flow rate comparison between the SCADA and simulated data does not exactly match; however, the trend of both data sets is close. This slight discrepancy is due to the constant wholesale demand used during the 48-hour period. To obtain a closer match, better diurnal information for the District's wholesale customers, who are served off the gravity system, would be required.

Although the flow rate comparison for the Hinkle Reservoir does not exactly match, the pressure recorders trend very closely with the simulated model trend as illustrated in Figure 6-12. This result indicates that the Gravity Pressure Zone system is correctly configured.

Figure 6-12: Hinkle Reservoir Flowrate and Pressure Comparison Between Field Recording and Model Simulation for Gravity Pressures



ARC-North

The northern area of American River Canyon analyzed in the verification process is supplied by ARC-North Pump Station. The SCADA information for the ARC-North Pump Station pressure and flow rate were used in the verification. Flow rate and pressure comparisons of this facility showed similar trends when compared to the SCADA data (see Figure 6-13).

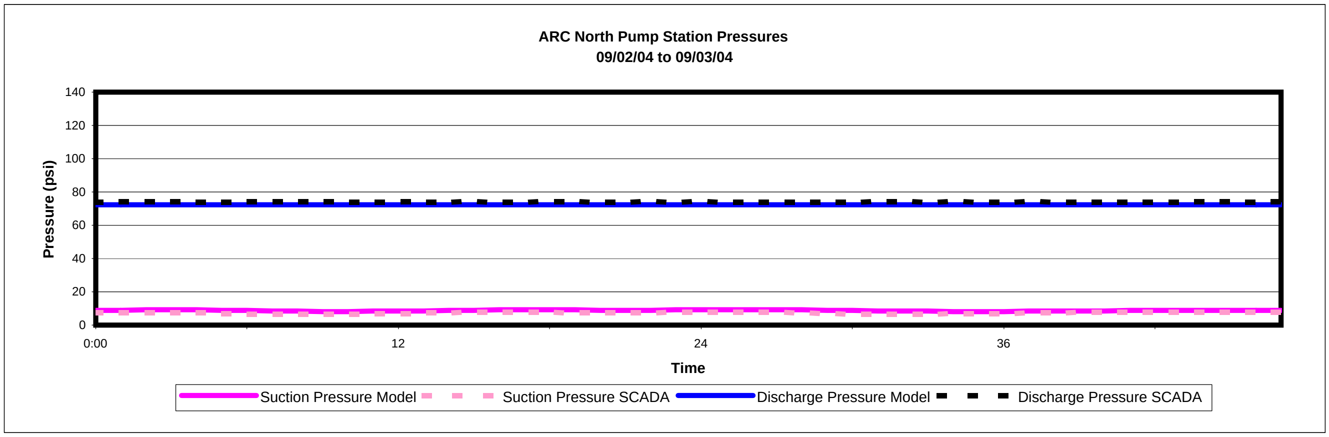
The pressure recorder comparisons for both readings trend exactly as shown in Figure 6-14. This result indicates that the system configuration and demands are allocated correctly.

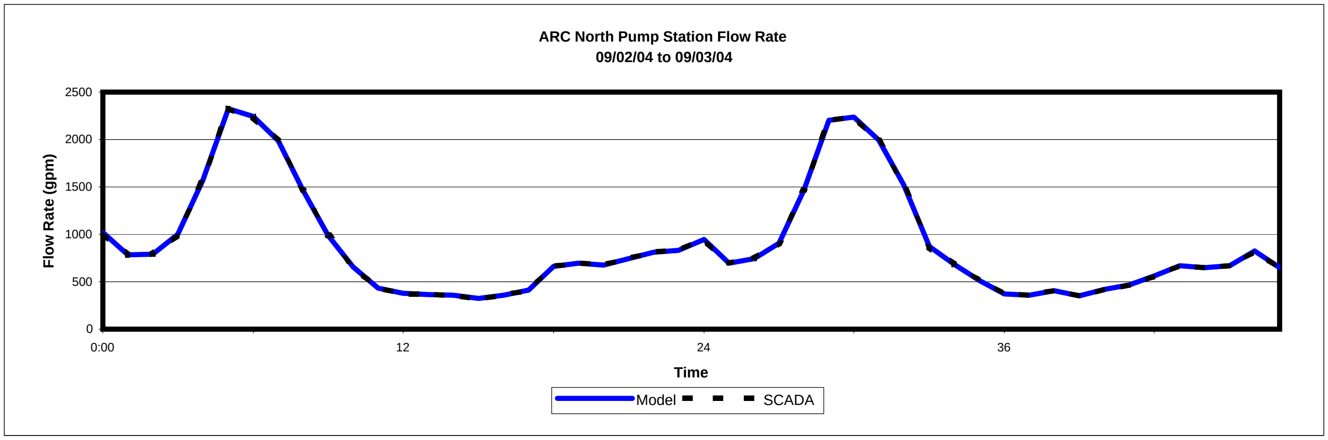
Sierra

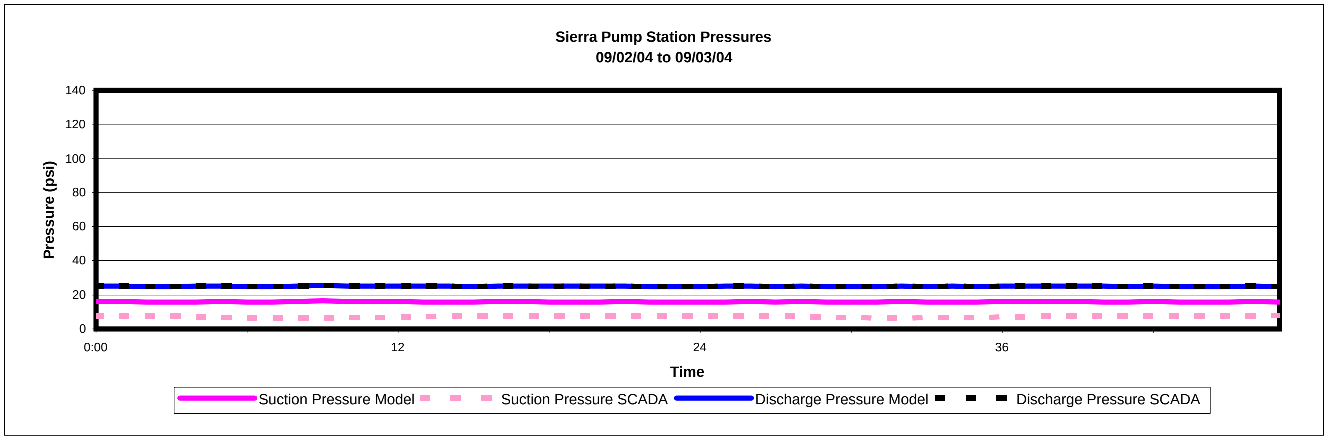
The Sierra Pressure Zone is supplied by the Sierra Pump Station located next to the Bacon Pump Station. The trend of Sierra Pump Station flow rate and pressure follows closely with the recorded SCADA readings (see Figure 6-13).

Comparisons of the simulated pressures and recorded pressures show a very close trend (see Figure 6-14).

Figure 6-13: ARC-North and Sierra Pump Stations Verification







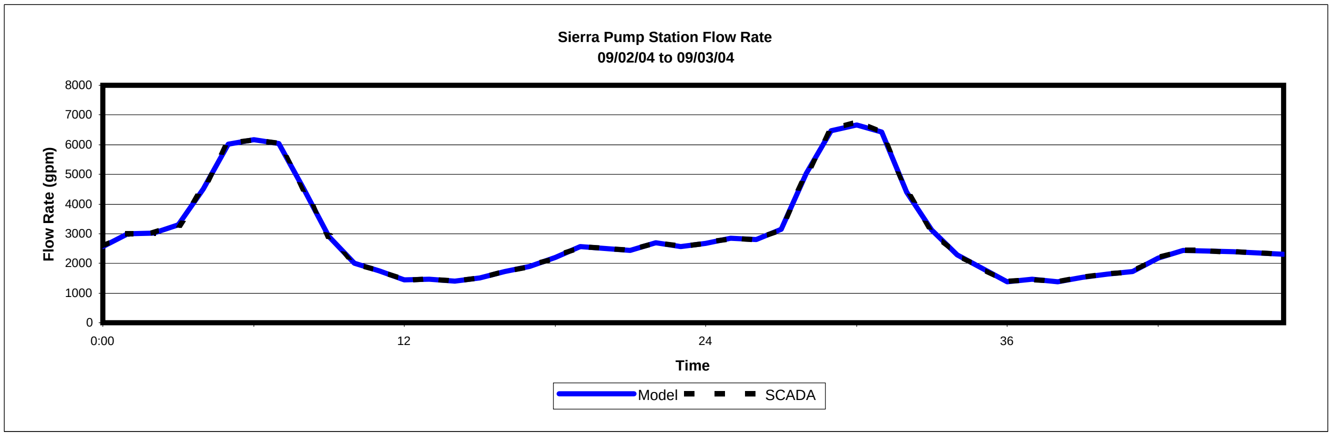
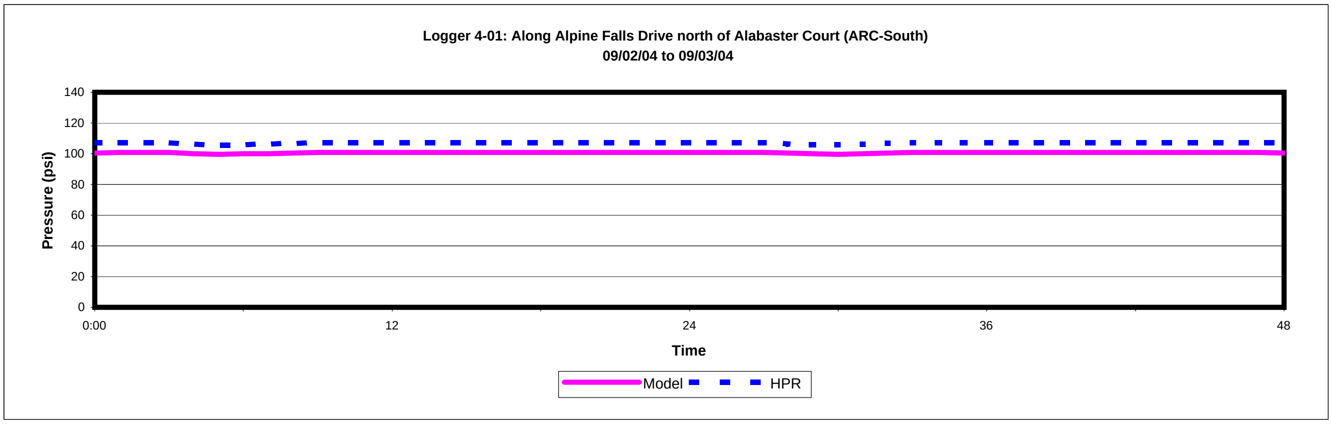
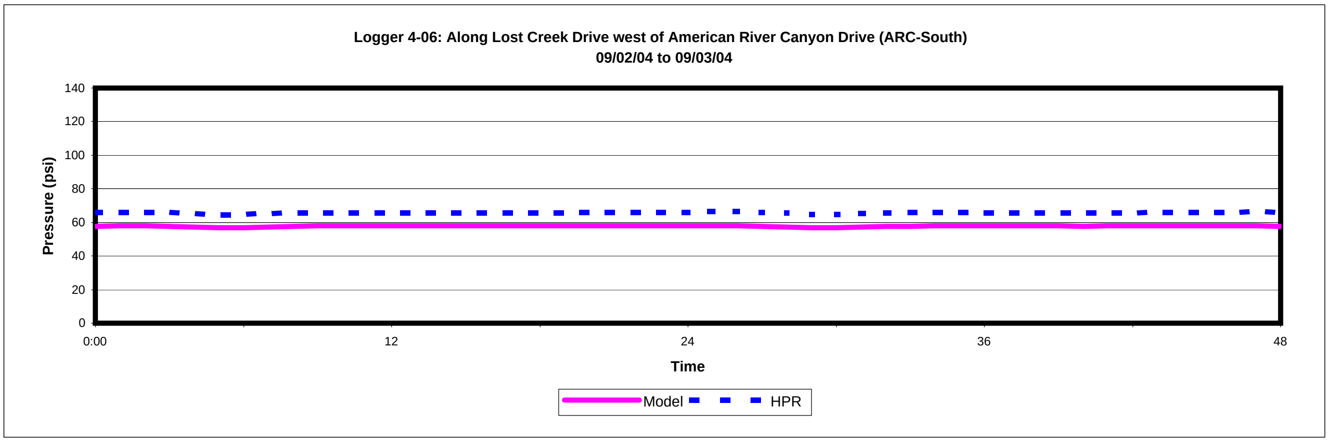
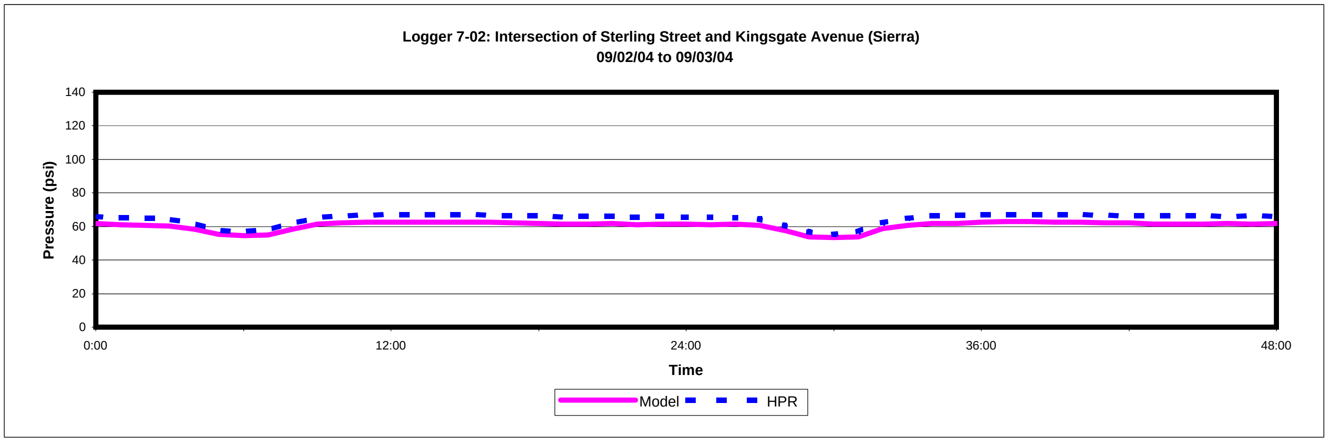
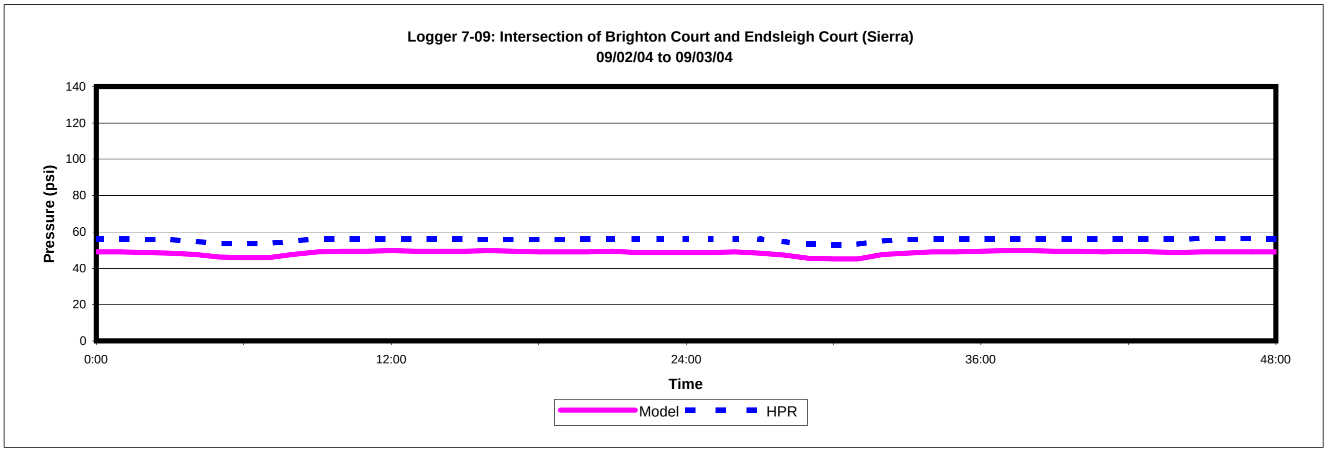


Figure 6-14: Pressure Comparison Between Field Recording and Model Simulation in ARC-North and Sierra Pressure Zones









FINDINGS AND CONCLUSIONS

Overall, the results from the hydraulic model calibration process validated the system pipeline configuration and estimated C-factors. The average pressure differentials between those pressures observed in the field and those predicted by the model were within ±5 psi. However, there are locations within the retail water system where the model results indicate the possibility of closed or partially closed valves and/or a different pipeline configuration in the field than is currently simulated by the model (see Appendix A). We recommend the District perform additional flow tests in these areas to further confirm system configuration.

The results of the verification process validated the modeled system configuration and demand allocation. Pump station flow rate comparisons at each of the District's operated facilities trended accurately for both SCADA and field readings. Comparisons of HPR and model-simulated data trended well. Most of the model result trends follow closely with the recorded HPR pressures, though not exact. It is recommended that the District continue to update/verify the pipeline system configuration in the model as new facilities are constructed.

Based on results of the calibration and verification efforts, it is concluded that the model provides an accurate operational representation of the District's retail water supply and distribution system, and is more than adequate for master planning purposes. This planning tool was used to evaluate the capability of the existing system to meet existing demand conditions (see Chapter 7).