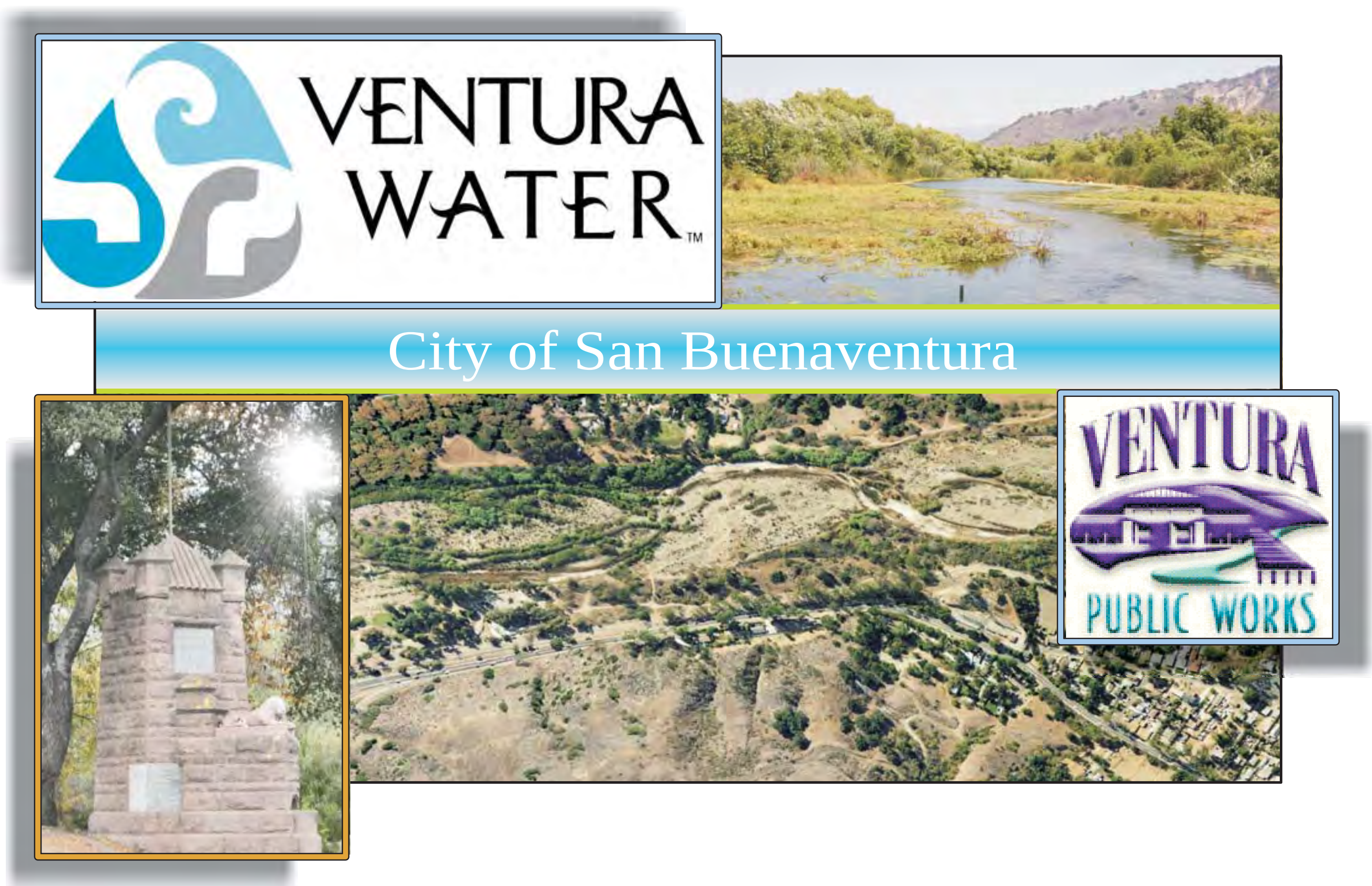
HOPKINS GROUNDWATER CONSULTANTS, INC.

PRELIMINARY HYDROGEOLOGICAL STUDY

CITY OF SAN BUENAVENTURA
SURFACE WATER/GROUNDWATER
INTERACTION STUDY
FOSTER PARK, CALIFORNIA

Prepared for:
City of San Buenaventura

June 2013



HOPKINS
GROUNDWATER
CONSULTANTS, INC.
THE WATER RESOURCE SPECIALISTS

June 24, 2013
Project No. 04-021-09B

City of San Buenaventura
Post Office Box 99
Ventura, California 93002-0099

Attention: Mr. Omar Castro
Water Utility Manager, Ventura Water

Subject: Preliminary Hydrogeological Study, City of San Buenaventura, Surface Water/Groundwater Interaction Study, Foster Park, California, June 2013.

Dear Mr. Castro:

Hopkins Groundwater Consultants, Inc. (Hopkins) is pleased to submit this final report summarizing the findings, conclusions, and recommendations developed from a preliminary study of the interaction between groundwater diversion and surface water flow in the Foster Park reach of the Ventura River (River) between May and September 2012. The study was conducted during dry River conditions when the upstream flow rate at Casitas Springs declined to below 2 cubic feet per second before reaching the Foster Park Reach of the River. The study is believed to provide detailed findings and conclusions of these critical River conditions and the corresponding effects on steelhead habitat.

As always, Hopkins is pleased to be of service. If you have questions or need any additional information, please give us a call.

Sincerely,

HOPKINS GROUNDWATER CONSULTANTS, INC.

REGISTERED GEOLOGIST
CURTIS J. HOPKINS
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Report Copies Submitted: Six (6) Bound Copies

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EXECUTIVE SUMMARY

This study is part of the City of San Buenaventura's (City) continuing efforts to develop data that will guide future operation of its Foster Park diversion facilities in an environmentally sensitive manner. Presented in this report is a summary of the findings, conclusions, and recommendations developed from a preliminary hydrogeological study of the interaction between operation of the City's Foster Park Wellfield and surface flows in the Ventura River (River). Hopkins Groundwater Consultants, Inc. (Hopkins) assisted the City in developing a River flow monitoring program that established four (4) flow monitoring stations located upstream, downstream, and within the Foster Park Wellfield reach of the River. Streamflow surveys were conducted at these stations on an approximate weekly basis during the May through September 2012 study-period when River flows typically decline.

For correlation with the streamflow surveys, the City conducted independent steelhead trout (Oncorhynchus mykiss) habitat assessment surveys to develop a preliminary understanding of the relationship between declining streamflow rates and the quality of steelhead habitat. The habitat assessment surveys were conducted by Padre Associates, Inc. (Padre) of Ventura, California, within the same reach of the River as the streamflow surveys. The steelhead habitat assessment methodology utilized for the study is the rainbow trout Habitat Suitability Index (HSI) model developed by the U.S. Fish and Wildlife Service (Raleigh et al., 1984), as modified by Thomas R. Payne & Associates (2007), (Padre, 2010). This methodology was selected to maintain consistency with previous steelhead trout studies conducted in this reach of the River.

The study program was designed to utilize and augment the existing City monitoring system which collects data from both the wellfield and select groundwater monitoring wells, and the USGS gaging station that is accessible through an internet website. Field measurements collected during the study included; a) River flow rates, b) surface water thalweg depths, c) River width, d) groundwater levels, and e) water quality and temperature data.

Water balance calculations using upstream surface water flow rates, City groundwater diversions, and downstream flow rates indicate that groundwater production at Foster Park during the low-flow season is substantially supported by underflow through the alluvial sediments. Approximately 3 to 4 cubic feet per second can be produced by the City at Foster Park while the flow rate downstream at the Casitas Vista Road Bridge (flowing out of Foster Park) is virtually the same as the upstream flow rate at Casitas Springs where surface water enters the Foster Park reach of the River.

The findings of this study indicate a flow threshold exists whereby when flows decrease below the threshold, the steelhead habitat suitability declines significantly. During the 2012 low-flow conditions when the City diversion was approximately 6.5 cfs and there was 4 cfs or greater upstream (at Casitas Springs) and 2 cfs or greater downstream (at Casitas Vista Road Bridge), the HSI scores for adult steelhead remained fairly constant and the River pools maintained substantial depths. Study data indicate the upstream flow threshold was approximately 4 cfs (at the Casitas Springs live reach), while the downstream flow threshold was approximately 2 cfs (at the USGS gage). After surface flows declined below these rates, the HSI scores for steelhead and the habitat volume estimates declined rapidly.

The HSI data show favorable dissolved oxygen levels in the run and riffle units throughout the duration of the study however, a significant decline in the dissolved oxygen concentration in the pools occurred when the flow into the pools being studied terminated as surface flow in the River declined. Study data indicate adult HSI values decline as the flow rate decreases. When the surface flow at the USGS gage fell below 2 cfs, the adult HSI scores declined substantially. However, we do not have sufficient data to support a correlation between the 2 cfs flow rate and the DO concentrations in pools because we do not have data over a full diurnal cycle. But, the study data collected indicates that when there is greater than 4 cfs flowing at Casitas Springs into the Foster Park River reach, the steelhead habitat generally improves because of reduced water temperatures, higher DO concentrations, and increased thalweg depth.

The steelhead habitat is generally degraded throughout the low-flow season because the declining river flow results in shallower thalweg depths in pools, runs, and riffles which allows the hotter atmospheric temperatures to increase the surface water temperatures. HSI observations also indicated that prior to portions of the River reach drying out, the higher daytime temperatures and the likely low nighttime oxygen levels from algae respiration, created habitat that was unsuitable to sustain steelhead populations.

Inflow from San Antonio Creek is a direct and significant influence on flow in this reach of the River system during the low-flow conditions observed by the study. High streambed infiltration rates resulting from high aquifer hydraulic conductivity values cause a very rapid rate of groundwater recharge. These conditions result in a quick groundwater level response to changes in City production.

The City can effectively divert groundwater and maintain favorable habitat conditions for the steelhead in the Foster Park reach of the River through the use of routine flow rate and habitat suitability monitoring. Optimal management of groundwater resources and steelhead habitat will require additional well facilities that are appropriately placed and operated within the groundwater basin. The merit of constructing additional well facilities to allow for greater production under higher River flow conditions when habitat impacts are anticipated to be insignificant should be considered by the City. The ability to divert at higher rates will permit the cessation of pumping during lower flow rates (to preserve steelhead habitat quality and quantity) and reduce the impact to the City's average annual yield from the River that is so vital to the City's total water supply. During low flow conditions, the City can observe streamflows documented by the USGS gage and consider reducing its diversion rates as the River flow rate declines toward 2 cfs. While the City has no control on how much water will seasonally flow into the Foster Park reach of the River, the reduction and eventual cessation of pumping during the dry season will serve to maintain a minimum River flow rate and the associated steelhead habitat until the main stem of the River dries out.

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INTRODUCTION

Presented in this report is a summary of the findings, conclusions, and recommendations developed from a preliminary hydrogeological study of the interaction between operation of the City of San Buenaventura's (City) Foster Park Wellfield and surface flows in the Ventura River (River). Hopkins Groundwater Consultants, Inc. (Hopkins) assisted the City in developing a River flow monitoring program that established four (4) flow monitoring stations located upstream, downstream, and within the Foster Park Wellfield reach of the River. Streamflow surveys were conducted at these stations during the May through September 2012 study period when River flows typically decline. This study is part of the City's continuing efforts to operate its Foster Park diversion facilities in an environmentally sensitive manner and develop data to understand movement of water through this reach of the River that can be used to guide future diversion operations.

For this study, a total of twenty-four (24) streamflow surveys were conducted between May and September 2012, to observe the relationship between groundwater produced from the City's production facilities and the surface water flow rates in the adjacent reach of the River. Based on the findings of previous study (Hopkins, 2010), correspondence with National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries), and the present geomorphology of the River channel, this study was designed to include four (4) streamflow monitoring stations in the Foster Park reach of the River that were measured concurrent with a biological assessment of the steelhead habitat.

For correlation with the streamflow surveys, the City conducted independent steelhead trout (Oncorhynchus mykiss) habitat assessment surveys to develop a preliminary understanding of the relationship between declining streamflow rates and the quality of steelhead habitat. A total of twenty-four (24) steelhead habitat assessment surveys were conducted concurrently with the streamflow surveys conducted by Hopkins. The habitat assessment surveys were conducted by Padre Associates, Inc. (Padre) of Ventura, California, within the same reach of the River as the streamflow surveys which is indicated on Plate 1 – Study Area Location Map.

Background

Historically, the City has relied upon the River source of water as a primary component of its municipal supply. The water has been diverted using a gravity fed surface water intake structure in combination with shallow groundwater production facilities. Since the mid-1990's, direct surface water diversions have stopped and a subsequent water supply Master Plan (KJC, 1999) was developed to produce all the River supply at Foster Park from groundwater wells to minimize impacts on the aquatic habitat. At present, the River is considered an impacted habitat that is impaired by dams and diversion structures that impede the seasonal migration of fish, and by groundwater extractions in the upper Ventura River Groundwater Basin and Ojai Groundwater Basin (which drains to San Antonio Creek) that reduce river flows.

It is our understanding that water agencies on the River are cooperatively developing a comprehensive Multiple Species Habitat Conservation Plan as a means to address these impacts and restore the River system to a condition that will support native wildlife species and ensure the sustainability of future diversions. The City desires to reduce environmental impacts in the reach of the River where its water diversion structures are located, even though it has no control over upstream extractions that impact River flows into the Foster Park reach. To control the amount of water the City can reliably generate in an environmentally sensitive manner from this source of supply, requires that the City understand the dynamics of surface flows in the Foster Park reach of the River.

Purpose and Scope

The purpose of this study was to continue the City's monitoring program that preliminarily identifies relationships between City groundwater diversions in the Foster Park reach of the River, River flow rates, and the quality of the steelhead habitat. The scope of work was developed through discussions with City staff and included the following components:

- Monitor and utilize data provided by the United States Geological Survey (USGS) gaging station located at the Casitas Vista Road Bridge,
- Measure in-stream flows at four (4) locations that include; a) upstream of Foster Park at Casitas Springs, b) upstream of the City's Nye Well No. 7 production facility, c) downstream of the City's Nye Well No. 8 production facility, and d) downstream at the Casitas Vista Road Bridge location to develop a correlation with the USGS gage,
- Measure groundwater level changes using the City test wells/monitoring wells established by a previous study,
- Conduct an independent assessment of steelhead habitat concurrent with streamflow and groundwater elevation measurements,
- Obtain data from the City SCADA system that automatically records well water levels and City production rates from its facilities in Foster Park,
- Analyze these data and draw preliminary correlations between changes in surface water flow rates, steelhead habitat quality, and City groundwater diversions in the Foster Park reach of the River, and
- Prepare this final report summarizing the findings, conclusions, and recommendations of the preliminary study.

This report provides a number of appendices that document the fieldwork conducted for the study along with technical information obtained during the study. These appendices include; Appendix A – Photographs of Streamflow Surveys and River Conditions, Appendix B –

Streamflow Survey Data, Appendix C – Steelhead Habitat Assessment Report, Appendix D – Dissolved Oxygen Versus Streamflow Data, and Appendix E – Groundwater Level Data.

DATA COLLECTION PROGRAM

Monitoring Period and Methods

The River study was conducted between May 3, and September 19, 2012, during the summer months when River flows typically decline to low-flow conditions. A listing of the measurement dates and the activities which provided the findings of this study is provided in Table 1 – Chronology of 2012 River Study Field Events.

The study program was designed to utilize the existing City monitoring system which collects data from both the wellfield and select monitoring wells, and the USGS gaging station that is accessible through an internet website. These data were used to augment field measurements of; a) River flow rates, b) surface water depths, and c) groundwater levels which were conducted on an approximate weekly basis. River flow rates were collected at four (4) locations designated as Streamflow Monitoring Station (SFMS) Nos. 1 through 4. The locations of the Foster Park Wellfield, streamflow monitoring stations and groundwater monitoring wells are shown on Plate 2 – Streamflow Monitoring Station and Well Location Map.

The method of streamflow measurement for this study utilized a surveyor's tape (tag line) and depth gage to construct a streambed profile at the streamflow measuring stations during each monitoring event. Depth measurements collected at various distances along the tag line were used to calculate the cross-sectional area of the River. A meter that provides electronic flow velocity readings in feet-per-second was used to measure the flow rate in the stream. The tag line was used as a guide for precise location of the streamflow measurements in relation to distance from the stream bank. Flow rates were measured using the "6-tenths method" which is recommended by the USGS for obtaining an average flow rate within the fluid column at each point of measurement (USGS, 1976). The USGS asserts that an average flow rate of a column of water in a stream can be estimated by the flow measurement collected at a depth below the water surface that is equal to 0.6 times the total depth of water.

The flowmeter used during the study is the USGS low velocity flowmeter, commonly referred to as the Price 'pygmy' meter. The pygmy meter consists of a balanced bucket wheel which is mounted on a vertical pivot attached to a vertical rod (wading rod). Measurements are taken, calculated, and logged utilizing a data logger that monitors the revolutions of the bucket wheel. The wading rod has a 1/2-inch hexagonal main rod marked in 0.10-foot increments for measuring depth and a 3/8-inch diameter round rod for setting the position of the current meter. The rod is placed in the stream so the base plate rests on the streambed, and the depth of water is read on the graduated main rod. When the setting rod is adjusted to read the depth of water, the meter is positioned automatically for the 0.6-depth method.

Table 1 – Chronology of 2012 River Study Field Events

DATE	STREAMFLOW STUDY ACTIVITY
MAY 3	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
MAY 10	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
MAY 15	USGS CONDUCTED STREAMFLOW SURVEY FOR RATING CURVE
MAY 17	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
MAY 18	STREAMFLOW SURVEY, QUALITY CONTROL OF LOW FLOW READINGS
MAY 24	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
MAY 31	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JUNE 7	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JUNE 7	USGS CONDUCTED STREAMFLOW SURVEY FOR RATING CURVE
JUNE 14	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JUNE 21	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JUNE 28	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JULY 5	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JULY 12	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JULY 16	USGS CONDUCTED STREAMFLOW SURVEY FOR RATING CURVE
JULY 19	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
JULY 26	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 2	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 8	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 13	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 14	USGS CONDUCTED STREAMFLOW SURVEY FOR RATING CURVE
AUGUST 16	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 20	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 23	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 28	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
AUGUST 31	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
SEPTEMBER 5	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
SEPTEMBER 11	USGS CONDUCTED STREAMFLOW SURVEY FOR RATING CURVE
SEPTEMBER 12	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
SEPTEMBER 19	STREAMFLOW SURVEY, STEELHEAD HABITAT SUITABILITY SURVEY
OCTOBER 12	USGS CONDUCTED STREAMFLOW SURVEY FOR RATING CURVE

The pygmy meter utilizes the wading rod to set the measurement depth and stabilize the bucket wheel in the stream. This provides a stable platform for the pygmy meter resulting in greater consistency with previous and subsequent streamflow measurements at each station. The United States Environmental Protection Agency (USEPA) recommends that measurement intervals across the profile of the river be established so that no single measurement exceeds 10 percent of the total streamflow volume (USEPA, 2003). The operation manual provided with the data logger used to record the pygmy meter measurements suggests establishing measurement intervals that maintain single readings of 5 percent (or less) of the total streamflow. For this study, we attempted to maintain measurement reading intervals at distances that gaged less than 5 percent of total flow volume.

Photographs of River conditions throughout the study period were taken at the streamflow measurement locations to provide visual documentation of the River conditions being measured (see Appendix A). At the time of each surface water monitoring event, the water levels in the City monitoring wells, which were not instrumented with automatic reading equipment, were collected using an electric sounder.

FINDINGS

River Flow Measurements

The City conducted an initial study of surface water/groundwater interaction at the Foster Park Wellfield in 2009 (Hopkins, 2009b). Subsequent study was performed in greater detail in 2010 and included a biological component to the field surveys (Hopkins, 2010). The findings of that study were used to assist in selecting the stream monitoring locations and the field measurement schedule for this study. A summary of the streamflow survey dates, times, and flow measurements for this study are provided in Table 2 – Summary of 2012 Streamflow Survey Results.

The magnitude of daily fluctuation in River flows recorded by the USGS gage is approximately 2 to 3 cubic feet-per-second (cfs). This observation indicated that monitoring of the dynamic River system could be problematic for reliable correlation of data if measurements are not consistently collected over a relatively short period of time. The USGS gage data indicate that the river flows typically peaked between 4:30 and 10:00 a.m., and declined to reach daily low-flows between 3:00 and 7:30 p.m. Based on these observations, Hopkins scheduled to begin River flow measurements at 7:00 to 7:30 a.m. and attempted to complete the measurements as quickly as practicable during the day. Hopkins was able to maintain a fairly consistent time frame of streamflow data collection throughout the study and generally completed the final streamflow survey at SFMS No. 4 before 1:30 p.m or earlier (see Table 2). Observations during the first portion of the monitoring program indicated that in-stream monitoring for the habitat suitability index survey dislodged algal material from the riverbed which was problematic for operation of the pygmy meter. This condition required that flow measurements be coordinated and maintain at a position upstream of the biological survey.

Table 2 – Summary of 2012 Streamflow Survey Results

DATE	SFMS[1] NO. 1[2]		SFMS[1] NO. 2		SFMS[1] NO. 3		SFMS[1] NO. 4[3]	
	TIME	FLOW RATE (CFS)	TIME	FLOW RATE (CFS)	TIME	FLOW RATE (CFS)	TIME	FLOW RATE (CFS)
5/3/2012	11:38-12:09	9.11	13:06-13:42	5.05	14:41-15:09	5.72	16:10-16:41	8.45
5/10/2012	07:38-08:53	5.21	09:45-10:15	3.86	11:21-11:48	4.6	13:04-13:55	9.24
5/17/2012	08:24-09:45	2.41	10:37-11:35	3.30	12:16-12:45	3.52	13:55-15:02	7.03
5/18/2012[4]	11:25-12:56	5.35	NA	NA	NA	NA	13:13-14:15	7.35
5/24/2012	07:43-08:53	4.70	09:59-10:17	2.61	11:01-11:18	3.33	12:16-12:57	7.90
5/31/2012	07:28-08:28	4.29	09:18-09:30	2.74	10:08-10:28	3.71	11:10-11:47	8.05
6/7/2012	07:20-08:15	4.20	09:06-09:23	3.26	10:12-10:33	3.29	11:38-12:22	8.24
6/14/2012	08:38-11:20	4.23	12:10-12:21	2.64	12:49-13:07	3.62	13:51-14:27	8.70
6/21/2012	07:24-07:49	4.37	08:40-09:02	1.91	09:45-10:17	3.19	11:32-12:20	7.69
6/28/2012	08:15-08:43	4.27	09:37-09:50	2.11	10:25-10:50	2.74	11:46-12:27	7.82
7/5/2012	07:45-08:07	3.56	08:59-09:15	2.51	10:05-10:29	2.42	11:28-12:16	7.75
7/12/2012	08:25-08:55	3.37	10:17-10:30	2.22	11:16-11:41	2.11	12:29-13:16	6.91
7/19/2012	07:46-08:18	3.32	09:14-09:30	1.63	10:19-10:42	2.1	11:59-12:48	6.00
7/26/2012	07:48-08:14	2.73	09:10-09:23	0.97	10:02-10:24	1.4	11:16-12:02	5.79
8/2/2012	06:52-07:20	5.68	08:32-08:57	2.46	10:13-10:33	1.72	11:32-12:29	4.83
8/8/2012	07:08-07:34	5.28	08:06-08:35	2.26	09:01-09:27	1.26	10:01-10:45	4.61
8/13/2012	07:27-07:54	3.31	08:31-08:47	1.74	09:44-09:55	0.97	10:37-11:36	4.42
8/16/2012	07:51-08:19	2.18	09:13-09:20	0.175	10:21-10:34	0.575	12:34-12:18	3.63
8/20/2012	07:43-08:08	1.72	09:00	0	09:22-09:32	0.11	10:17-11:05	3.5
8/23/2012	07:57-08:19	2.85	09:12-09:16	0.06	10:29-10:54	0.41	11:43-12:30	3.32
8/28/2012	07:12-07:37	1.6	07:30	0	08:00	0	09:06-10:04	3.05
8/31/2012	08:31-08:53	1.6	07:30	0	08:00	0	09:36-10:25	2.82
9/5/2012	08:10-08:33	1.05	07:30	0	08:00	0	09:59-11:02	2.43
9/12/2012	07:08-07:28	0.81	07:30	0	08:00	0	08:03-08:43	2.07
9/19/2012	07:08-07:34	0.56	08:30	0	09:00	0	08:21-09:04	1.76

[1] – STREAMFLOW MONITORING STATION
[2] – SFMS NO. 1A HAS BEEN TOTALED WITH SFMS NO. 1 WHERE APPLICABLE
[3] – SFMS NO. 4A HAS BEEN TOTALED WITH SFMS NO. 4 WHERE APPLICABLE
[4] – CONFIRMATORY STREAMFLOW MEASUREMENTS

Well Production

The City operates five (5) groundwater production facilities at the Foster Park location. The facility names and approximate average production rates over the study period are provided in Table 3 – Weekly Summary of Foster Park Groundwater Production. Nye Well No. 2 is currently not in operation because of damages it sustained in 2005 storm events. The Ventura County Watershed Protection District drilled two additional wells, Well Nos. 12 and 13 (see Plate 2), in Foster Park as part of the Matilija Dam Ecosystem Restoration Project undertaken by the United States Environmental Protection Agency. Though these wells have been drilled, they are not connected to the wellfield infrastructure and have not been permitted by the California Department of Public Health as a raw water source for the City's Avenue Water Treatment Plant.

Groundwater production was conducted during the study period in a manner that is typical of the summer season. Production was fairly constant with the exception of periodic shutdowns caused by technical difficulties. Production data for the four (4) active Foster Park facilities is automatically monitored by the City at its Ventura Avenue Water Treatment Plant. These data were subsequently logged and tabulated at 30-minute intervals for this study. The average daily production rates throughout the study period are graphically shown on Figure 1 – Daily Average Groundwater Production During 2012 Study Period. The average daily production rates for the active Foster Park facilities on the days where streamflow surveys were conducted are listed in Table 3.

Figure 1 – Daily Average Groundwater Production During 2012 Study Period

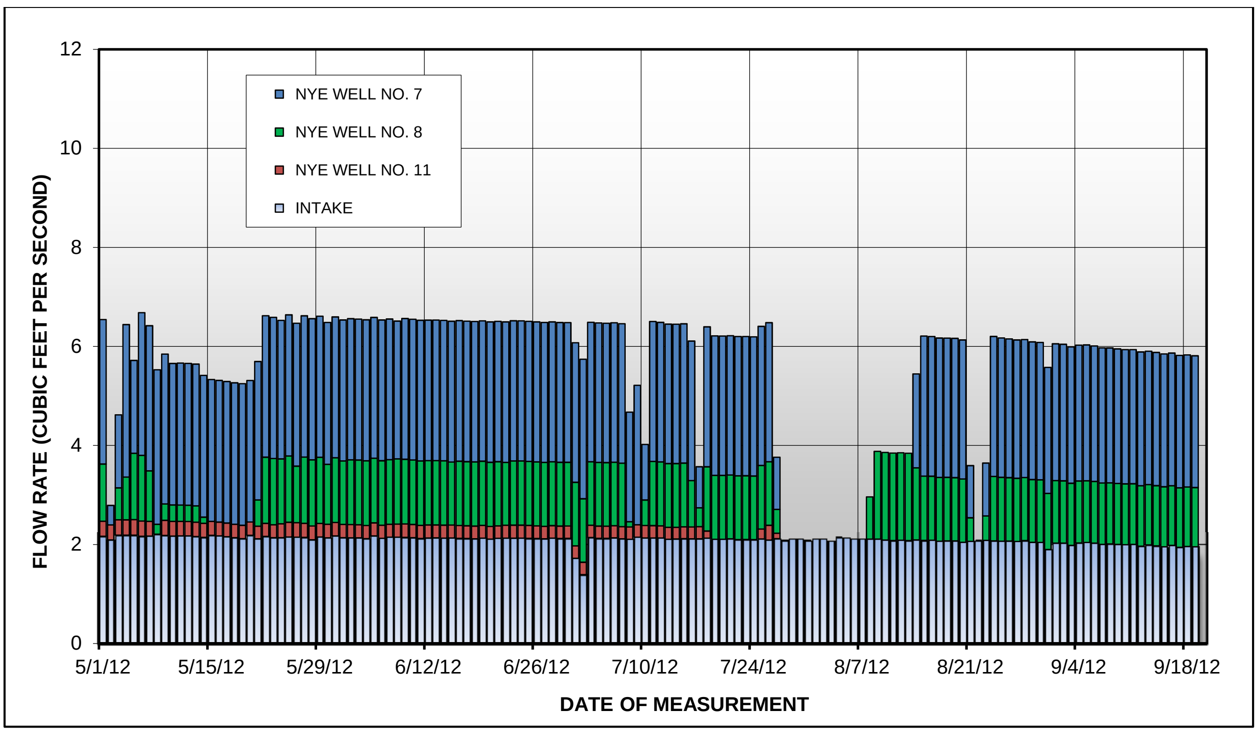


Table 3 – Weekly Summary of Foster Park Groundwater Production

DATE	NYE WELL NO. 7		NYE WELL NO. 8		NYE WELL NO. 11		SUBSURFACE COLLECTOR	
	PUMPING RATE (GPM)	PUMPING RATE (CFS)	PUMPING RATE (GPM)	PUMPING RATE (CFS)	PUMPING RATE (GPM)	PUMPING RATE (CFS)	PUMPING RATE (GPM)	PUMPING RATE (CFS)
5/3/2012	662	1.47	289	0.64	138	0.31	981	2.19
5/10/2012	1,283	2.86	148	0.33	134	0.30	973	2.17
5/17/2012	1,283	2.86	0	0	124	0.28	968	2.16
5/18/2012	1,282	2.86	0	0	122	0.27	959	2.14
5/24/2012	1,255	2.80	588	1.31	126	0.28	960	2.14
5/31/2012	1,277	2.84	587	1.31	122	0.27	975	2.17
6/7/2012	1,274	2.84	586	1.30	118	0.26	964	2.15
6/14/2012	1,273	2.84	583	1.30	118	0.26	955	2.13
6/21/2012	1,272	2.83	581	1.30	113	0.25	954	2.13
6/28/2012	1,267	2.82	579	1.29	114	0.25	955	2.13
7/5/2012	1,263	2.81	576	1.28	111	0.25	953	2.12
7/12/2012	1,264	2.82	580	1.29	110	0.25	957	2.13
7/19/2012	1,264	2.82	580	1.29	0	0	946	2.11
7/26/2012	1,260	2.81	576	1.28	134	0.30	938	2.09
8/2/2012	0	0	0	0	0	0	949	2.12
8/8/2012	0	0	382	0.85	0	0	947	2.11
8/13/2012	0	0	792	1.76	0	0	934	2.08
8/16/2012	1,266	2.82	581	1.29	0	0	936	2.09
8/20/2012	1,260	2.81	574	1.28	0	0	918	2.04
8/23/2012	479	1.07	222	0.49	0	0	935	2.08
8/28/2012	1,251	2.79	571	1.27	0	0	933	2.08
8/31/2012	1,142	2.55	508	1.13	0	0	852	1.90
9/5/2012	1,231	2.74	560	1.25	0	0	916	2.04
9/12/2012	1,212	2.70	548	1.22	0	0	882	1.97
9/19/2012	1,194	2.66	537	1.20	0	0	877	1.95

Observations of River Conditions

During the course of the study, Hopkins observed several changes in the River environment. These changes included; vegetative growth, surface water flow patterns, stream height and width, and streambed alterations by human activity (rock dams to create pools). Photographs of the River conditions at the observation stations are provided in Appendix A.

Groundwater Levels

Groundwater levels were measured in ten (10) monitoring wells throughout the study period. A summary of the monitoring wells included in the study and the water level measurements are provided in Table 4 – Summary of Depth to Groundwater Data. The location of the City monitoring wells is shown along with a graphical display of the water level data on Plate 3 – Depth to Groundwater Hydrographs.

Table 4 – Summary of Depth to Groundwater Data

DATE OF MEASUREMENT	DEPTH TO GROUNDWATER (FEET BELOW TOP OF CASING)									
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-7	MW-8	MW-9	MW-10	OW-2
5/3/2012	15.06	15.75	12.53	14.36	6.96	15.45	11.44	10.88	10.95	11.12
5/10/2012	15.19	15.88	12.61	14.51	7.21	16.44	12.68	11.63	11.61	12.78
5/17/2012	15.2	15.91	12.66	14.54	7.26	16.56	12.84	11.67	11.63	12.86
5/24/2012	15.2	15.92	12.63	14.54	7.27	16.58	12.82	11.67	11.61	12.86
5/31/2012	15.17	15.92	12.6	14.53	7.26	16.56	12.75	11.62	11.55	12.83
6/7/2012	15.2	15.91	12.58	14.53	7.27	16.57	12.73	11.6	11.51	12.81
6/14/2012	15.2	15.92	12.6	14.53	7.27	16.58	12.74	11.61	11.56	12.82
6/21/2012	15.21	15.92	12.6	14.54	7.29	16.62	12.89	11.66	11.62	12.88
6/28/2012	15.23	15.96	12.73	14.58	7.33	16.67	12.97	11.75	11.75	12.96
7/5/2012	15.23	15.97	12.68	14.56	7.35	16.75	13.18	11.79	11.75	13.03
7/12/2012	15.25	15.91	12.68	14.58	7.32	16.71	13.18	11.77	11.76	12.98
7/19/2012	15.27	16.02	12.67	14.58	7.09	16.72	13.21	11.8	11.82	13
7/26/2012	15.31	16.09	12.72	14.59	7.48	16.9	13.43	11.99	12.02	13.22
8/2/2012	15.21	15.9	12.55	14.36	6.71	15.53	11.78	10.62	11.24	10.74
8/8/2012	15.22	15.95	12.57	14.38	6.75	15.65	12.08	10.72	11.35	10.84
8/13/2012	15.29	16.07	12.62	14.47	7.05	16.75	12.61	10.94	11.6	10.94
8/16/2012	15.36	16.15	12.77	14.55	7.21	16.94	13.58	12.16	12.35	13.31
8/20/2012	15.41	16.26	12.8	14.63	7.45	17.35	14.16	12.58	12.75	13.81
8/23/2012	15.37	16.12	12.7	14.49	7	15.97	11.95	11.24	12.1	11.27
8/28/2012	15.4	16.29	12.82	14.67	7.57	17.53	14.49	13.03	13.3	14.23

Table 4 – Summary of Depth to Groundwater Data (continued)

DATE OF MEASUREMENT	DEPTH TO GROUNDWATER (FEET BELOW TOP OF CASING)									
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-7	MW-8	MW-9	MW-10	OW-2
8/31/2012	15.45	16.32	12.82	14.72	7.69	17.63	14.64	13.26	13.52	14.35
9/5/2012	15.52	16.42	12.88	14.85	7.99	18.17	15.33	14.05	14.36	15.24
9/12/2012	15.6	16.53	12.93	15.03	8.43	18.77	16.05	14.9	15.28	16.09
9/19/2012	15.72	16.79	13.01	15.22	8.94	19.42	16.79	15.68	16.09	16.89

MW – MONITORING WELL
OW – OBSERVATION WELL

Utilizing the reference elevations established at the time of construction (Fugro, 2002), the measured groundwater levels were converted to groundwater elevations. A summary of groundwater elevations during the study is provided in Table 5 – Summary of Groundwater Elevation Data. These data were used to construct groundwater contour maps representing groundwater elevations at the beginning of the study and at the end of the study. These contour maps are provided as Plate 4 – Groundwater Elevation Contour Map May 3, 2012, and Plate 5 – Groundwater Elevation Contour Map September 19, 2012.

Table 5 – Summary of Groundwater Elevation Data

DATE OF MEASUREMENT	GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)									
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-7	MW-8	MW-9	MW-10	OW-2[1]
5/3/2012	210.95	215.08	224.29	226.48	232.31	234.7	239.95	243.84	246.6	237.88
5/10/2012	210.82	214.95	224.21	226.33	232.06	233.71	238.71	243.09	245.94	236.22
5/17/2012	210.81	214.92	224.16	226.3	232.01	233.59	238.55	243.05	245.92	236.14
5/24/2012	210.81	214.91	224.19	226.3	232.00	233.57	238.57	243.05	245.94	236.14
5/31/2012	210.84	214.91	224.22	226.31	232.01	233.59	238.64	243.10	246.00	236.17
6/7/2012	210.81	214.92	224.24	226.31	232.00	233.58	238.66	243.12	246.04	236.19
6/14/2012	210.81	214.91	224.22	226.31	232.00	233.57	238.65	243.11	245.99	236.18
6/21/2012	210.8	214.91	224.22	226.3	231.98	233.53	238.5	243.06	245.93	236.12
6/28/2012	210.78	214.87	224.09	226.26	231.94	233.48	238.42	242.97	245.8	236.04
7/5/2012	210.78	214.86	224.14	226.28	231.92	233.4	238.21	242.93	245.8	235.97
7/12/2012	210.76	214.92	224.14	226.26	231.95	233.44	238.21	242.95	245.79	236.02
7/19/2012	210.74	214.81	224.15	226.26	232.18	233.43	238.18	242.92	245.73	236.00
7/26/2012	210.7	214.74	224.1	226.25	231.79	233.25	237.96	242.73	245.53	235.78
8/2/2012	210.8	214.93	224.27	226.48	232.56	234.62	239.61	244.10	246.31	238.26

Table 5 – Summary of Groundwater Elevation Data (continued)

DATE OF MEASUREMENT	GROUNDWATER ELEVATION (FEET ABOVE MEAN SEA LEVEL)									
	MW-1	MW-2	MW-3	MW-4	MW-5	MW-7	MW-8	MW-9	MW-10	OW-2[1]
8/8/2012	210.79	214.88	224.25	226.46	232.52	234.5	239.31	244.00	246.2	238.16
8/13/2012	210.72	214.76	224.2	226.37	232.22	233.4	238.78	243.78	245.95	238.06
8/16/2012	210.65	214.68	224.05	226.29	232.06	233.21	237.81	242.56	245.2	235.69
8/20/2012	210.60	214.57	224.02	226.21	231.82	232.80	237.23	242.14	244.8	235.19
8/23/2012	210.64	214.71	224.12	226.35	232.27	234.18	239.44	243.48	245.45	237.73
8/28/2012	210.61	214.54	224.00	226.17	231.7	232.62	236.9	241.69	244.25	234.77
8/31/2012	210.56	214.51	224.00	226.12	231.58	232.52	236.75	241.46	244.03	234.65
9/5/2012	210.49	214.41	223.94	225.99	231.28	231.98	236.06	240.67	243.19	233.76
9/12/2012	210.41	214.3	223.89	225.81	230.84	231.38	235.34	239.82	242.27	232.91
9/19/2012	210.29	214.04	223.81	225.62	230.33	230.73	234.6	239.04	241.46	232.11

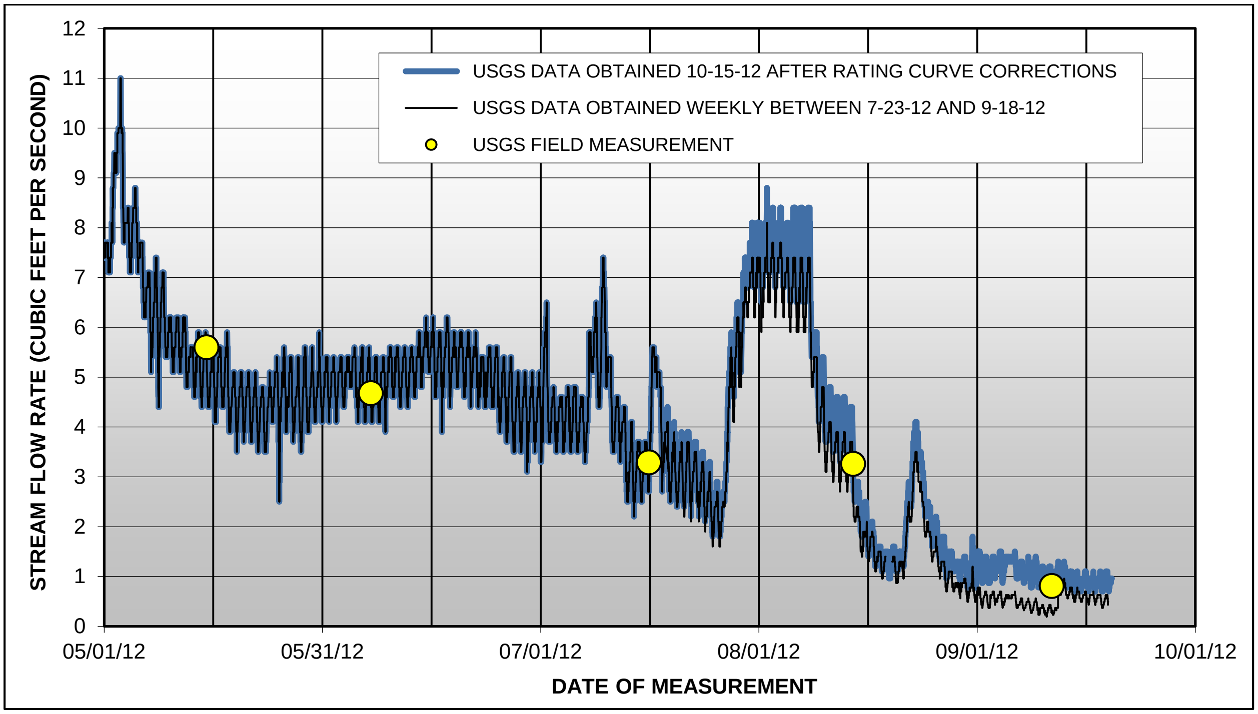
[1] – ESTIMATED REFERENCE POINT 249 FEET ABOVE MEAN SEA LEVEL
MW – MONITORING WELL
OW – OBSERVATION WELL

USGS Streamflow Gaging Station

The USGS operates a streamflow gaging station designated as Stream Gage No. 11118500 to measure stream height and rate of flow in the River at the SFMS No. 1 location. The USGS stream gage utilizes measurements of the stream height at Casitas Vista Road Bridge (SFMS No. 1) and transmits the data via wireless telemetry. The rate of flow in the River is subsequently estimated using the stream gage height data. The USGS provides public access to data collected from the stream gage. These data can be viewed and downloaded from the USGS website. As stated on the website, the real-time data are considered provisional and subject to change. The daily average data are also subject to change until it is reviewed for quality control and accepted.

Hopkins monitored the USGS streamflow data throughout the study for comparison purposes. Downloaded data for streamflows recorded by the USGS during the study period are provided in graphical format in Figure 2 – USGS Stream Gage No. 11118500 Streamflow Hydrograph. The data set used in Figure 2 is a combination of USGS real-time data flow estimates downloaded during the later portion of the study (July 23, 2012 to September 18, 2012) and flow estimates available from the USGS after data correction which were downloaded on October 15, 2012. As shown, the streamflow rates recorded by the gage were adjusted to reflect an increase in flow based on the field survey measurements conducted in August and September.

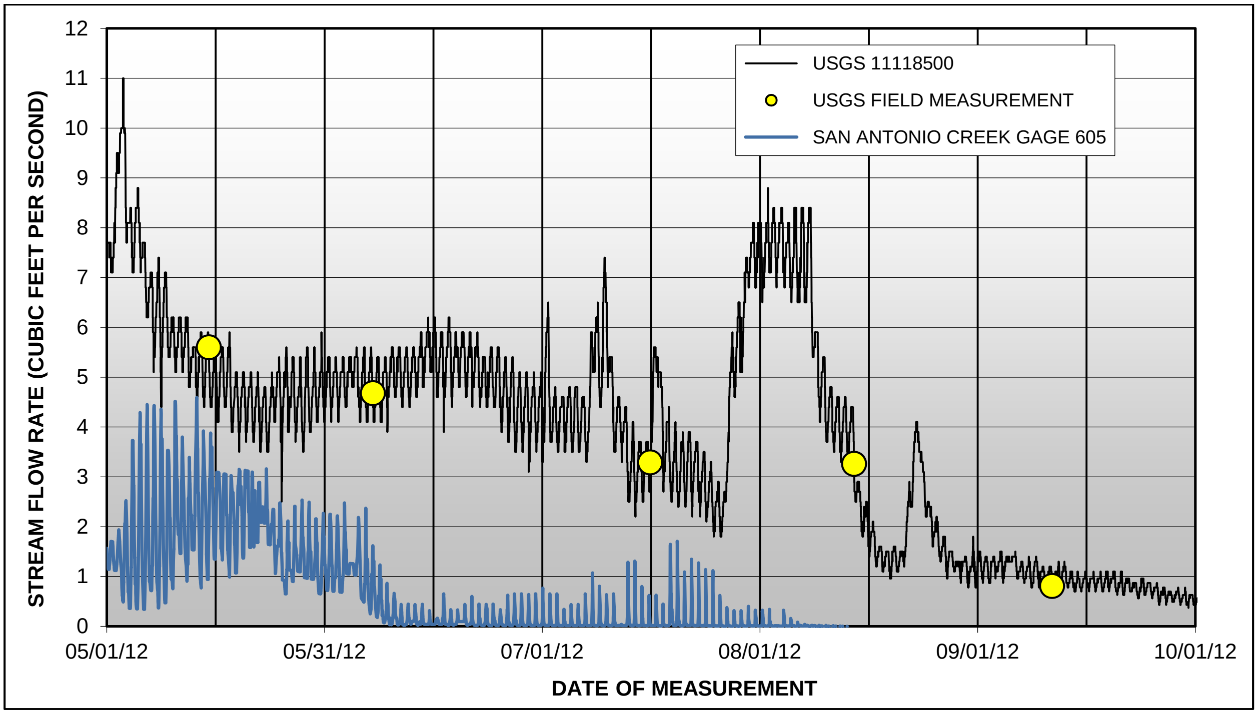
Figure 2 - USGS Stream Gage No. 11118500 Streamflow Hydrograph



As shown, the USGS gage data indicates that during the first 3 months of the study, the diurnal River flow variation was approximately 1.5 cfs. The cyclical changes in flow rate occur while City diversion facilities are producing at a constant rate and are attributed to effects of upstream diversions (well production) and riparian consumption (evapotranspiration) that increase during the daytime. These data also show that the diurnal cycle of streamflow rates was reduced to approximately 1 cfs or less when total flow at the gage was below 3 cfs (see Figure 2).

Additional streamflow data were provided by the Ventura County Watershed Protection District (VCWPD) which monitors and maintains the San Antonio Creek Gage 605 located at the confluence of San Antonio Creek and the River. A comparison of these creek flow data with the River flow data is provided in Figure 3 – VCWPD Stream Gage No. 605 Streamflow Hydrograph. It is our understanding that the San Antonio Creek gage was previously established and operated by the USGS as Gage No. 11117500. The San Antonio Creek gage data presented in the Figure 3 hydrograph are considered preliminary and subject to change after County review.

Figure 3 – VCWPD Stream Gage No. 605 Streamflow Hydrograph



CORRELATION OF FINDINGS

City Diversions and Streamflow Surveys

A summary of daily average wellfield diversion and the change in upstream/downstream flow measurements is provided in Table 6 – Summary of Wellfield Diversions and Change in Streamflow Rate. Throughout the course of the study, the City conducted wellfield operations at production rates dictated by system demands and constraints which were independent of study measurement events except during the controlled wellfield shutdown event at the end of July. Over the entire approximate 4 ½ -month-study period, upstream flow rates at SFMS No. 4 continued on a slow and relatively steady seasonal decline from a peak of 9.24 cfs on May 10, 2012, to a low of 1.76 cfs on September 19, 2012 (see Table 6). During the approximate 2-month-study period between May 24, and July 19, 2012, City facilities were extracting at an average rate of approximately 6.5 cfs (2,900 gpm). Over this period of time, the upstream flow measured at SFMS No. 4 gradually declined from a rate of about 8 cfs to just 6 cfs. Subsequent upstream flow rate declines accelerated, and during the remaining 2 months of the study, the rate of surface water flowing into the Foster Park reach of the River dropped from a rate of approximately 6 cfs to less than 2 cfs (see Table 6). The decline appears be coincident with the cessation in San Antonio Creek flows (see Figure 3).

Table 6 – Summary of Wellfield Diversions and Change in Streamflow Rate

STREAMFLOW SURVEYS [1]			CITY DIVERSION [2] (CFS)	DIFFERENCE BETWEEN UPSTREAM AND DOWNSTREAM FLOW RATES (CFS)
DATE	SFMS NO. 4 (CFS)	SFMS NO. 1 (CFS)		
5/3/2012	8.45	9.11	4.59	0.66
5/10/2012	9.24	5.21	5.66	-4.03
5/17/2012	7.03	2.41 [3]	5.35	-4.62
5/18/2012	7.35	5.35	5.27	-2.00
5/24/2012	7.90	4.70	6.53	-3.20
5/31/2012	8.05	4.25	6.59	-3.80
6/7/2012	8.24	4.20	6.55	-4.04
6/14/2012	8.70	4.23	6.53	-4.47
6/21/2012	7.69	4.37	6.51	-3.32
6/28/2012	7.82	4.27	6.50	-3.55
7/5/2012	7.75	3.56	6.47	-4.19
7/12/2012	6.91	3.67	6.41	-3.24
7/19/2012	6.00	3.32	6.22	-2.68
7/26/2012	5.79	2.73	6.48	-3.06
8/2/2012	4.83	5.68	2.12	0.85
8/8/2012	4.61	5.28	2.94	0.67
8/13/2012	4.42	3.31	3.84	-1.11
8/16/2012	3.63	2.18	6.20	-1.45
8/20/2012	3.50	1.72	6.13	-1.78
8/23/2012	3.32	2.85	3.61	-0.47
8/28/2012	3.05	1.60	6.14	-1.45
8/31/2012	2.82	1.60	5.59	-1.22
9/5/2012	2.43	1.05	6.03	-1.38
9/12/2012	2.07	0.81	5.89	-1.26
9/19/2012	1.76	0.56	5.81	-1.20
AVERAGE RATE (CFS)			**5.60**	**-2.21**

1 – HOPKINS STUDY MEASUREMENT UTILIZING PYGMY FLOW METER
2 – AVERAGE OVER 24 HOUR PERIOD ON DAY OF STUDY MEASUREMENT
3 – ERRONEOUS MEASUREMENT

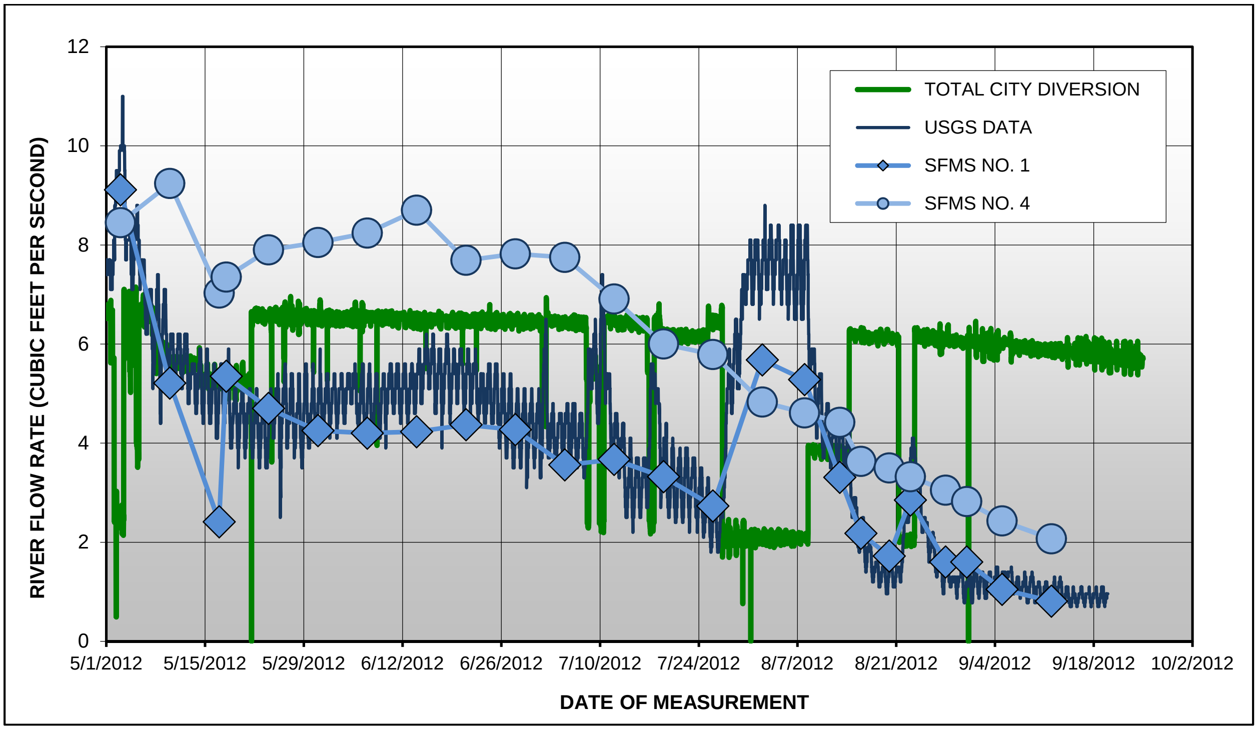
Observations made during the previous surface water/groundwater interaction study (Hopkins, 2009b) indicated that while the City operated the Foster Park Wellfield, the downstream measurements were on average approximately 0.8 cfs lower than the flows measured at the Casitas Springs Monitoring Station (SFMS No. 4) upstream. The subsequent study (Hopkins, 2010) indicated that the streamflow rates measured downstream at SFMS No. 1 averaged approximately 1.0 cfs lower than the flows measured upstream at SFMS No. 4. As shown in Table 6, the average downstream flow reduction measured over the 2012 study period was 2.2 cfs (a little more than double the average 2010 value). However, the upstream and downstream flow differential varied throughout the study period and the average value is biased by the approximate 2-week wellfield shutdown period (July 27, to August 9, 2012).

Plate 6 – Foster Park Diversion and River Flow Comparison Graph shows the results of all streamflow study measurements along with the daily average wellfield production rates. As indicated, streamflow rates remained fairly constant between mid-May and early-July, at approximately 8 cfs upstream at SFMS No. 4 and just above 4 cfs at SFMS No. 1. The flow differential of approximately 4 cfs was fairly consistent (see Plate 6). During this period of time, City diversions were fairly constant at approximately 6.5 cfs. Toward the end of July as upstream flow rates declined to approximately 6 cfs, the differential between the upstream and downstream flow declined to about 3 cfs. The data appear to show that as the upstream flow further declined to below 4 cfs and 3 cfs, the differential in flow declined to 2 cfs, and less than 1.5 cfs, respectively.

Streamflow rates measured at SFMS Nos. 1 and 2 showed a notable increase in flow rate when the production from the City wells stopped. After about a 1-week period, the flow rates peaked and began to decline at rates comparable to that of SFMS No. 4. Subsequent measurements at these 2 stations showed a decrease in flow in direct response to the resumed City diversions. The surface flow decrease continued for about 2 weeks until the water level in the aquifer stabilized and surface flows resumed the declining trend that was observed prior to well shutdown. During this test period, SFMS No. 3 showed a more modest increase and decrease in flow rate (compared to SFMS Nos. 1 and 2) while SFMS No. 4 proceeded to decline over the entire shutdown period (see Plate 6).

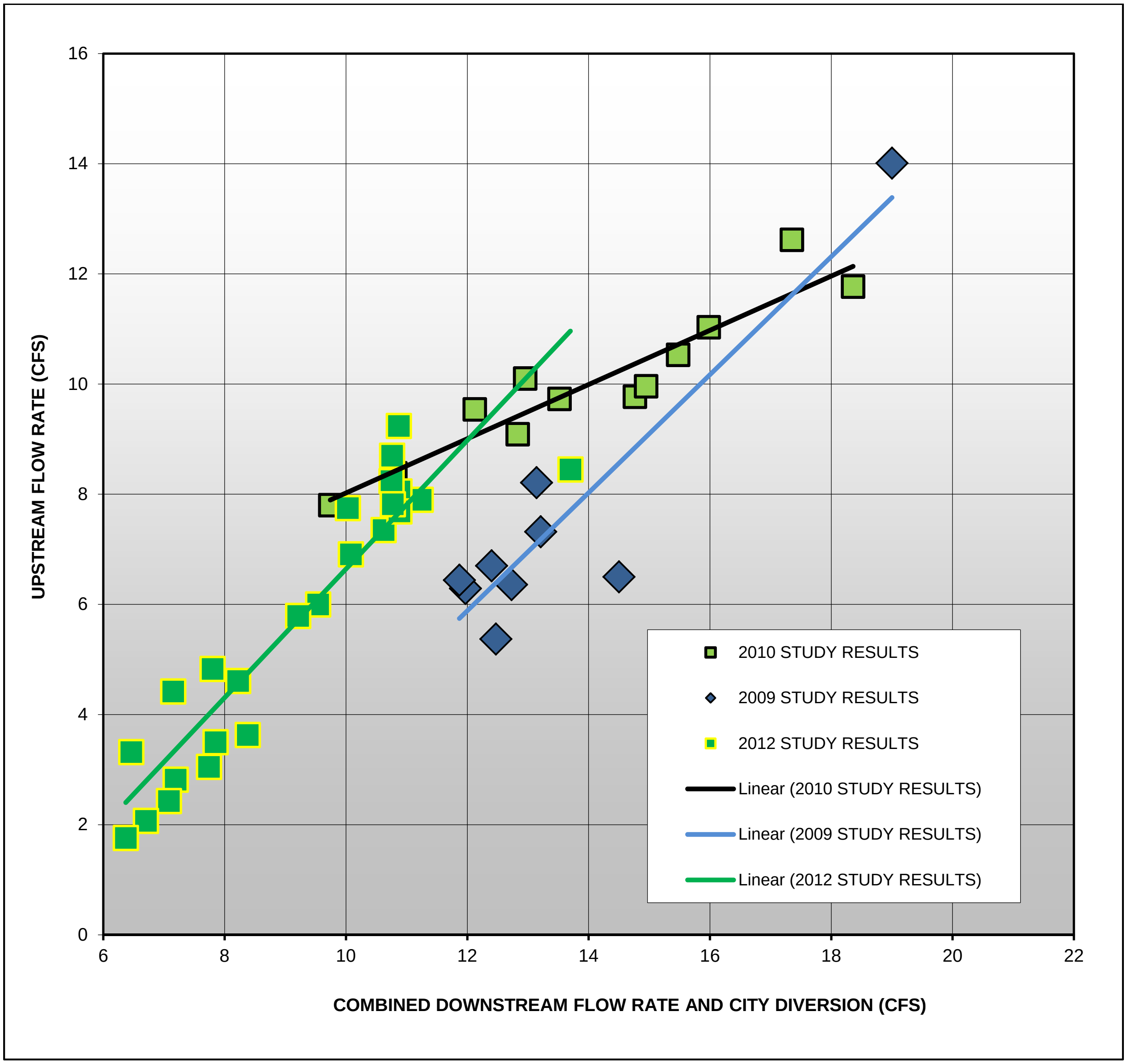
A comparison of the USGS gaging station measurements, the total Foster Park diversions, and the upstream and downstream flow measurements at SFMS Nos. 1 and 4 is provided in Figure 4 – Foster Park Diversion and USGS Gaging Station Comparison Graph. This extended data set provides an additional comparison of surface water/groundwater interaction as recorded at the USGS gaging station.

Figure 4 – Foster Park Diversion and USGS Gaging Station Comparison Graph



A visual comparison of the 2012 data with the upstream and downstream flows from the 2009 and 2010 study results is provided in Figure 5 – Comparison of River Survey Data. As shown, the 2012 survey results appear to correlate with 2010 survey results for flows under 10 cfs but do not have the same linear trend for flows above 10 cfs. While the cause of this observed difference is unknown, we speculate it may be attributable to the change in River morphology which establishes the grade, location, and elevation of the active river channel. Additionally, the exchange between groundwater and surface water flows in the shallowest coarse alluvial sediments that create a hyporheic zone may result in a non-linear function between high and low-flow conditions in this reach of the River.

Figure 5 – Comparison of River Survey Data



Diversion Effects on Groundwater Levels

Groundwater level measurements displayed on Plate 3 indicate that City production from the Foster Park facilities primarily affected water levels in the alluvial aquifer west of the River and upstream of the subsurface dam. The groundwater levels in this area of the basin declined approximately 4 to 6 feet over the study period. East of the active river channel, Nye Well No. 2 and Monitoring Well (MW) No. 5 showed 3.5 and 2 feet of drawdown, respectively. The operation of the City's well facilities had little affect on groundwater levels in the vicinity of MW Nos. 1, 2, 3, and 4 where a seasonal decline of up to 1 foot was observed (see Plate 3).

The water levels measured in MW No. 10 located approximately 1,000 feet upstream of Nye Well No. 7, show more overall drawdown and are less responsive to the cessation of City well pumping than MW No. 9 located approximately 500 feet downstream and closer to the center of pumping. This may indicate that MW No. 10 is affected by basin boundary (no-flow) conditions. The resolution of the water level data provided from Nye Well No. 2 indicate there are water level changes on the east side of the active channel that are concurrent with the operation of both Nye Well Nos. 7 and 8. Though the magnitude of drawdown is noticeably reduced in comparison to the west-side monitoring wells (see Plate 3), data from Nye Well No. 2 indicate the effects of the recharge boundary, provided by the active river channel.

Steelhead Habitat Assessment

The steelhead habitat assessment report documenting the habitat surveys that were conducted concurrently with this surface water/groundwater study is provided in Appendix C. The steelhead habitat assessment methodology utilized for the study is the rainbow trout Habitat Suitability Index (HSI) model developed by the U.S. Fish and Wildlife Service (Raleigh et al., 1984), as modified by Thomas R. Payne & Associates (2007), (Padre, 2010). This methodology was selected to maintain consistency with previous steelhead trout studies conducted in this reach of the River.

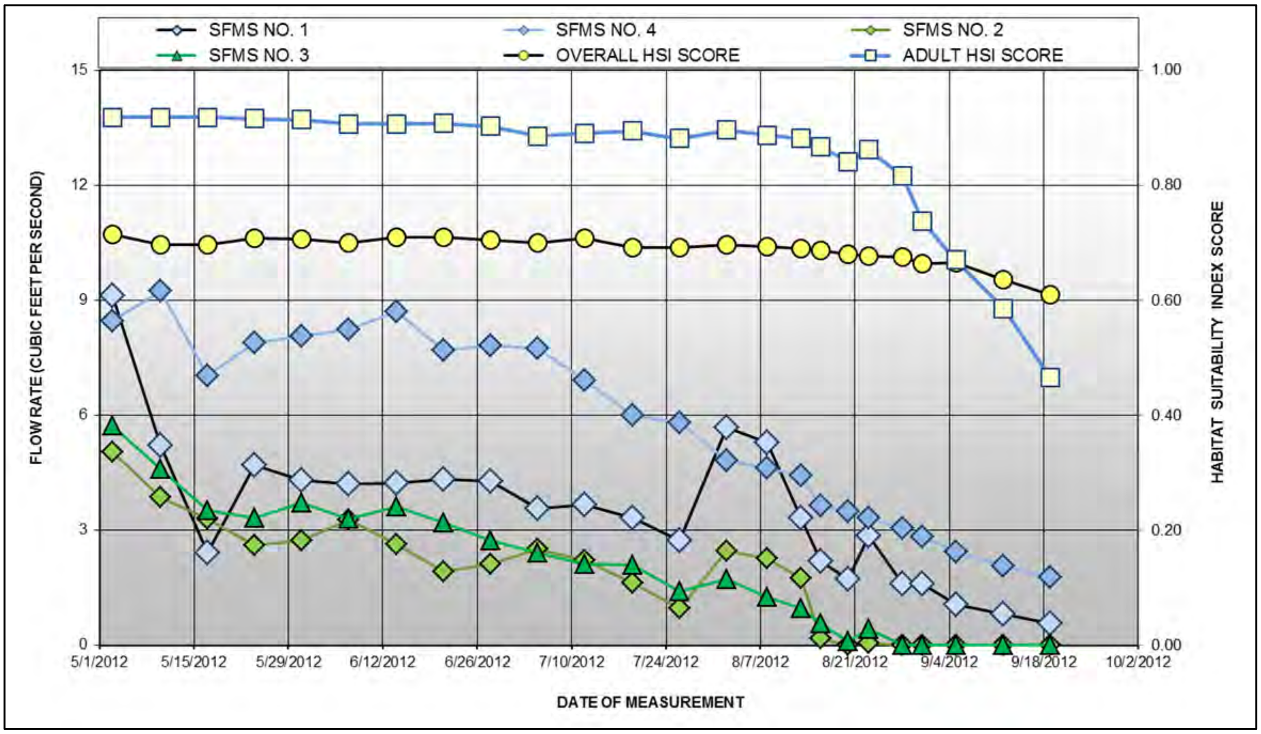
On May 2, 2012, Padre conducted the initial habitat typing survey and established 18 sampling units within the study area. The sampling units consisted of 6 pools, 6 runs, and 6 riffles (see Appendix C, Figures 2 and 3). On May 3, 2012, Padre conducted the first of 24 steelhead habitat suitability surveys performed in conjunction with this surface water/groundwater interaction study. Utilizing the observations and data collected during the habitat surveys, HSI scores were calculated for each survey event. The scoring was used to calculate values for adult, juvenile, fry, other, and overall steelhead habitat conditions.

The report concludes that the overall HSI values (ranging between 0.609 and 0.714) was affected most by the increase in maximum daily water temperatures and thalweg depth which changed while surface flows steadily declined in the River. The relatively minor change in overall HSI values was attributable primarily to variations in the maximum water temperature while the significant change in the Adult HSI values (ranging from 0.465 to 0.918) was primarily based on thalweg depth (Padre, 2012). The average thalweg depth (deepest part of the surface water features) was measured to decline from 53 to 16 cm over the study period (see Appendix C, Table 4).

The conclusions of this study are in contrast to the 2010 report conclusion that the overall HSI values (ranging between 0.690 to 0.702) did not substantially change over the period of study (June 24, to September 9, 2010) while surface flows steadily declined in the River (Padre, 2010). This is largely believed a result of the lower flow conditions during the 2012 study period. During the 2010 study, the upstream flow rates ranged between 8 and 12 cfs (see Figure 5). During the present 2012 study, the upstream flow rates ranged between 2 and 8 cfs.

The overall and adult HSI score values are presented for comparison with the results of the streamflow surveys in Figure 6 – Overall and Adult HSI Values and Streamflow Survey Correlation. As Figure 6 shows, the overall HSI scores do not correlate with the steady declines in streamflow at the 4 monitoring stations and is largely a result that thalweg depth does not significantly affect the scores for habitats other than adult habitat. The 4 lowest adult HSI scores (below 0.80) occurred between August 31, and September 19, 2012 when the upstream River flow rates declined at SFMS No. 4 to below 3 cfs, surface water flows had stopped at SFMS Nos. 2 and 3, and flow downstream at SFMS No. 1 was approximately 1.6 cfs (see Figure 6).

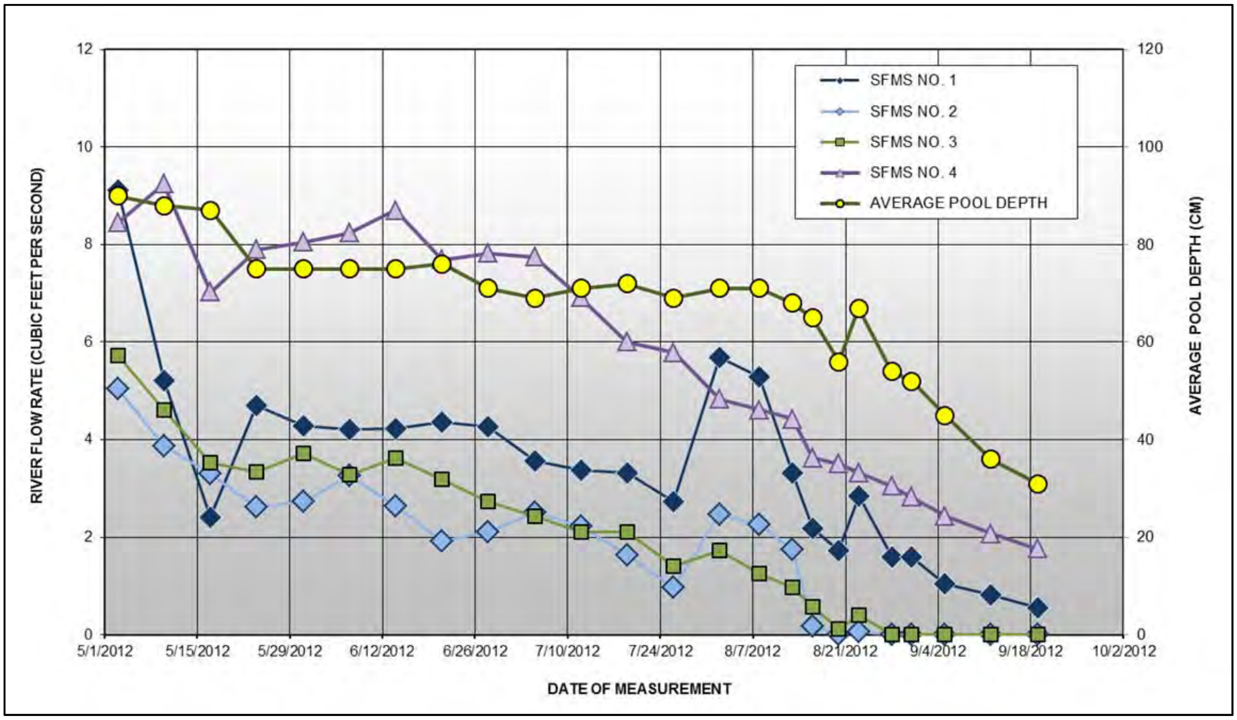
Figure 6 – Overall and Adult HSI Values and Streamflow Survey Correlation



River Thalweg Depth

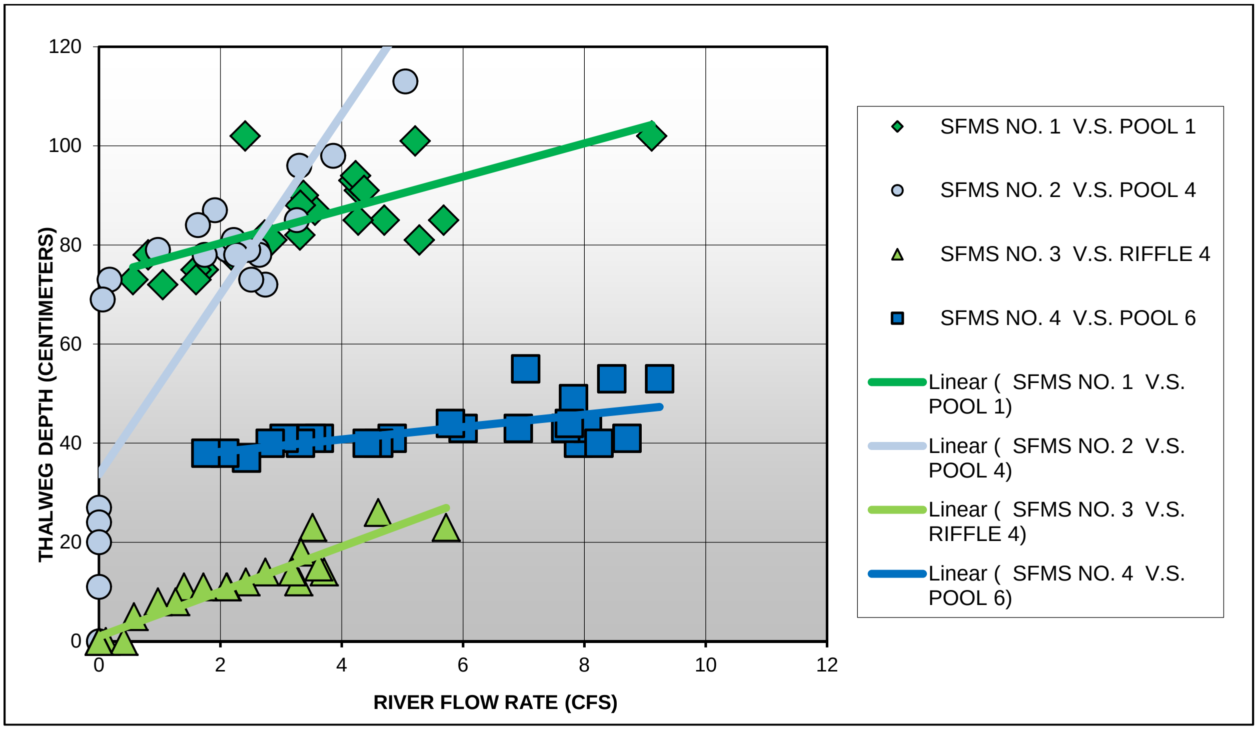
One of the parameters collected for the HSI study that was used to assess the quality of the aquatic habitat for steelhead is the depth of the thalweg (deepest part of the flow channel) in each surface water feature. Figure 7 – Streamflow and Average Pool Depth provides a comparison of the average thalweg depth of pools measured in the habitat assessment study and the streamflow surveys. As shown, these data indicate that the average depth of the pools studied declines considerably when upstream and downstream flow at SFMS Nos. 4 and 1 fall below 4 cfs and 2 cfs, respectively (see Figure 7).

Figure 7 – Streamflow and Average Pool Depth



The surface water features closest to SFMS Nos. 1, 2, 3, and 4 are Pool 1, Pool 4, Riffle 4, and Pool 6, respectively. A comparison of flow in the River and the specific thalweg depth of these features is provided in Figure 8 – Streamflow and Surface Water Feature Depth. A review of these data provides an interesting correlation. The riffle measured in the reach of the River measured by SFMS No. 3 displayed a very linear decline to the point where no flow converged with no depth. However, all three pools display a relatively modest decline in depth until the point there is virtually no flow into the pool. At this point, the pool declines to a depth coincident with the shallowest groundwater level in the surrounding aquifer. This occurrence can be seen in the Pool 4 data which indicate the pool maintained a depth of 70 centimeters until the surface water inflow dropped below 0.06 cfs and became less than the rate of outflow to percolation. At that time, the pool depth dropped significantly (see Figure 8). Throughout the study period, Pools 1 and 6 showed modest declines in thalweg depths, even at the end of the study period when very low flow rates were measured at Pool 1 (0.56 cfs).

Figure 8 – Streamflow and Surface Water Feature Depth

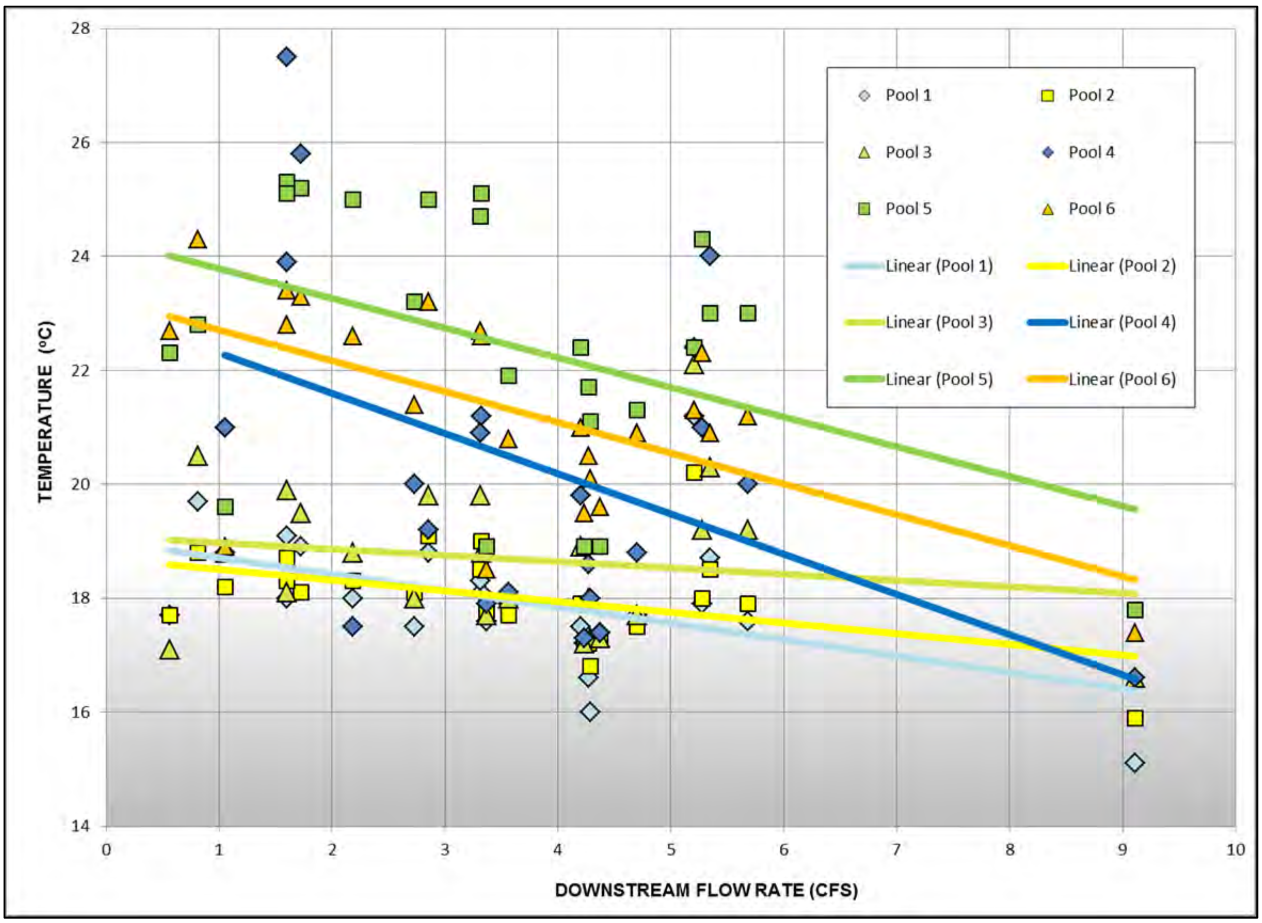


During the course of the study, human activity in the River consisted of people moving cobble sized and smaller stones to create pools. The effect of this activity on thalweg depth at the HSI stations is unknown but the rock dams were observed to cause significant changes in surface water depths at various places in the River channel. While localized pools were enlarged by this human activity, water impounded in the elevated surface water feature was observed to flow through the artificial dams and emerge from the face of the dams as dispersed flow over a large area. The dispersal of flow was observed to effectively eliminate the natural channel that could allow fish passage in or out of these enlarged pool features. Documentation and study of man-made effects on fish habitat was beyond the scope of this study. However, it is possible that significant localized effects from this human activity could be detrimental to steelhead habitat (i.e. increasing wetted riverbed surface area that induces more percolation to groundwater and may reduce surface flow into natural downstream pools).

Surface Water Temperature Variations

The steelhead habitat study results during these low-flow conditions provide valuable water temperature data that are indicative of a hyporheic zone interaction between groundwater and surface water. During the higher flow rates observed between May and June, the temperature gradient showed a gradual decline of 2 to 3 degrees centigrade (^{o}C) at measurement locations progressing downstream through the study reach of the River. This condition is indicative of rising groundwater that is mixing with and cooling the warmer surface water flowing into and across the reach. As flows began to decline in mid-July, and particularly on hotter days, the water temperature differential became greater (see Appendix C). Figure 9 – Temperature of River Pool Units shows the relationship between River flow rate measured at the USGS gage and the change in temperature measured in the River pool units monitored as part of the HSI survey. The study data indicate that pool water temperatures in the study reach of the River generally rose as surface flows declined and the daytime temperatures increased (see linear trend lines on Figure 9). Upstream water temperatures flowing into the Foster Park reach of the River (pools 5 and 6) were higher than downstream temperatures in the Foster Park reach of the River (pools 1 through 4). As River flow rates at the USGS gage declined below 2 cfs surface flow into pools 4 and 5 virtually stopped and the temperature of the standing water rose during the heat of the day.

Figure 9 – Temperature of River Pool Units



Field observations indicate that at the time of the study, there is a significant elevation change in the River channel between these two locations. Riffle-4 is located just upstream of where the alluvial basin becomes wider and deeper. This change in basin geometry appears to allow infiltration of surface flow and creates a losing River reach. This condition results in the notable reduction in streamflow during the low-flow conditions of the study period and explains why at the end of the controlled shutdown period, the surface water flow rate still declined between SFMS No. 4 and SFMS No. 3, but increased significantly downstream at SFMS No. 1.

Additionally, Riffle-4 is the last surface water feature located above the inferred subsurface flow boundary (perhaps a fault) referenced by other studies (Hopkins, 2007). Above Riffle-4 is the stretch of River historically referred to by previous River surface water studies as the “live reach”. The water temperature data indicate that during low-flow conditions the surface water flowing through the live reach has little interaction (hyporheic exchange) with the underlying groundwater.

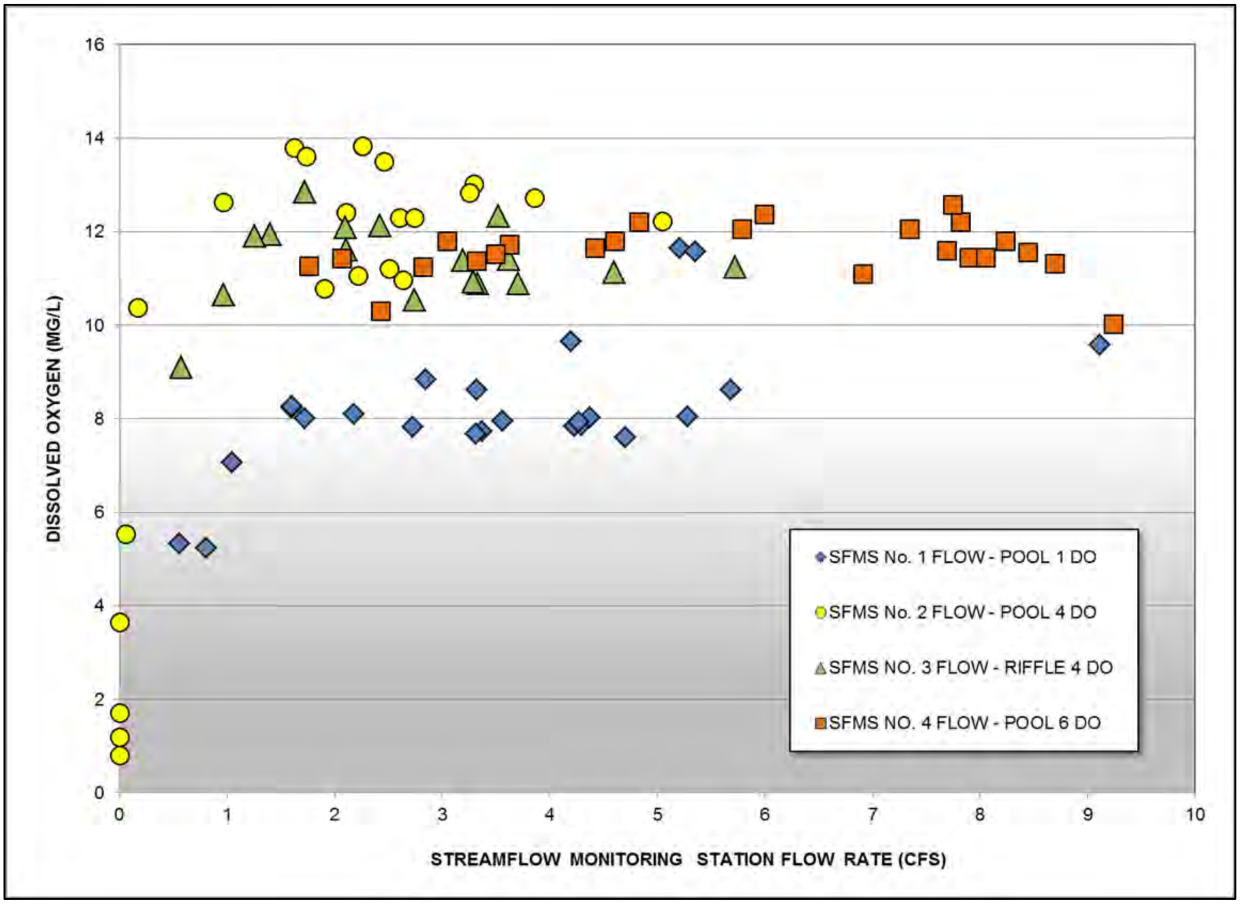
As seasonal temperatures increased, the temperature differential between the upstream live reach and the downstream Foster Park reach increased. For example, on August 13, 2012, the uppermost measurement station at Run-6 indicated a water temperature of 22.2 ^{o}C flowing into the River reach. The surface water temperature continued to increase down through the live reach to Riffle-4 where it was measured at 26.1 ^{o}C. The next surface water feature measured is approximately a 1,000 feet downstream where the temperature (at Pool-4) was 20.9 ^{o}C. Below Pool-4, the water temperature on average continues to decline downstream to Pool-1 at the Casitas Vista Road Bridge below Foster Park. On August 13, 2012, the temperature at Pool-1 was 18.3 ^{o}C. These water temperature data confirm the streamflow data that indicate rising groundwater is a component of the surface water flow between Casitas Springs and the Casitas Vista Road Bridge. Downstream of Pool-4, where the underlying bedrock contact (which defines the base of the alluvial groundwater basin) becomes shallower and narrower, the River is predominantly a gaining reach.

Surface Water Dissolved Oxygen Concentrations

One of the water quality parameters collected during the field surveys and utilized for calculation of the HSI index is the dissolved oxygen (DO) concentration. The use of dissolved oxygen as an indicator of habitat suitability provides a good correlation to changes in flow conditions. Appendix D provides the data collected by Padre throughout the study period (see Table D1). Plate D1 and D2 show the DO concentrations measured in the River run and riffle sample units, respectively, throughout the range of the River flows measured at the USGS gage. These data indicate that the dissolved oxygen concentrations in these sample units were generally in the range of 8 to 15 mg/l and support a habitat that is suitable under all but the lowest flow conditions.

Figure 10 – River Unit Dissolved Oxygen Concentrations at Streamflow Monitoring Stations provides a correlation of river flow rates measured in the vicinity of the HSI sample units where DO concentrations were measured. These data show a decline in the DO concentrations as the River flow rates at the corresponding streamflow monitoring stations declined below 1 cfs.

Figure 10 – River Unit Dissolved Oxygen Concentrations at Streamflow Monitoring Stations



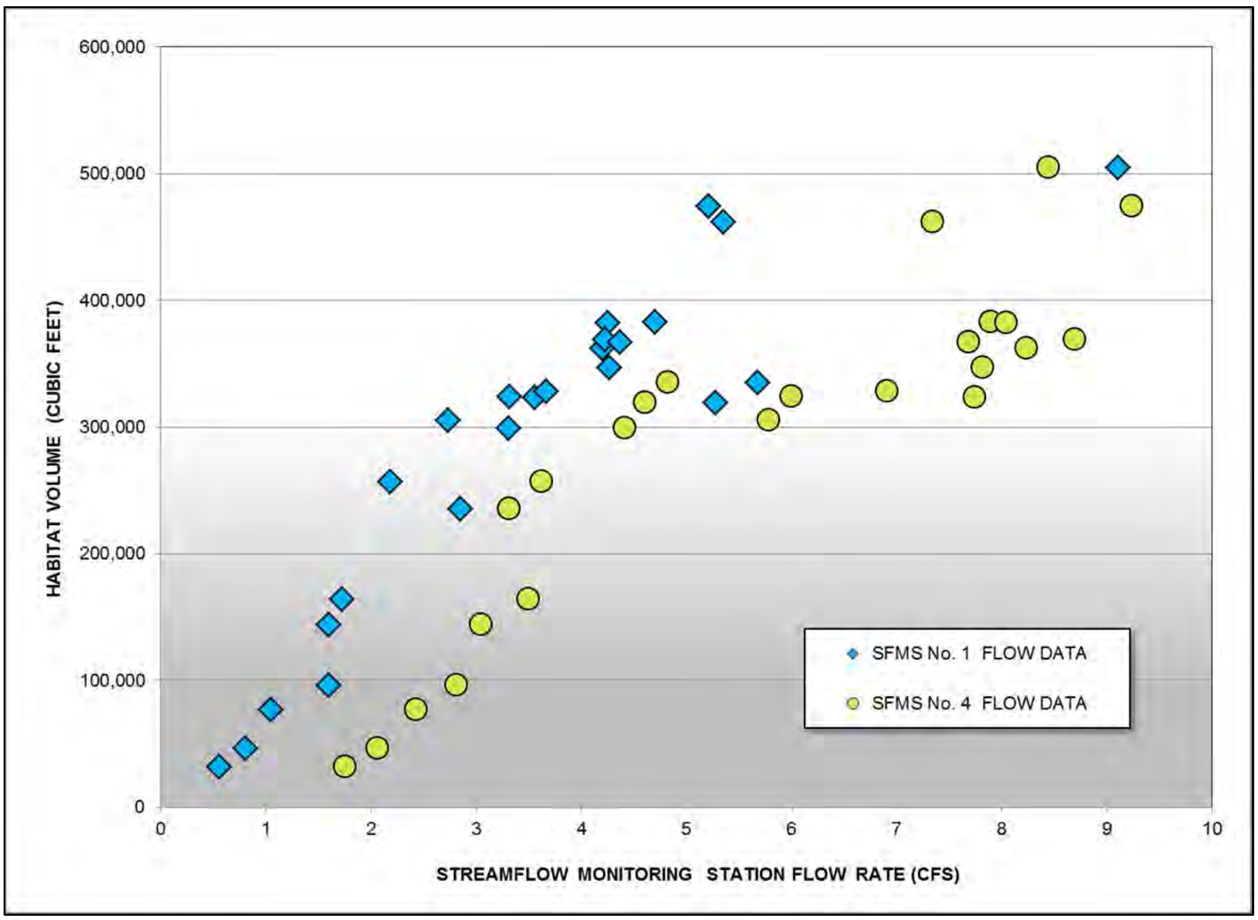
The most significant change in the DO concentrations that was documented by the study was the concentration in the River pool sample units. Plate D3 shows that the DO levels in the pools abruptly declined when inflow from upstream reaches ceased as flow seasonally declined.. For comparison, Plate D4 shows these same DO data compared to flows upstream at SFMS No. 4. This comparison of data shows that a drastic DO concentration decline occured when there was less than 4 cfs flowing downstream from the live reach into the Foster Park reach of the River (see Plate D4).

These data also indicate that pool sample units 4, 5, and 6 were generally several mg/l higher than the downstream sample units where rising groundwater becomes a greater component of the surface water flow. While it was not measured during this study, we infer that the groundwater has a considerably lower dissolved oxygen concentration than the surface water.

Habitat Quantity Estimates

In addition to the suitability of River flow, temperature, and water quality parameters used in the HSI model for fish habitat, the study also included an estimate of the change in the quantity of the fish habitat volume (see Appendix C). Figure 11 – River Habitat Volume Estimates Versus River Flow Rates shows the relationship of the estimated volume change under the variable flow rates measured upstream and downstream. The method utilized by the study to estimate fish habitat quantity was to multiply the average channel width by the thalweg depth, and by the live stream length measured (Padre, 2012). While admittedly this is only a crude estimate, the correlation of these results confirms the results of the other data used to assess fish habitat. As shown in Figure 11, the estimated volumes of fish habitat quantity declines gradually as the upstream River flows declined from 9 cfs to 4 cfs. After which, the rate of habitat volume decline was noticeably greater. Correlation of habitat volume decline with downstream data show similar trends with an extreme drop in habitat volume that occurred when River flow rates declined to below approximately 2 cfs.

Figure 11 – River Habitat Volume Estimates Versus River Flow Rates



CONCLUSIONS AND RECOMMENDATIONS

The present study has documented the dynamic relationship between surface water flows and groundwater diversions in the Foster Park reach of the River which occurred under lower River flow conditions than were observed in the previous City studies (Hopkins, 2009 and 2010). The inclusion of the steelhead habitat assessment during this surface water/groundwater study has proved beneficial to understanding the relationship between changes in low-flow conditions and the change in the suitability of the steelhead habitat. The findings of this study indicate a flow threshold exists whereby when flows decrease below the threshold, the habitat suitability declines significantly.

We conclude that groundwater production at Foster Park during the low-flow season is substantially supported by underflow. This conclusion is supported by the temperature data collected for the HSI survey which indicates the River is losing warmer surface water flows below Riffle 4 and gaining cooler rising groundwater in the reach downstream of Pool 4 (see Appendix C, Figures 2 and 3).

During the 2012 low-flow conditions when the City diversion was approximately 6.5 cfs and there was 4 cfs or greater upstream (at Casitas Springs) and 2 cfs or greater downstream (at Casitas Vista Road Bridge), the HSI scores for adult steelhead remained fairly constant (see Figure 6) and the pools maintained substantial depths (see Figures 7 and 8). Additionally, the HSI data show favorable dissolved oxygen levels in the runs and riffles throughout the duration of the study Although data are limited, preliminary analysis indicates a significant decline in both the dissolved oxygen concentration in the pools and the habitat volume estimates when the flow at the Casitas Vista Road Bridge declined to below 2 cfs and when the inflow from the live reach fell below 4 cfs. HSI observations also indicated that prior to portions of the River reach drying out, the higher daytime temperatures and the likely low nighttime oxygen levels from algae respiration, created habitat unsuitable to sustain steelhead populations.

We conclude that the steelhead habitat is generally degraded throughout the low-flow season because the declining river flow results in shallower thalweg depths in pools, runs, and riffles which allows the hotter atmospheric temperatures to increase the surface water temperatures. However, we conclude that under the study conditions when there is greater than 4 cfs flowing at Casitas Springs into the Foster Park River reach, the steelhead habitat generally improves because of reduced water temperatures and higher DO concentrations.

We conclude that the inflow from San Antonio Creek is a direct and significant influence on flow in this reach of the River system during the low-flow conditions observed by the study. We also conclude that high streambed infiltration rates and high aquifer hydraulic conductivity values result in a very rapid rate of groundwater recharge. These conditions result in a quick groundwater level response to changes in City production. Based on data provided from the controlled shutdown period when the wells were turned off, we conclude that when the surface flow entering the Foster Park reach from the live reach of the River is 5 cfs or greater, the alluvial aquifer affected by City wellfield diversions is completely refilled within a week (or sooner) after cessation of City pumping (see Plates 3 and 6).

We conclude that the City can effectively operate at higher rates of groundwater diversion and maintain favorable habitat conditions for the steelhead in the Foster Park reach of the River through the use of routine habitat monitoring. Optimal management of groundwater resources and steelhead habitat will require additional well facilities that are appropriately placed and operated within the groundwater basin. Additional wells will allow higher diversion rates when River flows are higher. Subsequently, gradual reductions in well production can be made to maintain habitat as the River flow rates decrease. We conclude that at the time of this study, the upstream flow threshold was approximately 4 cfs (at the Casitas Springs live reach) while the downstream flow threshold was approximately 2 cfs (at the USGS gage). After surface flows declined below these levels, the HSI scores for steelhead declined rapidly (see Figure 6).

Based on the conclusions of this study, we recommend the City consider the merits of conducting future low-flow studies that include steelhead habitat assessment (HSI surveys) that can be used to confirm the findings of this study and further understand the relationship between River flows, City diversions, and the suitability of the steelhead habitat. We also recommend that the City consider the merits of conducting River flow monitoring when the River is flowing over 15 cfs. These studies could be useful to develop an understanding of the habitat suitability under higher flow conditions.

We recommend the City consider additional monitoring measures that may improve the present study methodology. Automated data collection probes may be advantageous to deploy at strategic locations to improve the resolution of data collection, development of flow rating curves (at locations other than the USGS gage), and better define the cause and effect relationship between the City diversions and the River responses that affect the suitability of the steelhead habitat. Because Foster Park is highly used by the public, and the City has observed frequent vandalism, the instrumentation will need to be secured in a manner that minimizes public exposure. The close comparison of manual streamflow measurements with the USGS gage data confirm the accuracy of the applied methodology that was used to measure flow at the designated SFMS locations. Additionally, comparison of the groundwater level measurements collected during the study with the available City transducer data and the temporary transducer data collected in many of the monitoring wells toward the end of the study period confirm the accuracy of the groundwater level measurements collected during the River surveys. This comparison is provided in Appendix E.

We also recommend the City consider the merit of constructing additional well facilities to allow for greater production under higher River flow conditions when habitat impacts are anticipated to be insignificant. The ability to divert at higher rates will permit the cessation of pumping during lower flow rates (to preserve steelhead habitat quality) and reduce the impact to the average annual yield from the River that is so vital to the City's water supply. We also recommend that during low flow conditions, the City observe streamflows documented by the USGS gage and consider reducing its diversion rates during the dry season as the River flow rate declines to 2 cfs. While the City has no control on how much water will seasonally flow into the Foster Park reach of the River, the reduction and eventual cessation of pumping will serve to maintain the steelhead habitat as long as it will last while the main stem of the River dries out.

CLOSURE

This report has been prepared for the exclusive use of the City of San Buenaventura and its agents for specific application to the occurrence and movement of groundwater and surface water in the Foster Park Wellfield reach of the Ventura River. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeological planning study practices. No other warranty, express or implied is made.

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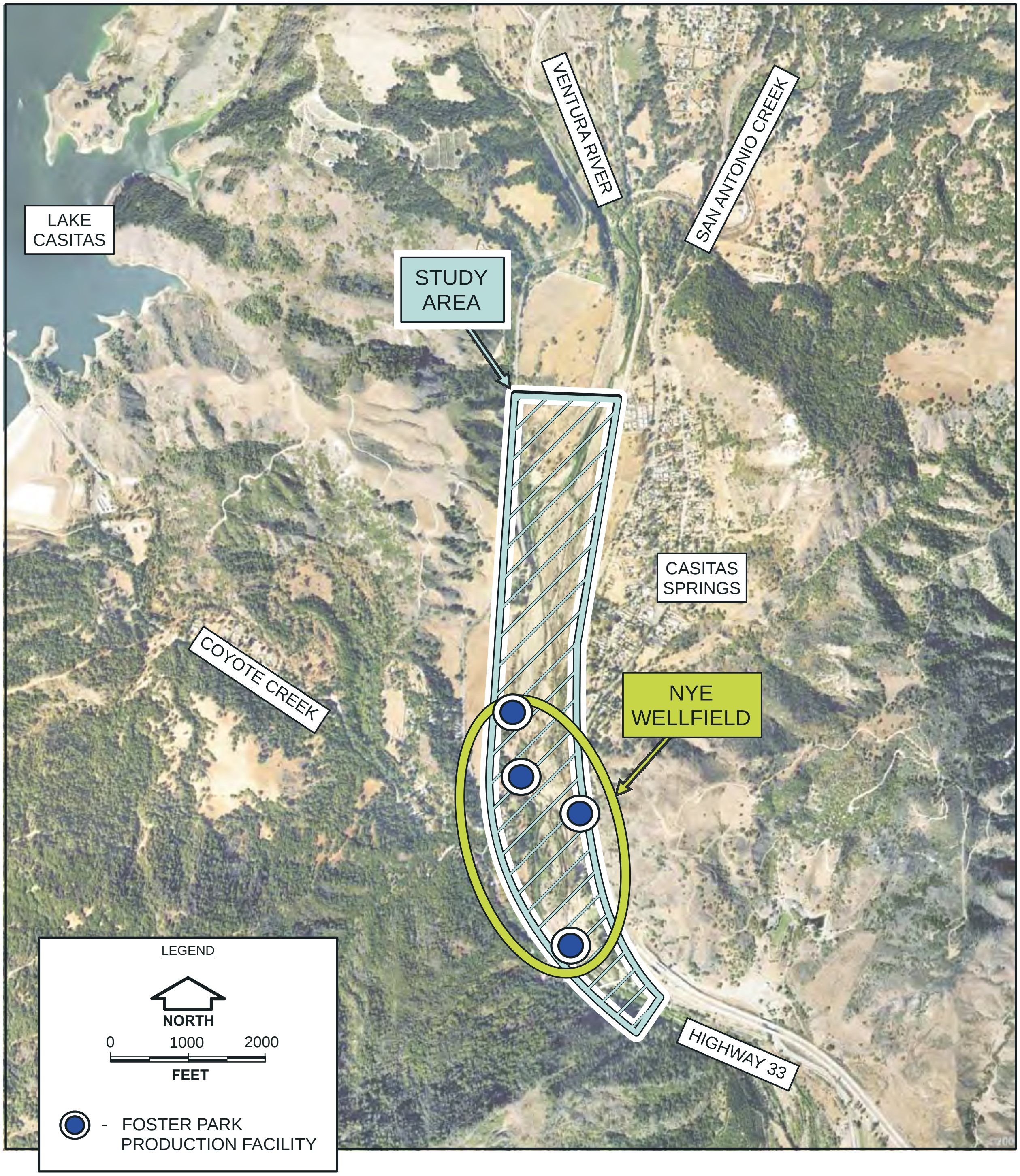
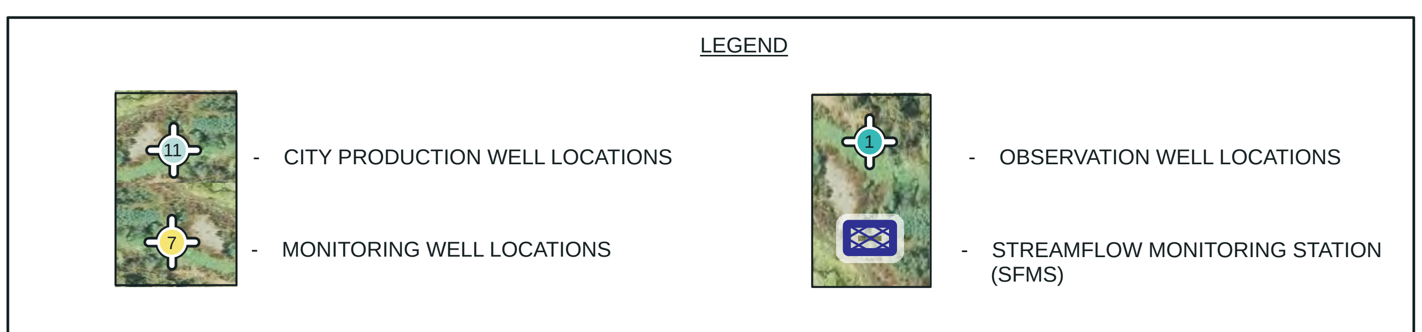
PLATES



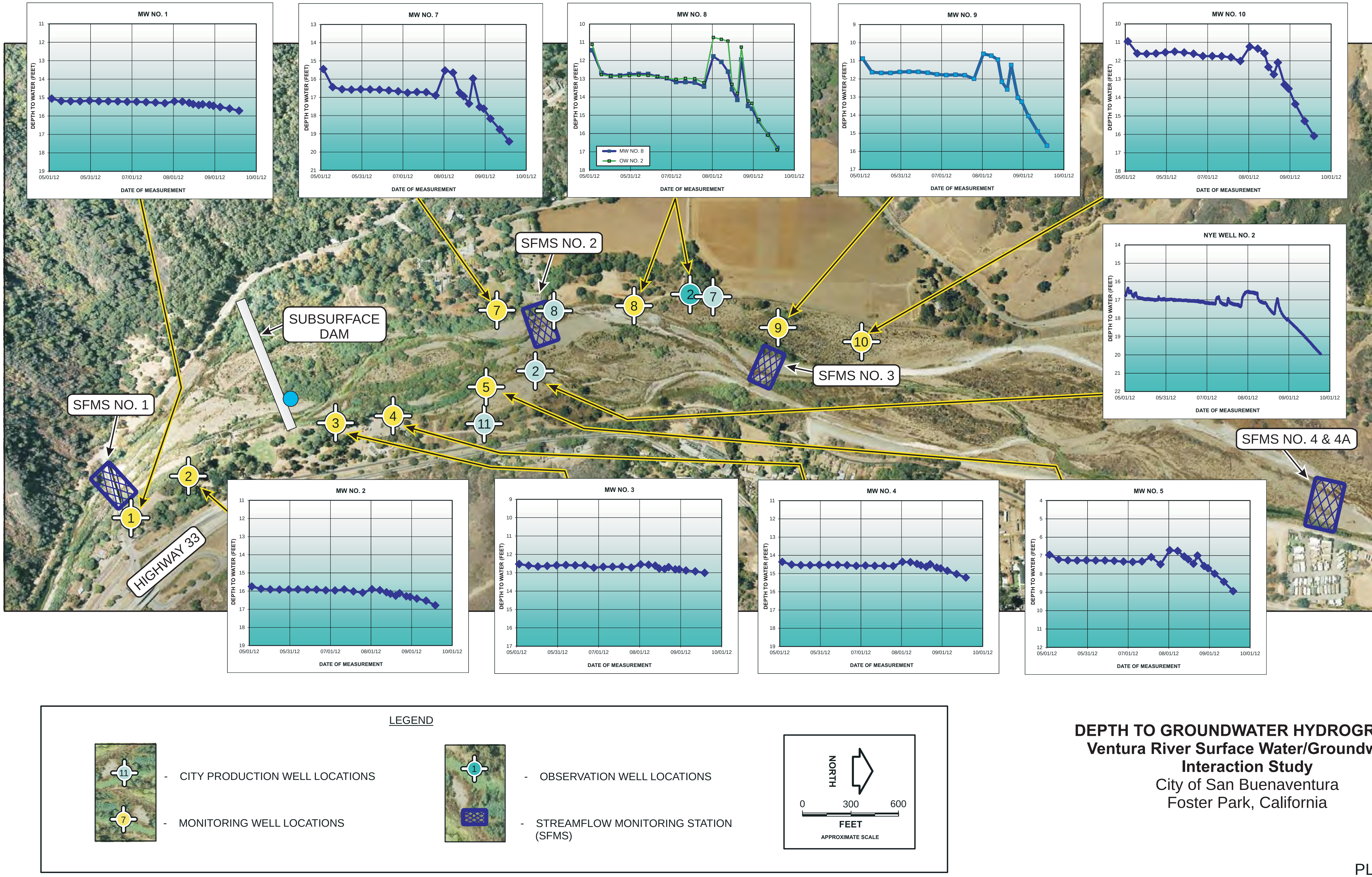
STUDY AREA LOCATION MAP
Ventura River Surface Water/Groundwater
Interaction Study
City of San Buenaventura
Foster Park, California

PLATE 1



STREAMFLOW MONITORING STATION AND WELL LOCATION MAP
Ventura River Surface Water/Groundwater Interaction Study
City of San Buenaventura
Foster Park, California

HOPKINS GROUNDWATER CONSULTANTS



DEPTH TO GROUNDWATER HYDROGRAPHS
Ventura River Surface Water/Groundwater Interaction Study
City of San Buenaventura
Foster Park, California

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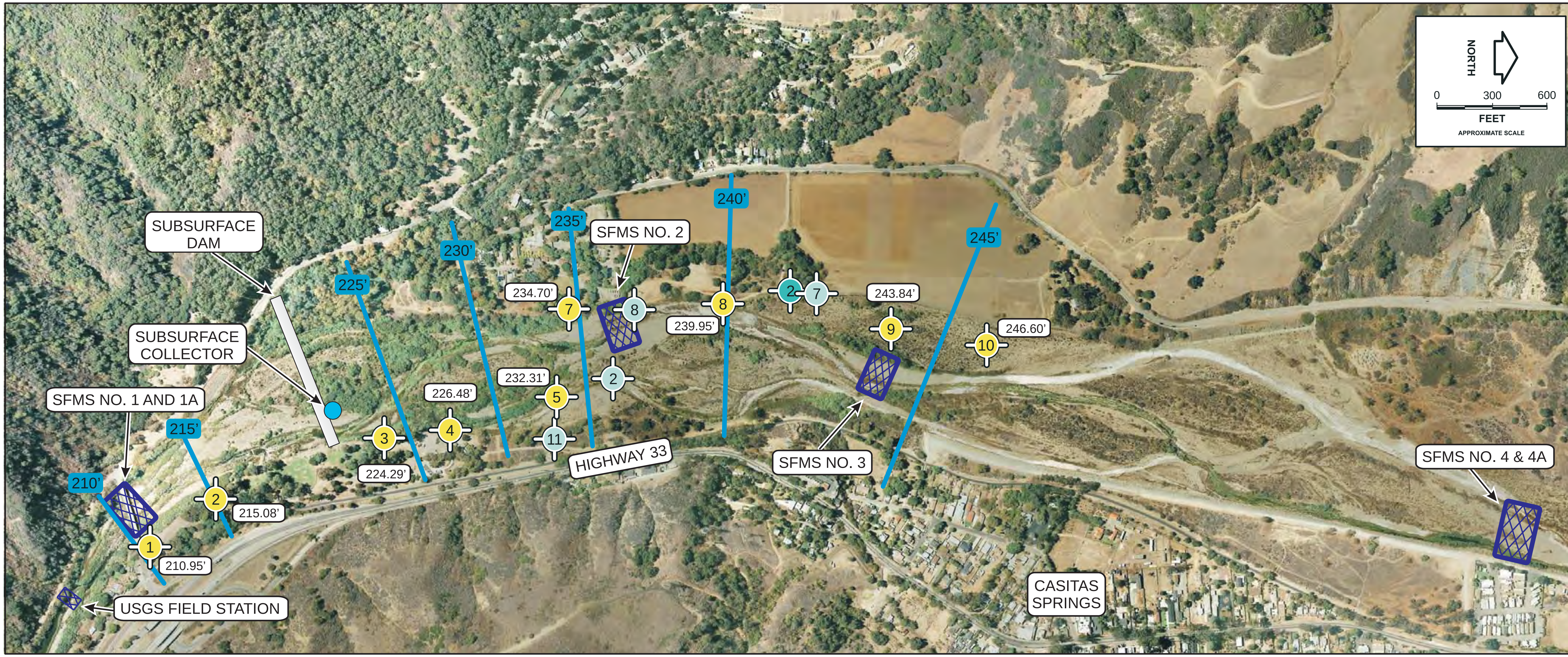
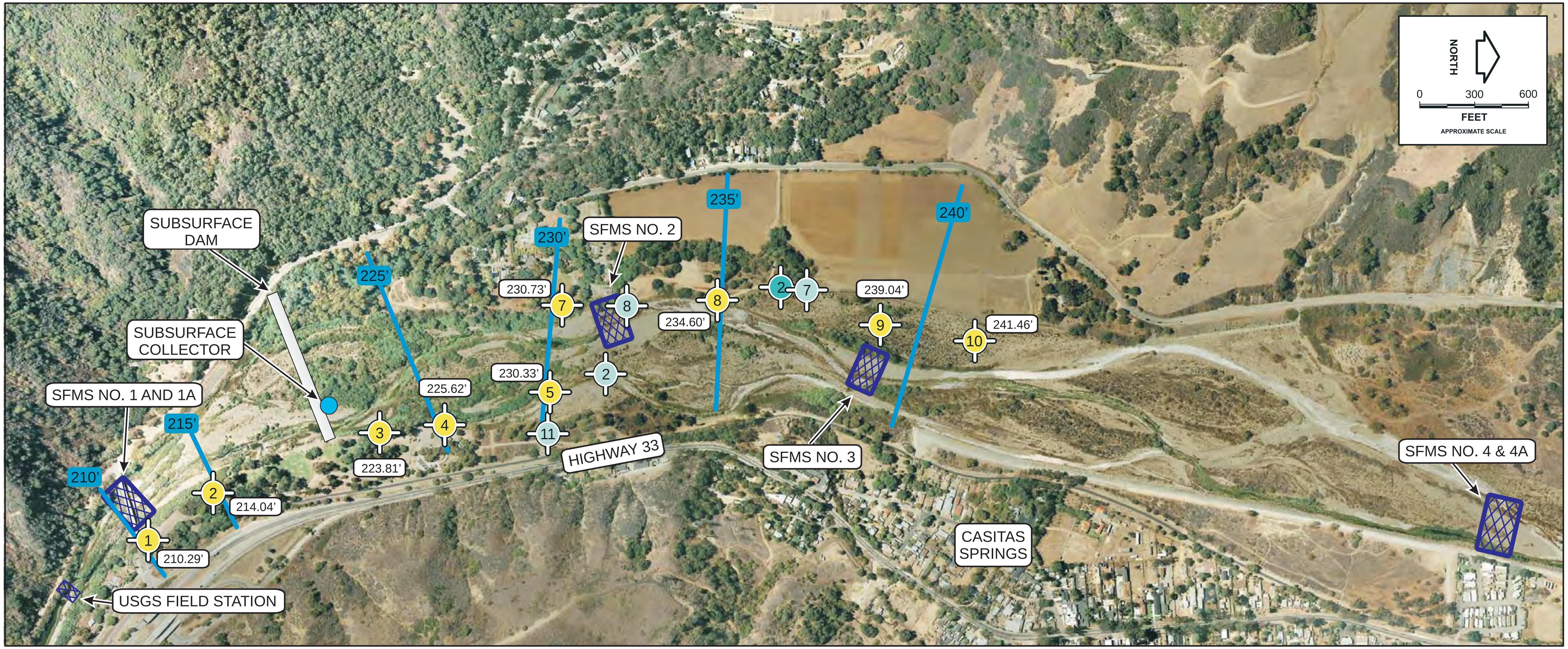


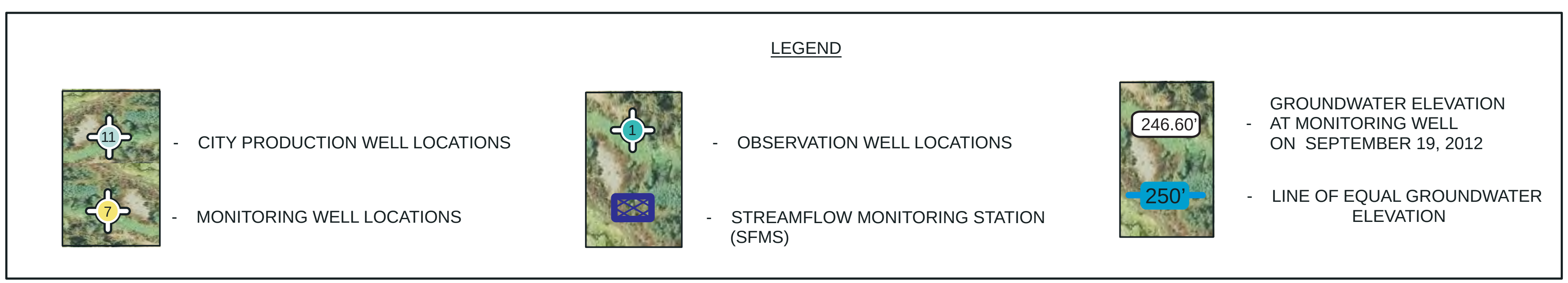
LEGEND

- CITY PRODUCTION WELL LOCATIONS
- MONITORING WELL LOCATIONS
- OBSERVATION WELL LOCATIONS
- STREAMFLOW MONITORING STATION (SFMS)
- 246.60' GROUNDWATER ELEVATION AT MONITORING WELL ON MAY 3, 2012
- 250' LINE OF EQUAL GROUNDWATER ELEVATION

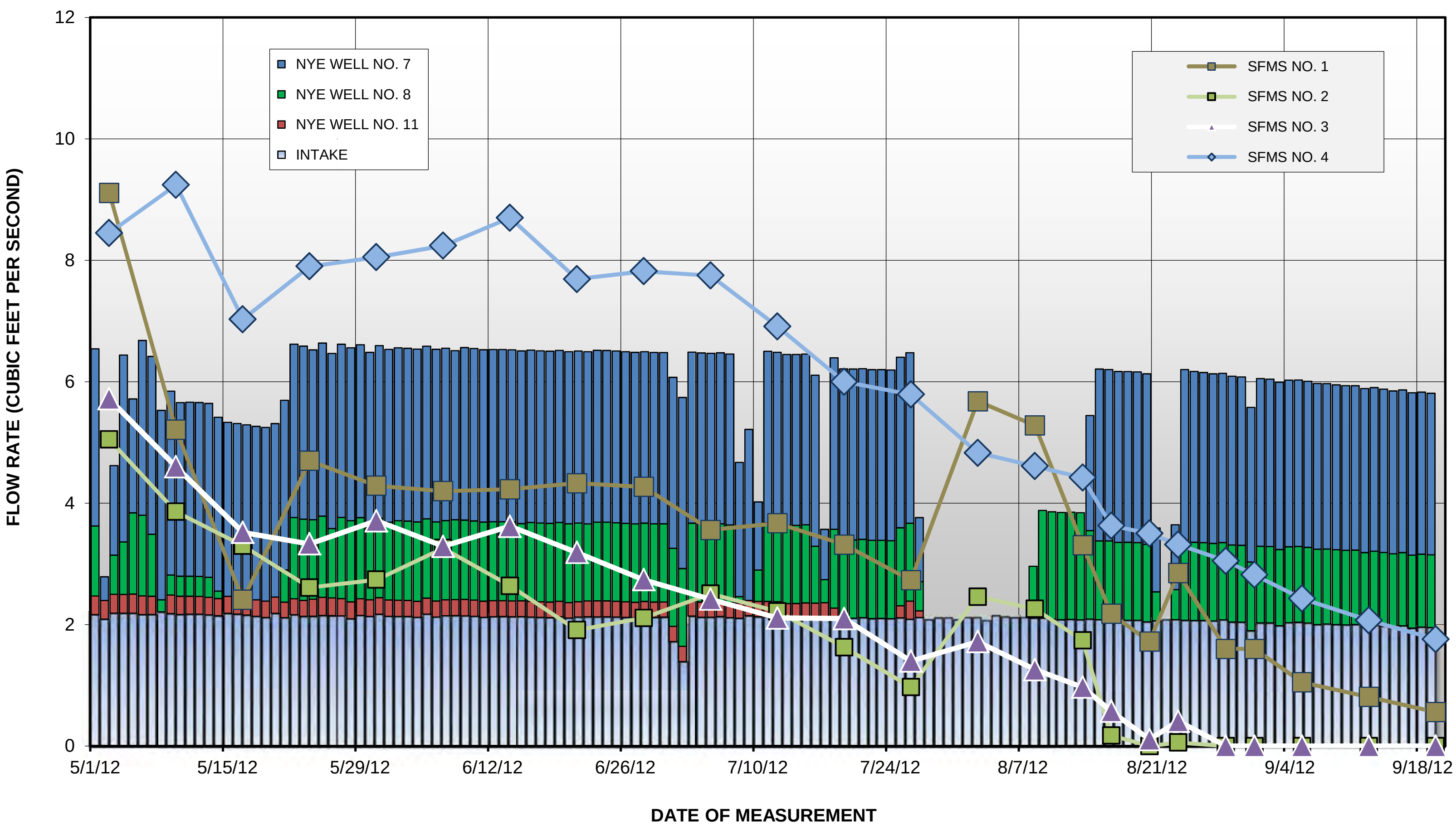
GROUNDWATER ELEVATION CONTOUR MAP
MAY 3, 2012
Ventura River Surface Water/Groundwater Interaction Study
City of San Buenaventura
Foster Park, California

HOPKINS GROUNDWATER CONSULTANTS





GROUNDWATER ELEVATION CONTOUR MAP
SEPTEMBER 19, 2012
Ventura River Surface Water/Groundwater Interaction Study
City of San Buenaventura
Foster Park, California



FOSTER PARK DIVERSION AND RIVER FLOW COMPARISON GRAPH
Ventura River Surface Water/Groundwater Interaction Study
City of San Buenaventura
Foster Park, California

PLATE 6

June 2013
Project No. 04-021-09B

HOPKINS GROUNDWATER