ARCGIS MAPPING OF THE SIX BASINS GROUNDWATER BASIN IN CLAREMONT, CA

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Term Project

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Nick Brethorst

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1 SIX BASINS GROUNDWATER BASIN SIGNIFICANCE

1.1 THE INCREASING IMPORTANCE OF GROUNDWATER

Southern California receives most of its potable water from two mega engineering water projects - The State Water Project and the Colorado Aqueduct. The State Water Project was completed in 1971 and is owned and operated by the California Department of Water Resources. This mega engineering water project is comprised of over 600 miles of concrete open channels and steel pipelines that transports 3.7 trillion gallons of water per year (3.7×10^{12} gallons of water per year) to five dams, beginning in the San Francisco Bay area and ending in Southern California (Rashidi, 2009), as shown in Figure 1. The Colorado Aqueduct was completed in 1961 and is owned and operated by the Metropolitan Water District. This mega engineering water project is comprised of 1,440 miles of concrete open channels and steel pipelines that transports 0.62 trillion gallons of water per year (6.2×10^{11} gallons of water per year) from the Colorado River to Southern California, where the water is distributed from Los Angeles to as far south as San Diego, as shown in Figure 1 and Figure 2. The Metropolitan Water District is comprised of 26 member agencies that are allotted both State Water Project and Colorado Aqueduct water, treat it, and distribute it to businesses and residents throughout their service areas, as shown in Figure 2. Combined, these two mega engineering water projects provide over 80% of the water supply for 24 million Californians across Southern California (Rashidi, 2009).

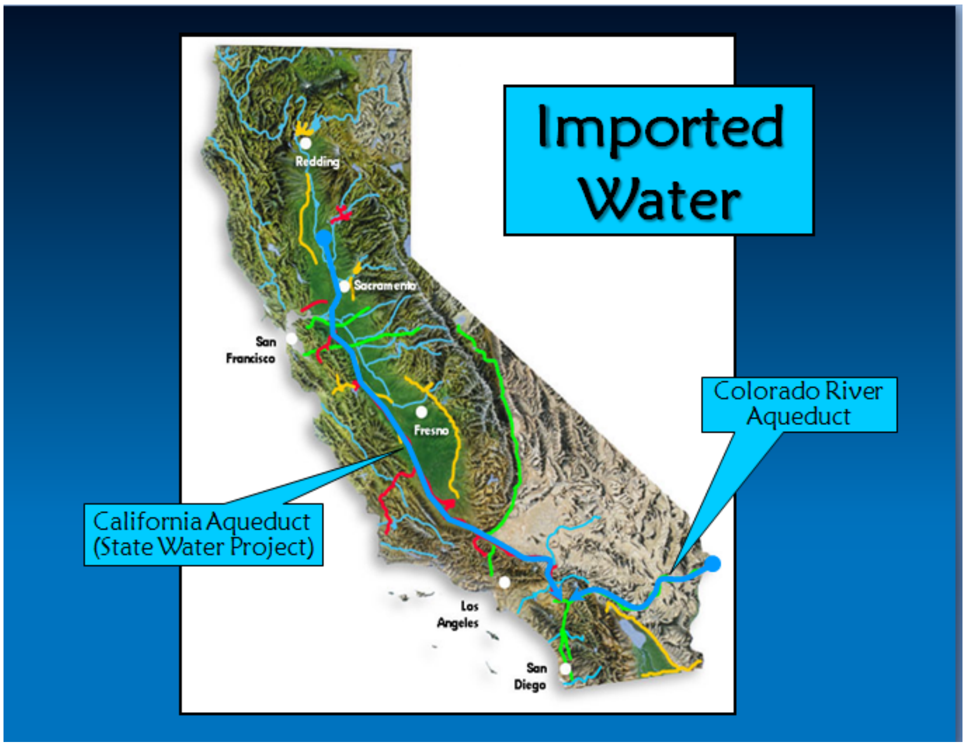


Figure 1: California State Water Project and Colorado Aqueduct (Three Valleys Municipal Water District, 2012)

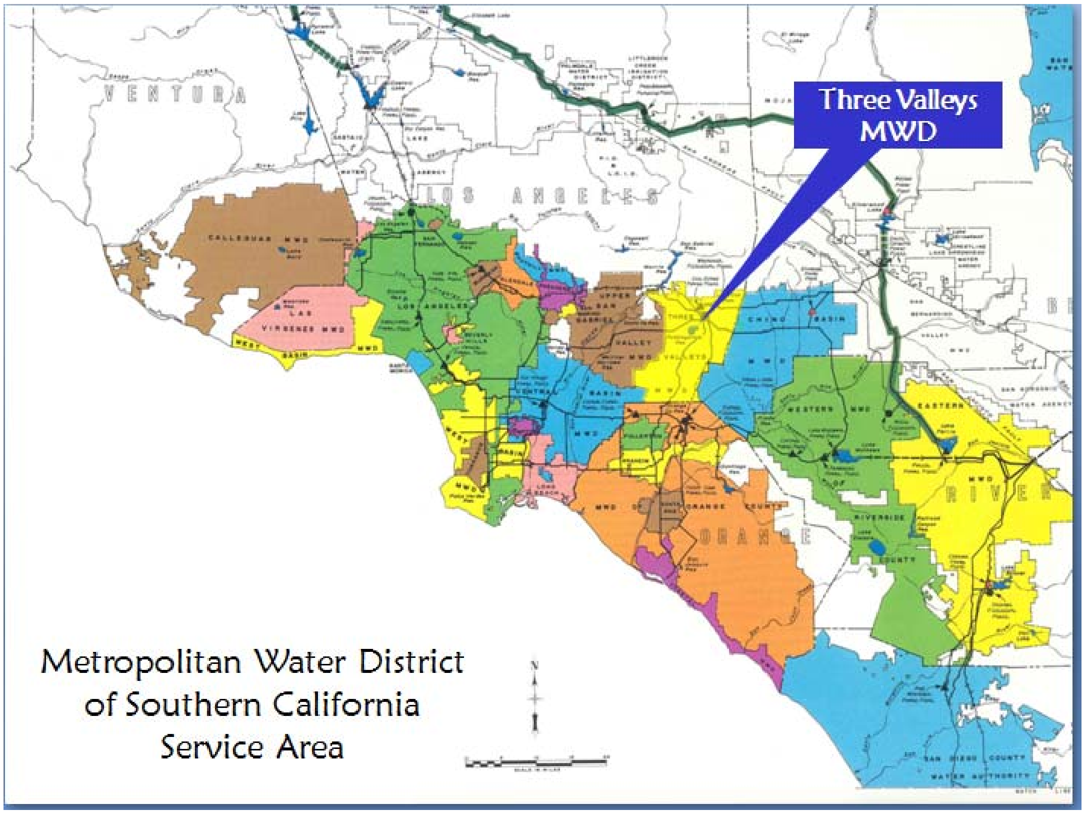


Figure 2: Metropolitan Water District's Member Agency Service Area (Three Valleys Municipal Water District, 2012)

Southern California's water demands are expected to increase nearly 20 percent by 2020 and the ability to meet the demand to supply a sufficient amount of water is becoming harder and harder (Groundwater Replenishment System, 2009). For decades, water purchased from outside of Southern California, such as the Colorado Aqueduct and State Water Project, provided a sufficient amount to Southern California's drinking water supply. However, that method has proven unsustainable in times of prolonged drought and increasing population growth. In recent times, these two projects have run into serious problems that have adversely affected their ability to supplement enough water to Southern California. Southern Californians have realized that they need to supplement their water supply with more sustainable alternatives because of these burdens.

Since 2004, California has been experiencing a series of intermittent, yet prolonged droughts. Without the local supply that the rain provides, California has been forced to pump more water from the Colorado River to make up for the local supply deficit. However, this temporary solution created a long term problem. Over that period, the Colorado River has been over-pumped to meet the additional needs of Southern California, along with the growing population demands from other nearby states such as Arizona, New Mexico, and Colorado; states that also draw water from the Colorado River. The water supply deficit has been compounded due to the additional water allocation cuts from the State Water Project because of the Delta Smelt. The Delta Smelt is a small freshwater-fish population that lives in the San Francisco Bay area. The Delta Smelt has become endangered because their populations are being killed by the pumps that help transport water from the San Francisco Bay area to Southern California. To reverse this process, the pumps are being shut down and redesigned to minimize Delta Smelt death tolls. With the pumps shut down, less raw water for drinking water use can reach Southern California.

In order to preserve a long term supply of import water, the Metropolitan Water District mandated a 30% water supply allocation cut from the Colorado Aqueduct and distributed the cut amongst its member agencies. In addition, the Metropolitan Water District enforced mandatory water conservation rules to its member agencies, that if not followed are punished by monetary penalties. Three Valleys Municipal Water District (TVMWD), one of the twenty six Metropolitan member agencies, witnessed that its allotment of annual water deliveries from the Metropolitan Water District decreased 10% from 70,000 acre-feet to 63,000 acre-feet (TVMWD, 2012). Three Valleys services nearly 500,000 people in 9 cities, as shown in Figure 3. Three Valleys has been planning to make up for the cut by bolstering its water supply through more efficient use of its groundwater supply, since a portion of its service area encompasses a small groundwater basin called the Six Basins.

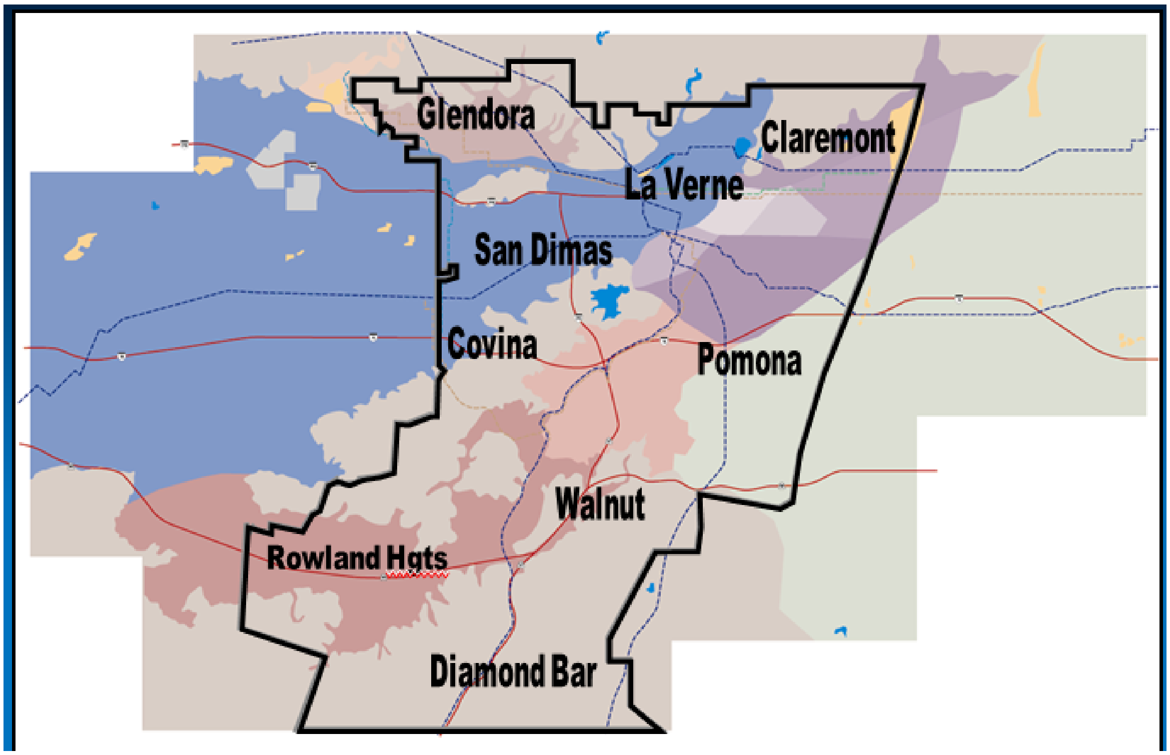


Figure 3: Three Valleys Municipal Water District's Service Area (TVMWD, 2012)

The Six Basins refers to the region of the cities of Claremont, La Verne, Pomona and Upland, and surrounding unincorporated areas of Los Angeles and San Bernardino counties within Southern California. This land mass overlies six interconnected groundwater basins. These basins include Canyon, Upper Claremont Heights, Lower Claremont Heights, Pomona, Live Oak, and Ganesha Basins. The Six Basins has member agencies that oversee the management of the groundwater within the basin and all have several monitoring and pumping wells. These member agencies include The City of Upland, The City of Pomona, The City of La Verne, Golden State Water Company, Pomona College, Pomona Valley Protection Agency, San Antonio Water Company, and Three Valleys Municipal Water District.

No mapping of the Six Basins has been conducted using sophisticated programs like ArcGIS, and in light of groundwater's increasing importance within this region, it would be interesting to see how groundwater pumping affects the Six Basins.

1.2 PROJECT OBJECTIVE

The objective of this term project is to map the Six Basins using ArcGIS and to try and determine how the groundwater basins are affected by groundwater pumping.

1.3 PROJECT EXECUTION

The following steps will be taken to meet the Project Objective:

1) Delineate the Six Basins and its six subwatersheds using ArcGIS and various sources.
2) Determine the geology and soil characteristics within the subwatersheds.
3) Determine the annual precipitation within Six Basins using USGS and other sources.
4) Create a 2D soil cross section of the Six Basins using Boring Logs of three monitoring wells.
5) Using the 2D soil cross section, determine a weighted average porosity of the Six Basins.
6) Locate and gather information on all of the pumping wells and static water level monitoring wells within the Six Basins.
   a) Locate the pumping wells and static water level monitoring wells in global coordinates.
   b) Request static water level data of the monitoring wells from the Six Basins Watermaster. Add the static water level data using Excel to ArcGIS.
   c) Request pumping water level data of the pumping wells from the Six Basins Member Agencies. Add the pumping water level data using Excel to ArcGIS.
7) Determine the average static groundwater elevation and pumping groundwater elevation using the Thiessen Polygon Tools in ArcGIS.
8) Determine the storage capacity of the Six Basins using the weighted porosity and average static groundwater elevations and pumping groundwater elevations.
9) Model the basin, if possible in ArcGIS, for the following scenarios and make comparisons:
   a) With and without pumping the aquifer.

2 SIX BASINS

2.1 SIX BASINS DESCRIPTION

Six Basins is the name for the six interconnected groundwater basins underlying north eastern Los Angeles County and western San Bernardino County, specifically the cities of Pomona, Claremont, La Verne and Upland. The Six Basins are comprised of the Ganesha, Live Oak, Pomona, Lower Claremont Heights, Upper Claremont Heights, and Canyon Basins. The Six Basins area is bounded by the San Jose Hills to the south, the Chino Basin to the south and east, the San Gabriel Mountains to the north and the Main San Gabriel Basin to the west (TVMWD, 2012).

2.2 SIX BASINS DELINEATION

A digital elevation model (dem) was found through the United States Geological Survey that spanned the Los Angeles and San Bernardino county (USGS, 2012). This dem was used to aid in the delineation of the Six Basins, as shown in Figure 4. The Six Basins drains into Puddingstone Reservoir, where an outlet point was placed. Using the outlet point, the dem, and ArcGIS Spatial Analyst Tools, the Six Basins was delineated as shown in Figure 5. The individual boundaries of the Six Basins were created by adding shapefiles that were requested from Three Valleys Municipal Water District, the former Six Basins Watermaster, as shown in Figure 5.

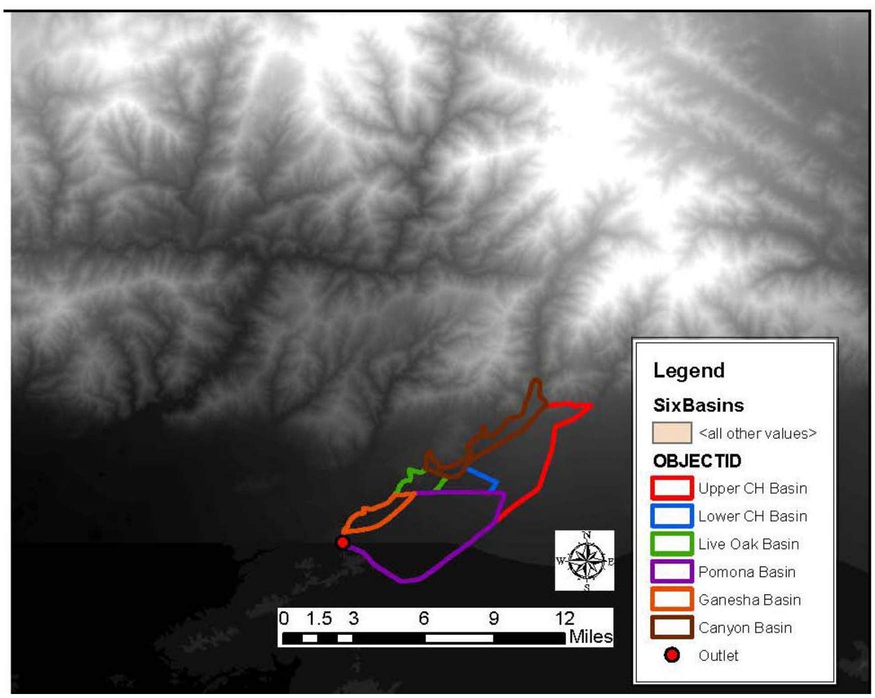


Figure 4: Digital Elevation Model of the Six Basins

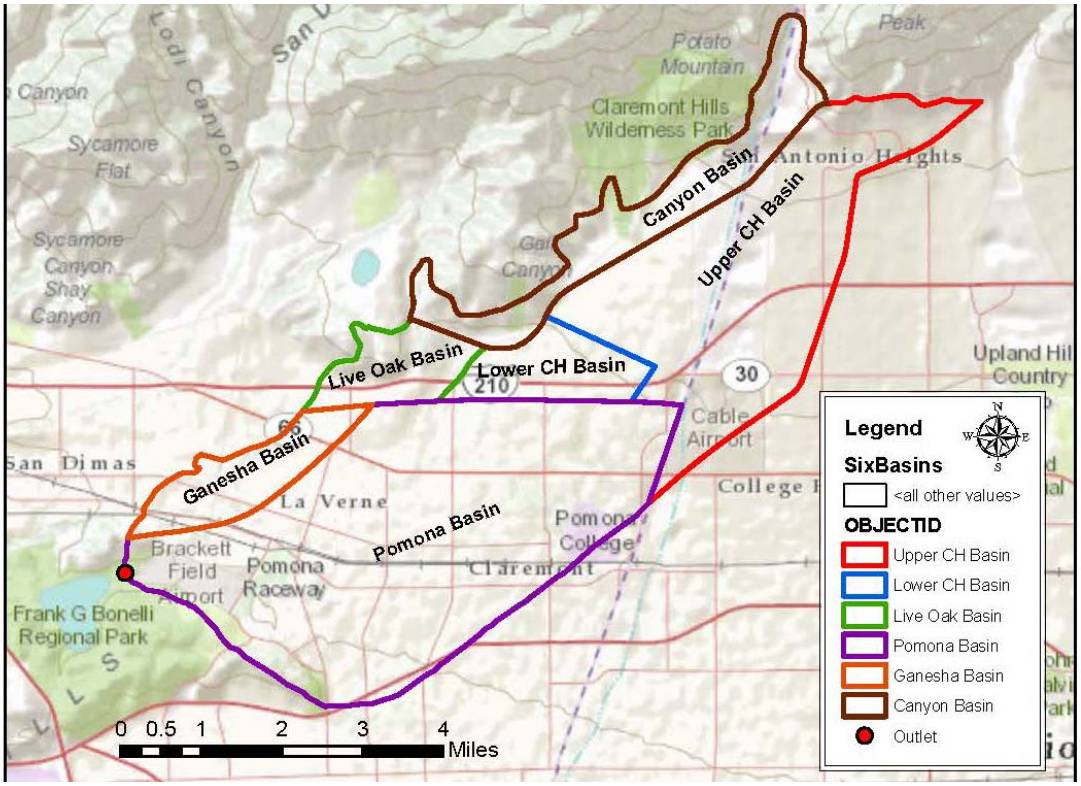


Figure 5: Six Basins Delineated

The Six Basins lies within five HUC12 Subwatersheds that span the Los Angeles and San Bernardino Counties within Southern California. The data was found off the United States Geological Survey (USGS) website and uploaded to ArcGIS. These HUC12 Subwatersheds include 180701060402, 180701060501, 180702030702, 180702030703, 180702030706, as shown in Figure 6.

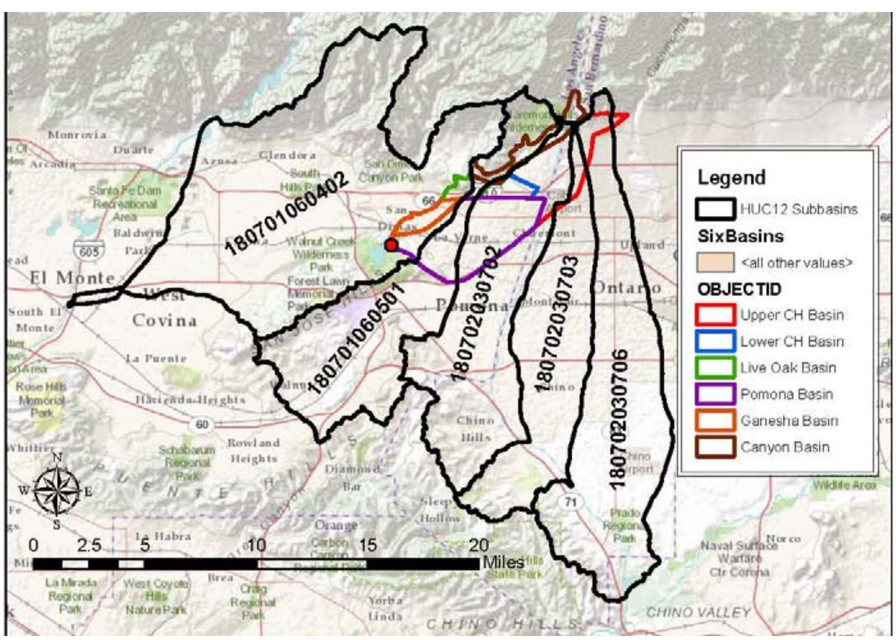


Figure 6: HUC12 Subwatersheds encompassing the Six Basins

3 SIX BASINS MONITORING WELLS

3.1 MONITORING WELL DESCRIPTION

There are nine monitoring wells throughout the Six Basins, where their general locations are provided in Figure 7. These monitoring wells include Ford, MW-1, MW-2, MW-3, Old Baldy Tunnel #4, Pomona #1, Pomona #20, SAWC #28, and SAWC #33. These monitoring wells' latitude, longitude, well address, ground surface elevation (GSE), and well depths were collected from the Six Basins Watermaster and are provided in Table 1, where this data was compiled using Excel and added to ArcGIS, resulting in what is shown in Figure 7.

These monitoring wells continuously measure the static water depth of the groundwater table at their respective locations using radio pulses. The radio pulses that bounce off the groundwater surface return to the transducers within the monitoring well and are converted to depth to water measurements and static groundwater elevations. These measurements are compiled into formats that are compatible with Excel. Monthly static water level elevations for 2010 were used in Section 17, to determine the storage capacity of the Six Basins, and in Section 18, to model the groundwater elevations of the Six Basins.

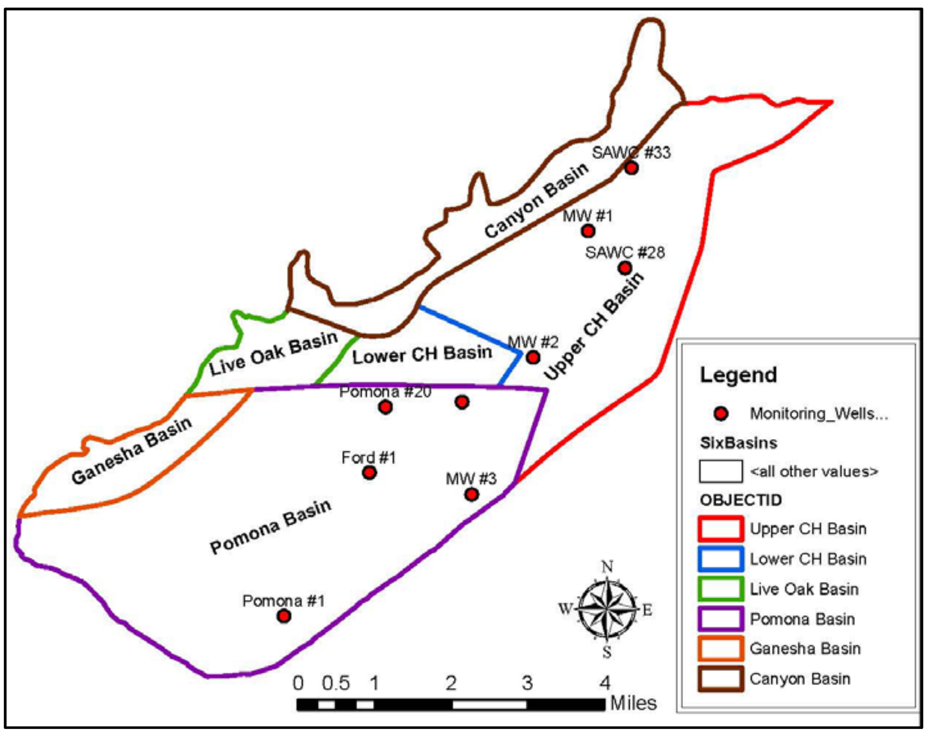


Figure 7: Monitoring Well Locations within the Six Basins

Table 1: Six Basins Monitoring Wells Parameters added to ArcGIS

Monitoring Well	Owner	Latitude (°N)	Longitude (°W)	Well Address	GSE (ft)	Well Depth (ft)
Ford #1	SAWC	34.10396944	-117.7288889	806 W. 10th Street, Claremont, CA	1,168.0	442.0
MW #1	Six Basins	34.14162587	-117.6876145	1098 Pomello Drive, Claremont, CA	1,852.8	390.0
MW #2	Six Basins	34.12190631	117.6980135	1007 E. Baseline, Claremont, CA	1,527.2	390.0
MW #3	Six Basins	34.10056077	117.7096031	NW Corner of Amherst & 6th Street in Pomona College Parking Lot, Claremont, CA	1,228.8	490.0
Old Pomona Tunnel #4	Pomona	34.11498611	-117.7114278	1674 Longwood Avenue, Claremont, CA	1,369.0	238.0
Pomona #1	Pomona	34.08157778	-117.7450306	406 E. La Verne Ave. Pomona, CA	995.0	400.0
Pomona #20	Pomona	34.11419167	-117.7258583	1630 Oxford Avenue, Claremont, CA	1,296.0	420.0
SAWC #28	SAWC	34.13586111	-117.6806667	2044 Birkdale Avenue, Upland, CA	1,757.0	429.0
SAWC #33	SAWC	34.15146667	-117.67945	1689 W. 24th Street, Upland, CA	2,027.0	340.0

4 FORD MONITORING WELL

4.1 MONITORING WELL DESCRIPTION

Ford is one of the nine monitoring wells within the Six Basins. This monitoring well is located within the Pomona Basin of the Six Basins, as shown in Figure 8. It is located at 806 W. 10th Street Claremont, CA. The Latitude and Longitude for this location is 34°06’13”N and 117°43’44”W, respectively. It is currently owned by the San Antonio Water Company (TVMWD, 2012). This monitoring well was drilled in 2002 and reaches a depth of 442 feet. Table 2 includes the characteristics of this well and Figure 8 and Figure 9 provide its regional and specific location.

Table 2: Ford Monitoring Well Description

Characteristics	Description
Monitoring Well Name	Ford
Owner	San Antonio Water Company
Ground Surface Elevation	1,168 ft
Depth of Monitoring Well	442 ft
Year Drilled	2002
Global Coordinates	Latitude: 34°06’13”N Longitude: 117°43’44”W
Nearest Address/Cross Street	806 W. 10th Street Claremont, CA

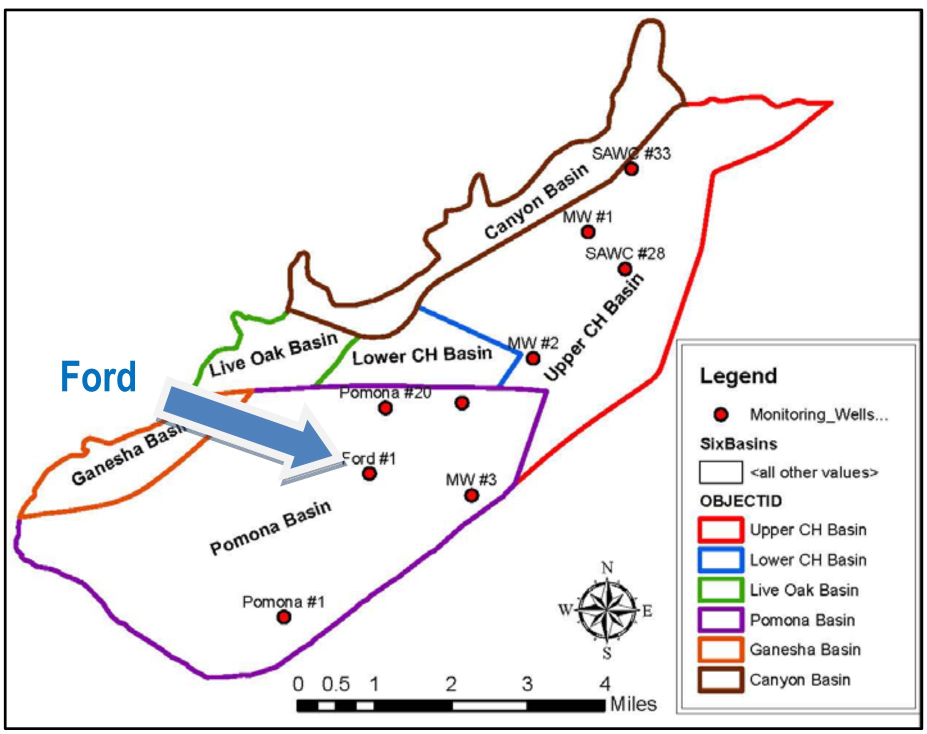


Figure 8: Regional Location of Ford within the Six Basins

Google Maps (2012) (Satellite)

Site Visit

Figure 9: Ford Monitoring Well Specific Location

4.2 TRANSDUCER HYDROGRAPH DESCRIPTION

Ford has been monitored since September 1, 2002 and initially recorded a relatively constant static groundwater elevation of 1,040.0 feet (ft), as shown in Figure 10. The Six Basins experienced a brief, but intense rainfall at the beginning of 2005, resulting in a sharp increase in static groundwater elevation, peaking in April 2006 at 1,100.0 ft. Since April 2006, the static groundwater elevation levels gradually subsided to 1,040.0 ft by June 2007. The monitoring well's equipment became faulty after May 2009, recording the rapid declines as shown in Figure 10. By May 2010, the equipment was fixed and recorded a constant static groundwater elevation at about 1,020.0 ft.

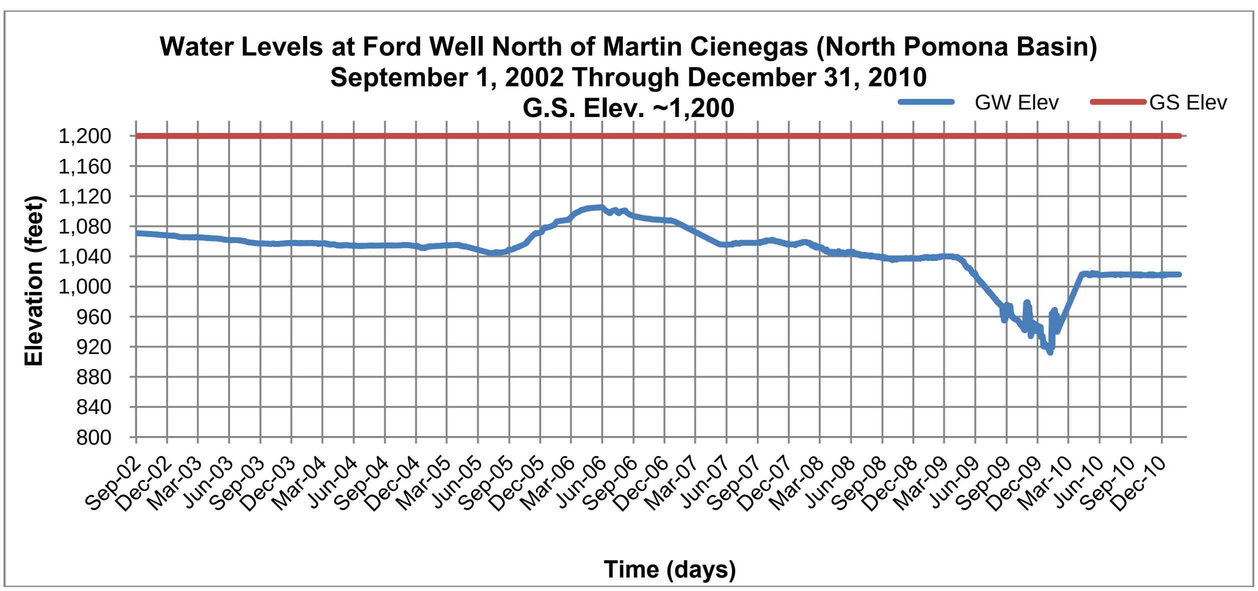


Figure 10: Ford Transducer Hydrograph

5 MW-1 MONITORING WELL

5.1 MONITORING WELL DESCRIPTION

MW-1 is one of the nine monitoring wells within the Six Basins. This monitoring well is located within the Upper Claremont Heights Basin of the Six Basins, as shown in Figure 11. Its exact location is Latitude 34°08'29.9"N and Longitude 117°41'15.4"W. It is located in Claremont, California at 1098 Pomello Drive, Claremont, CA and is owned by the Six Basins (TVMWD, 2012). This monitoring well was drilled in 2003 and reaches a depth of 390 ft. Table 3 includes the characteristics of this well and Figure 11 and Figure 12 provide regional and specific locations of the monitoring well, respectively.

Table 3: MW-1 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	MW-1
Owner	Six Basins
Ground Surface Elevation	1,852.8
Depth of Monitoring Well	390 ft
Year Drilled	2003
Global Coordinates	Latitude: 34°08'29.9"N Longitude: 117°41'15.4"W
Nearest Address/Cross Street	1098 Pomello Drive, Claremont, CA

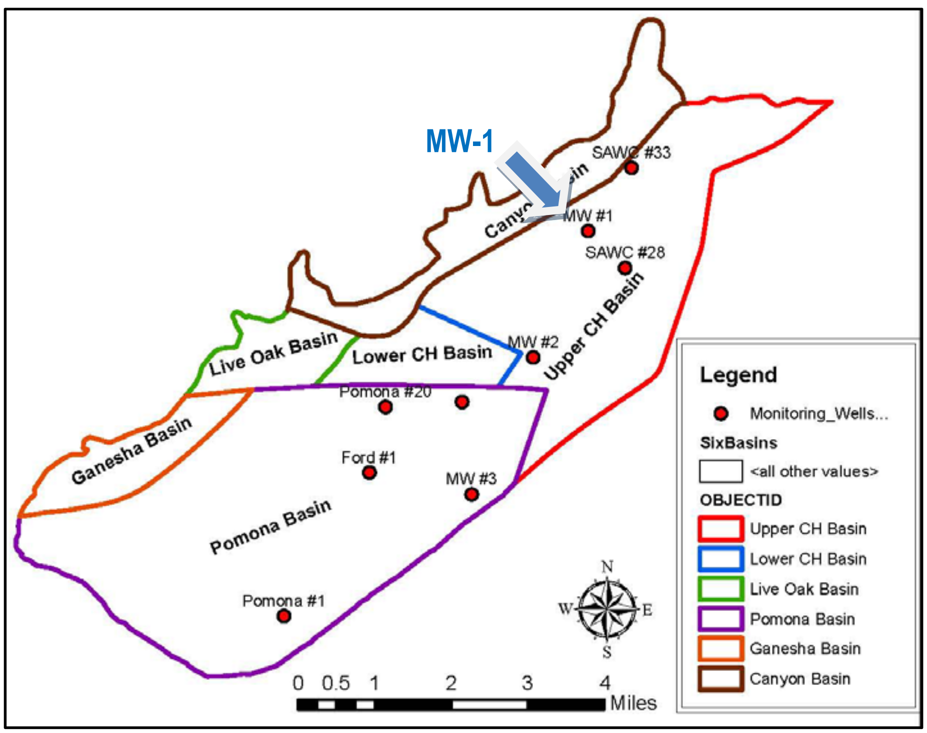


Figure 11: Regional Location of MW-1 within the Six Basins

Figure 12: MW-1 Monitoring Well Specific Location, (Google Maps, 2012)

5.2 TRANSDUCER HYDROGRAPH DESCRIPTION

MW-1 has been monitored since April 21, 2004, initially recording a static groundwater elevation of about 1,560.0 ft, as shown in Figure 13. MW-1 recorded two extreme increases in static groundwater elevations at the beginning of 2005 and 2006. The static groundwater elevation rapidly increased 200 ft in groundwater elevation at the beginning of 2005, peaking at about 1,730.0 ft in April 2005, followed by a rapid decline to about its initial static groundwater level recording. At the beginning of 2006, the Six Basins experienced another brief, but intense rainfall, resulting in a sharp increase in static groundwater elevation of about 150 ft, peaking at a static groundwater elevation of 1,680.0 ft in May 2006. Since May 2006, the static groundwater elevation declined and has remained relatively constant, at its original static groundwater elevation, only increasing above 1,600.0 ft at the beginning of 2008 and the middle of 2010. At the end of 2010, another intense rainfall occurred, raising the static groundwater elevation to 1,650.0 ft.

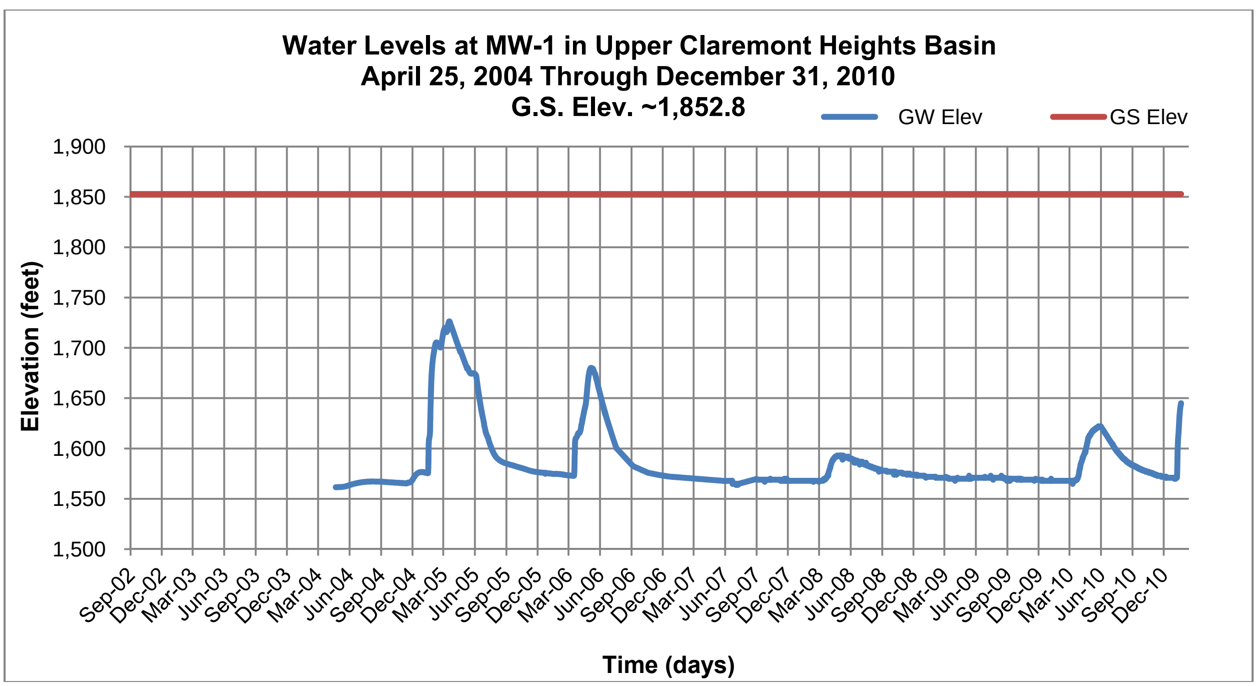


Figure 13: MW-1 Transducer Hydrograph

6 MW-2 MONITORING WELL

6.1 MONITORING WELL DESCRIPTION

MW-2 is one of the nine monitoring wells within the Six Basins, as shown in Figure 14. This monitoring well is located in the Upper Claremont Heights Basin of the Six Basins. Its exact location is Latitude 34°07'18.8"N and Longitude 117°41'52.8"W. It is located in Claremont, California at 1007 E. Baseline, Claremont, CA and is owned by the Six Basins (TVMWD, 2012). This monitoring well was drilled in 2003 and reaches a depth of 390 ft. Table 4 provides the characteristics of this well and Figure 14 and Figure 15 provide its regional and specific location, respectively.

Table 4: MW-2 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	MW-2
Owner	Six Basins
Ground Surface Elevation	1,527.2
Depth of Monitoring Well	390 ft
Year Drilled	2003
Global Coordinates	Latitude: 34°07'18.8"N Longitude: 117°41'52.8"W
Nearest Address/Cross Street	1007 E. Baseline, Claremont, CA

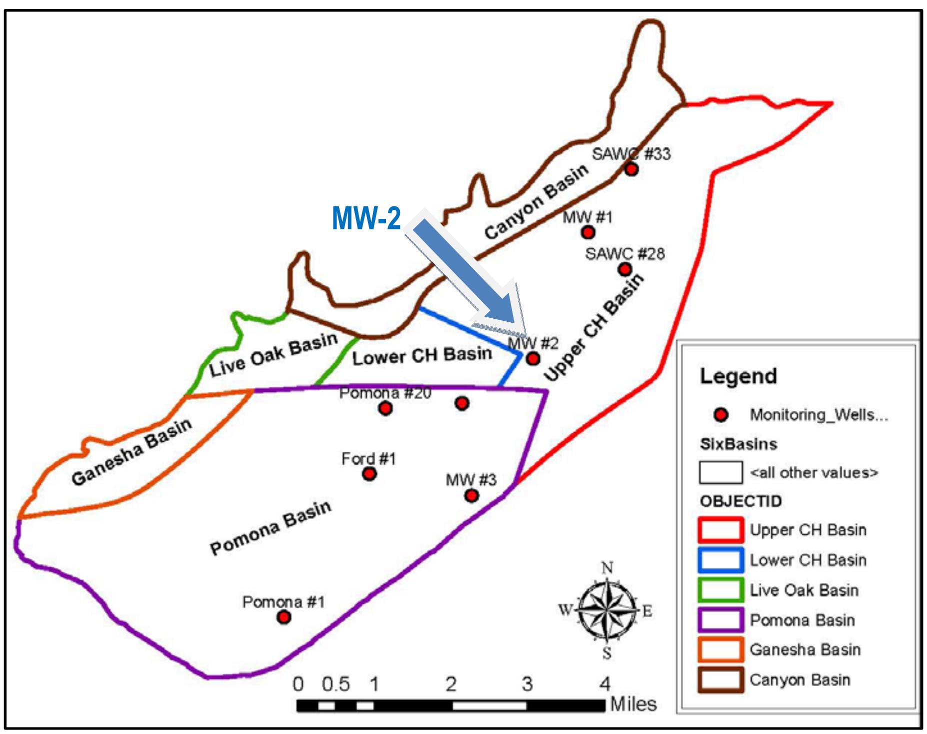


Figure 14: Regional Location of MW-2 within the Six Basins

Google Maps (2012) (Satellite)

Site Visit

Figure 15: MW-2 Monitoring Well Specific Location

6.2 TRANSDUCER HYDROGRAPH DESCRIPTION

MW-2 has been monitored since February 15, 2003 and initially recorded a constant static groundwater elevation of 1,280.0 ft, as shown in Figure 16. After March 2005, the Six Basins experienced a brief, but intense rainfall event, resulting in an extreme increase of about 150 ft in groundwater elevation, peaking just under 1,450.0 ft in June 2005. After June 2005, the static groundwater elevations gradually decreased 100 ft to a static groundwater elevation just above 1,350.0 ft in June 2006, but rapidly increased about 25 ft in July 2006 due to another small intense rainfall. Since July 2006, the static groundwater elevations have gradually declined to 1,320.0 ft by March 2008 and stabilized around a static groundwater elevation around 1,340.0 ft, only to gradually increase in static groundwater elevation from September to December 2010.

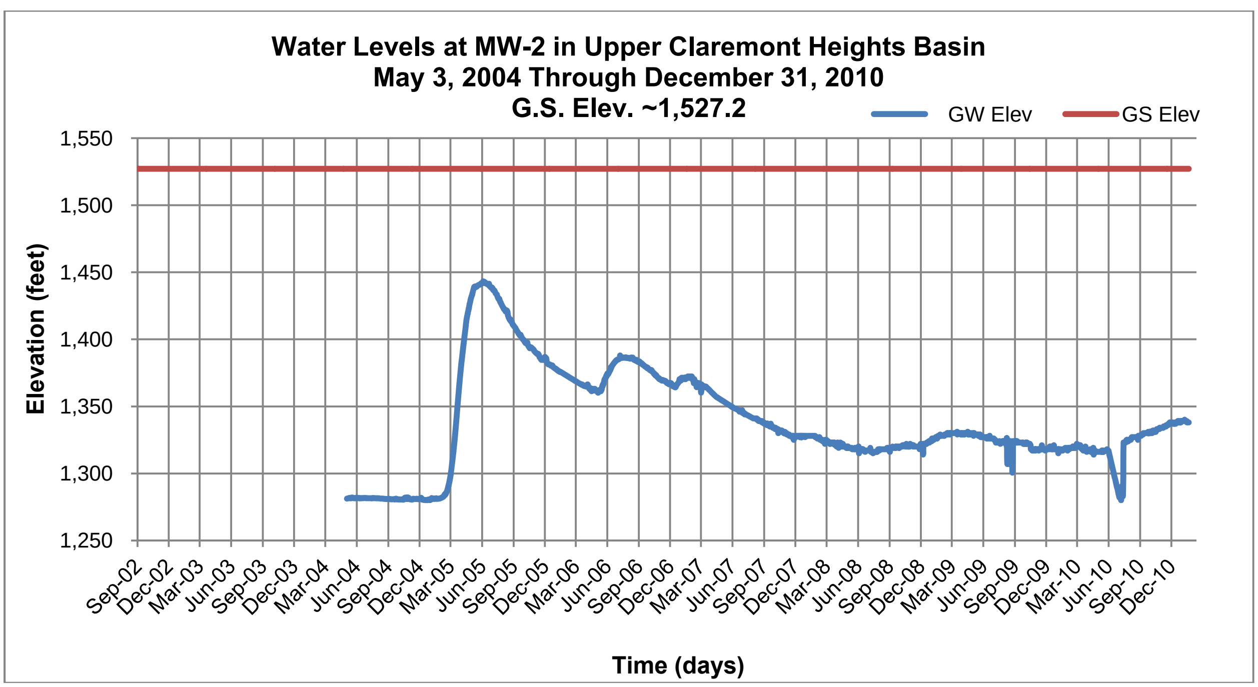


Figure 16: MW-2 Transducer Hydrograph

7 MW-3 MONITORING WELL

7.1 MONITORING WELL DESCRIPTION

MW-3 is one of the nine monitoring wells within the Six Basins. This monitoring well is located within the Pomona Basin of the Six Basins, provided in Figure 17. Its exact location is Latitude 34°06'2.0"N and Longitude 117°42'34.6"W. It is located in the Claremont Colleges at the northwest corner of Amherst and 6th Street in Claremont, CA and is owned by the Six Basins (TVMWD, 2012). This monitoring well was drilled in 2003 and reaches a depth of 490 ft. Table 5 provides the characteristics of this well and Figure 17 and Figure 18 provide its regional and specific location, respectively.

Table 5: MW-3 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	MW-3
Owner	Six Basins
Ground Surface Elevation	1,228.8 ft
Depth of Monitoring Well	490 ft
Year Drilled	2003
Global Coordinates	Latitude: 34°06'2.0"N Longitude: 117°42'34.6"W
Nearest Address/Cross Street	Amherst and 6th St. Claremont, CA

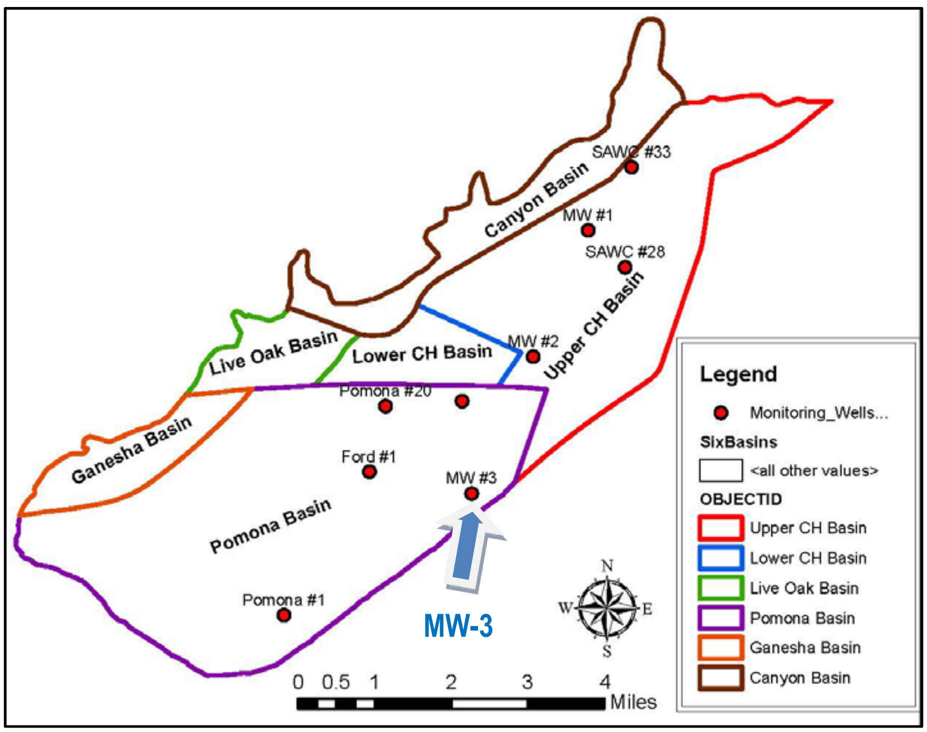


Figure 17: Regional Location of MW-3 in the Six Basins

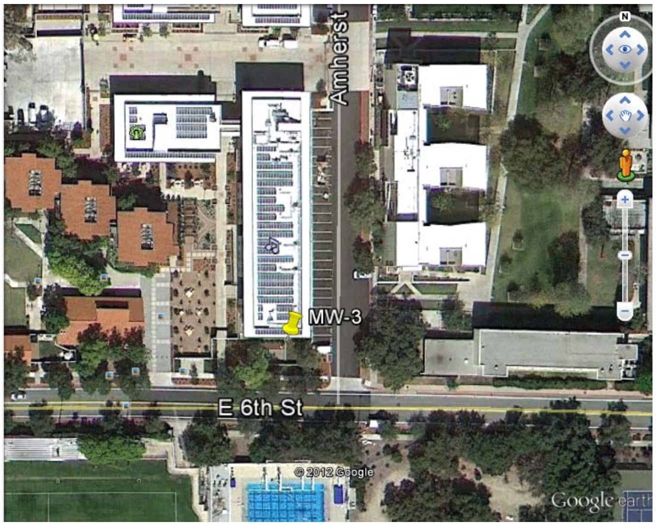


Figure 18: MW-3 Monitoring Well Specific Location, (Google Maps, 2012)

7.2 TRANSDUCER HYDROGRAPH DESCRIPTION

MW-3 has been monitored since April 21, 2004 and initially recorded a constant static groundwater elevation of just above 1,050.0 ft, as shown in Figure 19. In July 2005, the monitoring well recorded an extreme increase of about 75 ft in static groundwater elevation, peaking around 1,130.0 ft in January 2006, then gradually decreased 80 feet in groundwater elevation to about 1,060.0 ft between January 2006 through 2010. Back in 2005, the groundwater elevation dramatically increased due the intense storms that occurred within the Six Basins. However, the storm most likely occurred in the six months that preceded the dramatic increase because the well is quite south within the Six Basins, requiring significantly more time for the groundwater to percolate into the aquifer and raise the groundwater level at the location of MW-3.

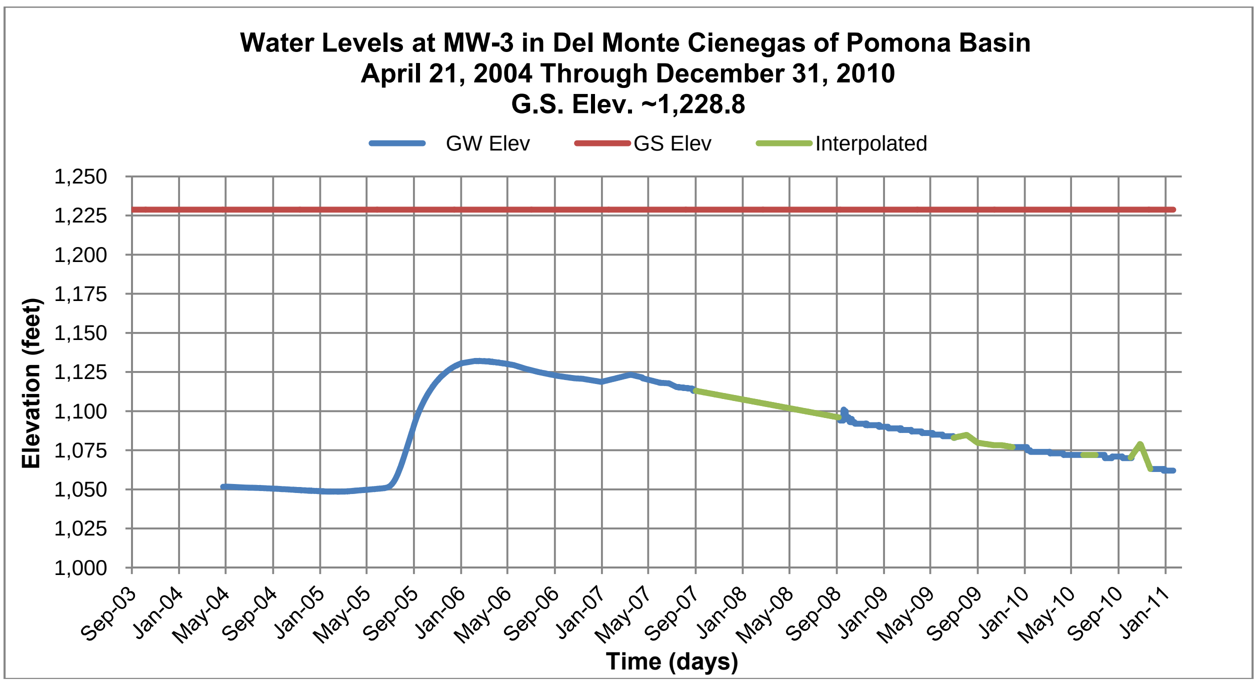


Figure 19: MW-3 Transducer Hydrograph

8 OLD BALDY TUNNEL #4 MONITORING WELL

8.1 MONITORING WELL DESCRIPTION

Old Baldy #4 is one of the nine monitoring wells within the Six Basins. This monitoring well is located within the Pomona Basin of the Six Basins, as shown in Figure 20. Its exact location is Latitude 34º6'53.9"N and Longitude 117º42'41.1"W. It is located in Claremont, California at 1674 Longwood Avenue and is owned by the City of Pomona (TVMWD, 2012). This monitoring well was drilled in 2001 and reaches a depth of 238 feet. Table 6 includes the characteristics of this well and Figure 20 and Figure 21 provide its regional and specific location, respectively.

Table 6: Old Baldy Tunnel #4 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	Old Baldy #4
Owner	City of Pomona
Ground Surface Elevation	1,369 ft
Depth of Monitoring Well	238 ft
Year Drilled	2001
Global Coordinates	Latitude: 34º6'53.9"N Longitude: 117º42'41.1"W
Nearest Address/Cross Street	1674 Longwood Ave., Claremont, CA

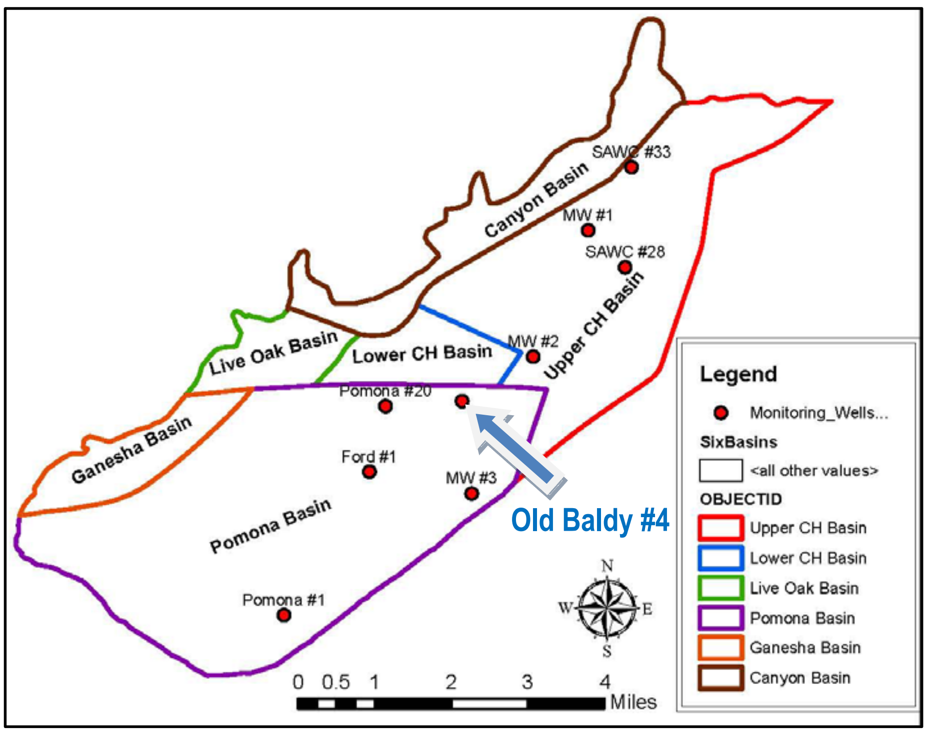


Figure 20: Location of Old Baldy #4 within the Six Basins

Figure 21: Old Baldy #4 Monitoring Well Specific Location

8.2 TRANSDUCER HYDROGRAPH DESCRIPTION

Old Baldy Tunnel #4 has been monitored since September 1, 2002. In Figure 22, the monitoring well recorded significant static water level rises and declines between December 2002 and August 2005 since its initial groundwater elevation of 1,230.0 ft. In the beginning of 2005, the groundwater elevation dramatically increased about 40 ft to a peak static groundwater elevation of 1,300.0 ft in July 2005, due the intense storms that occurred within the Six Basins in the preceding months. After July 2005, the static groundwater levels gradually declined 50 ft and have been stable at 1,250.0 ft ever since.

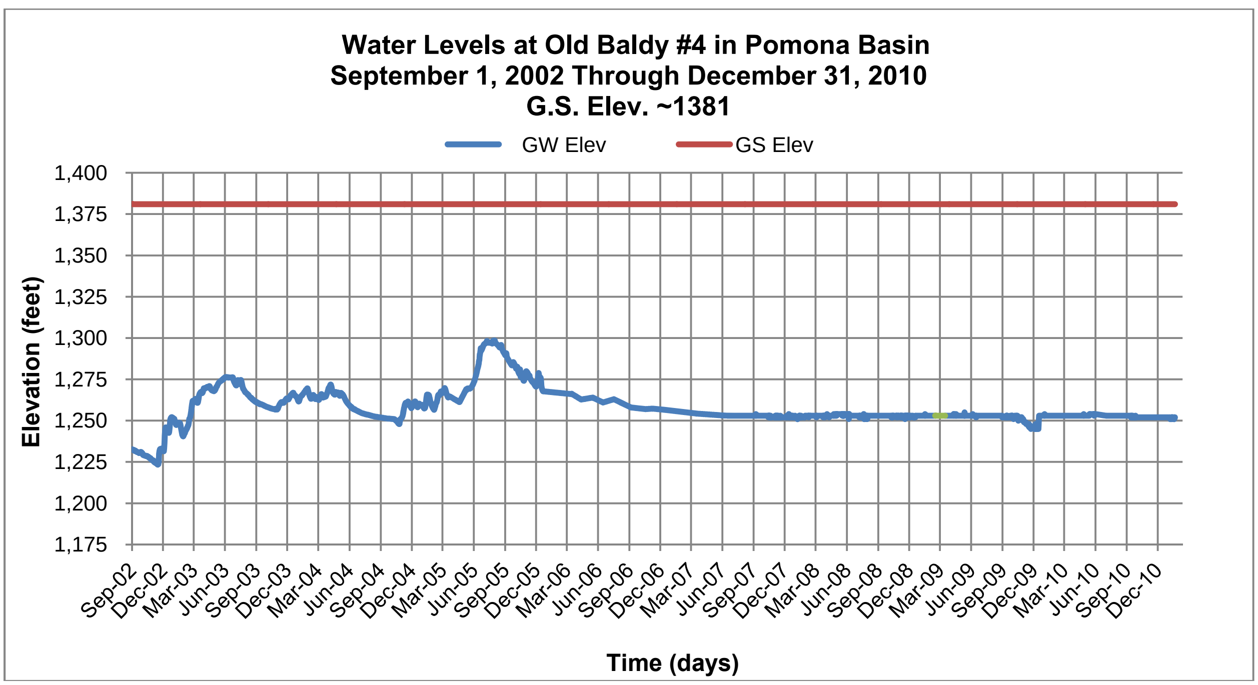


Figure 22: Old Baldy #4 Transducer Hydrograph

9 POMONA #1 MONITORING WELL

9.1 MONITORING WELL DESCRIPTION

Pomona #1 is one of the nine monitoring wells within the Six Basins. This monitoring well is located in the southernmost portion of the Pomona Basin within the Six Basins, as shown in Figure 23. Its exact location is Latitude 34º4'53.7"N and Longitude 117º44'42.1"W. It is located at 406 E. La Verne Avenue, Pomona, CA and is owned by the City of Pomona (TVMWD, 2012). This monitoring well was drilled in 2002 and reaches a depth of 400 feet. Table 7 includes the characteristics of this well and Figure 23 and Figure 24 provide its regional and specific location, respectively.

Table 7: Pomona #1 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	Pomona #1
Owner	City of Pomona
Ground Surface Elevation	995 ft
Depth of Monitoring Well	400 ft
Year Drilled	2002
Global Coordinates	Latitude: 34º4'53.7"N Longitude: 117º44'42.1"W
Nearest Address/Cross Street	406 E. La Verne Avenue, Pomona, CA

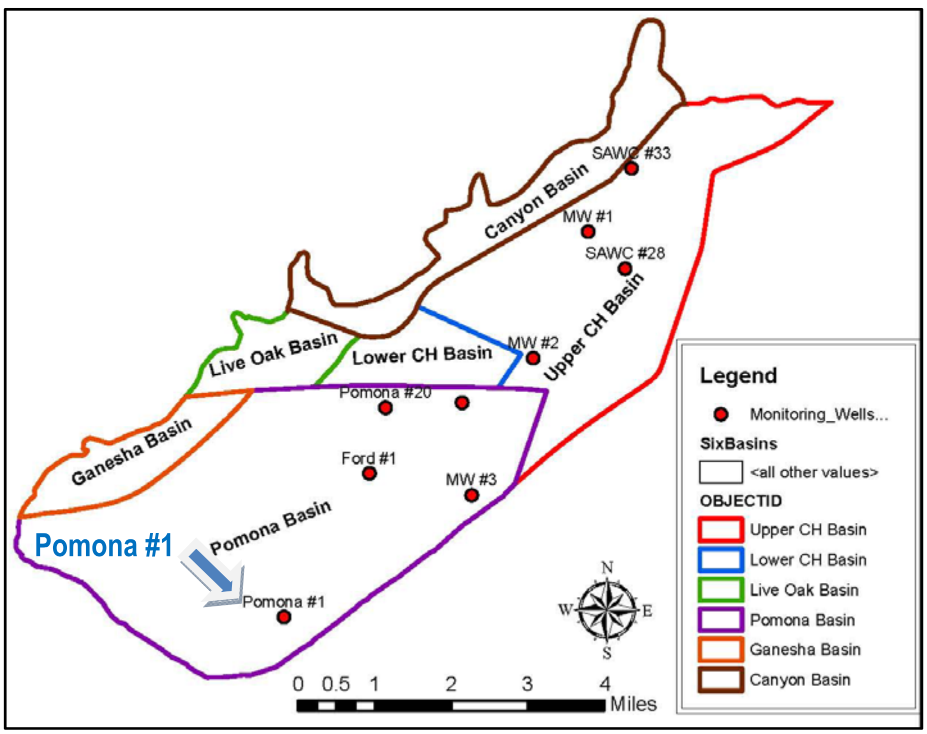


Figure 23: Location of Pomona #1 within the Six Basins

Figure 24: Pomona #1 Monitoring Well Specific Location, (Google Maps, 2012)

9.2 TRANSDUCER HYDROGRAPH DESCRIPTION

Pomona #1 has been monitored since September 1, 2002, as shown in Figure 25. The monitoring well recorded an initial static groundwater elevation of 970.0 ft, but since recorded significant static water level rises and declines between May 2005 and the end of 2010 because Pomona #1 is located near a groundwater spreading basin owned and operated by the Chino Basin Watermaster. Stormwater captured in the adjacent basin is spread and allowed to percolate into the groundwater aquifer, resulting in frequent rises and declines in static groundwater elevation. Between May 2006 and September 2007 the static groundwater elevation remained constant at 940.0 ft. However, the Chino Basin Watermaster began spreading groundwater in late 2007. In April 2008, April 2009, and April 2010, the static groundwater elevation peaked at 975.0 ft, 970.0 ft, and 955.0 ft, and began to rise again in late 2010.

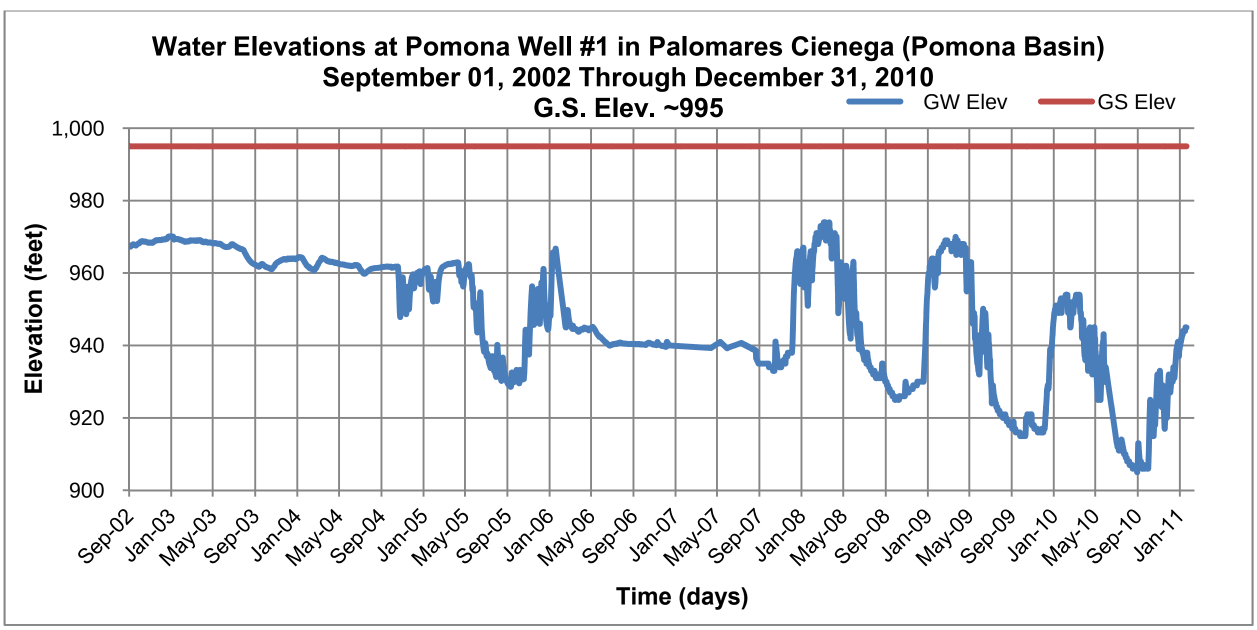


Figure 25: Pomona #1 Transducer Hydrograph

10 POMONA #20 MONITORING WELL

10.1 MONITORING WELL DESCRIPTION

Pomona #20 is one of the nine monitoring wells within the Six Basins. This monitoring well is located in the northernmost part of Pomona Basin of the Six Basins, as shown in Figure 26. Its exact location is Latitude 34º6’51.1”N and Longitude 117º43’33.1”W. It is located at 1630 Oxford Avenue, Claremont, CA and is owned by the City of Pomona (TVMWD, 2012). This monitoring well was drilled in 2002 and reaches a depth of 420 feet. Table 8 includes the characteristics of this well and Figure 26 and Figure 27 provide its regional and specific location, respectively.

Table 8: Pomona #20 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	Pomona #20
Owner	City of Pomona
Ground Surface Elevation	1,296 ft
Depth of Monitoring Well	420 ft
Year Drilled	2002
Global Coordinates	Latitude: 34º6’51.1”N Longitude: 117º43’33.1”W
Nearest Address/Cross Street	1630 Oxford Avenue, Claremont, CA

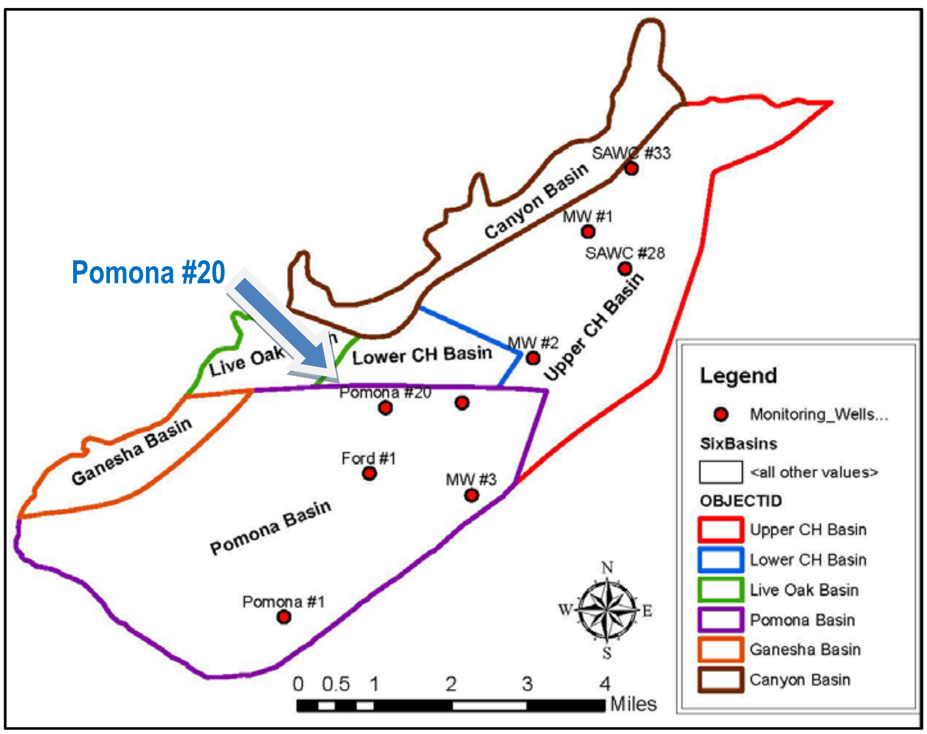


Figure 26: Location of Pomona #20 within the Six Basins

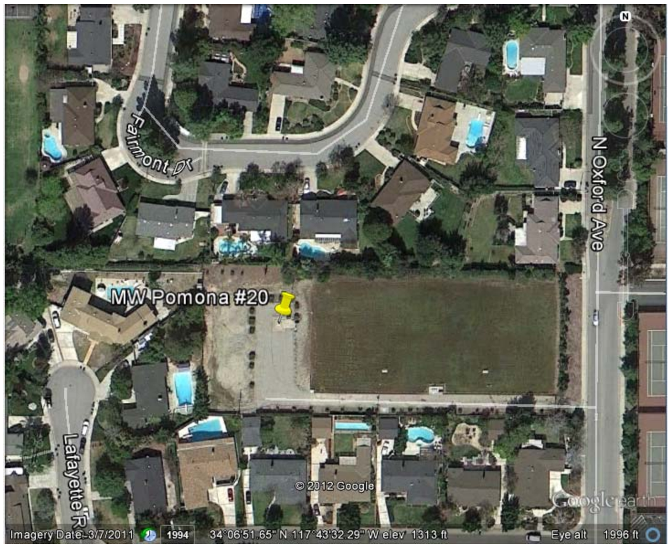


Figure 27: Pomona #20 Specific Location, (Google Maps, 2012)

10.2 TRANSDUCER HYDROGRAPH DESCRIPTION

Pomona #20 has been monitored since September 1, 2002 and recorded an initial static groundwater elevation of 1,200.0 ft that remained constant until November 2005, as shown in Figure 28. At the end of 2005, the static groundwater elevation began to rise due to the intense rainfall that occurred within the Six Basins, which resulted in a sharp rise of 60.0 ft, peaking at 1,260.0 ft in July 2005. After July 2005, the static groundwater elevation gradually declined 40.0 ft to 1,210.0 ft by May 2009. The monitoring well's electronics stopped working after that time, recording inaccurate static groundwater elevations.

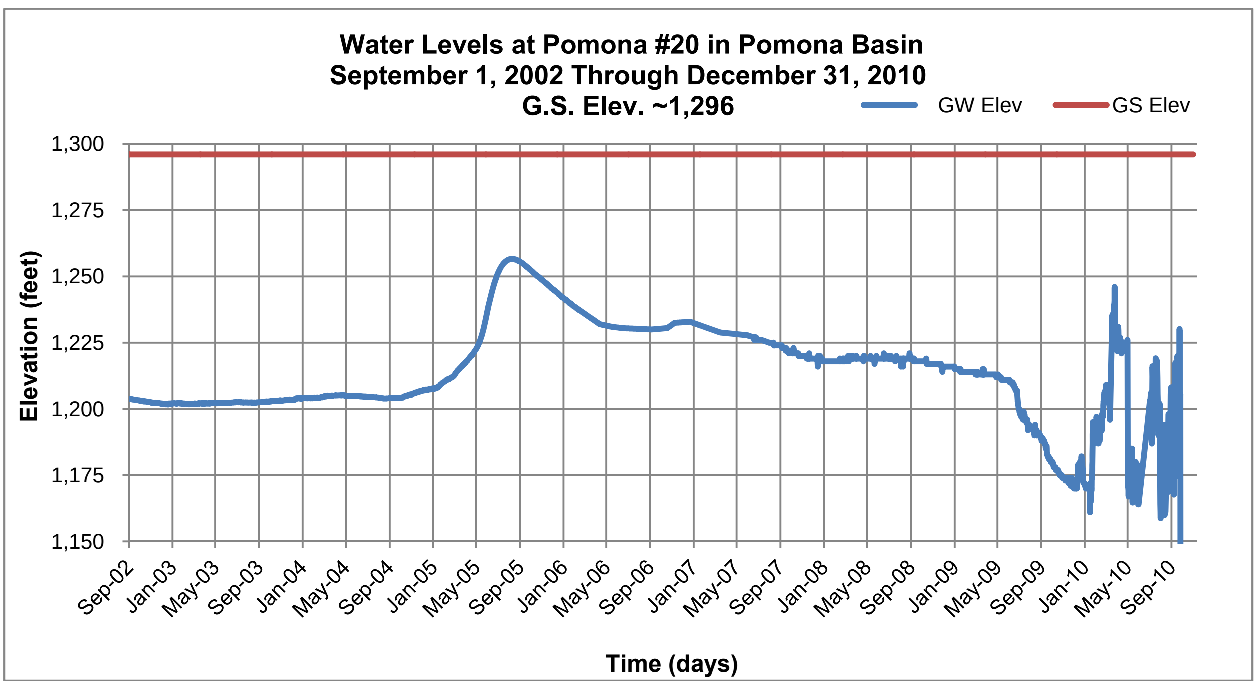


Figure 28: Pomona #20 Transducer Hydrograph

11 SAWC NO. 28 MONITORING WELL

11.1 MONITORING WELL DESCRIPTION

SAWC #28 is one of the nine monitoring wells within the Six Basins. This monitoring well is located within the Upper Claremont Heights Basin of the Six Basins, as shown in Figure 29. Its exact location is Latitude 34°8'9.1"N and Longitude 117°40'50.4"W. SAWC #28 reaches a depth of 429 feet below ground surface. It is located at 2044 Birkdale Avenue in Upland, California. This monitoring well was drilled in 1953 and is owned by the San Antonio Water Company (TVMWD, 2012). Table 9 includes the characteristics of this well and Figure 29 and Figure 30 provides its regional and specific location, respectively.

Table 9: SAWC #28 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	SAWC #28
Owner	San Antonio Water Company
Ground Surface Elevation	1,757.0 ft
Depth of Monitoring Well	429 ft
Year Drilled	1953
Global Coordinates	Latitude: 34°8'9.1"N Longitude: 117°40'50.4"W
Nearest Address/Cross Street	2044 Birkdale Ave, Upland, CA

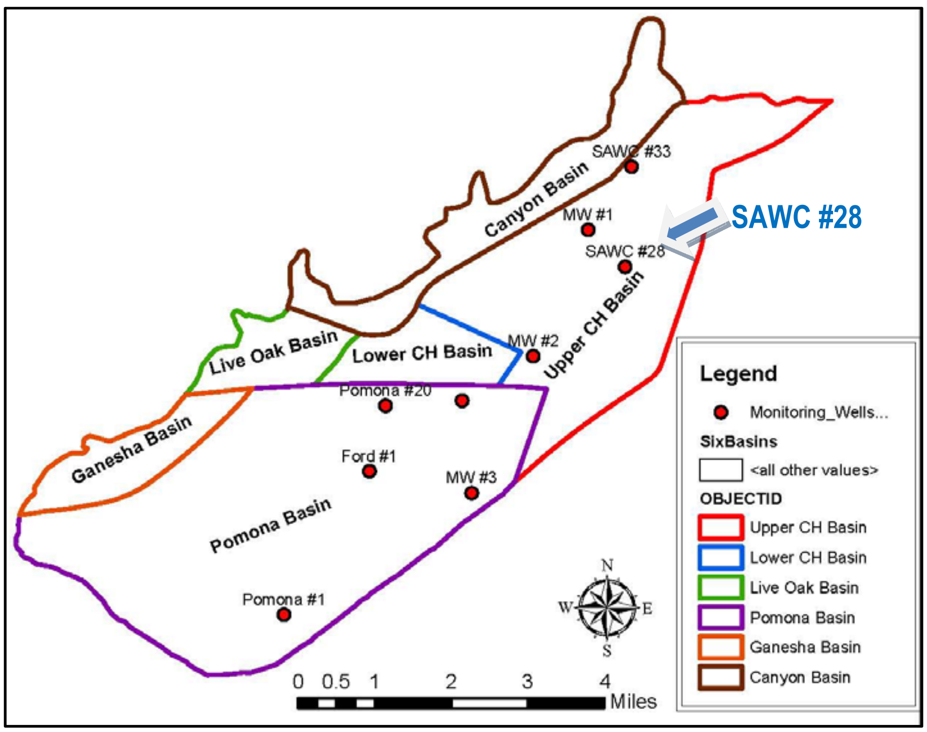


Figure 29: Regional Location of SAWC #28 within the Six Basins

Google Maps (2012) (Satellite)

Site Visit

Figure 30: SAWC #28 Monitoring Well Specific Location

11.2 TRANSDUCER HYDROGRAPH DESCRIPTION

SAWC #28 has been monitored since February 3, 2003, initially recording a constant static groundwater elevation of 1,475.0 ft, as shown in Figure 31. In January 2005, the static groundwater elevation dramatically increased more than 150 ft, peaking in April 2005 at a groundwater elevation of 1630.0 ft due to the significant amount of rainfall in the Six Basins. After April 2005, the groundwater levels subsided below a groundwater elevation of 1,500.0 ft until April 2006. The Six Basins experienced another intense rainfall season, resulting in a static groundwater level increase exceeding 50 ft, where the static groundwater elevation peaked at about 1,550.0 ft in May 2006. After May 2006, the groundwater elevation subsided and has remained relatively constant around 1,480.0 ft, only increasing above 1,500.0 ft in 2008 and 2010 due to small rain events.

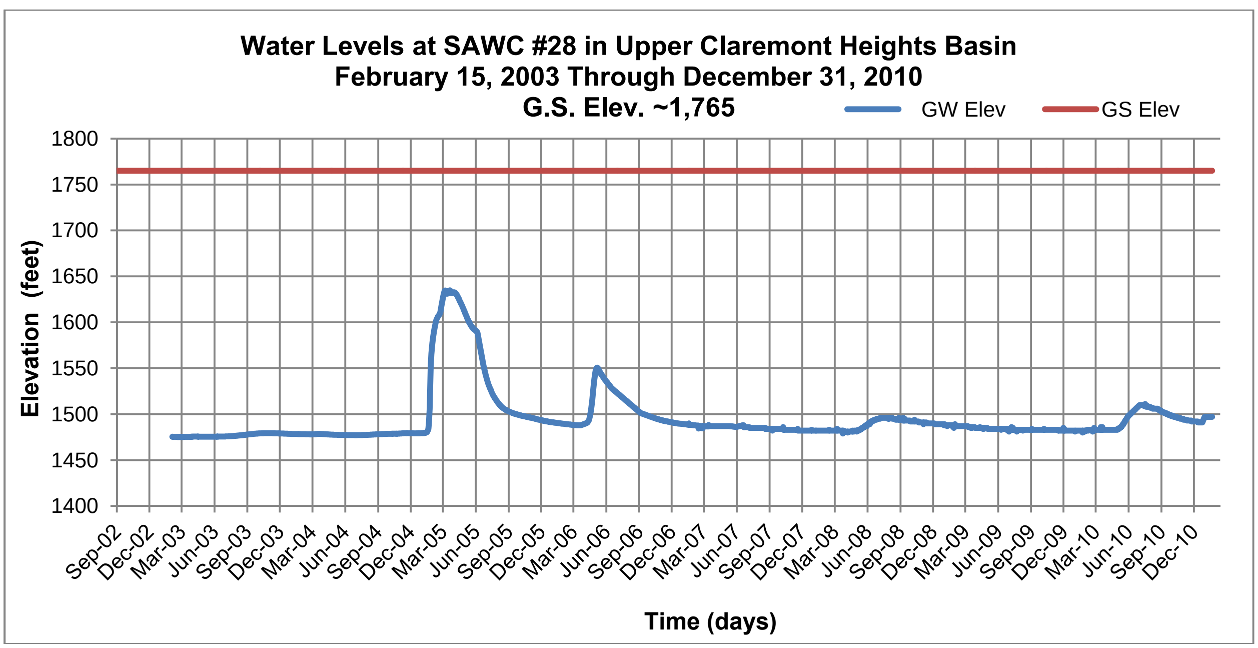


Figure 31: SAWC #28 Transducer Hydrograph

12 SAWC NO. 33 MONITORING WELL

12.1 MONITORING WELL DESCRITION

SAWC #33 is one of the nine monitoring wells within the Six Basins. This monitoring well is located within the Upper Claremont Heights Basin of the Six Basins, as shown in Figure 32. Its exact location is Latitude 34°9.1"N and Longitude 117°40.8"W. It is located at 1689 W. 24th Street, Upland and is owned by San Antonio Water Company, (TVMWD, 2012). This monitoring well was drilled in 2001 and reaches a depth of 340 feet. Table 10 includes the characteristics of this well and Figure 32 and Figure 33 provides its regional and specific location.

Table 10: SAWC #33 Monitoring Well Description

Characteristics	Description
Monitoring Well Name	SAWC #33
Owner	San Antonio Water Company
Ground Surface Elevation	2,027 ft
Depth of Monitoring Well	340 ft
Year Drilled	2001
Global Coordinates	Latitude: 34°9.1"N Longitude: 117°40.8"W
Nearest Address/Cross Street	1689 W. 24th Street, Upland, CA

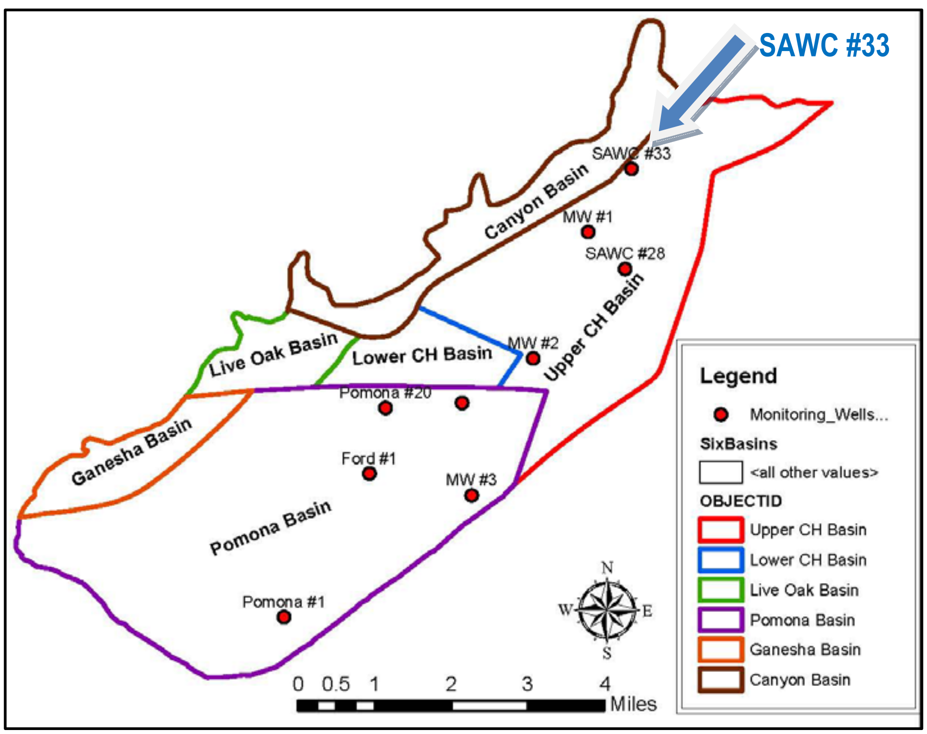
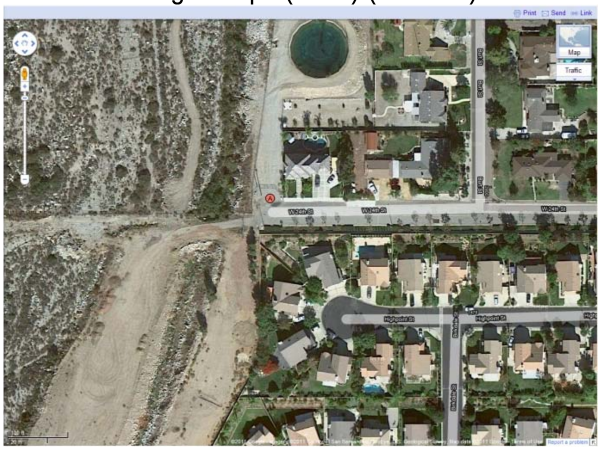


Figure 32: Regional Location of SAWC #33 within the Six Basins

Google Maps (2012) (Satellite)



Site Visit

Figure 33: SAWC #33 Monitoring Well Specific Location

12.2 TRANSDUCER HYDROGRAPH DESCRIPTION

SAWC #33 has been monitored since February 3, 2003 as shown in Figure 34. This monitoring well initially recorded a static groundwater elevation of 1,850.0 ft, but gradually rose in early 2003 and 2004 due to small rainfalls. At the beginning of 2005, the static groundwater elevation sharply rose 75.0 ft to 1,925.0 ft, peaking in April 2005. Since 2005, the monitoring well has gone through long periods of relatively static groundwater levels, followed by sharp static groundwater level rises in April 2006, January 2008, and March 2010 due to rainfall events. The respective peaks in April 2006, January 2008, and March 2010 were 1,900.0 ft, 1,888.0 ft, and 1,895.0 ft. Between these peaks the static groundwater elevation declined back to 1,860.0 ft.

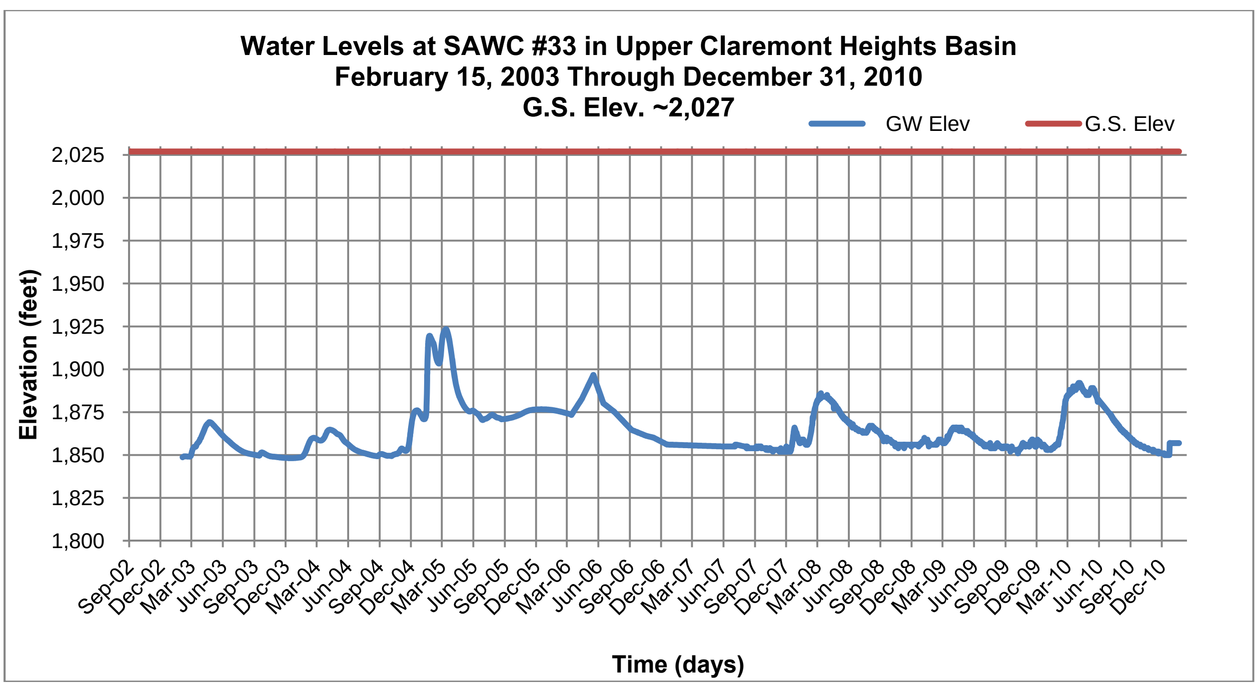


Figure 34: SAWC #33 Transducer Hydrograph

13 SIX BASINS GROUNDWATER PRODUCTION WELLS

13.1 SIX BASINS WATERMASTER GROUNDWATER RIGHTS

The Six Basins Watermaster is a committee (board) whose powers and duties are defined by a Judgment approved by the Los Angeles County Judicial Court. The parties that make up the Six Basins Watermaster are the cities of La Verne, Pomona, Upland, and Claremont, Golden State Water Company (GSWC), Pomona College, West End Consolidated Water Company (WECWC), San Antonio Water Company (SAWC), Three Valleys Municipal Water District (TVMWD), and the Pomona Valley Protective Association (TVMWD, 2012). The allotted groundwater pumping rights per party are shown in Table 11. The major parties in the Watermaster are those with the highest percentage of rights allotted (Six Basins Watermaster, 2012).

Table 11: Pumping Rights Allotted to Six Basins Constituents (CY 2010)

Party to the Judgment	Allotted Rights (AF)	Percent Allotted (%)
Major Parties to the Judgment		
City of La Verne	1,492	7.73
City of Pomona	4,014	20.80
City of Upland	1,842	9.54
GSWC	6,705	34.74
SAWC	1,383	7.17
WECWC	2,972	15.40
Minor Parties to the Judgment		
City of Claremont	535	2.77
Pomona College	357	1.85
PVPA	-	-
TV MWD	-	-
Total	**19,300**	**100**

13.2 SIX BASINS GROUNDWATER PRODUCTION WELLS

Each member agency within the Six Basins has a number of groundwater production wells. These production wells pump out water deep within the aquifer, treat the extracted water, and then add it to the distribution system within their service areas to provide additional water for residents. Table 12 through Table 17 provides the groundwater pumping wells data by member agency that was required to generate the production wells in ArcGIS. The pumping well data was added to ArcGIS, resulting in what is shown in Figure 35.

Table 12: GSWC Production Wells in Six Basins

Well Name	State Well #	Latitude °N	Longitude °W	GSE (ft)	DTW Pump (ft)	DTW Static (ft)	Well Depth (ft)	Upper Screen Depth (ft)	Lower Screen Depth (ft)
Alamosa 2	01N08W34A03	34.131567	-117.699186	1,636.0	336.0	301.0	450.0	300.0	435.0
Berkeley	01S08W09G03	34.100278	-117.722500	1,193.0	116.0	105.0	162.0	112.0	135.0
Berkeley	01S08W09G03	34.100278	-117.722500	1,193.0	98.0	96.0	162.0	112.0	135.0
College 1	01N08W35Q01	34.094858	-117.714678	1,150.0	424.0	371.0	620.0	450.0	590.0
College 2	01S08W10F01	34.095008	-117.713211	1,150.0	442.0	385.0	620.0	460.0	590.0
Del Monte 1	01S08W10N01	34.093783	-117.714464	1,145.0	362.0	353.0	450.0	400.0	435.0
Del Monte 2	01S08W10N03	34.093783	-117.714464	1,145.0	296.0	264.0	620.0	400.0	590.0
Fairoaks	01S08W10B01	34.106214	-117.707031	1,303.0	493.0	442.0	800.0	550.0	775.0
Harrison 2	01S08W09L02	34.098706	-117.727256	1,170.0	138.0	125.0	190.0	135.0	160.0
Indian Hill 3	01N08W33Q	34.124661	-117.720494	1,424.0	200.0	180.0	645.0	188.0	640.0
Marlboro	01N08W34R01	34.124869	-117.700683	1,545.0	366.0	334.0	776.0	350.0	529.0
Mills	01S08W03G02	34.117439	-117.705906	1,432.0	170.0	153.0	309.0	185.0	210.0
Miramar 3	01N08W35E01	34.130006	-117.696306	1,632.0	396.0	311.0	734.0	450.0	722.0
Miramar 3	01N08W35E01	34.130006	-117.696306	1,632.0	398.0	331.0	734.0	450.0	722.0
Miramar 5	01N08W34H01	34.129025	-117.698300	1,610.0	233.0	214.0	666.0	325.0	580.0
Pomello 1	01N08W34A01	34.134947	-117.700353	1,670.0	243.0	243.0	345.0	275.0	311.0
Pomello 4	01N08W34A02	34.134436	-117.700550	1,660.0	234.0	234.0	480.0	358.0	448.0

Table 13: La Verne Production Wells in Six Basins

Well Name	State Well #	Latitude °N	Longitude °W	GSE (ft)	DTW Pump (ft)	DTW Static (ft)	Well Depth (ft)	Upper Screen Depth (ft)	Lower Screen Depth (ft)
Amherst	1S08W06A03	34.117411	-117.756047	1,219.0	116.0	105.0	162.0	112.0	135.0
Beech	1S08W06A01	34.119056	-117.753858	1,238.0	212.5	212.5	450.0	250.0	435.0
LV Heights 1	01S08W06A02	34.118133	-117.749950	1,266.0	165.9	165.9	450.0	185.0	435.0
LV Heights 3	01S08W05B01	34.122331	-117.739328	1,288.0	116.0	116.0	309.0	185.0	210.0
Lincoln	01S08W07F01	34.101153	-117.762147	1,078.0	110.1	110.1	309.0	150.0	210.0
Mills Tract	01S08W07F02	34.101886	-117.762781	1,080.0	112.1	112.1	309.0	150.0	210.0
Old Baldy	01S08W07F03	34.102947	-117.780281	1,040.0	65.1	65.1	162.0	112.0	135.0

Table 14: Pomona Production Wells in Six Basins

Well Name	State Well #	Latitude °N	Longitude °W	GSE (ft)	DTW Pump (ft)	DTW Static (ft)	Well Depth (ft)	Upper Screen Depth (ft)	Lower Screen Depth (ft)
P-3	01S08W18J02	34.085764	-117.780147	1,034.0	57.0	57.0	309.0	185.0	210.0
P-7	01S08W17K02	34.084178	-117.753675	993.3	94.5	86.1	345.0	275.0	311.0
P-8B	01S08W17P05	34.082667	-117.747628	992.2	152.1	152.1	345.0	275.0	311.0
P-9B	01S08W08H02	34.102614	-117.734667	1,177.0	326.1	287.2	450.0	350.0	435.0
P-13	01S08W09D01	34.106503	-117.729508	1,228.0	316.8	229.0	450.0	350.0	435.0
P-32B	01S08W17N01	34.078392	-117.751750	952.0	55.2	42.2	190.0	112.0	160.0
P-37	01S08W08L001	34.10113611	-117.7427806	1,133.0	216.0	194.4	345.0	250.0	311.0
P-T1	01S08W03F02	34.112267	-117.718103	1,351.0	224.1	170.1	345.0	265.0	311.0
P-T2	01S08W03F04	34.111772	-117.719114	1,342.0	156.8	156.8	309.0	180.0	210.0
P-T4B	01S08W03F01	34.112433	-117.718325	1,352.0	223.8	191.8	345.0	265.0	311.0

Table 15: Three Valleys Production Well in Six Basins

Well Name	State Well #	Latitude °N	Longitude °W	GSE (ft)	DTW Pump (ft)	DTW Static (ft)	Well Depth (ft)	Upper Screen Depth (ft)	Lower Screen Depth (ft)
TVMWD 1	01N08W35E02	34.130519	-117.694358	1,644.0	464.5	464.5	800.0	550.0	775.0

Table 16: Upland Production Wells in Six Basins

Well Name	State Well #	Latitude °N	Longitude °W	GSE (ft)	DTW Pump (ft)	DTW Static (ft)	Well Depth (ft)	Upper Screen Depth (ft)	Lower Screen Depth (ft)
Upland 1A	01N08W24E01	34.158197	-117.677636	2,155.0	156.0	156.0	227.0	195.0	215.0
Upland 2	01N08W24E02	34.158197	-117.677636	2,155.0	136.6	136.6	176.0	125.0	160.0
Upland 5	01N08W25K03	34.141606	-117.667342	1,846.0	233.0	178.0	491.0	300.0	480.0
Upland 7A	01N08W25K02	34.095489	-117.642761	1,218.0	-	-	1,070.0	640.0	1,020.0
Upland 8	01S08W11R01	34.095136	-117.681100	1,228.0	-	-	1,000.0	522.0	985.0
Upland 9	01S07W17E01	34.087550	-117.641686	1,153.0	-	-	1,003.0	445.0	870.0
Upland 13	01S08W11S01	34.097153	-117.681733	1,249.0	-	-	928.0	528.0	915.0
Upland 15	01N07W29P01	34.133469	-117.645725	1,618.0	-	-	1,000.0	470.0	990.0
Upland 16	01N07W29E01	34.095494	-117.642761	1,576.0	-	-	1,084.0	450.0	1,070.0
Upland 17	01N08W36N01	34.123189	-117.680408	1,217.0	554.0	483.4	962.0	650.0	910.0

Table 17: West End Consolidated Water Company Production Wells in Six Basins

Well Name	State Well #	Latitude °N	Longitude °W	GSE (ft)	DTW Pump (ft)	DTW Static (ft)	Well Depth (ft)	Upper Screen Depth (ft)	Lower Screen Depth (ft)
Lemon Hts 4	01S08W01D03	34.121353	-117.679792	1,545.0	400.0	365.0	701.0	450.0	690.0
Mtn View 4	01S08W02F01	34.114006	-117.692525	1,465.0	159.0	150.0	373.0	225.0	370.0
West End-3	01S08W02B01	34.125339	-117.684733	1,612.0	276.0	234.0	794.0	400.0	750.0
West End-3 BD	01S08W02B01BD	34.121194	-117.684539	1,547.0	252.3	228.3	794.0	425.0	750.0
West End-4	01S08W02B02	34.121325	-117.688167	1,527.0	240.0	216.0	725.0	425.0	700.0
West End-4 BD	01S08W02B02BD	34.123056	-117.686875	1,564.0	253.4	229.4	725.0	425.0	700.0

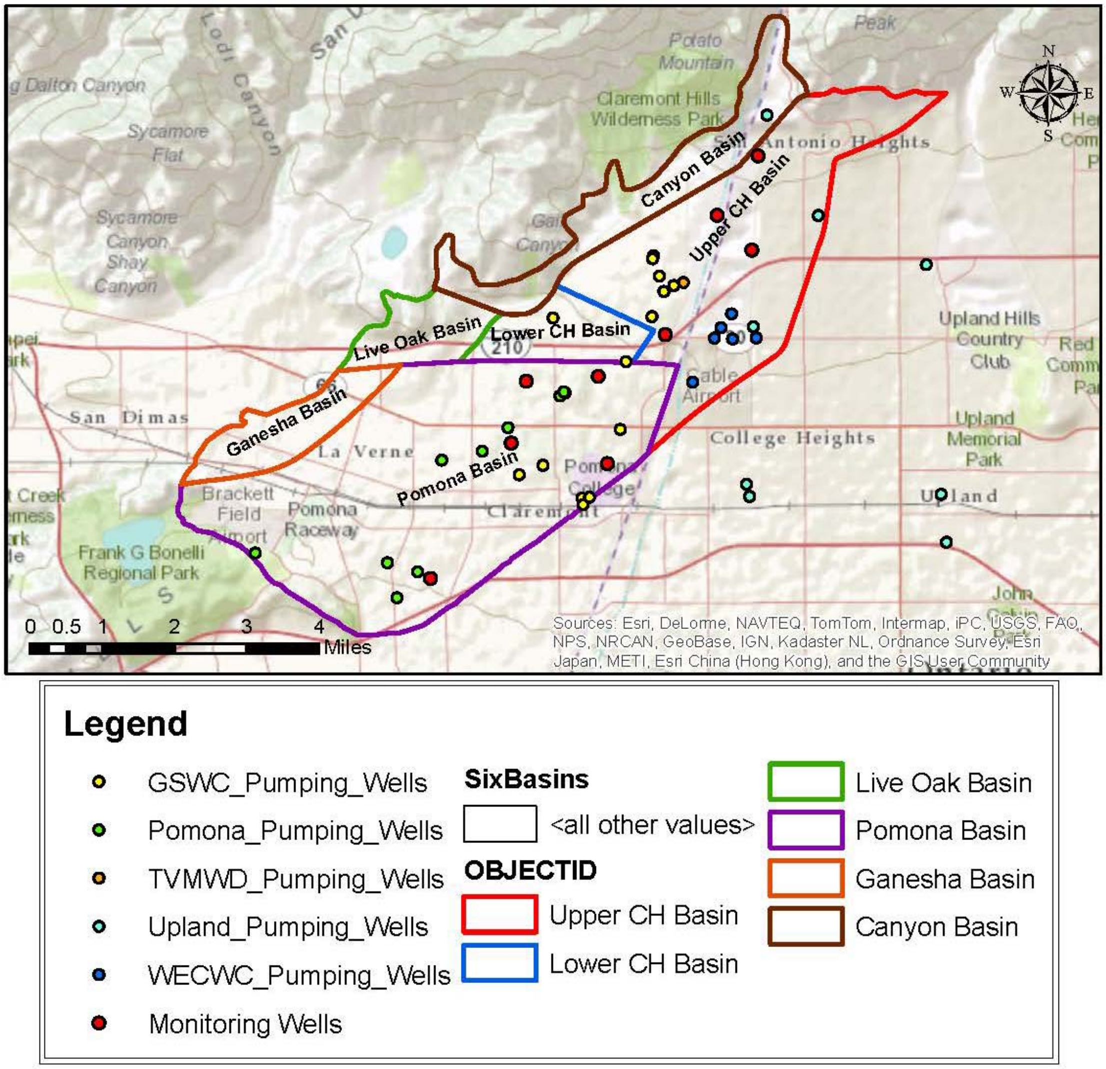


Figure 35: Locations of Active Production Wells in the Six Basins

13.3 SIX BASINS GROUNDWATER PRODUCTION

The groundwater production in the Six Basins for the 2010 calendar year is provided in Table 18. This table provides the monthly groundwater production by each party in 2010. The monthly groundwater production is the summation of the volume of water (in acre-feet, AF) pumped per month by each member agency's respective wells shown in the production well tables in Section 13.2.

Table 18: Groundwater Production (CY 2010)

2010 Six Basins Monthly Groundwater Production (AF)													
CY 2010	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**YTD Totals**
GSWC	257.0	223.8	277.8	283.7	322.7	313.3	305.0	335.2	315.2	297.1	311.6	260.5	3,502.8
La Verne	43.6	1.2	16.9	96.7	132.0	139.4	142.8	143.8	137.1	92.0	91.7	62.7	1,099.7
Pomona	197.1	208.1	287.0	293.5	390.8	449.9	470.2	471.1	411.8	282.5	303.7	237.0	4,002.5
Pomona College	156.0	141.4	181.6	193.2	189.3	169.8	167.4	166.9	172.4	166.7	175.5	146.7	2,026.8
SAWC	0.3	0.6	0.1	2.4	25.9	43.9	66.5	137.3	125.0	80.6	104.3	164.2	751.2
TVMWD	53.4	2.7	57.5	72.5	74.0	68.1	75.8	79.8	89.7	73.7	62.1	59.9	769.2
Upland	112.9	25.6	55.7	101.1	180.0	242.5	225.2	248.4	213.5	219.1	218.3	117.2	1,959.3
WECWC	244.6	100.0	225.8	222.9	276.1	271.7	262.8	244.3	256.2	311.4	313.7	215.5	2,944.9
Monthly Totals	**1,064.8**	**703.4**	**1,102.3**	**1,265.8**	**1,590.7**	**1,698.7**	**1,715.7**	**1,826.9**	**1,720.8**	**1,523.1**	**1,580.8**	**1,263.7**	**17,056.5**

14 SIX BASINS SOIL PROFILE

14.1 SIX BASINS SOIL CHARACTERISTICS

In general, young alluvial fan deposits underlie the Six Basins. The deposits consist of unconsolidated to slightly consolidated, undissected to slightly dissected boulder, cobble, gravel, sand, and silt deposits issued from a confined valley or canyon, as shown in Figure 36, provided in the Geologic Map of the San Bernardino and Santa Ana 30'x60' Quadrangles (TVMWD, 2012).

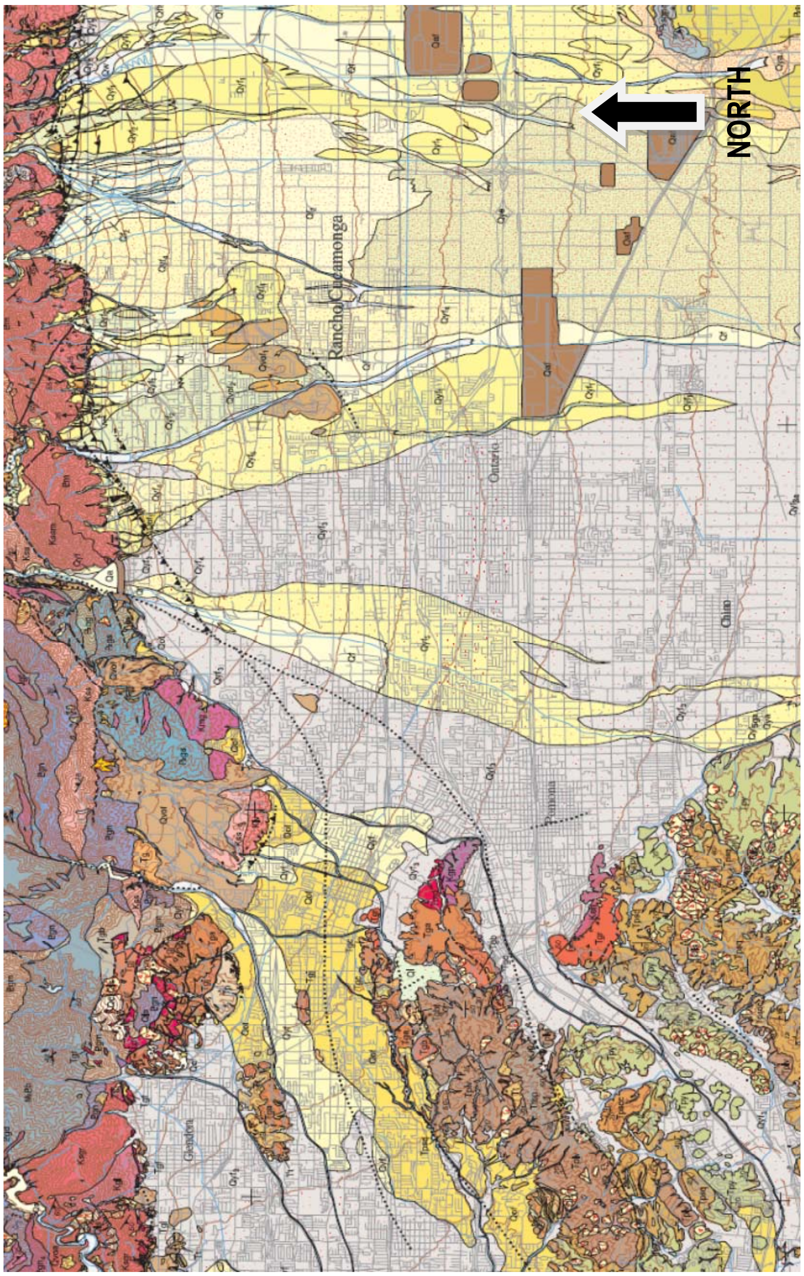


Figure 36: Excerpt from Geologic Map of the San Bernardino and Santa Ana 30'x60' Quadrangles, (TVMWD, 2012)

The soil information for the Six Basins was downloaded using STATSGO (2012). This data set is a digital general soil association map developed by the National Cooperative Soil Survey and distributed by the Natural Resources Conservation Service of the U.S. Department of Agriculture. STATSGO Data map was downloaded for the Los Angeles and San Bernardino counties, as shown in Figure 37. The Dissolve tool was used to provide only the soil data necessary for the Six Basins, as shown in Figure 38. The STATSGO Soil data gather shows that the soil that overlies the Six Basins is mainly comprised of sands and gravels, and sands and silts, as shown in Figure 39, confirming the Geologic Map of San Bernardino and Santa Ana Quadrangles (TVMWD, 2012).

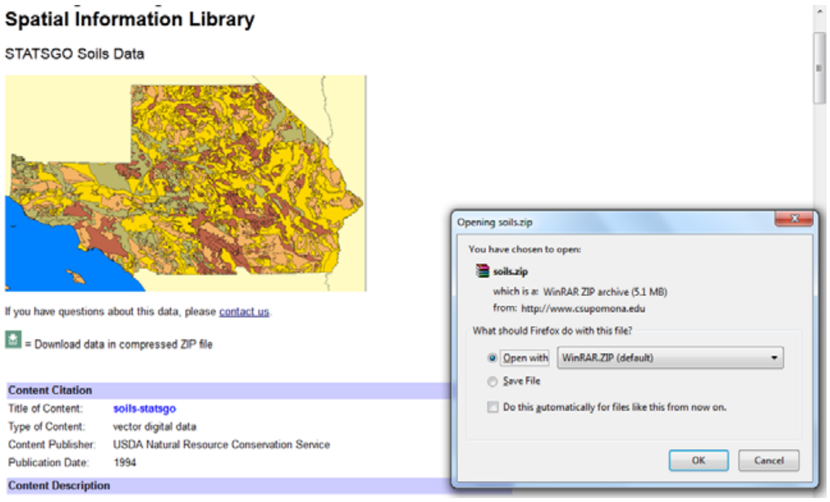


Figure 37: Soil Data Map Package Download for the Six Basins, (STATSGO, 2012)

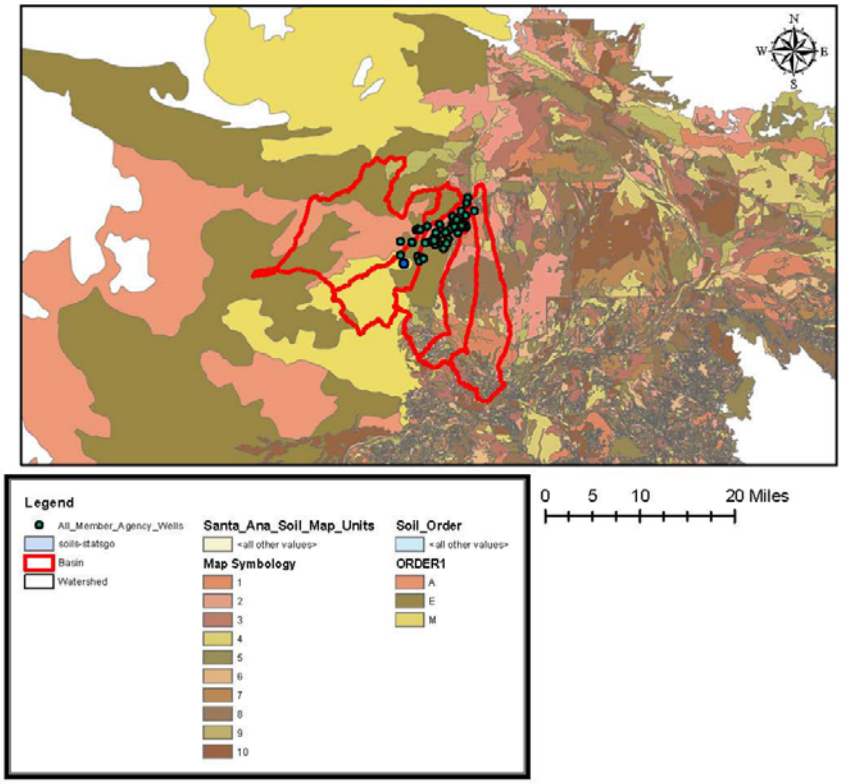


Figure 38: Regional Soil Properties of Six Basins

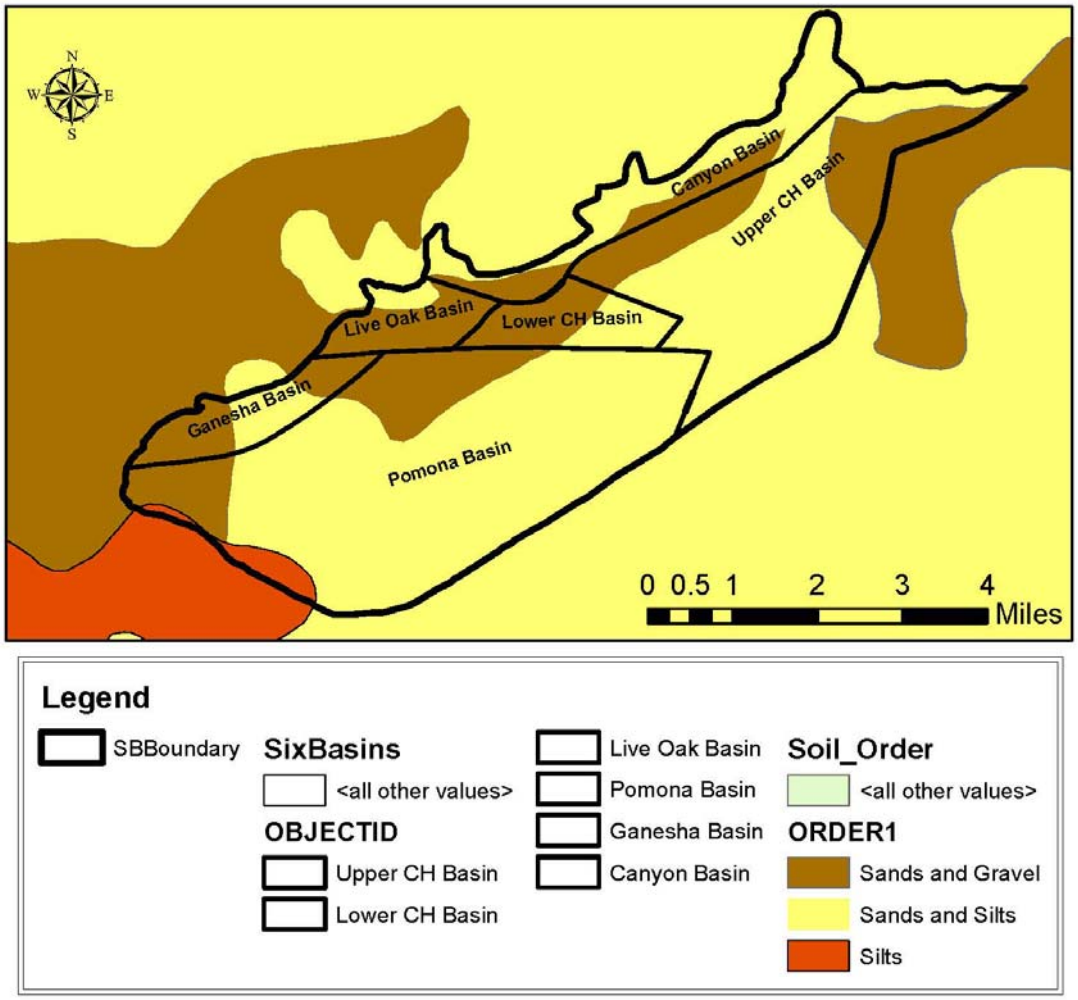


Figure 39: Six Basins Local Soil Profile

15 PRECIPITATION

15.1 PRECIPITATION DESCRIPTION

Precipitation generally means the amount of rain or snow that falls in a specific region. A region's precipitation can have significant impacts on the groundwater table. The amount of rainfall during each month can significantly change the groundwater table, especially in regions with low precipitation. The total precipitation within a year can help indicate if a region is or isn't under drought conditions. This information could be useful for water agencies because of its effects on water conservation and potentially water rates.

15.2 SIX BASINS PRECIPITATION

Table 19 shows the total precipitation that occurred each month in the Six Basins in calendar year 2010. The data was compiled off of San Antonio Water Company's website (2012) and the California Irrigation Management Information System (CIMIS) website for calendar year 2010. The San Antonio Water Company works with the Army Corp of Engineers, who operates the San Antonio Dam. The Army Corp measures the precipitation in the Six Basins at an evaporation pan stationed at the San Antonio Dam. The City of Pomona also measures local precipitation at an evaporation pan just southwest of the Six Basins boundary and provides the data on the CIMIS website (CIMIS, 2012). The data collected from these two entities were compiled in Excel and added to ArcGIS, as shown in Table 19. The Spline Tool was used to interpolate how the annual precipitation varied across the Six Basins for 2010, as shown in Figure 40 and Figure 41.

Table 19: Precipitation Data in the Six Basins (CY 2010)

CY 2010 Six Basins Precipitation (in)													
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
San Antonio Dam	8.10	5.53	0.87	2.48	0.07	0.02	0.00	0.00	0.03	1.38	2.15	17.80	38.43
Station #82	7.56	4.89	0.68	2.24	0.02	0.00	0.00	0.00	0.03	1.25	2.00	10.09	28.76

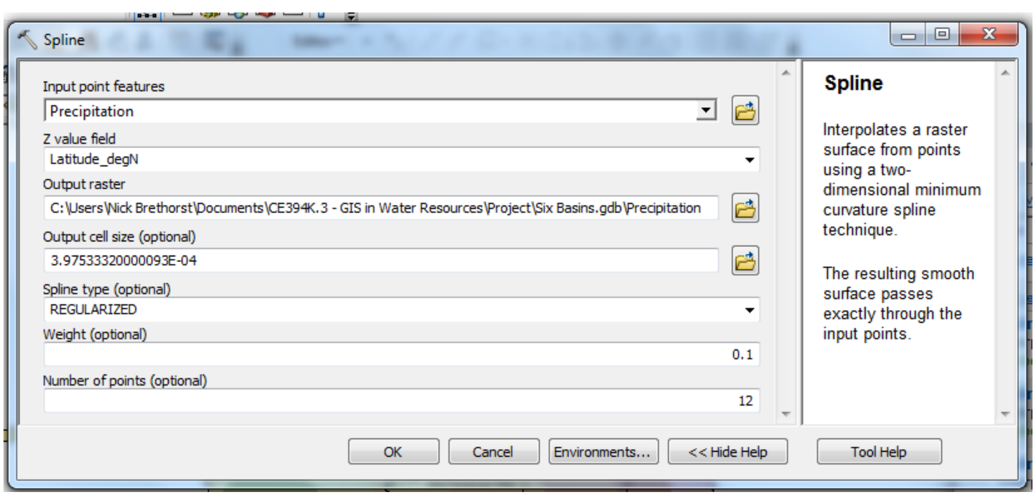


Figure 40: ArcGIS Spline Tool Input for Precipitation Interpolation

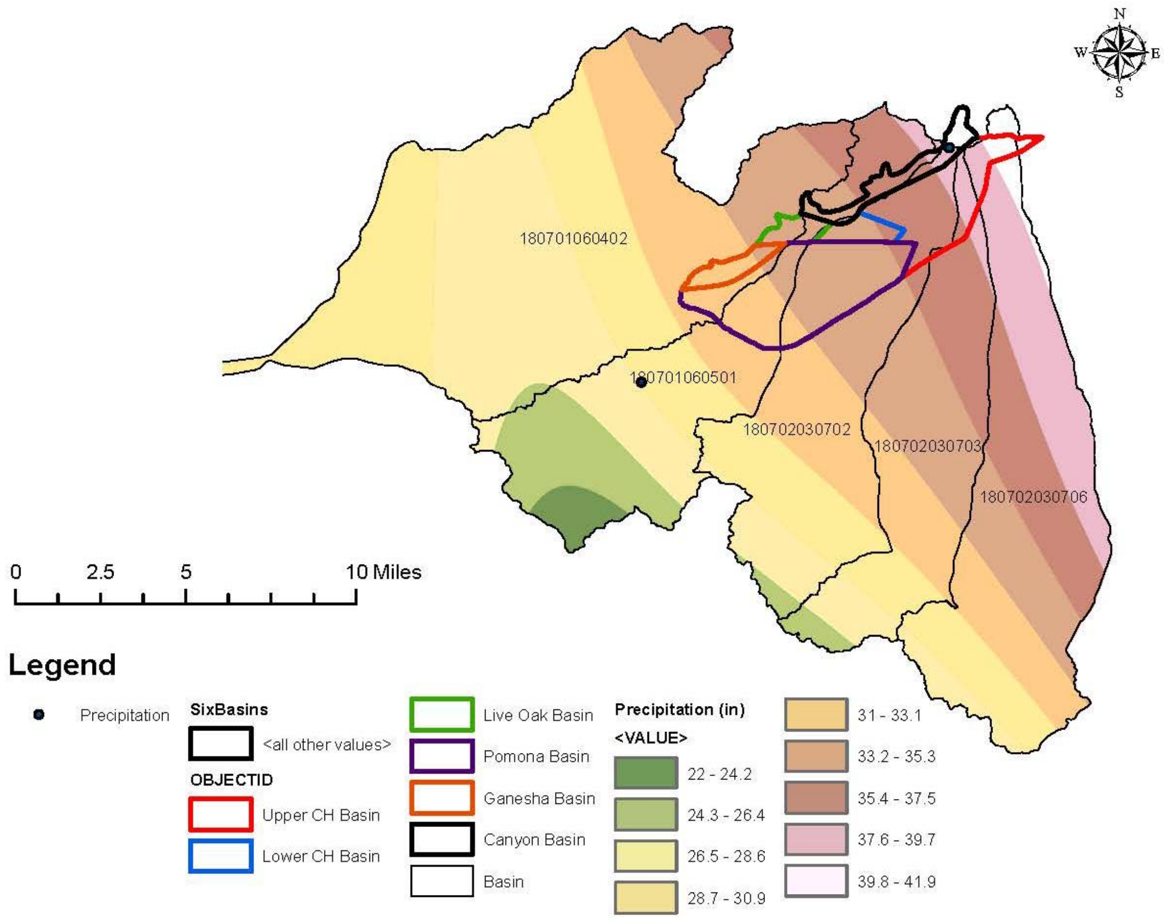


Figure 41: Six Basins Annual Precipitation Distribution in 2010

The general precipitation trend within the Six Basins is that regions that receive the highest precipitation are within the northernmost basins (i.e. Canyon Basin and Upper Claremont Heights Basin), basins with highest elevation. Precipitation linearly declines from northeastern border of the Six Basins to southwestern border of the Six Basins. The Canyon Basin received between 35.4 - 41.9 inches of rainfall in 2010. The Upper and Lower Claremont Heights Basin, Ganesha Basin, Live Oak Basin, and Pomona Basin received between 31.0 - 35.4 inches of rainfall in 2010.

16 MONITORING WELL BORING LOGS

16.1 BOREHOLE PROFILE AND 2D CROSS SECTION

Boring log data was attained from Three Valleys Municipal Water District for Monitoring Wells MW-1, MW-2, and MW-3 (TVMWD, 2012). The boring logs of monitoring wells MW-1, MW-2, and MW-3 were translated into borehole profiles using AutoCAD, as shown in Figure 42. The boring logs denote that the top layer of the soil profile within the Six Basins consists of sands and gravels, and then followed by sands silts, clays, and bedrock. The deepest layers below the sands and gravels consist of clayey sands, clay, and bedrock. It was assumed that the groundwater, as well as the surface water that percolates into the soil and passes through the sand and gravel layer, is confined in the sand layer, between the silt layer and sand and gravel layer. The boring profiles were used in ArcGIS to aid in the construction of the 2D subsurface profile.

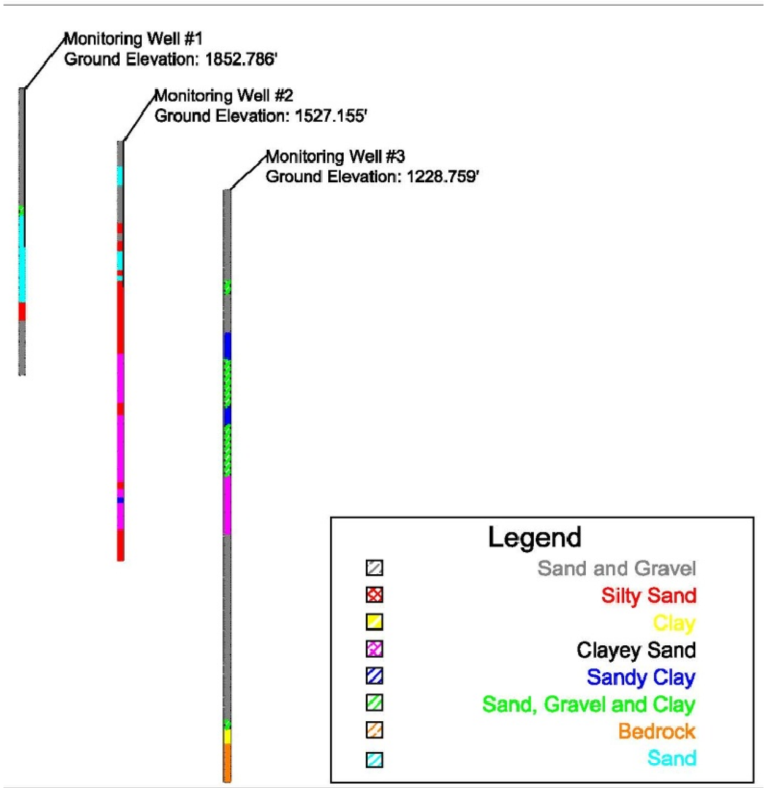


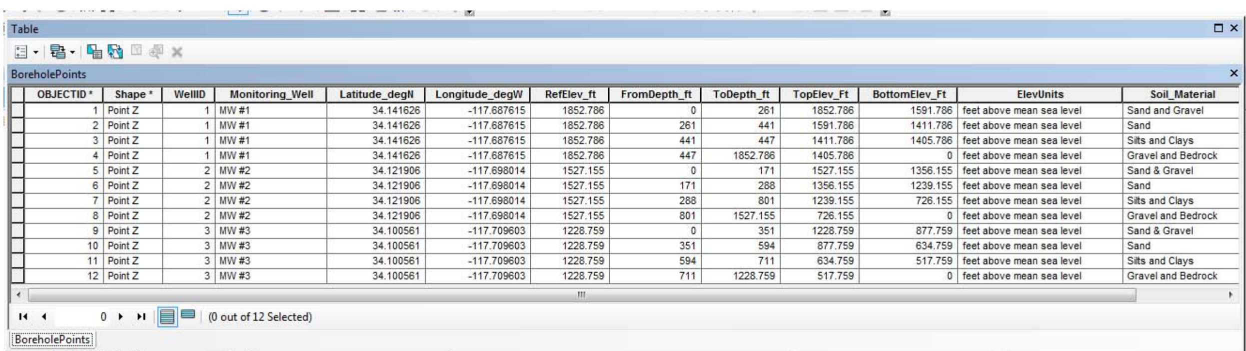
Figure 42: Borehole Profiles of MW-1, MW-2, MW-3

16.2 BOREHOLE PROFILE SIMPLIFIED

Initially, the boreholes that were created in Figure 42, were too complex and would make creating boreholes and 2D sections in ArcGIS difficult. Dr. Jones of Brigham Young University (2012) strongly recommended to simplify the boreholes before creating them in ArcGIS. Table 20 and Figure 43 provide the simplified borehole log table that was uploaded to ArcGIS. Using that data, borehole points and cross section lines were created, as shown in Figure 44.

Table 20: Borehole Log Table

WellID	Monitoring Well	RefElev (ft)	FromDepth (ft)	ToDepth (ft)	TopElev (ft)	BottomElev (ft)	Soil Material	SoilLayer	HGUID	HGUCode
1	MW #1	1,852.786	0	261	1,852.786	1,591.786	Sand and Gravel	Younger Alluvium	1	HGU1 - Confining Layer
1	MW #1	1,852.786	261	441	1,591.786	1,411.786	Sand	Younger Alluvium	2	HGU2 - Aquifer
1	MW #1	1,852.786	441	447	1,411.786	1,405.786	Silts and Clays	Semi Confining Unit	1	HGU1 - Confining Layer
1	MW #1	1,852.786	447	1,852.786	1,405.786	0	Gravel and Bedrock	Bedrock	1	HGU1 - Confining Layer
2	MW #2	1,527.155	0	171	1,527.155	1,356.155	Sand & Gravel	Younger Alluvium	1	HGU1 - Confining Layer
2	MW #2	1,527.155	171	288	1,356.155	1,239.155	Sand	Older Alluvium	2	HGU2 - Aquifer
2	MW #2	1,527.155	288	801	1,239.155	726.155	Silts and Clays	Older Alluvium	1	HGU1 - Confining Layer
2	MW #2	1,527.155	801	1,527.155	726.155	0	Gravel and Bedrock	Bedrock	1	HGU1 - Confining Layer
3	MW #3	1,228.759	0	351	1,228.759	877.759	Sand & Gravel	Younger Alluvium	1	HGU1 - Confining Layer
3	MW #3	1,228.759	351	594	877.759	634.759	Sand	Older Alluvium	2	HGU2 - Aquifer
3	MW #3	1,228.759	594	711	634.759	517.759	Silts and Clays	Older Alluvium	1	HGU1 - Confining Layer
3	MW #3	1,228.759	711	1,228.759	517.759	0	Gravel and Bedrock	Bedrock	1	HGU1 - Confining Layer



Table

BoreholePoints

OBJECTID *	Shape *	WellID	Monitoring_Well	Latitude_degN	Longitude_degW	RefElev_ft	FromDepth_ft	ToDepth_ft	TopElev_Ft	BottomElev_Ft	ElevUnits	Soil_Material
1	Point Z	1	MW #1	34.141626	-117.687615	1852.786	0	261	1852.786	1591.786	feet above mean sea level	Sand and Gravel
2	Point Z	1	MW #1	34.141626	-117.687615	1852.786	261	441	1591.786	1411.786	feet above mean sea level	Sand
3	Point Z	1	MW #1	34.141626	-117.687615	1852.786	441	447	1411.786	1405.786	feet above mean sea level	Silts and Clays
4	Point Z	1	MW #1	34.141626	-117.687615	1852.786	447	1852.786	1405.786	0	feet above mean sea level	Gravel and Bedrock
5	Point Z	2	MW #2	34.121906	-117.698014	1527.155	0	171	1527.155	1356.155	feet above mean sea level	Sand & Gravel
6	Point Z	2	MW #2	34.121906	-117.698014	1527.155	171	288	1356.155	1239.155	feet above mean sea level	Sand
7	Point Z	2	MW #2	34.121906	-117.698014	1527.155	288	801	1239.155	726.155	feet above mean sea level	Silts and Clays
8	Point Z	2	MW #2	34.121906	-117.698014	1527.155	801	1527.155	726.155	0	feet above mean sea level	Gravel and Bedrock
9	Point Z	3	MW #3	34.100561	-117.709603	1228.759	0	351	1228.759	877.759	feet above mean sea level	Sand & Gravel
10	Point Z	3	MW #3	34.100561	-117.709603	1228.759	351	594	877.759	634.759	feet above mean sea level	Sand
11	Point Z	3	MW #3	34.100561	-117.709603	1228.759	594	711	634.759	517.759	feet above mean sea level	Silts and Clays
12	Point Z	3	MW #3	34.100561	-117.709603	1228.759	711	1228.759	517.759	0	feet above mean sea level	Gravel and Bedrock

(0 out of 12 Selected)

BoreholePoints

Figure 43: Borehole Log Table in ArcGIS

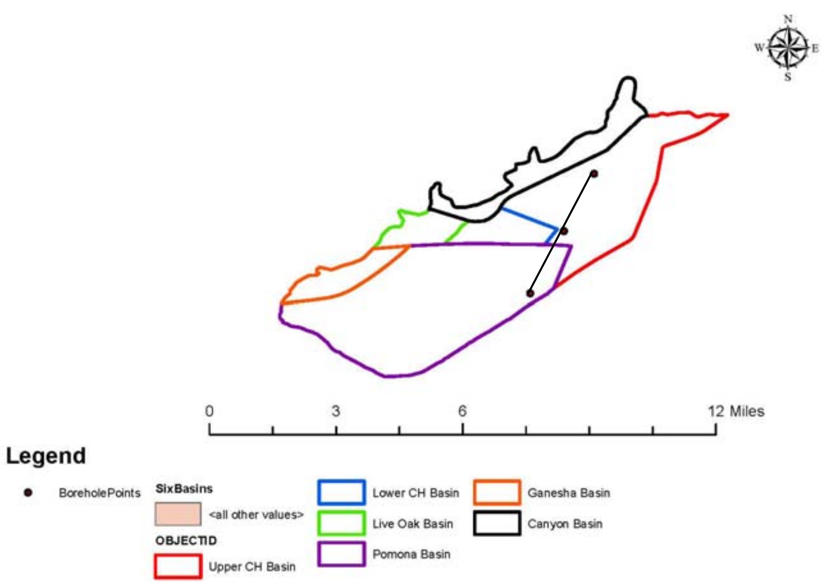


Figure 44: Borehole Points of MW-1, MW-2, MW-3

Using the borehole points data, Arc Hydro Groundwater Tools, AutoCAD (for measurement intervals) and Adobe Photoshop (for coloring), the 2D cross section of the Six Basins that encompasses MW-1, MW-2, and MW-3 was created and shown in Figure 45. Like the bore logs, the 2D cross section provides the soil layer profile of the Six Basins that spans from MW-1 to MW-3. Sands and gravels (Younger Alluvium) make the topmost soil layer, followed by a silt confining layer. Groundwater is confined within the sand layer (Older Alluvium), between the silt confining layer and the bedrock. Groundwater pumping wells, at minimum, must penetrate into the Older Alluvium layer if water is to be withdrawn from the Six Basins Aquifer.

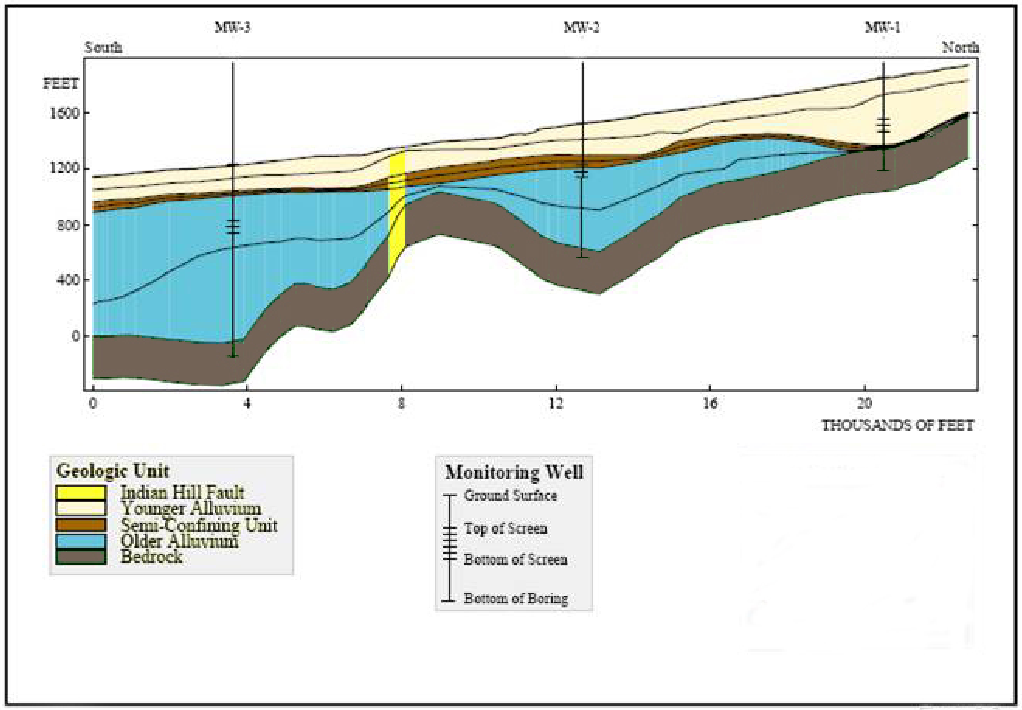


Figure 45: 2D Cross Section of the Six Basins

16.3 WEIGHTED POROSITY

Porosity ("e") is the ratio between the volume of voids (i.e. the volume of air and volume of water) and the volume of solids within a given volume of soil, as shown in Equation 1 and Figure 46.

$$e = \frac{V_v}{V_s} = \frac{V_a + V_w}{V_s}; (EQ - 1)$$

$Where,$
$e = Porosity$
$V_a = Volume\ of\ Air$
$V_s = Volume\ of\ Solids$
$V_v = Volume\ of\ Voids$
$V_w = Volume\ of\ Water$

Within an aquifer, very little volume is occupied by air; most of it is occupied by water. Therefore, the volume of the voids is mostly volume of water, as shown in Figure 46. Using the porosity, the volume of the water in an aquifer can be approximated.

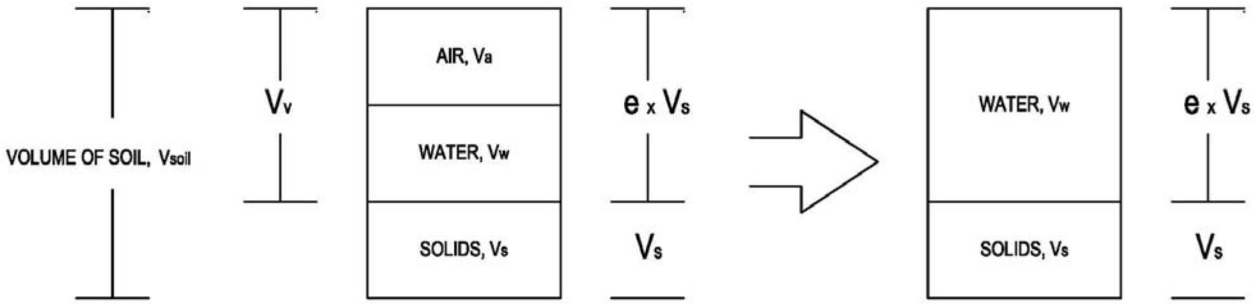


Figure 46: Definition of Porosity

Porosity values were obtained for soil material within the Six Basins, as shown in Table 20 and Table 21 from Coduto (1999). These porosity values were used to determine a weighted porosity at each of the three monitoring wells, as shown in Figure 45, according to Equation 2:

$$Weighted\ Porosity = \frac{\sum_i^n (Soil\ Depth_i)(\varphi_i)}{\sum H}\ ; (EQ-2)$$

$Where,$

$\varphi = Soil\ Porosity$

$Soil\ Depth_i = Soil\ Depth\ of\ each\ soil\ layer\ within\ each\ monitoring\ well$

$\sum_i^n (Soil\ Depth_i)(\varphi_i) = Product\ of\ each\ soil\ layer\ depth\ at\ monitoring\ well\ \&\ its\ soil\ porosity$

$\sum H = Total\ Depth\ of\ Soil\ at\ each\ monitoring\ well$

The weighted porosities at each monitoring well are provided in Table 21. Once the weighted porosity was determined at each monitoring well, the weighted porosities were averaged to determine an average weighted porosity for the entire Six Basins. This average weighted porosity of 0.27 will be used to determine the storage capacity in the Six Basins, discussed in Section 17.

Table 21: Average Weighted Porosity of the Six Basins

Soil Layer	Monitoring Well #1			Monitoring Well #2			Monitoring Well #3		
	ϕ	H (ft)	ϕ-H (ft)	ϕ	H (ft)	ϕ-H (ft)	ϕ	H (ft)	ϕ-H (ft)
Young Alluvium	0.4	700	280	0.4	200	80	0.4	200	80
Silts & Clay	0.35	50	17.5	0.35	100	35	0.35	50	17.5
Older Alluvium	0.2	0	0	0.2	600	120	0.2	850	170
Bedrock	0.07	150	10.5	0.07	100	7	0.07	100	7
Weighted Porosity	**0.34**			**0.24**			**0.23**		
Average Weighted Porosity	**0.27**								

17 STORAGE CAPACITY

17.1 DESCRIPTION

Storage capacity pertains to how much volume of water is stored within an aquifer. Using ArcGIS, the storage capacity of the Six Basins was determined using Spatial Analyst Tools, specifically the Thiessen Polygons Tool.

17.2 THIESSEN POLYGONS METHOD

All of the monitoring wells and the pumping wells static and pumping groundwater elevations were uploaded to ArcGIS. All of their locations were displayed within the Six Basins boundary. Using the Construct Thiessen Polygons Tools, Thiessen Polygons were created around each well, as shown in Figure 47.

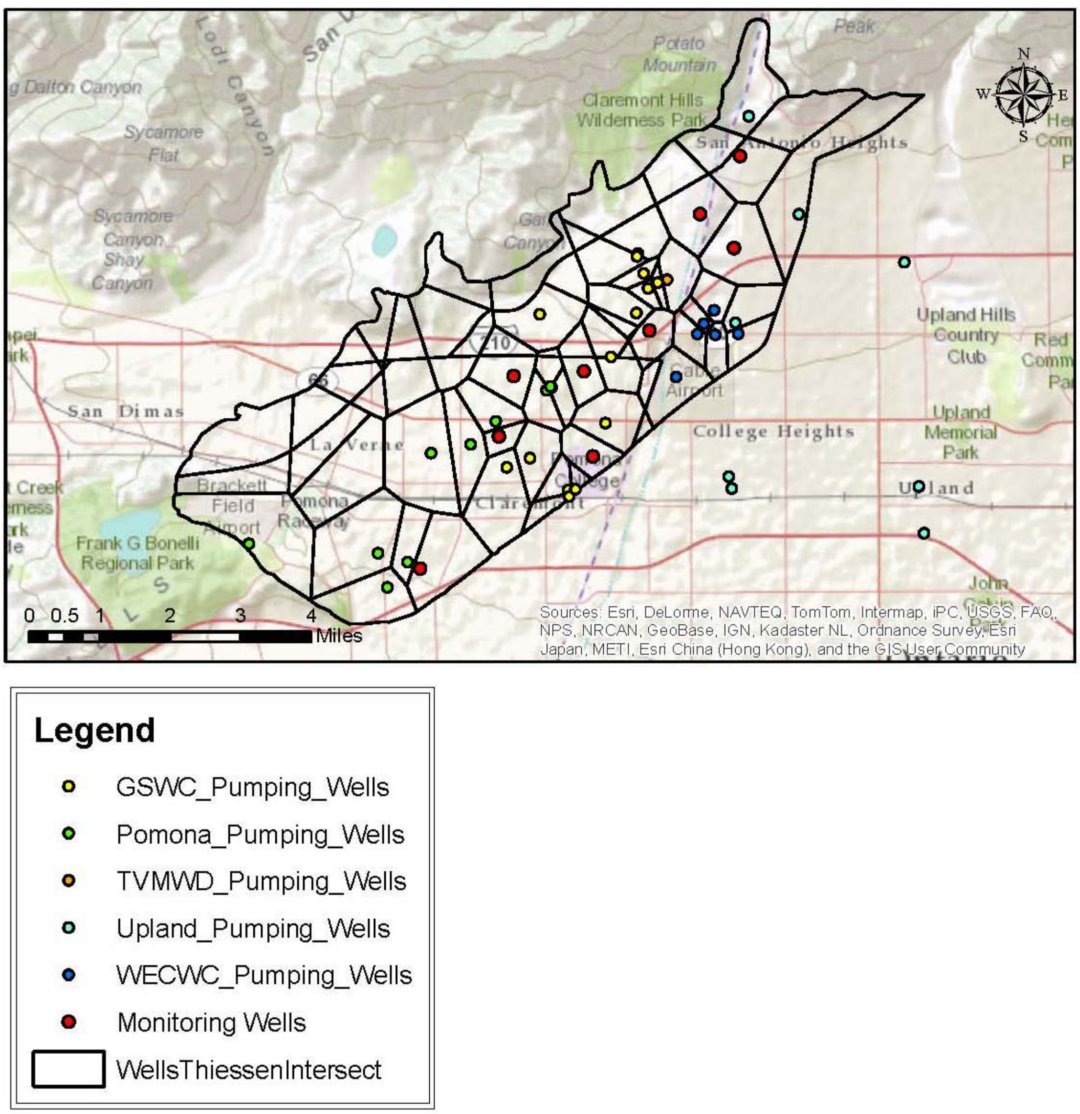


Figure 47: Constructed Thiessen Polygons within the Six Basins

17.3 AVERAGE GROUNDWATER ELEVATIONS

After the Thiessen polygons were constructed, the Wells Thiessen Intersect Attribute Table was exported to Excel and arranged to determine the average static and pumping groundwater elevations across the entire Six Basins, as shown in Table 22. Within this table, the static groundwater elevations and the pumping groundwater elevations of each well were associated with a Thiessen polygon area. For each well, the product of its static groundwater elevation and its associated Thiessen polygon area were taken and summed ($\sum Static\ GWE - A_k$). Similarly, the product of each wells pumping groundwater elevation and their associated Thiessen polygon area were taken and summed ($\sum Pumping\ GWE - A_k$). In addition, all of the Thiessen polygon areas were summed, ($\sum A_k$), establishing the area of the Six Basins. Using these parameters, an average static and pumping groundwater elevation across the entire Six Basins boundary was determined according to Equation 3 and Equation 4. The resulting average static and pumping groundwater elevation by month is provided in Table 22.

$$GWE_{STAT} = \frac{\sum Static\ GWE - A_k}{\sum A_k}\ ;\ (EQ - 3)$$

$$GWE_{PUMP} = \frac{\sum Pumping\ GWE - A_k}{\sum A_k}\ ;\ (EQ - 4)$$

$Where,$

$GWE_{STAT} = Average\ Static\ Groundwater\ Elevation\ in\ the\ Six\ Basins$

$GWE_{PUMP} = Average\ Pumping\ Groundwater\ Elevation\ in\ the\ Six\ Basins$

$\sum Static\ GWE - A_k = Product\ of\ Static\ Groundwater\ Elevation\ \&\ Associated\ Thiessen\ Polygon$

$\sum Pumping\ GWE - A_k = Product\ of\ Pumping\ Groundwater\ Elevation\ \&\ Associated\ Thiessen\ Polygon$

$\sum A_k = Sum\ of\ All\ Thiessen\ Polygons$

Table 22: Wells Thiessen Intersect Attribute Table

Month	ΣA_k (ft^2)	ΣGWE_{STAT}-A_k (ft^3)	ΣGWE_{PUMP}-A_k (ft^3)	GWE_{STAT} (ft)	GWE_{PUMP} (ft)	ΔGWE (ft)
January	622,844,540	70,291,236,329	69,248,069,013	1,214.7	1,196.7	18.0
February	622,844,540	70,342,823,699	69,394,224,565	1,215.6	1,199.2	16.4
March	622,844,540	70,234,292,493	69,309,143,713	1,213.7	1,197.8	16.0
April	622,844,540	70,168,207,401	69,058,396,599	1,212.6	1,193.4	19.2
May	622,844,540	69,911,553,847	68,858,956,188	1,208.2	1,190.0	18.2
June	622,844,540	69,732,120,645	68,697,562,235	1,205.1	1,187.2	17.9
July	622,844,540	69,802,992,186	68,488,889,124	1,206.3	1,183.6	22.7
August	622,844,540	69,825,560,860	68,309,478,276	1,206.7	1,180.5	26.2
September	622,844,540	69,691,768,432	68,456,649,540	1,204.4	1,183.0	21.3
October	622,844,540	69,890,083,934	68,784,028,980	1,207.8	1,188.7	19.1
November	622,844,540	69,699,147,387	68,582,890,361	1,204.5	1,185.2	19.3
December	622,844,540	69,877,084,175	69,098,720,353	1,207.6	1,194.1	13.5

17.4 SIX BASINS STORAGE CAPACITY

The Six Basins storage capacity was determined using the weighted porosity determined in Section 16.3 and the static and pumping groundwater elevations determined in Section 17.3. The monthly static storage capacity was determined by multiplying the average weighted porosity ("e", 0.27) by the static groundwater elevation and the surface area of the Six Basins (622,844,540.5 ft^2), and then was summed up to obtain the annual storage capacity (in acre-feet, AF), according to Equation 5. Similarly, the monthly pumping storage capacity was determined by multiplying the weighted porosity by the pumping groundwater elevation and the surface area of the Six Basins, and then was summed up to obtain the annual storage capacity, according to Equation 6. The storage capacity results are shown in Table 23.

$$Storage_{STAT} = \sum \left(e \times 622{,}844{,}540.5\ ft^2 \times GWE_{STAT} \times \frac{1\ AF}{43{,}560 ft^2} \right) ; (EQ-5)$$

$$Storage_{PUMP} = \sum \left(e \times 622{,}844{,}540.5\ ft^2 \times GWE_{PUMP} \times \frac{1\ AF}{43{,}560 ft^2} \right) ; (EQ-6)$$

Table 23: Six Basins Storage Capacity

Month	GWE_{STAT} (ft)	GWE_{PUMP} (ft)	Six Basins Area (ft^2)	Weighted Porosity	$Storage_{STAT}$ (AF)	$Storage_{PUMP}$ (AF)	∆Storage (AF)
January	1,214.7	1,196.7	622,844,540.5	0.27	46,896	46,200	696
February	1,215.6	1,199.2	622,844,540.5	0.27	46,930	46,297	633
March	1,213.7	1,197.8	622,844,540.5	0.27	46,858	46,240	617
April	1,212.6	1,193.4	622,844,540.5	0.27	46,814	46,073	740
May	1,208.2	1,190.0	622,844,540.5	0.27	46,642	45,940	702
June	1,205.1	1,187.2	622,844,540.5	0.27	46,523	45,832	690
July	1,206.3	1,183.6	622,844,540.5	0.27	46,570	45,693	877
August	1,206.7	1,180.5	622,844,540.5	0.27	46,585	45,574	1,011
September	1,204.4	1,183.0	622,844,540.5	0.27	46,496	45,672	824
October	1,207.8	1,188.7	622,844,540.5	0.27	46,628	45,890	738
November	1,204.5	1,185.2	622,844,540.5	0.27	46,501	45,756	745
December	1,207.6	1,194.1	622,844,541.5	0.27	46,619	46,100	519
				Total =	560,061	551,268	8,793

The Six Basins storage capacity has approximately 560,061 AF of water when no pumping occurs. With the production wells, the Six Basins storage capacity decreases to 551,268 AF, resulting in a reduction of 8,793 AF. The amount of storage capacity lost using a weighted porosity and the Thiessen Polygon Method grossly underestimates the amount of water that was pumped from the aquifer. In 2010, approximately 17,056.5 AF was pumped from the aquifer, resulting in a difference of 8,263.5 AF from the storage capacity lost value of 8,793 AF. Most of the error generated is most likely due to the average weighted porosity, signifying that the Six Basins soil profile is much more complex than the simplified profile used in ArcGIS. In addition, the static and pumping groundwater levels most likely were not measured all at the same time, providing multiple time interval snapshots of the groundwater levels within the Six Basins. More research on the Six Basins would need to be conducted to more accurately adjust the methodology used, as discussed throughout Section 17.

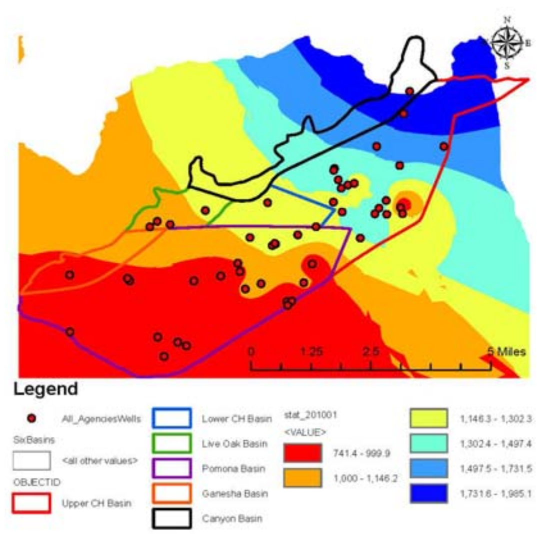
18 SIX BASINS GROUNDWATER MODELING

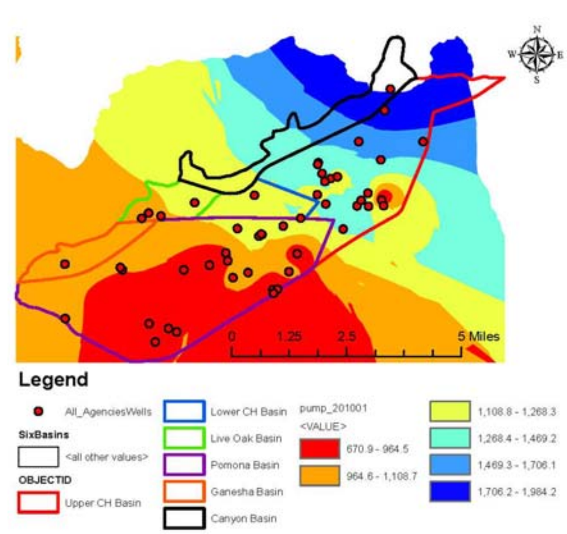
18.1 GROUNDWATER MODELING DESCRIPTION

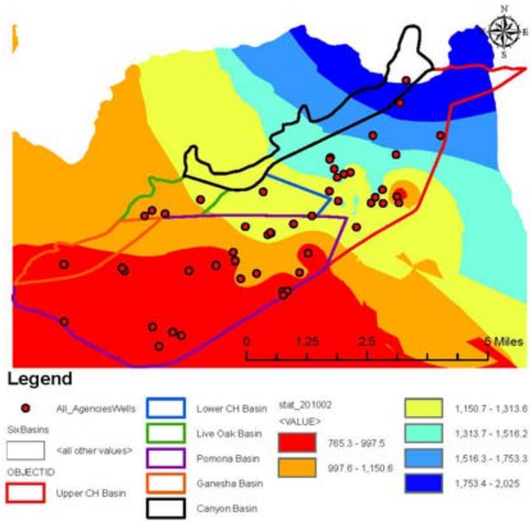
All of the groundwater wells and monitoring wells were uploaded and displayed with monthly time series static and pumping groundwater elevations, as shown throughout Sections 4 - 13 and also shown in Appendix 1.0. Every month's static and pumping groundwater elevations (i.e. January 2010, February 2010, March 2010, etc.) were separately isolated and modeled using the Kriging Bayesian Interpolation Tools in ArcGIS to show how the static and pumping groundwater levels changed with time. In addition for the presentation, the time slider tools in ArcGIS were utilized to create a video demonstrating how the static and pumping groundwater elevations changed every month through 2010.

18.2 GROUNDWATER MODELING RESULTS AND COMPARISON

After uploading the static and pumping groundwater elevations and running the Kriging Bayesian Spatial Analyst Tool for every month, the resulting changes in static and pumping groundwater elevations are displayed, as shown in Figure 48. Six static and pumping groundwater elevation breaks (six colored layers) were used in the Kriging Bayesian Interpolation Tools to categorize the groundwater elevations throughout the Six Basins. The left side pictures displays the static groundwater elevations by month, while the right side pictures displays the pumping groundwater elevations by month.



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All_AgenciesWells
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Lower CH Basin
Live Oak Basin
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Ganesha Basin
Canyon Basin
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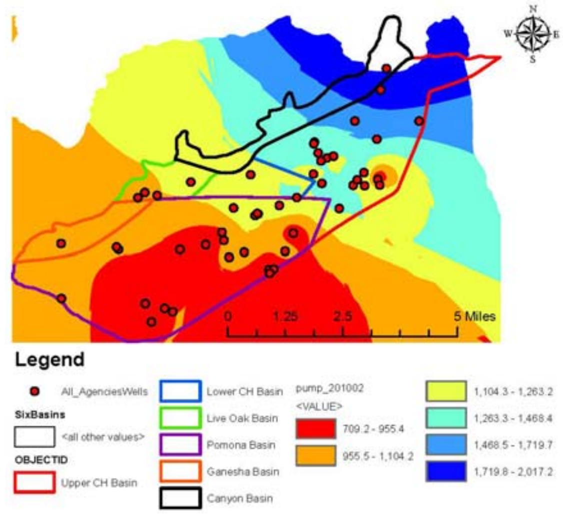
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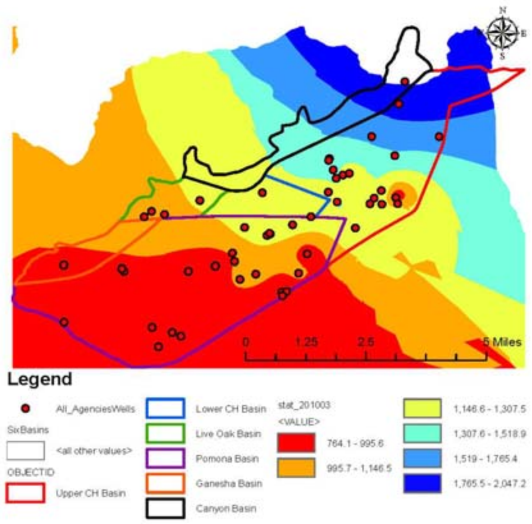
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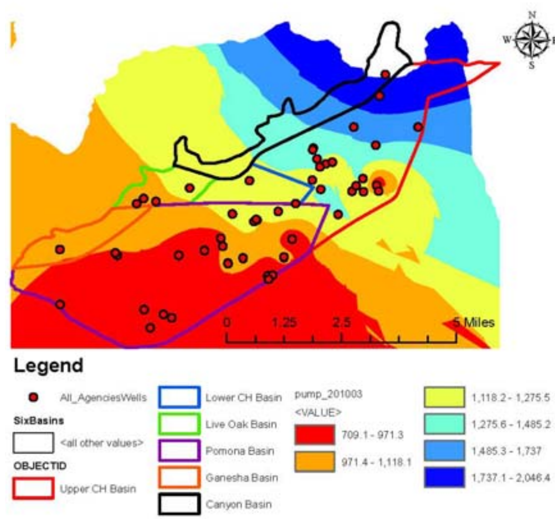
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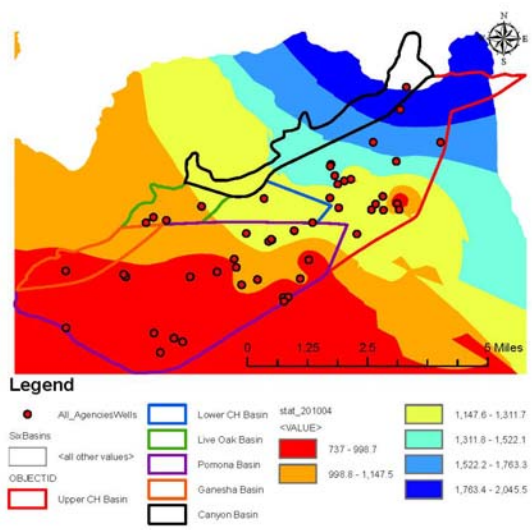
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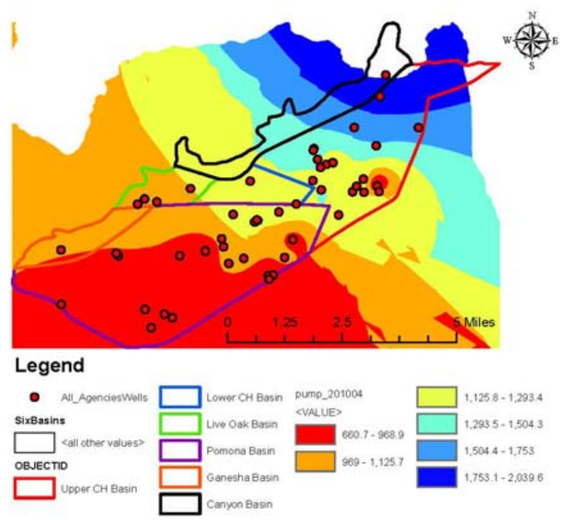
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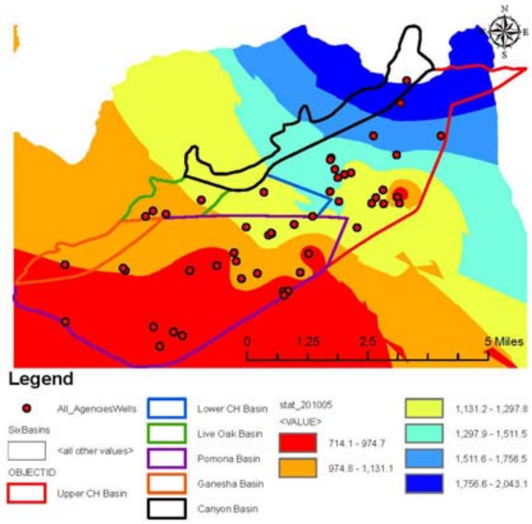
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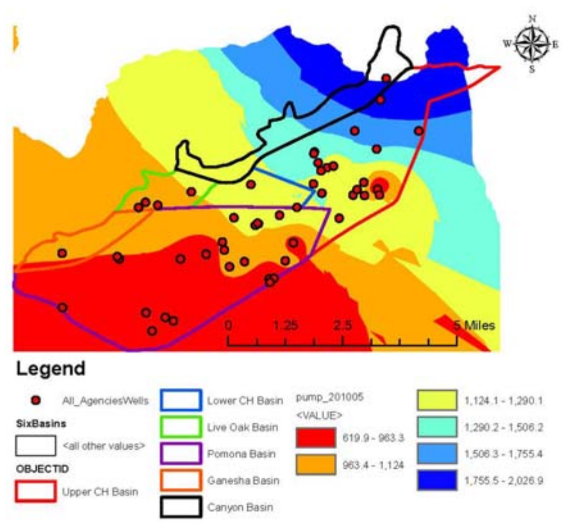
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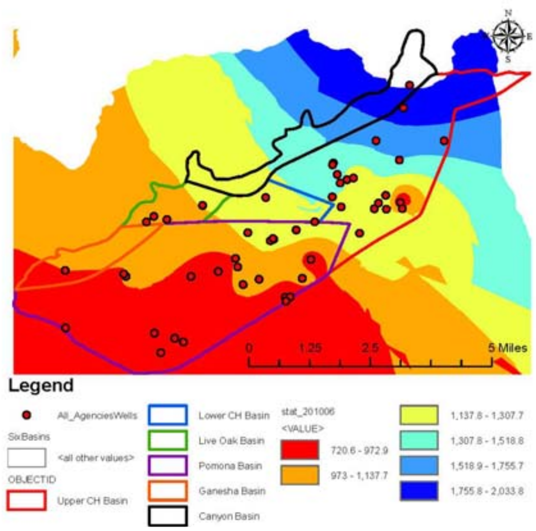
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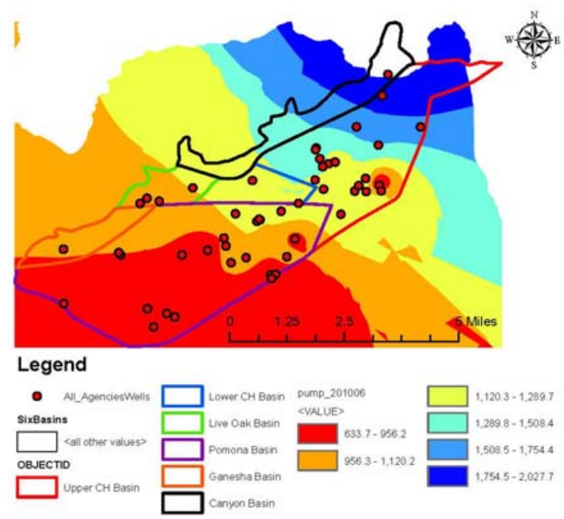
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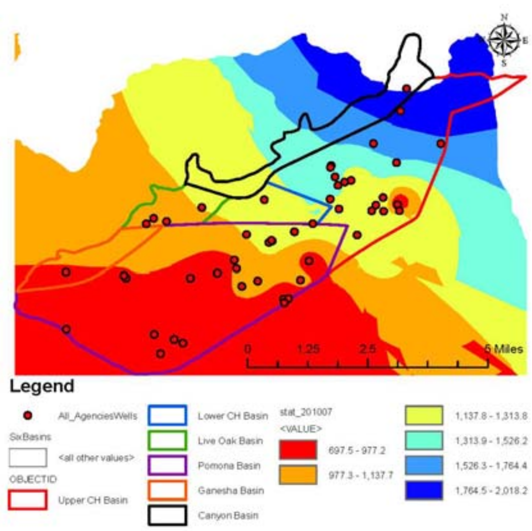
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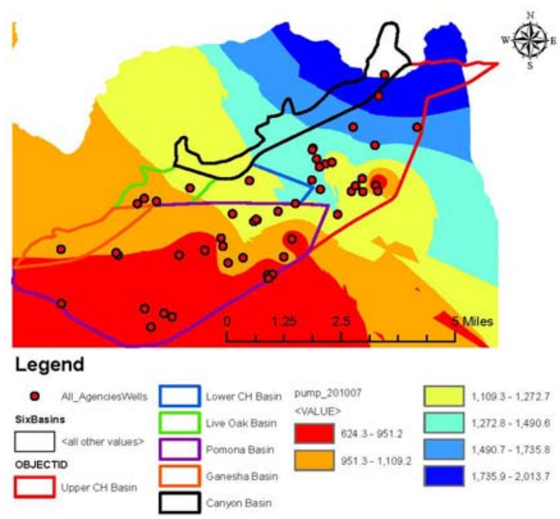
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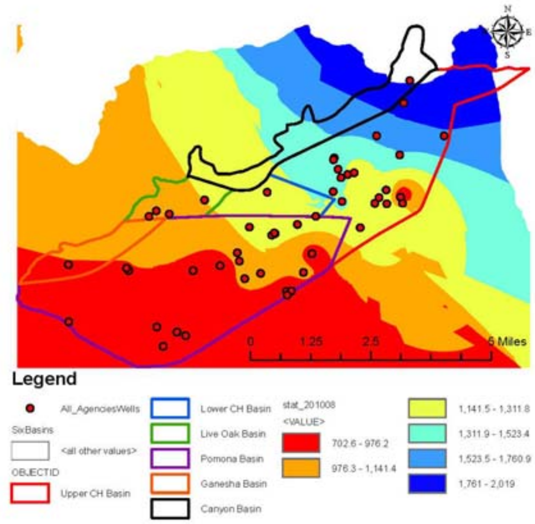
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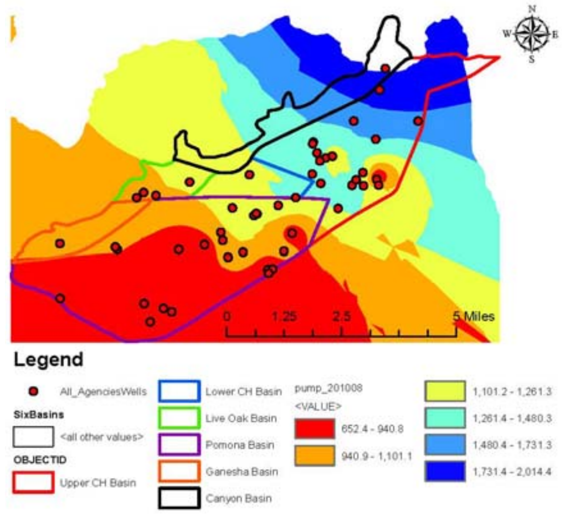
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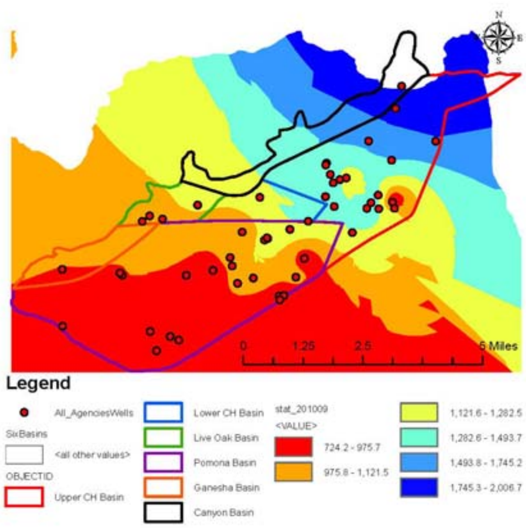
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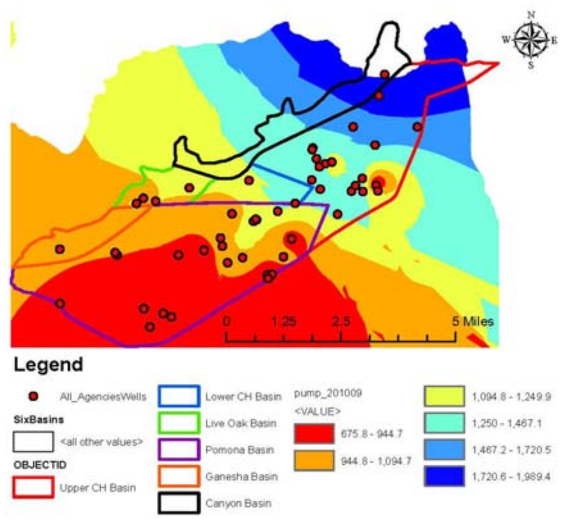
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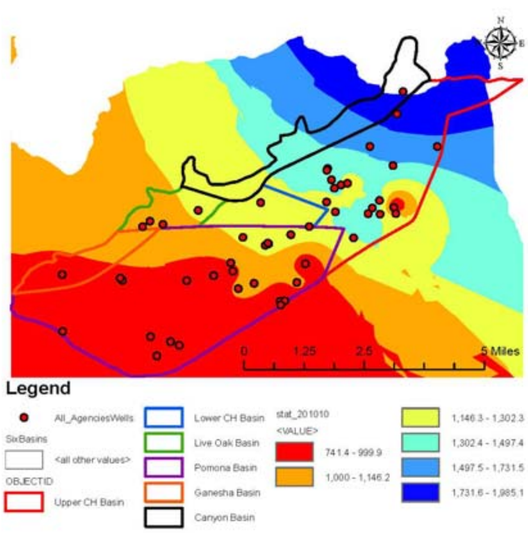
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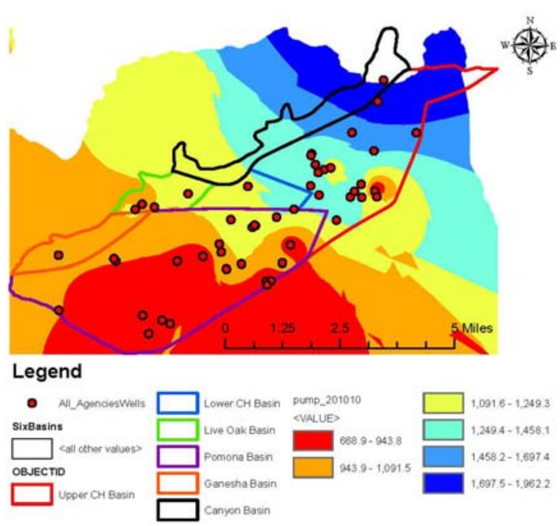
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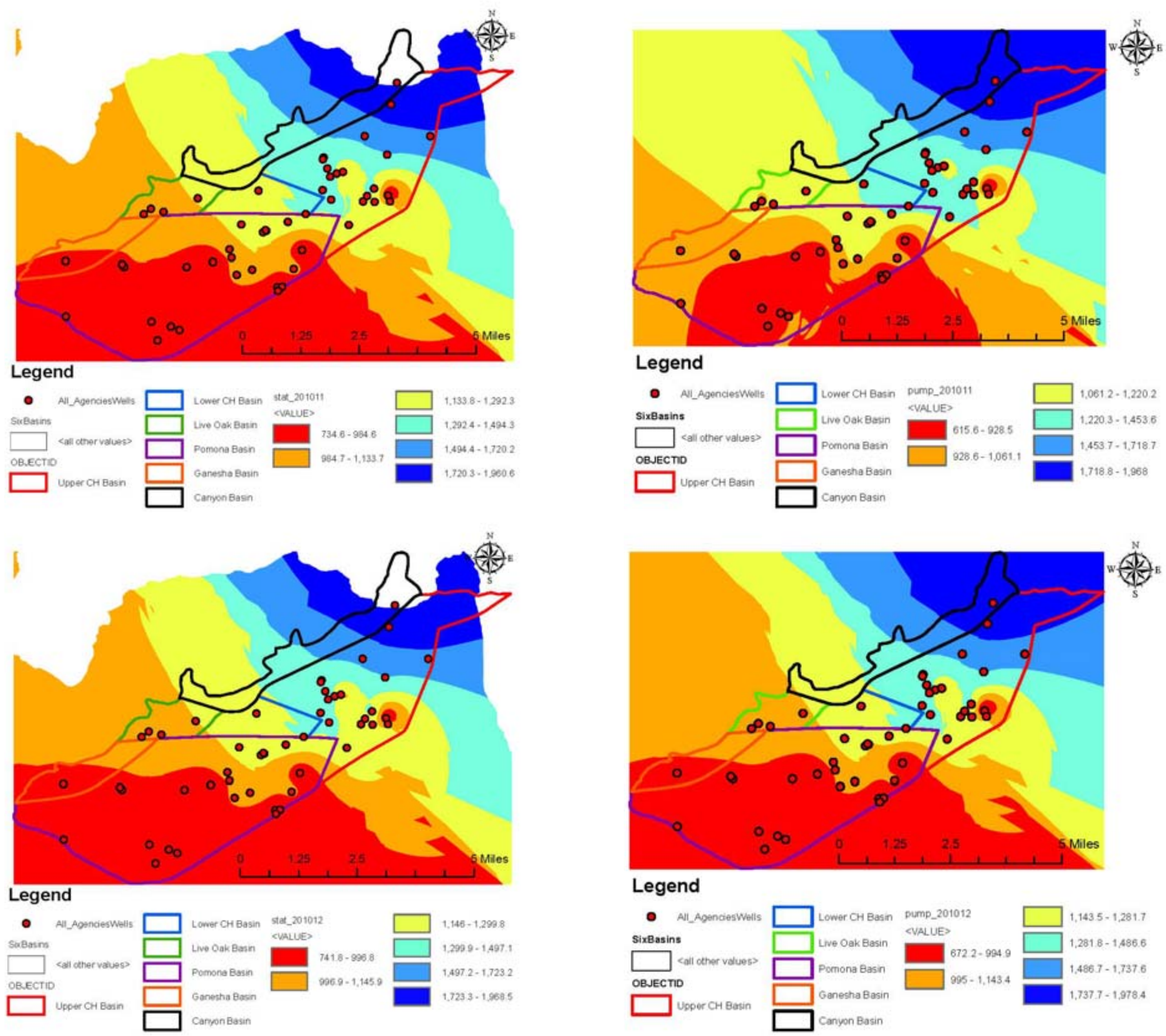

Figure 48: Six Basins Groundwater Modeling

Table 24 through Table 26 provide the six groundwater elevation breaks as illustrated in Figure 48 that contain the monthly static groundwater elevation, monthly pumping groundwater elevation, and monthly groundwater elevation difference. Table 26 shows that the greatest difference in groundwater elevation occurs at the low end of the first groundwater elevation category break (Break 1), the least difference in groundwater elevation occurs at the high end of the last groundwater elevation category break (Break 6). The location of the greatest difference in groundwater elevation seems realistic because most of the groundwater pumping wells are located within the Pomona Basin, where the lowest groundsurface elevation and groundwater elevation is located. The location of the least difference in groundwater elevation is also accurate because very few pumping wells are located within the Canyon and Upper Claremont Heights Basins. Groundwater moves quickest out of that basin because the highest elevation and greatest elevation difference exists there, where water cannot be captured as easily, as shown in Figure 45.

Table 24: Monthly Static Groundwater Elevations

2010 Monthly Static Groundwater Elevations												
Month	Break 1 (ft)		Break 2 (ft)		Break 3 (ft)		Break 4 (ft)		Break 5 (ft)		Break 6 (ft)	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
January	741.4	999.9	1,000.0	1,146.2	1,146.3	1,302.3	1,302.4	1,497.4	1,497.5	1,731.5	1,731.6	1,985.1
February	765.3	997.5	997.6	1,150.6	1,150.7	1,313.6	1,313.7	1,516.2	1,516.3	1,753.3	1,753.4	2,025.0
March	764.1	995.6	995.7	1,146.5	1,146.6	1,307.5	1,307.6	1,518.9	1,519.0	1,765.4	1,765.5	2,047.2
April	737.0	998.7	998.8	1,147.5	1,147.6	1,311.7	1,311.8	1,522.1	1,522.2	1,763.3	1,763.4	2,045.5
May	714.1	974.7	974.8	1,131.1	1,131.2	1,297.8	1,297.9	1,511.5	1,511.6	1,756.5	1,756.6	2,043.1
June	720.6	972.9	973.0	1,137.7	1,137.8	1,307.7	1,307.8	1,518.8	1,518.9	1,755.7	1,755.8	2,033.8
July	697.5	977.2	977.3	1,137.7	1,137.8	1,313.8	1,313.9	1,526.2	1,526.3	1,764.4	1,764.5	2,018.2
August	702.6	976.2	976.3	1,141.4	1,141.5	1,311.8	1,311.9	1,523.4	1,523.5	1,760.9	1,761.0	2,019.0
September	724.2	975.7	975.8	1,121.5	1,121.6	1,282.5	1,282.6	1,493.7	1,493.8	1,745.2	1,745.3	2,006.7
October	741.4	999.9	1,000.0	1,146.2	1,146.3	1,302.3	1,302.4	1,497.4	1,497.5	1,731.5	1,731.6	1,985.1
November	734.6	984.6	984.7	1,133.7	1,133.8	1,292.3	1,292.4	1,494.3	1,494.4	1,720.2	1,720.3	1,960.6
December	741.8	996.8	996.9	1,145.9	1,146.0	1,299.8	1,299.9	1,497.1	1,497.2	1,723.2	1,723.3	1,968.5

Table 25: Monthly Pumping Groundwater Elevations

2010 Monthly Pumping Groundwater Elevations												
Month	Break 1 (ft)		Break 2 (ft)		Break 3 (ft)		Break 4 (ft)		Break 5 (ft)		Break 6 (ft)	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
January	670.9	964.5	964.6	1,108.7	1,108.8	1,268.3	1,268.4	1,469.2	1,469.3	1,706.1	1,706.2	1,984.2
February	709.2	955.4	955.5	1,104.2	1,104.3	1,263.2	1,263.3	1,468.4	1,468.5	1,719.7	1,719.8	2,017.2
March	709.1	971.3	971.4	1,118.1	1,118.2	1,275.5	1,275.6	1,485.2	1,485.3	1,737.0	1,737.1	2,046.4
April	660.7	968.9	969.0	1,125.7	1,125.8	1,293.4	1,293.5	1,504.3	1,504.4	1,753.0	1,753.1	2,039.6
May	619.9	963.3	963.4	1,124.0	1,124.1	1,290.1	1,290.2	1,506.2	1,506.3	1,755.4	1,755.5	2,026.9
June	633.7	956.2	956.3	1,120.2	1,120.3	1,289.7	1,289.8	1,508.4	1,508.5	1,754.4	1,754.5	2,027.7
July	624.3	951.2	951.3	1,109.2	1,109.3	1,272.7	1,272.8	1,490.6	1,490.7	1,735.8	1,735.9	2,013.7
August	652.4	940.8	940.9	1,101.1	1,101.2	1,261.3	1,261.4	1,480.3	1,480.4	1,731.3	1,731.4	2,014.4
September	675.8	944.7	944.8	1,094.7	1,094.8	1,249.9	1,250.0	1,467.1	1,467.2	1,720.5	1,720.6	1,989.4
October	668.9	943.8	943.9	1,091.5	1,091.6	1,249.3	1,249.4	1,458.1	1,458.2	1,697.4	1,697.5	1,962.2
November	615.6	928.5	928.6	1,061.1	1,061.2	1,220.2	1,220.3	1,453.6	1,453.7	1,718.7	1,718.8	1,968.0
December	672.2	994.9	995.0	1,143.4	1,143.5	1,281.7	1,281.8	1,486.6	1,486.7	1,737.6	1,737.7	1,978.4

Table 26: Monthly Groundwater Elevations Difference

2010 Monthly Groundwater Elevations Difference												
Month	Break 1 (ft)		Break 2 (ft)		Break 3 (ft)		Break 4 (ft)		Break 5 (ft)		Break 6 (ft)	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
January	70.5	35.4	35.4	37.5	37.5	34.0	34.0	28.2	28.2	25.4	25.4	0.9
February	56.1	42.1	42.1	46.4	46.4	50.4	50.4	47.8	47.8	33.6	33.6	7.8
March	55.0	24.3	24.3	28.4	28.4	32.0	32.0	33.7	33.7	28.4	28.4	0.8
April	76.3	29.8	29.8	21.8	21.8	18.3	18.3	17.8	17.8	10.3	10.3	5.9
May	94.2	11.4	11.4	7.1	7.1	7.7	7.7	5.3	5.3	1.1	1.1	16.2
June	86.9	16.7	16.7	17.5	17.5	18.0	18.0	10.4	10.4	1.3	1.3	6.1
July	73.2	26.0	26.0	28.5	28.5	41.1	41.1	35.6	35.6	28.6	28.6	4.5
August	50.2	35.4	35.4	40.3	40.3	50.5	50.5	43.1	43.1	29.6	29.6	4.6
September	48.4	31.0	31.0	26.8	26.8	32.6	32.6	26.6	26.6	24.7	24.7	17.3
October	72.5	56.1	56.1	54.7	54.7	53.0	53.0	39.3	39.3	34.1	34.1	22.9
November	119.0	56.1	56.1	72.6	72.6	72.1	72.1	40.7	40.7	1.5	1.5	7.4
December	69.6	1.9	1.9	2.5	2.5	18.1	18.1	10.5	10.5	14.4	14.4	9.9

19 CONCLUSION

19.1 SIX BASINS DESCRIPTION

Six Basins is the name for the six interconnected groundwater basins underlying north eastern Los Angeles County and western San Bernardino County, specifically the cities of Pomona, Claremont, La Verne and Upland. The Six Basins are comprised of the Ganesha, Like Oak, Pomona, Lower Claremont Heights, Upper Claremont Heights, and Canyon Basins. The Six Basins is becoming more significant because it can provide a substantial amount of water via groundwater to the local water supply in a portion of Southern California. The objective of this term project was to map the Six Basins using ArcGIS and try to determine how the groundwater basins are affected by groundwater pumping using calendar year 2010 data.

19.2 SIX BASINS DELINEATION

The Six Basins was delineated using a digital elevation model that spanned the Los Angeles and San Bernardino counties. Using an outlet point near Puddingstone Reservoir, the Six Basins region was delineated using ArcGIS. The Six Basins boundaries were added by requesting shapefiles from Three Valleys Municipal Water District, the former Six Basins Watermaster.

19.3 SIX BASINS SOIL PROFILE

Using STATSGO (2012), a soil profile was created that lied within the Six Basins boundary. It was determined that the Six Basins soil surface is mainly sands and gravels, and sands and silts.

19.4 SIX BASINS PRECIPITATION

Using CIMIS (2012) and the San Antonio Water Company (2012) websites, the precipitation data was gathered. The monthly annual precipitation was compiled in Excel and uploaded and displayed in ArcGIS. Using the Spline Tool, an annual precipitation interpolation was made across the Six Basins boundary. It was determined that the Canyon Basin received the most precipitation between 35.4 in - 41.9 in. The Upper and Lower Claremont Heights Basin, Ganesha Basin, Live Oak Basin, and Pomona Basin received between 31.0 - 35.4 inches of rainfall in 2010.

19.5 SIX BASINS BORING LOGS, BOREHOLES, AND 2D CROSS SECTION

Boring log data was available for the MW-1, MW-2, and MW-3 monitoring wells. Using the data, a borelog table was made in Excel, uploaded to ArcGIS, and was used to make the borehole points in ArcGIS using Arc Hydro Groundwater Tools (Jones, 2012). Using ArcGIS, AutoCAD, and Photoshop, the borehole points were used to create a 2D cross section of the Six Basins that encompassed the three monitoring wells. This 2D cross section was used to determine the weighted average porosities at the monitoring wells, and ultimately the weighted average porosity throughout the Six Basins. The weighted average porosity was used to approximate the storage capacity within the Six Basins.

19.6 SIX BASINS MONITORING WELLS AND PRODUCTION WELLS

Monitoring well and pumping well data were requested from the Six Basins Watermaster and member agencies. Their locations, static and pumping groundwater elevations, and the pumping wells production values were compiled into Excel and uploaded and displayed in ArcGIS. The monitoring wells monthly times series data and the available pumping well static and pumping groundwater elevations were used to model the monthly change in groundwater elevation in the Six Basins. In addition, the data was used to determine the Six Basins area, the average monthly static groundwater elevation, the average monthly pumping groundwater elevation, and the storage capacity using the Construct Thiessen Polygons Tool in ArcGIS.

19.7 SIX BASINS STORAGE CAPACITY

Using ArcGIS, the Six Basins was determined to have an approximate area of 622,844,540.5 ft^2. The average monthly static groundwater elevation varied between 1,204.6 ft - 1,215.6 ft, while the average monthly pumping groundwater elevation varied between 1,180.5 ft - 1,199.2 ft. Using the weighted average porosity, the average monthly static and pumping groundwater elevations, the Six Basins's area, and the Construct Thiessen Polygons Tool in ArcGIS, the Six Basin's annual storage capacity was approximated to be between 551,268 AF - 560,061 AF, a difference of 8,793 AF. The Thiessen Polygons Method grossly underestimated the difference in storage capacity, since 17,056.5 AF of groundwater was pumped from the Six Basins in 2010. Most of the error can be attributed to the weighted average porosity determined and used to calculate the storage capacity. It signified that the Six Basins subsurface profile is much more complex and a simplified subsurface profile is not a valid simplification. Much more research would need to be conducted to improve upon the methodology used to determine the Six Basins storage capacity.

19.8 SIX BASINS GROUNDWATER MODELING

Using the monitoring well and pumping well data, the Six Basins static and pumping groundwater elevation was modeled and compared. Using the ArcGIS Kriging Bayesian Interpolation Tool, the monthly changes in static and pumping groundwater elevations were modeled. It was determined that the Pomona Basin had the largest change in groundwater elevation and that the lowest change in groundwater elevation occurred within the Canyon and Upper Claremont Heights Basins. The model seems realistic since most of the groundwater production wells lie within the Pomona Basin, while few pumping wells exist in the Canyon and Upper Claremont Heights Basins.

19.9 PROJECT SUMMARY

The project was a success and met its objective. Very little modification had to be made to the project from its initial project proposal.

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21 APPENDIX 1.0

This Appendix describes the steps taken to create the Pumping Groundwater Level Interpolations and the Static Groundwater Level Interpolations within the Six Basins.

The **All Agencies Well Feature Class** was opened to provide a snapshot of all of the pumping well and monitoring well data uploaded from Excel Sheets, as shown in Figure A1-1 and A1-2.

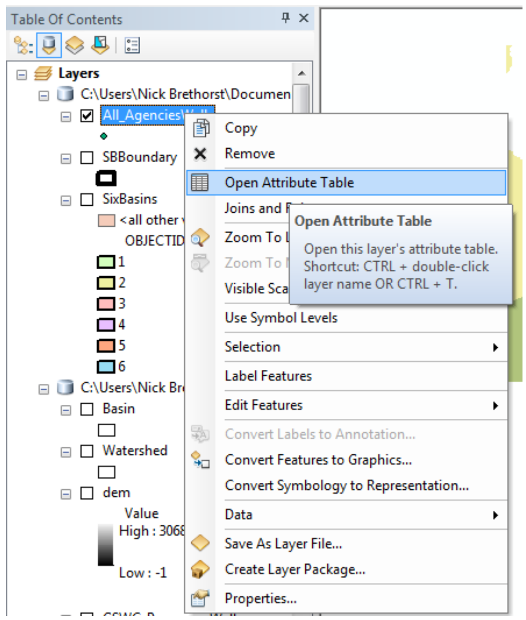

Figure A1-1: Opening of the All Agencies Well Feature Class

Table

All_AgenciesWells

OBJECTID *	Well_Name	State_Well_Number	Latitude_degN	Longitude_degW	YYYYMM	Date_	GSE_ft	DTWPUMP_ft	DTWSTAT_ft	GWEPUMP_ft	GWESTAT_ft
1	Alamosa 2	01N08W34A03	34.131567	-117.699186	201001	1/31/2010	1636	336	301	1300	1335
2	Alamosa 2	01N08W34A03	34.131567	-117.699186	201002	1/28/2010	1636	336	301	1300	1335
3	Alamosa 2	01N08W34A03	34.131567	-117.699186	201003	3/31/2010	1636	337	304	1299	1332
4	Alamosa 2	01N08W34A03	34.131567	-117.699186	201004	4/30/2010	1636	337	301	1299	1335
5	Alamosa 2	01N08W34A03	34.131567	-117.699186	201005	5/31/2010	1636	327	299	1309	1337
6	Alamosa 2	01N08W34A03	34.131567	-117.699186	201006	6/30/2010	1636	299	279	1337	1357
7	Alamosa 2	01N08W34A03	34.131567	-117.699186	201007	7/31/2010	1636	280	262	1356	1374
8	Alamosa 2	01N08W34A03	34.131567	-117.699186	201008	8/30/2010	1636	281	262	1355	1374
9	Alamosa 2	01N08W34A03	34.131567	-117.699186	201009	9/30/2010	1636	275	257	1361	1379
10	Alamosa 2	01N08W34A03	34.131567	-117.699186	201010	10/31/2010	1636	276	260	1360	1376
11	Alamosa 2	01N08W34A03	34.131567	-117.699186	201011	11/30/2010	1636	277	261	1359	1375
12	Alamosa 2	01N08W34A03	34.131567	-117.699186	201012	12/31/2010	1636	282	268	1354	1368
13	Berkeley	01S08W09G03	34.100278	-117.7225	201001	1/31/2010	1193	116	105	1077	1088
14	Berkeley	01S08W09G03	34.100278	-117.7225	201002	1/28/2010	1193	120.5	110.5	1072.5	1082.5
15	Berkeley	01S08W09G03	34.100278	-117.7225	201003	3/31/2010	1193	125	116	1068	1077
16	Berkeley	01S08W09G03	34.100278	-117.7225	201004	4/30/2010	1193	120	106	1073	1087
17	Berkeley	01S08W09G03	34.100278	-117.7225	201005	5/31/2010	1193	124	111	1069	1082
18	Berkeley	01S08W09G03	34.100278	-117.7225	201006	6/30/2010	1193	124	115	1069	1078
19	Berkeley	01S08W09G03	34.100278	-117.7225	201007	7/31/2010	1193	115	110	1078	1083
20	Berkeley	01S08W09G03	34.100278	-117.7225	201008	8/30/2010	1193	113	109	1080	1084
21	Berkeley	01S08W09G03	34.100278	-117.7225	201009	9/30/2010	1193	106	102	1087	1091
22	Berkeley	01S08W09G03	34.100278	-117.7225	201010	10/31/2010	1193	101	99	1092	1094
23	Berkeley	01S08W09G03	34.100278	-117.7225	201011	11/30/2010	1193	99.5	97.5	1093.5	1095.5

1 (52 out of 624 Selected)

All_AgenciesWells

Figure A1-2: All Agencies Well Feature Class Attribute Table

With all of the monitoring and pumping wells on, I used the **Select Features Tool** and highlighted all the wells as shown in Figure A1-3.

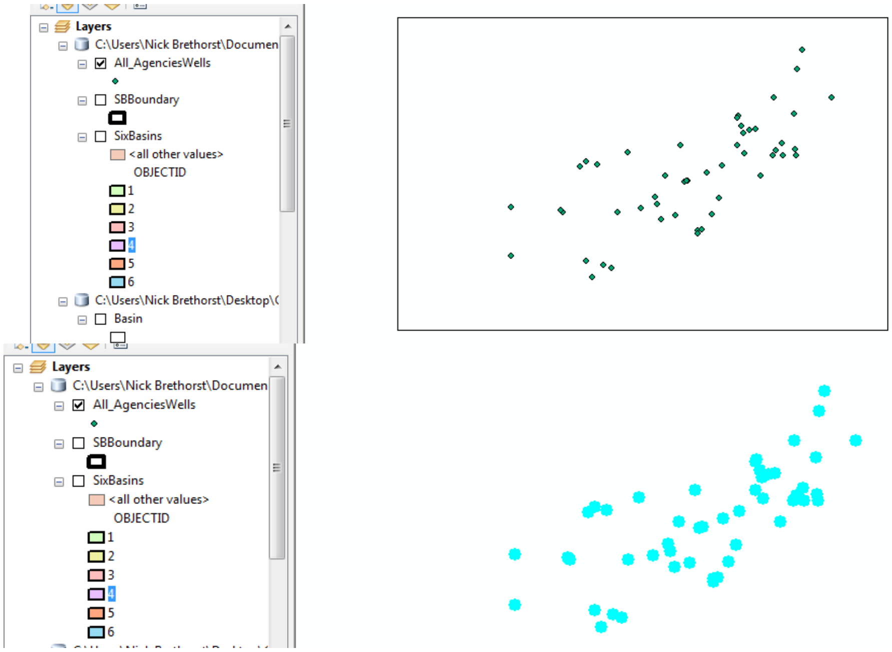

Figure A1-3: Highlighting of all of the Wells using the Select Features Tool

Then I navigated to **Selection - Select By Attributes Table** and inputted the field YYYYMM to isolate a pumping water levels interpolation throughout the basin for one specific month. In this example, 201009 was selected from the get unique values of the YYYYMM layer within the Attribute Table of the All Agencies Well Feature Class. This means that an interpolation will be conducted for September 2010, as shown in Figure A1-4.

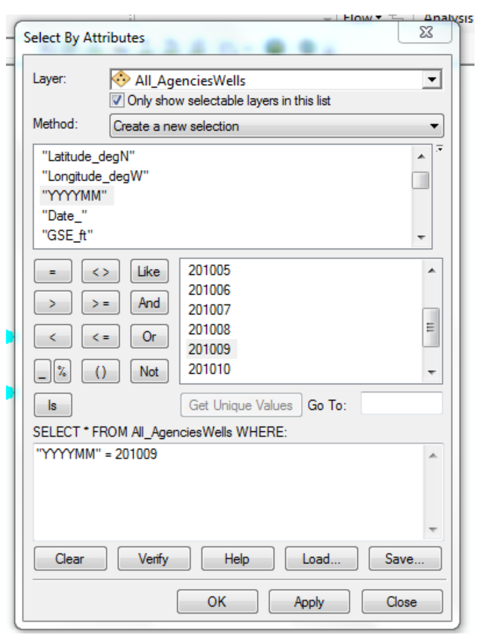

Figure A1-4: Select By Attributes Table

Then I navigated to **Spatial Analyst Tools** → **Interpolation** → **Kriging** and added the following input, as shown in Figure A1-5 and Figure A1-6:

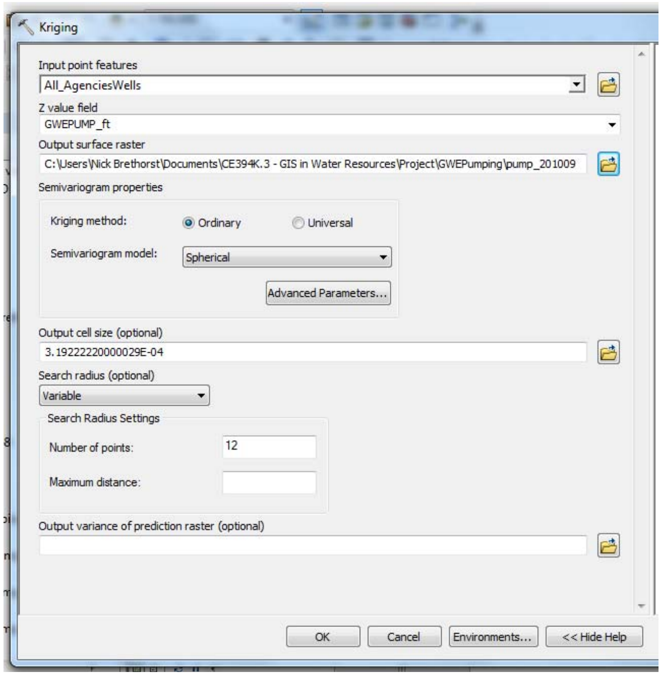

Figure A1-5: Kriging Tool Input

The Environments Settings Button was pressed and the following inputs were added.

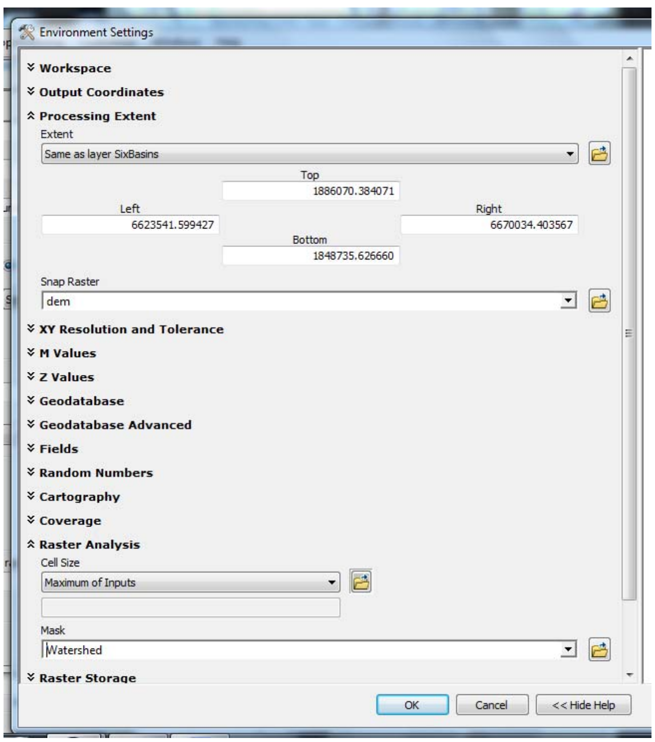

Figure A1-6: Kriging Tool Environment Settings Input

Then the Kriging Interpolation was ran, and the following groundwater pumping levels throughout the Six Basins for January 2010 resulted, as shown in Figure A1-7:

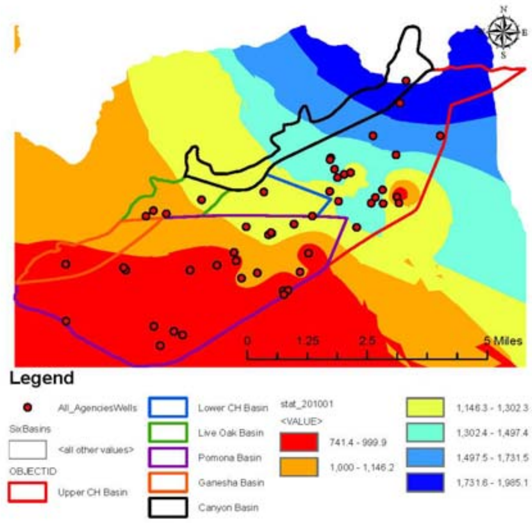

Figure A1-7: Kriging Bayesian Output

The process was repeated for every month in 2010. The same process was followed for the static water level interpolation, but the Z Value Field was changed in the Kriging Bayesian Tool from GWEPump_ft to GWEStat_ft, as shown in Figure A1-8:

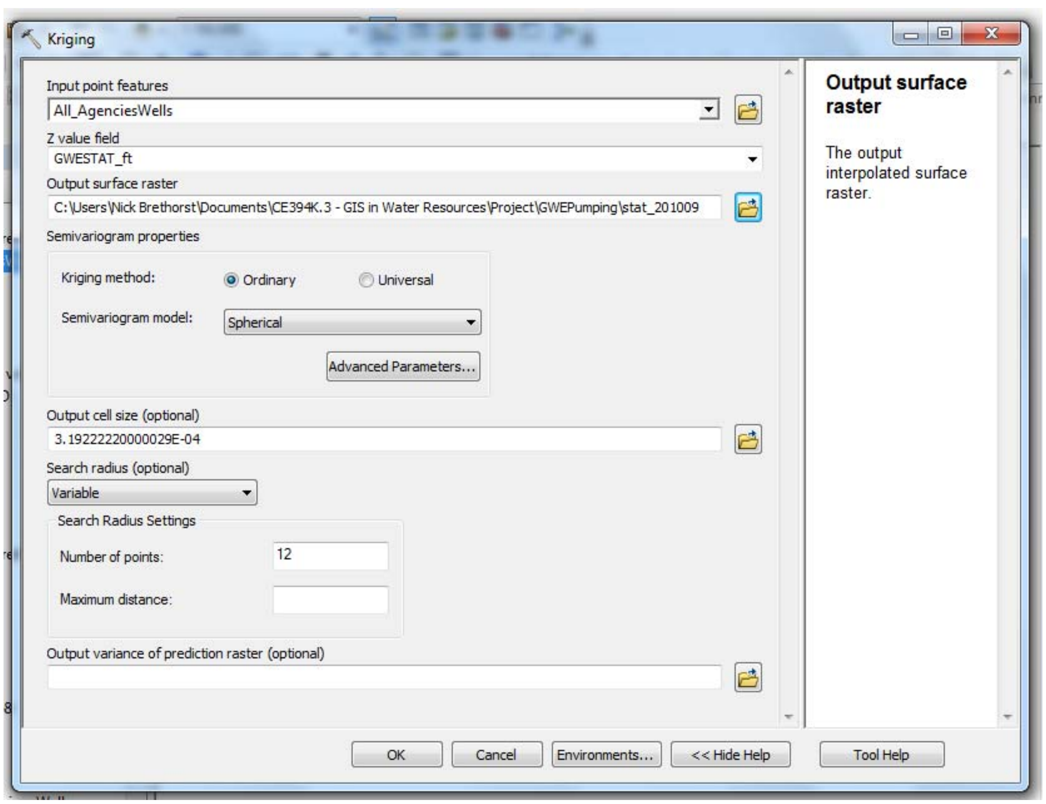

Figure A1-8: Kriging Tool Input for Static Groundwater Level Interpolation