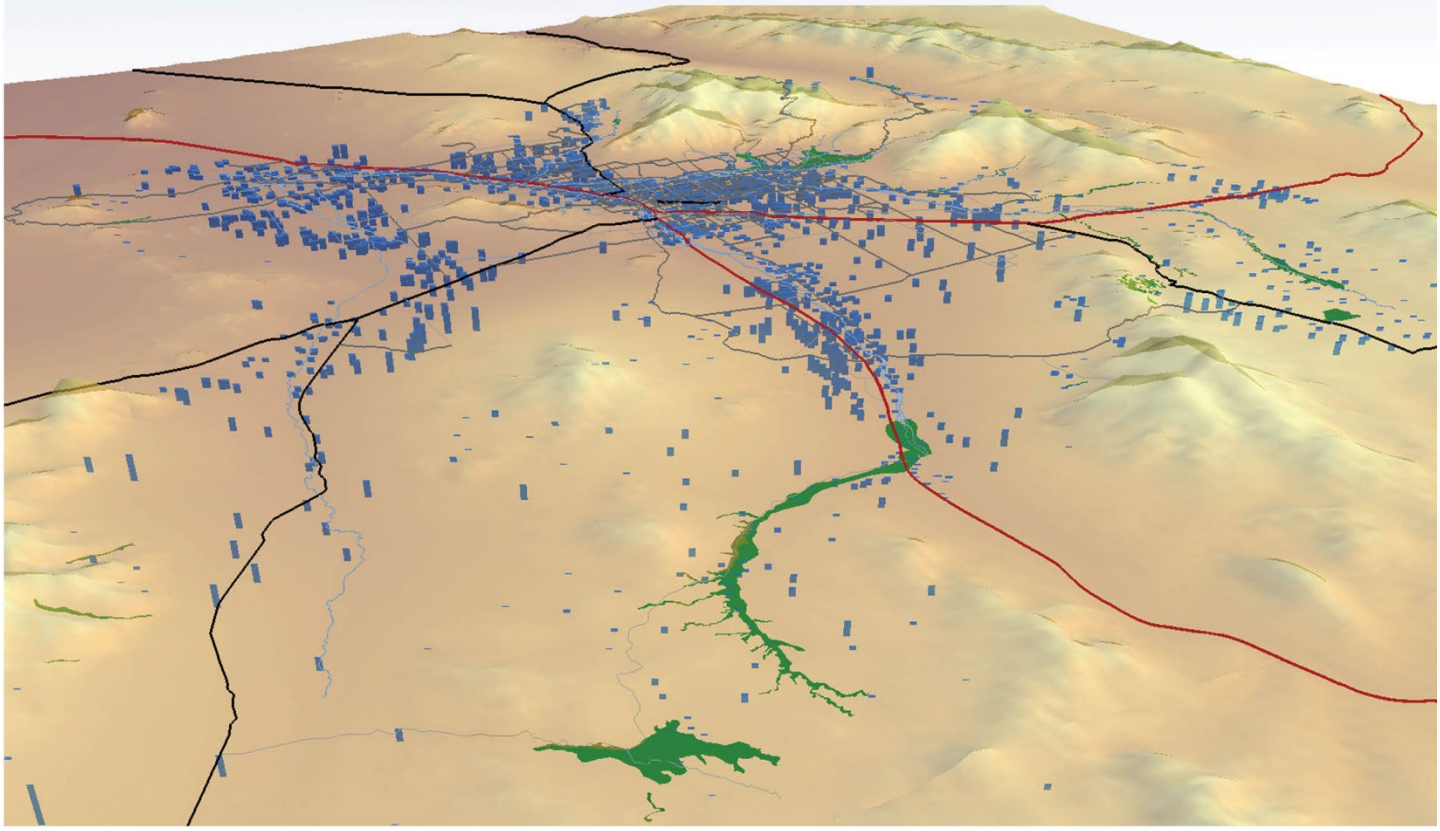
Shallow Groundwater Areas in Eastern Pima County, Arizona

WATER WELL INVENTORY AND PUMPING TREND ANALYSIS

Pima Association of Governments

October 2012



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EXECUTIVE SUMMARY

This report is the fifth in a series of documents detailing information about shallow groundwater areas of eastern Pima County produced by Pima Association of Governments (PAG) since 2000. A shallow groundwater area is defined as a site where groundwater is within 50 ft. of the land surface. In eastern Pima County, these areas not only provide water to vegetation and sensitive wildlife habitat, but also to numerous private and public well owners. Competition for limited subsurface water in these areas will likely intensify with drought and climate change in the coming years. This project was conducted with input by the Pima County Regional Flood Control District and the Pima County Office of Sustainability and Conservation, and is an outgrowth of an investigation originally conducted for the Sonoran Desert Conservation Plan.

A total of 32 shallow groundwater areas, grouped into 10 regions, were included in the project. Three large shallow groundwater regions ring the eastern side of the Tucson basin and two extensive systems are found in the area southwest of Green Valley, Arizona, along the Pima/Santa Cruz county line. In addition, several smaller shallow groundwater areas are identified, many of which not only support a significant number of wells, but also support, valued riparian habitat. Surface flows through these regions recharge into the eastern part of the Tucson basin, the upper Santa Cruz River and the Altar Valley aquifers. Because shallow groundwater areas are generally located along mountain fronts and upland drainages, the habitat they support is critical to the large scale wildlife corridor system within the region.

State and local well data were used to inventory wells, determine well densities and drilling trends, and to evaluate water withdrawals and groundwater levels. The primary sources of well data were the State of Arizona's Well Registry and the Groundwater Site Inventory, both of which were last updated in April 2012 and are maintained by the Arizona Department of Water Resources (ADWR). PAG's groundwater monitoring data from the Cienega Creek and Davidson Canyon areas, dated May 2012, also were utilized. Since state databases have limited quality control, this evaluation is most appropriate for use in developing a broad understanding of water trends rather than for site specific studies. As of 2012, a total of 2,560 wells were found to be located within or near shallow groundwater areas, with 81 percent of those being exempt. Exempt wells must pump less than 35 gallons per minute and are typically used for watering stock, household or noncommercial irrigation purposes of less than two acres of land. Total withdrawals within the shallow groundwater areas, including their one-mile buffer zones, were estimated to be 27,821 acre feet (AF) in 2010, with the assumption that each exempt well pumped one AF per year.

For each shallow groundwater area the following information is provided:

1) A map of all wells within the shallow groundwater area and its one-mile buffer zone;
2) A table including the exempt and non-exempt wells and the density per square mile;
3) A table and map showing the drilling history in 10-year increments;
4) A table with water withdrawal information including total water withdrawals for 2010; and
5) Hydrographs showing depth-to-water for wells with repeat water level measurements.

Hydrographs presented in the report show all of the wells within each shallow groundwater area and its one-mile buffer area. Information such as the well's geographic location, the well type or the nearby pumping history was not considered when compiling the information. It was beyond the scope of this study to parse out data for individual wells or to identify a representative well for each area. Even so, the hydrographs offer a wealth of information that we hope will provoke interest in these areas and potentially encourage future site specific-studies.

This investigation provides information that may be useful to land managers, planners, water providers, private water well owners and ecologists.

- **Well drilling is still in progress:** Well drilling continues to be active in eastern Pima County, resulting in numerous wells being drilled either in shallow groundwater areas or in their associated buffer areas since 2000. Well drilling during this time was most active in the Rillito-Tanque Verde System, the Cienega-Davidson System and the Pantano-Rincon System. Regions with relatively low drilling activity included the San Pedro River, Cocio Wash, Sutherland Wash and Central Santa Cruz River.

- **Repeat water level measurements are needed to determine water level trends:** Water level measurements are the best means of determining if the shallow groundwater aquifers are in decline, yet 14 of the 32 areas studied have insufficient data to determine trends. Monitoring studies to repeatedly collect groundwater level information is recommended for basins where critical riparian resources in addition to significant reliance on local groundwater are found.

- **Most of the water is being pumped from two regions:** Together, the Santa Cruz-Sopori System and in the Rillito-Tanque Verde System represent 92.3 percent of all withdrawals from shallow groundwater areas. However, it is important to note that water withdrawal by volume may not be the only cause for concern. Many of the other basins have significant water withdrawals, or numerous wells (high well densities) that could become more active in the future. Even relatively small withdrawals can adversely affect riparian vegetation depending on the aquifer storage, geometry of the basin, and relative locations of wells and vegetation.

- **Water level trends vary across the region:** The Central Santa Cruz River region and the Rillito-Tanque Verde System showed similar long-term water level declines of 100 feet to 150 feet since the 1950s until the early 2000s, when reduced water withdrawals resulted in aquifer rebound. A different trend of stable water levels until the 1990s, followed by water level declines until present was noted in the Tortolita Mountains, Box Canyon (Rincon), Rincon Creek Area, Agua Verde-Posta Quemada, Santa Cruz River (Canoa), Sopori Wash, Arivaca Area, and possibly Cienega Creek (Lower). At present, water levels appear to be stable in San Pedro River (Bingham Cienega), Cienega Creek (Upper) and Gardner Canyon.

Shallow Groundwater Areas in Eastern Pima County, Arizona

Water Well Inventory and Pumping Trend Analysis

INTRODUCTION

Eastern Pima County is a semi-arid landscape that receives approximately 12 inches of precipitation annually in the basin area, making the presence of water and riparian habitats especially rare and valued by the community (National Weather Service, 2012). Groundwater aquifers are generally deep in eastern Pima County, except where they interact with shallow bedrock or alluvium and where they intersect natural recharge areas, such as water courses and mountain fronts. In these areas, the groundwater table may be as shallow as 50 feet below the ground surface, thus constituting a shallow groundwater area (SGWA). These areas are commonly associated with perennial and intermittent stream reaches, as well as rare riparian environments. In this region, many riparian habitats exist along intermittently flowing streams because the tree roots can reach down and access subsurface water.

Historically, the Tucson region has depended largely on groundwater to meet its water needs. As water from the Central Arizona Project (CAP) became a significant alternative since 2005 (City of Tucson and Pima County, 2009), reliance on groundwater has lessened for several of the region's municipalities. Private sector well owners, especially those in shallow groundwater areas, generally depend solely on groundwater for their potable water supplies. As the region's population expands and the groundwater aquifers continue to be developed, it becomes increasingly important to understand groundwater usage trends for sensitive areas, so that riparian habitats are not compromised.

This report is fifth in a series of reports on shallow groundwater in eastern Pima County published by Pima Association of Governments (PAG) since January 2000. The intent of these documents is to support the Sonoran Desert Conservation Plan and to provide information for the Pima County Regional Flood Control District (PCRFCD), the Pima County Office of Sustainability & Conservation, and other regional planners and water managers.

The first report, *Sonoran Desert Conservation Plan: GIS Coverage of Perennial Streams, Intermittent Streams and Areas of Shallow Groundwater* (PAG, 2000a), developed criteria for identifying shallow groundwater areas and used these criteria to select areas of interest. Subsequent reports by PAG in July 2000, 2007 and 2008 examined water usage more extensively and expanded the number of study sites over time.

Whereas previous reports focused mostly on well inventories and water withdrawals within the study sites, this report expands on the well analyses to include:

- Well inventories and densities
- Drilling trends
- Water withdrawal volumes
- Groundwater level temporal trends
- A survey of other potential shallow groundwater sites for possible future study

The approach is similar to previous studies conducted by PAG. However, in some cases the methodology was slightly changed, additional shallow groundwater areas were compiled by Pima County and, in a few cases, boundaries of the existing shallow groundwater areas were modified. Therefore, a direct comparison between the results given in the 2008 report and the current report is not recommended without a thorough understanding of project expansions and modifications. Although the results of this study contribute to our knowledge of shallow groundwater areas, the report is limited by the availability and reliability of well data. In addition, a comprehensive understanding of these areas would need to include analysis of vegetation, hydrogeology and climate. In order to give the report a logical order, shallow groundwater areas were grouped into 10 regions and were presented in geographic order from north to south, with summary information provided at the end of the report.

DATA SOURCES

The major categories of data used in this study were (1) a GIS layer representing the boundaries of the shallow groundwater areas, and (2) water well data in the form of GIS layers and ancillary tables. Though the primary source of well data was from the Arizona Department of Water Resources (ADWR), this report also incorporated PAG's detailed water level data from nine wells in the Cienega Creek and Davidson Canyon areas. In addition, vegetation information was obtained from existing sources as explained below.

Shallow Groundwater Areas

A GIS shapefile layer representing the boundaries of the shallow groundwater areas was provided to PAG by Pima County in late 2011. This layer was very similar to that used in the previous study conducted by PAG in 2008. Based on conversations with Pima County personnel in May 2012, PAG made further refinements to the layer to include a new section of Tanque Verde Creek (called "Tanque Verde Creek (Mid)") and to extend the existing Rincon Creek Area. Details regarding changes to the shallow groundwater area GIS layer since 2000 are discussed in the section, *"Study Sites,"* starting on page 8.

Vegetation

Vegetation descriptions in this report were obtained from PAG's report, *Sonoran Desert Conservation Plan: GIS Coverage of Perennial Streams, Intermittent Streams and Areas of Shallow Groundwater (*PAG, 2000a) and from the shallow groundwater area GIS layer provided by Pima County in 2011.

Water Well Data

New water wells are required by law to be permitted by and registered with the State of Arizona. The well owner or the well driller is responsible for reporting all well information to ADWR.

The level of well regulation exercised by ADWR is dependent upon the geographic location of the well and the pumping capacity of the well. In 1980 five Active Management Areas (AMAs) and two Irrigation Non-Expansion Areas (INAs) were established in the state in order to preserve the state's groundwater resources. The AMAs are Prescott, Phoenix, Pinal, Tucson and Santa Cruz. (Note: AMA boundaries do not coincide with municipal or county boundaries.) The two original INAs were Joseph City and Douglas, with Harquahala being added later. The Arizona Groundwater Code authorizes ADWR to manage groundwater resources with regulations specific to each of the AMAs or INAs. Wells outside of these areas are subject to fewer regulatory and reporting requirements. Two AMAs are present in this project area, the Tucson AMA and the Santa Cruz AMA. Because no INAs are near eastern Pima County, they are not considered in this report.

Throughout the state, ADWR recognizes two classes of wells, exempt vs. non-exempt, based on pumping capacity. ADWR defines these two types of wells as:

> "An exempt well has a maximum pump capacity of 35 gallons per minute. Typical uses include non-irrigation purposes, noncommercial irrigation of less than 2 acres of land, and watering stock. Most exempt wells are used for residences and are more than adequate for household use. In AMAs, new exempt wells used for non-residential purposes can withdraw a maximum of 10 acre-feet per year." (ADWR, 2012)

> "A non-exempt well has a pump capacity exceeding 35 gallons per minute. This type of well is generally used for irrigation or industry." (ADWR, 2012)

Non-exempt wells within AMAs must report water withdrawals to ADWR annually; however, there is no such reporting requirement for non-exempt wells outside of AMAs or for any exempt well.

The State of Arizona maintains two sets of well databases for storing well data: the Well Registry (or Wells-55 database) and the Groundwater Site Inventory (GWSI). Because there is no single database that can provide a complete description of wells in Arizona, both of these databases were used to compile the final database used for this shallow groundwater area report. When there were duplicates, the more precise location point was used.

The Well Registry includes all wells registered with the State of Arizona, numbering 159,787 wells as of April 2012. The registry contains information such as the well owner, the driller, a legal description, the installation date, the well depth, the well type, the depth-to-water, water use and site use. Annual water withdrawals from non-exempt wells also are available online from the Well Registry. The Well Registry is based on information submitted by well owners and well drillers, and has not been verified by the State of Arizona. Therefore, ADWR is unable to guarantee the accuracy of this information.

Well locations in the Well Registry are inexact. The positional accuracy is limited because the well locations are reported to ADWR by township, range, section and section subdivision down to the nearest 10 acres (quarter-quarter-quarter section). In order to map these locations, every section in the state is subdivided into 64 10-acre cells, 16 40-acre cells and four 160-acre cells with a label point assigned to the center of each cell. These center points are then used to represent the approximate locations of the wells. There can be more than one well on a location point because all wells within the same 10-acre cell are assigned to the same label point.

The GWSI database is based on a subset of the wells registered with ADWR. The database contains field data that were collected by ADWR's Hydrology Division or by hydrologists at the U.S. Geological Survey. The information in GWSI is constantly being updated by ADWR through ongoing field investigations and through continued monitoring of a statewide network of water level monitoring sites. Field personnel determine well locations with Global Positioning Systems (GPS), thus geographic coordinates in the GWSI database are much more precise than those provided by the Well Registry. As with the Well Registry, the GWSI database provides information on the well type, site use, water use and drilling information. However, GWSI provides some information not given in the Well Registry, including the well elevation, and frequently, multiple water level readings.

Datasets from the Well Registry and the GWSI are available for download via ADWR's website at http://www.azwater.gov/azdwr/gis/. Users should be aware of ADWR's disclaimer that accompanies the data:

> "The data on this website was developed by the Arizona Department of Water Resources ("Department"), for uses beneficial to the State of Arizona. The information is available to interested members of the public. While the Department believes the information to be reliable and made efforts to assure its reliability at the time the information was compiled, the information is provided "as is." The Department is not responsible for the accuracy, completeness, quality or legal sufficiency of the information. Any expressed or implied warranties, including, but not limited to, the implied warranties of merchantability and fitness for the purpose ARE SPECIFICALLY DISCLAIMED. Neither the Department nor the State of

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Using ADWR's GIS website, PAG retrieved Wells-55 datasets, last updated on April 27, 2012, and the GWSI datasets, last updated on April 25, 2012. Each of the datasets included a GIS layer and an extensive set of ancillary spreadsheets. Table 1 describes the sources of ADWR data used during this project. In addition, PAG obtained the most recently updated set of historic pumping data (1984-2010) from ADWR's Well Registry website at https://gisweb.azwater.gov/waterresourcedata/WellRegistry.aspx. Annual pumping data are made available to the public approximately one year after being submitted to the State by the owners.

Several data and methodology limitations were encountered when conducting this investigation. Data were often incomplete in the various databases, and sometimes the water withdrawal information was unavailable from ADWR. Water withdrawals from non-exempt wells were not available for properties outside the Tucson or Santa Cruz AMAs because owners are not required to report pumping volumes to ADWR. The lack of availability of pumping data for some wells limits the conclusions that can be made from the data.

Table 1. ADWR data sources for well analysis.

GWSI/Wells-55	Source	Description
GWSI	GWSI.shp	GIS layer containing well information from GWSI database
	GWSI_SITES.csv	Source of ancillary water use and site use information
	GWSI_WW_LEVELS.csv	Source of ancillary depth-to-water information
Wells-55	Wells-55.shp	GIS layer containing well information from Wells-55 database
	WELLS_SITE_USES.csv	Source of ancillary site use information
	WELLS_WATER_USES.csv	Source of ancillary water use information

STUDY SITES

This section describes a brief history of PAG's studies of shallow groundwater areas with emphasis on modifications that were made to the study sites since the last report. Issues related to the aggregation of the 32 areas into 10 regions and to the creation of buffer zones also are discussed.

Shallow groundwater areas are locations where water exists within 50 ft. of the land surface making it accessible to typical riparian vegetation, such as cottonwood, Arizona sycamore, willows and mesquite bosques. PAG's January 2000 report on *Sonoran Desert Conservation Plan: GIS Coverage of Perennial Streams, Intermittent Streams and Areas of Shallow Groundwater* specified criteria for identifying shallow groundwater areas in eastern Pima County based on several factors. Briefly, these criteria included (1) the existence of riparian vegetation based on ground surveys and/or aerial photography, (2) the presence of springs and surface water and (3) indications of water within 50 ft. of the land surface based on well information reported since 1980.

PAG's first report on water usage, entitled *Water Usage along Selected Streams in Pima County, Arizona* written in July 2000, examined a large number of streams, as well as 22 areas that exhibited shallow groundwater. When the project was updated in 2007 another area of interest, Rincon Valley was temporarily added to the study, bringing the total to 23. The number of shallow groundwater areas was increased again in 2008 when a total of 31 sites were evaluated. All of these new areas were compiled by Pima County from various sources with the exception of Sopori Wash, which PAG extended into Santa Cruz County for continuity. As such, Sopori Wash is the only shallow groundwater study site to extend into another county.

This report includes all areas studied by PAG in 2008 with several modifications and additions for the sake of contiguous hydrologic connection to known shallow groundwater. For this analysis two formerly separate areas, Agua Verde Creek Area and Posta Quemada, were analyzed as one unit, called Agua Verde-Posta Quemada. This seemed reasonable as Posta Quemada is contiguous with the Agua Verde Creek Area, is relatively small and contains few wells. Two new areas added to this study were Barrel Canyon and Tanque Verde Creek (Mid). Extensive water level measurements of the Barrel Canyon area were performed by E.L. Montgomery for Rosemont Copper. This information led to the Barrel Canyon delineation by Pima County (Fonseca, 2012). Following discussions with representatives from Pima County regarding a preliminary analysis of the 2012 data, PAG added a new area, called Tanque Verde Creek (Mid), in order to fill the spatial gap between the two established Tanque Verde Creek units. It was also decided at that time that PAG should extend the existing Rincon Creek Area upstream to capture additional riparian vegetation and several new wells displaying shallow groundwater levels. Another small, new area, called Tres Lomas North, had been delineated and added to Pima County's compiled dataset since PAG's last report was published, due to the presence of a spring (Helfrich et. al., 2012; Fonseca, 2012); however, PAG's preliminary analysis determined that all wells within one mile of Tres Lomas North were already part of the Sabino Canyon Area buffer. Thus, any analysis related to the Sabino Canyon Area includes Tres Lomas North.

PAG also recognized that the naming convention for some of the areas was confusing in prior reports. In an effort to make the names more consistent and meaningful several names were altered in this report. A direct comparison between the names used in this report and those used in the 2008 report is given in Appendix A. In consideration of these changes, this report now includes 32 shallow groundwater areas in eastern Pima County, aggregated into 10 regions. Regions contain between one and eight areas, based on their proximity and common watershed characteristics.

As in previous reports, one-mile buffers were created around each of the shallow groundwater areas. Because water pumping can cause far-reaching effects beyond the immediate vicinity of a well, any wells that were encompassed by the one-mile buffer areas were considered for analysis. Due to the close proximity of some shallow groundwater areas within a region, their one-mile buffers may overlap, with the consequence that some wells coincide with more than one area. In contrast, none of the regions overlap each other due to the larger distances separating them.

The most detailed findings in this report are discussed on a regional basis. In each case, the regions are presented in a roughly north to south order as shown in Table 2. The table includes the regions, their watershed descriptions and their areas. Figure 1 shows the locations of the 10 regions in eastern Pima County. More detailed maps of the study sites are given in later sections.

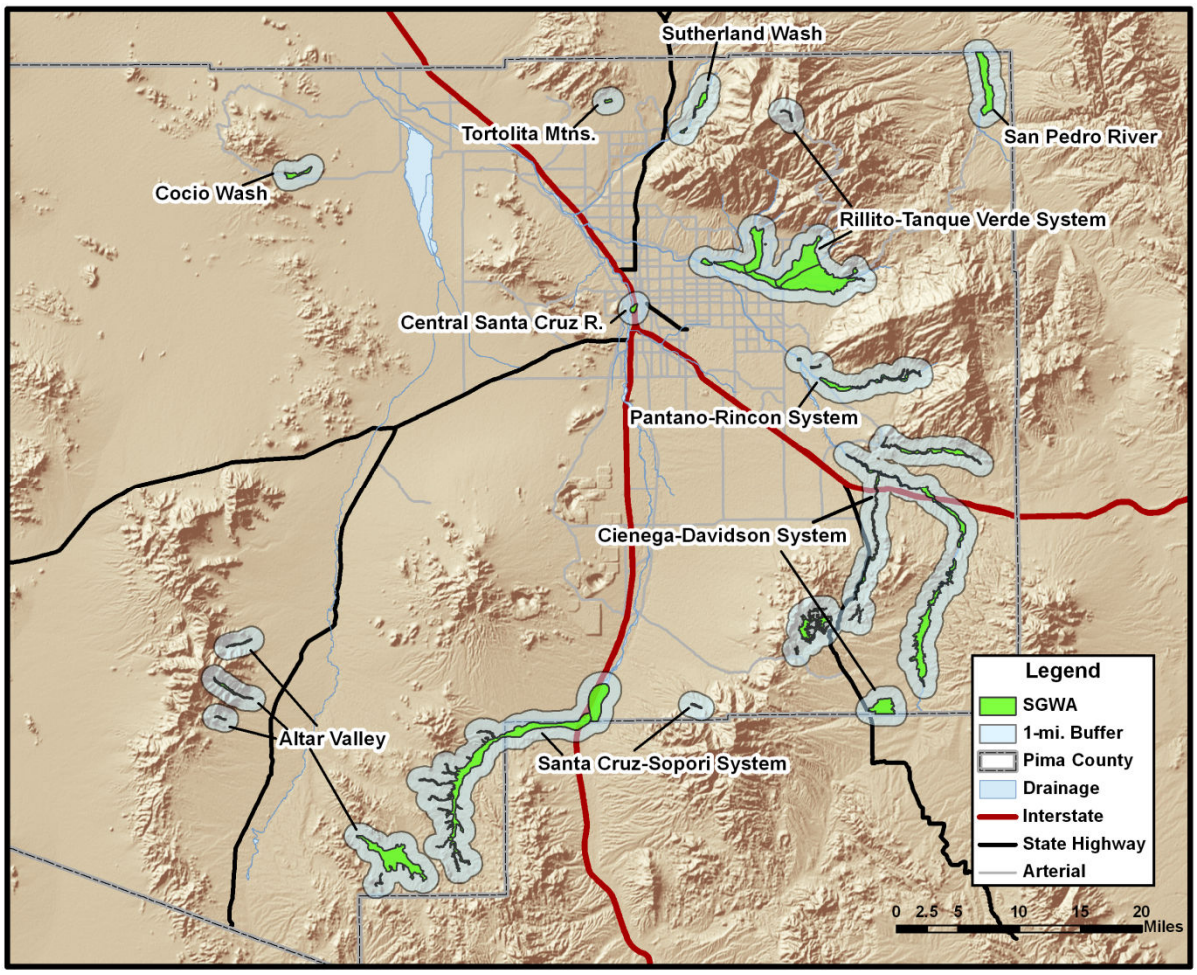
Table 2. List of regions with their respective shallow groundwater areas.

Region	Watershed Description	Shallow Groundwater Areas[1]
San Pedro River	San Pedro River in NE Pima Co.; flows north into the Gila River	San Pedro River (Bingham Cienega)
Sutherland Wash	NW side of Santa Catalina Mountains.; flows via Cañada del Oro to the Santa Cruz River	Sutherland Wash (Lower) Sutherland Wash (Upper)
Tortolita Mountains	South side of Tortolita Mountains; flows into Santa Cruz River via minor washes	Tortolita Mountains
Cocio Wash	SE of Silverbell Mountains, down slope of Silverbell Tailings Pond; flows to Santa Cruz River via minor washes	Cocio Wash Area
Rillito-Tanque Verde System	Drainages from the south side of the Santa Catalina Mountains, the north side of the Rincon Mountains and Reddington Pass; drainages flows into the Santa Cruz River via Rillito Creek	Agua Caliente Canyon Area Rillito Creek Area Sabino Canyon Area Sabino Canyon (Summerhaven) Tanque Verde Creek (Lower) Tanque Verde Creek (Mid) Tanque Verde Creek (Upper)
Central Santa Cruz River	Short section of Santa Cruz River west of downtown Tucson	Santa Cruz River (Tucson)
Pantano-Rincon System	West side of Rincon Mountains between Tanque Verde Ridge and Rincon Peak; flows into Rillito Creek via Pantano Wash	Box Canyon (Rincon) Pantano Wash Rincon Creek Area
Cienega-Davidson System	Region between the Rincon Mountains and the Santa Rita Mountains; drainages converge and flow into Pantano Wash	Agua Verde-Posta Quemada Barrel Canyon Cienega Creek (Upper) Cienega Creek (Mid) Cienega Creek (Lower) Davidson Canyon (Upper) Davidson Canyon (Lower) Gardner Canyon

Region	Watershed Description	Shallow Groundwater Areas[1]
Santa Cruz-Sopori System	Upper section of Santa Cruz River watershed; part of Sopori Wash flows through Santa Cruz County	Madera Canyon Santa Cruz River (Canoa) Sopori Wash
Altar Valley	Area between Baboquivari Mountains and town of Arivaca; flows into Altar Wash	Arivaca Area Brown Canyon Fraguita Wash Sabino Canyon (Baboquivari) Thomas Canyon

[1] *See Appendix A for cross-reference of names used in previous report.*

Figure 1. Shallow groundwater regions of eastern Pima County.



Note: SGWA = Shallow groundwater area

WELL ANALYSIS

Data mining is defined as "the science of extracting useful information from large data sets or data bases" (Hand et al., 2001). Data mined from the GWSI and the Wells-55 database were the basis of all calculations and findings used in this report. In general, the objective of well data processing was to merge both databases, as required, and to clip the resulting dataset to the geographic extents of the areas. One exception was the analysis of potential areas of shallow groundwater throughout Pima County. For that part of the study, well data were clipped with the boundary of Pima County rather than the shallow groundwater areas. A significant amount of well information stored in the GWSI and the Wells-55 databases was not useful for this work, so a series of data extraction steps were used to refine the information.

The geographic extents, well selection and time period for processing the well data depended on the kind of analysis that was being performed (Table 3). The major data processing steps for each type of analysis follow Table 3.

Table 3. Constraints on data analysis.

Type of Analysis	Geographic Extents	Well Categories	Time Constraint
Well Inventory	SGWA[1] buffers	Water-producing wells	All years
Drilling Trends	SGWA[1] buffers	Water-producing wells	All years
Water Withdrawals	SGWA[1] buffers	Water-producing wells	1984-2010
Water Level Trends	SGWA[1] buffers	Wells with multiple water level measurements; PAG monitoring wells	All years
Survey of Shallow Groundwater	Eastern Pima Co.	Wells with depth-to-water <50 ft.	After Jan. 1, 1980

[1] *Shallow groundwater area*

Processing Steps for Well Inventory and Drilling Trends

The major steps in preparing the well data for these analyses are shown in Figure 2 (steps 1-7) and are described as follows:

1. Project the GWSI and Wells-55 data from UTM coordinates into Arizona State Plane coordinates (International Feet, Central Arizona) in order to match the shallow groundwater area GIS layer.
2. Clip the statewide well data with a buffered boundary of Pima County. A three-mile buffer around the county was used so as to ensure coverage of Sopori Wash, which courses through a corner of Santa Cruz County, and other areas that touch the county border.
3. Merge the GWSI and Wells-55 data into one dataset. There will be multiple records for some wells, not only from the merging process, but also because the GWSI database may contain more than one record for a given well.

4. Remove duplicate records for wells, keeping the newest, most complete information. After editing, there should be one record per well.
5. Join GIS layers to ancillary spreadsheets to obtain more thorough information on site use and water use (Table 1).
6. Based on well type, cancellation, site use and water use, remove wells from the dataset which are not involved in water production. For example, some wells may be capped or destroyed, or used for non-water-producing purposes. The criteria that are used for filtering well data are given in Table 4.
7. Clip the filtered database with the one-mile buffers of each region/area.

Upon completion of the steps outlined above, each of the regions and areas contained a set of water-producing wells ready for the analysis of well inventory, drilling trends and pumping histories. The final well GIS layers included more than 80 attribute fields, of which only a subset were relevant to this study. Table 5 lists those fields that were of primary importance to this analysis.

Figure 2. Workflow for preparing ADWR well data for well inventories and drilling trends.

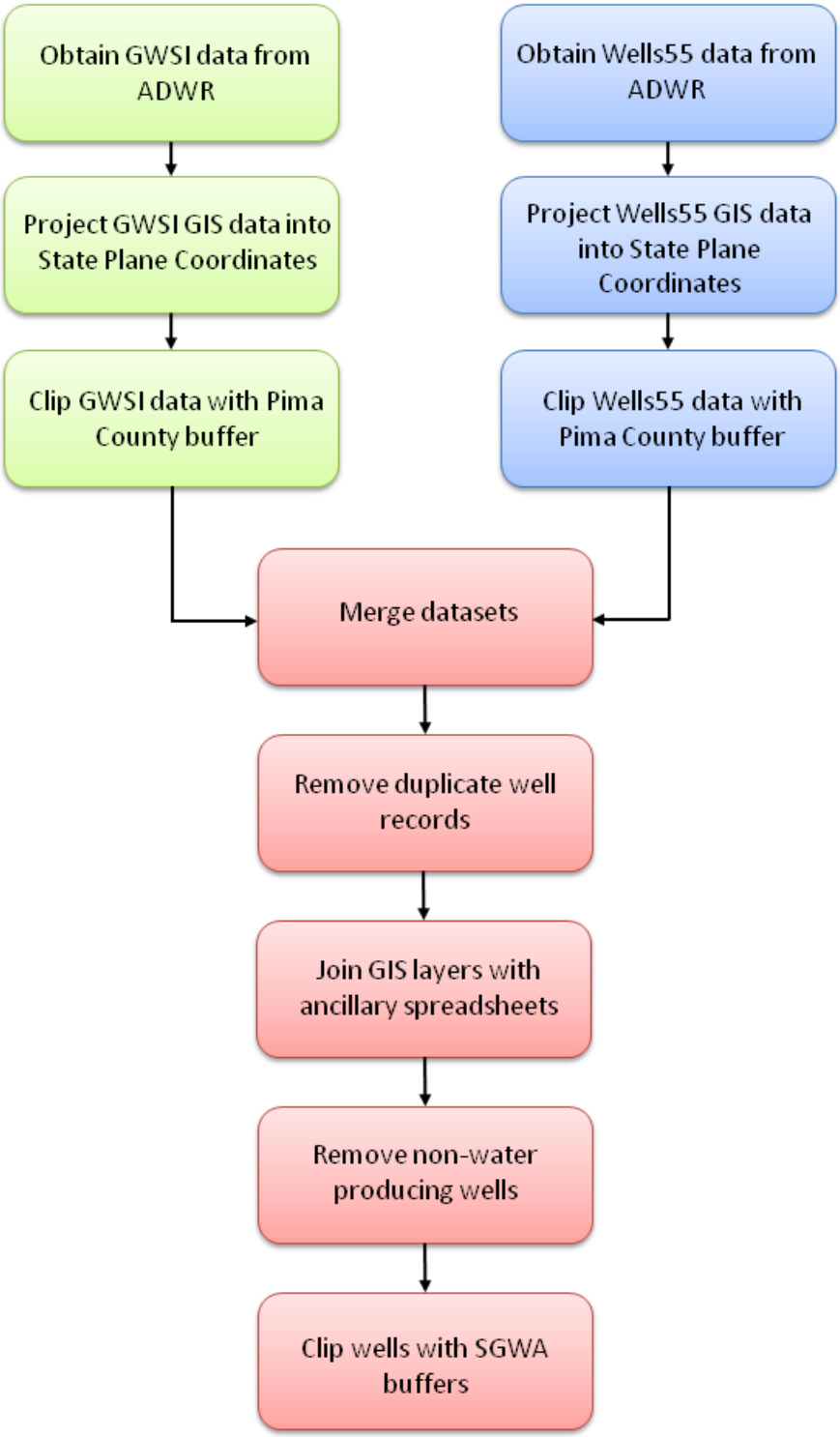


Table 4. Attributes used for well record removal from the merged well database.

Characteristic	Attribute	Values Indicating Removal
Canceled	Well_Cance[1]	Y
Well Type	Welltype[1]	Cathodic, geotechnical, heat reservoir, soil vapor extraction, injection, piezometer, observation, monitor, exploration[3], air sparging
Site Use	SUSE_Code[1]	Anode, capped, geotechnical, heat reservoir, mineral exploration[3], cathodic, observation, piezometer, monitor, recharge, seismic, test, abandoned, waste disposal, destroyed
	Site_Use_1[2] Site_Use_2[2] Site_Use_3[2]	Anode, geothermal, seismic, heat reservoir, mine, observation, water quality monitoring, recharge, repressurized, test, unused, waste, destroyed
Water Use	WUSE_Code[1]	Mineral explore[3], monitoring, recharge, test
	Water_Use[2]	Observation, unused
	Site_Water_Use_1[2] Site_Water_Use_2[2] Site_Water_Use_3[2]	Observation, unused

[1] *Originally a Wells-55 attribute*
[2] *Originally a GWSI attribute*
[3] *Though exploration wells may pump large amounts of water, they are temporary in production.*

Table 5. Data fields of primary importance in final well layers.

Field Names	Definition	Source
SITE_ID	Site Identification Number	GWSI
REG_ID, REGISTRY_I, REG_NUM	Registration ID Number	GWSI, Wells-55, PAG
WELL_ALT	Well Altitude (ft.)	GWSI
WATER_USE	Water Use	GWSI
LASTWLDATE	Date of Water Level Measurement	GWSI
WL_DTW	Depth-to-Water (ft.)	GWSI
WL_ELEV	Water Level Elevation (ft.)	GWSI
GWSI	Flag to Indicate Record Source	PAG
WELLTYPE	Well Type	Wells-55
WELL_TYPE_, WELL_CAT	Exempt or Non-exempt	Wells-55, PAG
APPROVED	Well Approval Date	Wells-55
DRILL_DATE, INSTALLED	Well Installation Date	GWSI, Wells-55
WATER_LEVE	Depth-to-Water (usually upon Installation)	Wells-55
WELL_CANCE	Cancellation Status	Wells-55
AMA	Active Management Area	Wells-55
W55	Flag to Indicate Record Source	PAG
G_SUSE1, G_SUSE2, G_SUSE3	Site Use	GWSI
G_WUSE1, G_WUSE2, G_WUSE3	Water Use	GWSI
SUSE_CODE	Site Use	Wells-55
WUSE_CODE	Water Use	Wells-55
DRILL_YR	Year of Installation	PAG
PUMP2010	Volume of Water Pumped in 2010	Online Well Registry

Processing Steps for Water Withdrawals

As noted earlier, water withdrawal data in eastern Pima County are available only for non-exempt wells within AMAs. Because ADWR does not collect water withdrawal information for any exempt wells in the state or for any non-exempt wells outside of management areas, it is difficult to estimate precisely how much water is being pumped from the aquifers annually.

To estimate pumping from exempt wells, ADWR staff indicated to PAG in 2008 that 0.5-1.0 Acre Feet (AF) would be a safe assumption of annual withdrawals in the Tucson AMA (Seasholes, 2008). To put that amount in context, if each person in a family of four used 100 gallons of water per day, during one year the amount of water would be 0.45 acre-feet. In keeping with previous reports, this study assumes that each exempt well withdraws one acre-foot per year (AF/Y).

Starting with the set of wells clipped with the area buffers (see previous section), several additional steps were required to obtain and analyze the water withdrawal data. These steps are described below:

1. Make a list of the registration IDs of non-exempt wells for each area.
2. Submit each list of registration IDs to ADWR's website at https://gisweb.azwater.gov/WellRegistry/SearchWellReg.aspx. Download tables containing the historic water withdrawal data. (Note: At the time of this report data were available for the period of 1984-2010.)
3. Create a new numeric field in the well databases called "PUMP2010."
4. Join the water withdrawal tables to the well databases based on the registration ID number.
5. For exempt wells set the value of PUMP2010 to 1.0. For non-exempt wells set the value of PUMP2010 to be equal to the value found in the "2010" column of the water withdrawal tables.

A trend analysis of water withdrawals from non-exempt wells for 1984-2010 was done for each region where data were available. As such, pumping rate trends are presented for eight out of the 10 regions.

Processing Steps for Water Level Trends

ADWR records measurements of the depth-to-water and the water elevation of some of the wells in the GWSI database repeatedly. For some wells there may be more than 70 water level readings spanning six decades. Data from any type of well with multiple depth-to-water measurements was included, not just readings from water-producing wells. Thus, the processing steps were considerably different from those described for the well inventory and were as follows:

1. Project the GWSI GIS data from UTM coordinates into Arizona State Plane coordinates (International Feet, Central Arizona).
2. Clip the projected GWSI data with the buffers of the shallow groundwater areas.
3. In ArcGIS relate the tables of the clipped GWSI to the GWSI_WW_LEVELS.csv spreadsheet, which contains multiple water level readings.
4. Select wells within each shallow groundwater buffer, and export selected water level records into a new table. Repeat for each area.
5. Remove any records in the water level tables that lack depth-to-water data (i.e., depth-of–water and water elevation values are 0.0).

The resulting water level tables have several fields that are relevant for water level analysis as given in Table 6.

Because nine of the shallow groundwater areas contained no wells with multiple water level readings, the trend analysis was limited to 23 of the 32 areas. Besides the GWSI water level data from ADWR, PAG has led a monitoring effort of selected wells in the Cienega-Davidson region at monthly intervals for more than 20 years. The dataset includes additional measurements from several sources far back as the late 1980s. These data are also incorporated into this report.

Table 6. Data fields of primary importance in the water level tables.

Field Names	Definition
WLWA_SITE_	Site Identification Number
WLWA_MEASU	Date of Water Level Measurement
WLWA_DEPTH	Depth-to-Water from Land Surface (ft.)
WLWA_WATER	Elevation of Water above Sea Level (ft.)
YR_MEAS	Year of Water Level Measurement (Extracted from Date by PAG)

Processing Steps for Survey of Additional Shallow Groundwater Areas

In order to perform a survey of potential shallow groundwater water sites for future study, PAG analyzed water level information for all wells in the GWSI and Wells-55 databases that were measured since January 1, 1980, the same date used for previously delineating areas. In wells where there were multiple depth-to-water measurements, such as in some of the GWSI data, the most recent depth measurements were used in order to depict the latest information.

As described in the section, "*Processing Steps for Well Inventory and Drilling Trends"* (page 11), the GWSI and Wells-55 GIS layers were projected into State Plane coordinates for the Central Zone of Arizona and clipped with a buffered boundary of Pima County. Subsequently, the following steps were used to refine the data.

1. Delete wells in which the depth-to-water was either unknown or greater than 50 ft. (Refer to the WL_DTW attribute of the GWIS layer and the WATER_LEVE attribute of the Wells-55 layer.)
2. Delete wells in which the water level measurements were made before 1980. (Refer to the LASTWLDATE attribute of the GWSI layer and the INSTALLED date attribute of the Wells-55 layer.)
3. Merge the GWSI and Wells-55 data, and delete duplicates based on Registration ID, giving priority to GWSI records.

RESULTS OF DATA ANALYSIS

The results of the well analysis are presented in three sub-sections. The first sub-section gives an overview of well inventories, drilling trends and water withdrawals among the 10 regions. The second sub-section presents more detail on each of these topics region-by-region, in addition to water level trends. Finally, the third sub-section presents the results of other shallow groundwater areas of interest not included in the current set of study sites.

Overview of Results

This general overview compares the regions with respect to their well inventories, drilling trends and water withdrawals. For further detail, refer to the individual regions which follow this overview.

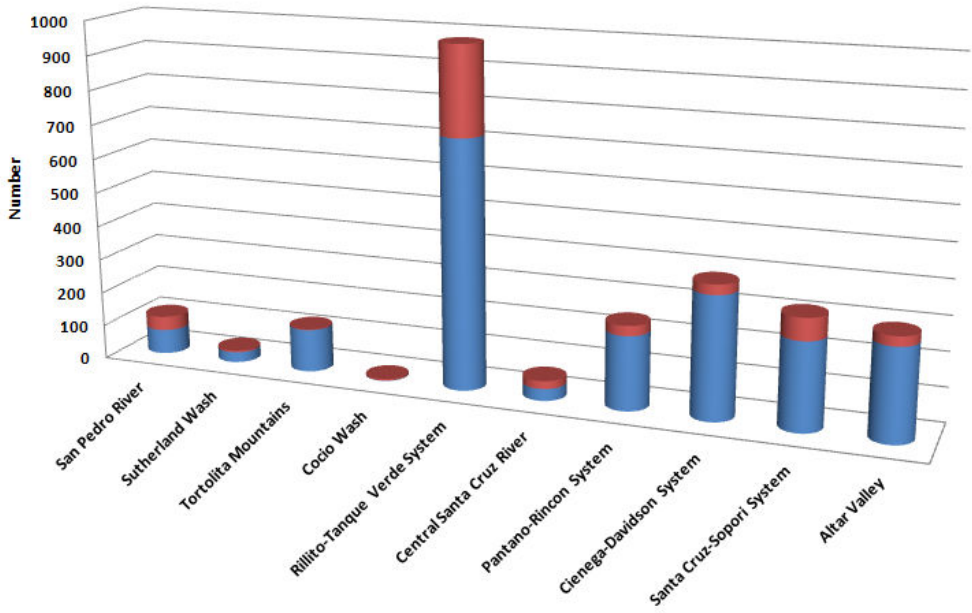
Well Inventory

As of April 2012, there were a total of 2,560 water-producing wells in shallow groundwater areas (including their one-mile buffer zones), consisting of 2,078 (81%) exempt wells and 482 (19%) non-exempt wells. The Tucson AMA included 2,011 wells, whereas 254 were in the Santa Cruz AMA and 295 were outside of any AMA.

Figure 3 shows the number of exempt and non-exempt water-producing wells in each region. By far, the Rillito-Tanque Verde System had the largest inventory of wells with 722 exempt wells and 257 non-exempt wells. Other regions with large numbers of wells included the Cienega-Davidson System (384 wells), the Santa Cruz-Sopori System (319 wells), the Altar Valley (296 wells) and the Pantano-Rincon System (244 wells).

Given that the regions vary considerably in area, well density is also a useful way to compare regional well inventories. To compute well density, the total number of wells within a buffer was divided by the area of that buffer in square miles (Figure 4). The Tortolita Mountains region had the highest well density with 26.5 wells/sq. mile while Cocio Wash had the lowest density at 0.5 wells/sq. mile. As will be seen in the following sections, several individual shallow groundwater areas in other regions also had high well densities.

Figure 3. Inventory of wells by region in 2012.



Region	San Pedro River	Sutherland Wash	Tortolita Mountains	Cocio Wash	Rillito-Tanque Verde System	Central Santa Cruz River	Pantano-Rincon System	Cienega-Davidson System	Santa Cruz-Sopori System	Altar Valley
# Non-exempt Wells	41	5	2	4	257	23	29	29	64	28
# Exempt Wells	72	30	125	1	722	35	215	355	255	268

Drilling Trends

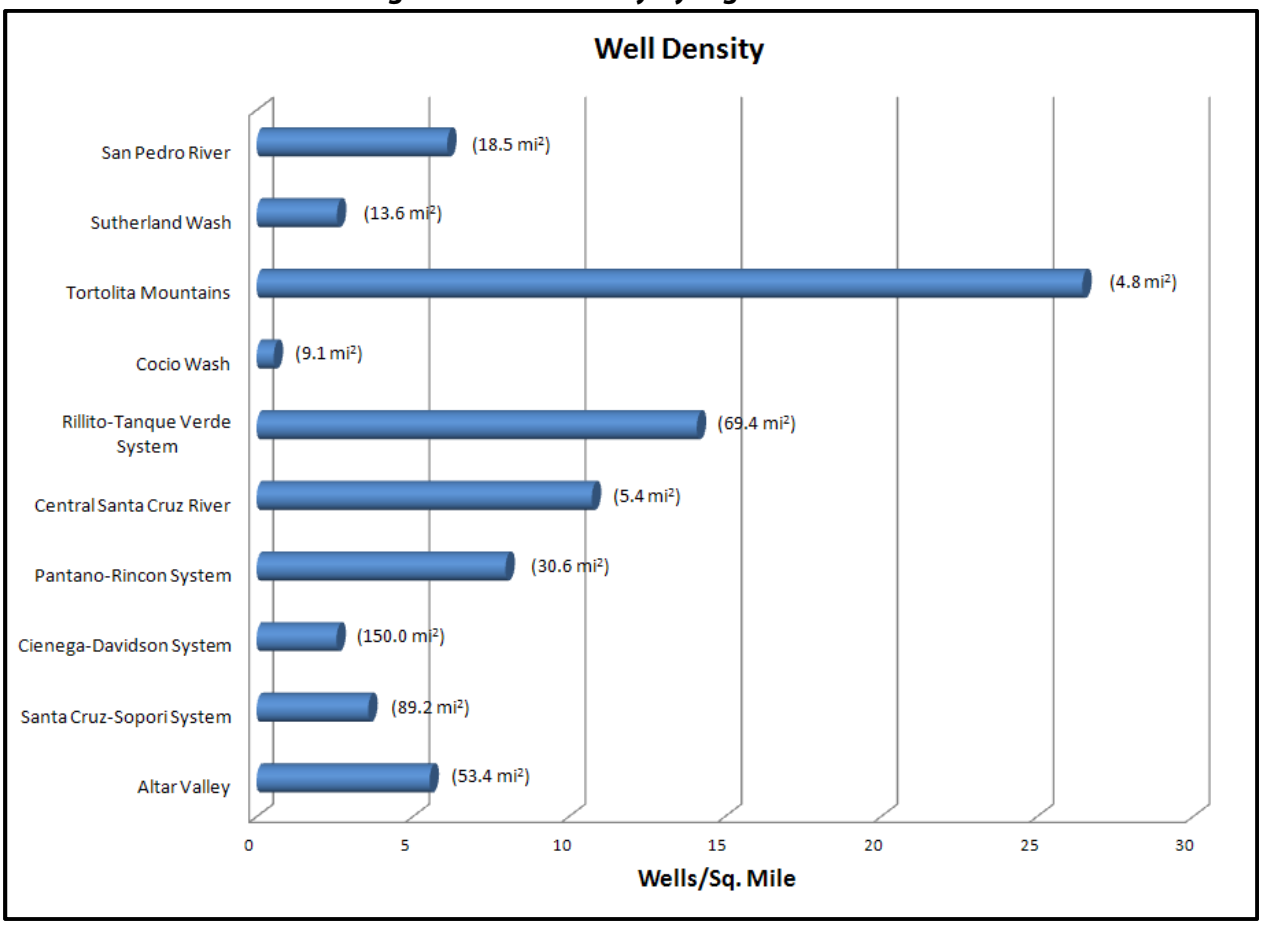
To analyze drilling trends, exempt and non-exempt wells were sorted into five categories based on their installation dates: (1) unknown, (2) before 1980, (3) 1980-1989, (4) 1990-1999 and (5) 2000 through April 2012[1]. Figures 5 and 6 show the drilling trends of exempt and non-exempt water-producing wells, respectively, for each of the 10 regions.

Among exempt wells, drilling activity trended upward in many regions between 1980 and 2012, especially in the San Pedro River, the Tortolita Mountains, the Rillito-Tanque Verde System, the Pantano-Rincon System and in the Cienega-Davidson System. Since 2000, the two regions experiencing the greatest drilling activity were the Rillito-Tanque Verde System and the Cienega-Davidson System.

In contrast, the vast majority of non-exempt wells were installed before 1980. The Rillito-Tanque Verde System is one of the few regions where installation of non-exempt wells has continued in considerable numbers. Of the 32 non-exempt wells installed in shallow groundwater areas since 2000, 23 of them were in this one region.

[1] The newest entry in the Wells-55 database was dated April 25, 2012.

Figure 4. Well density by region in 2012.



Note: Areas of regions (mi²), including one-mile buffers, in parenthesis at right.

Figure 5. Drilling trends of exempt wells.

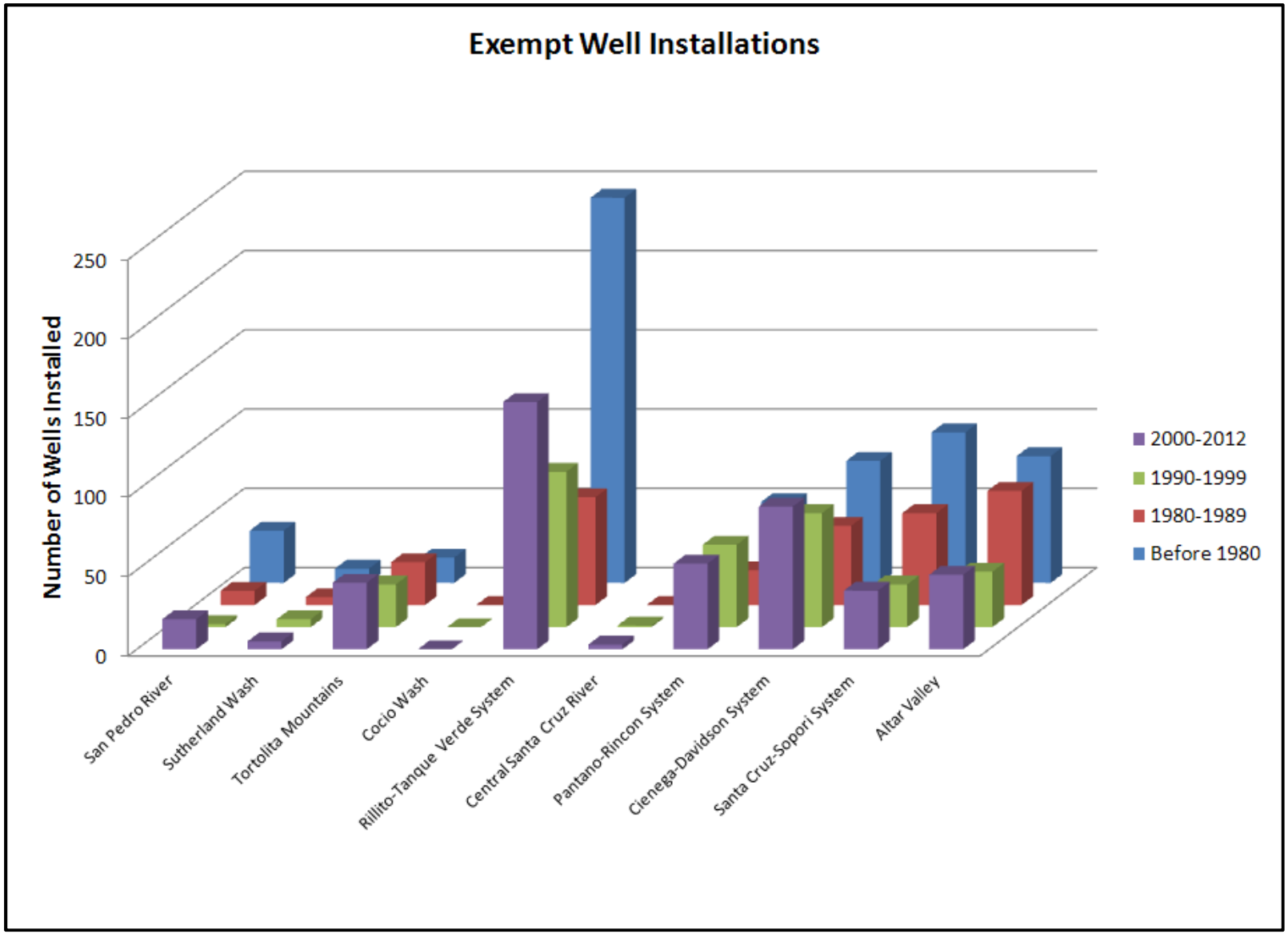
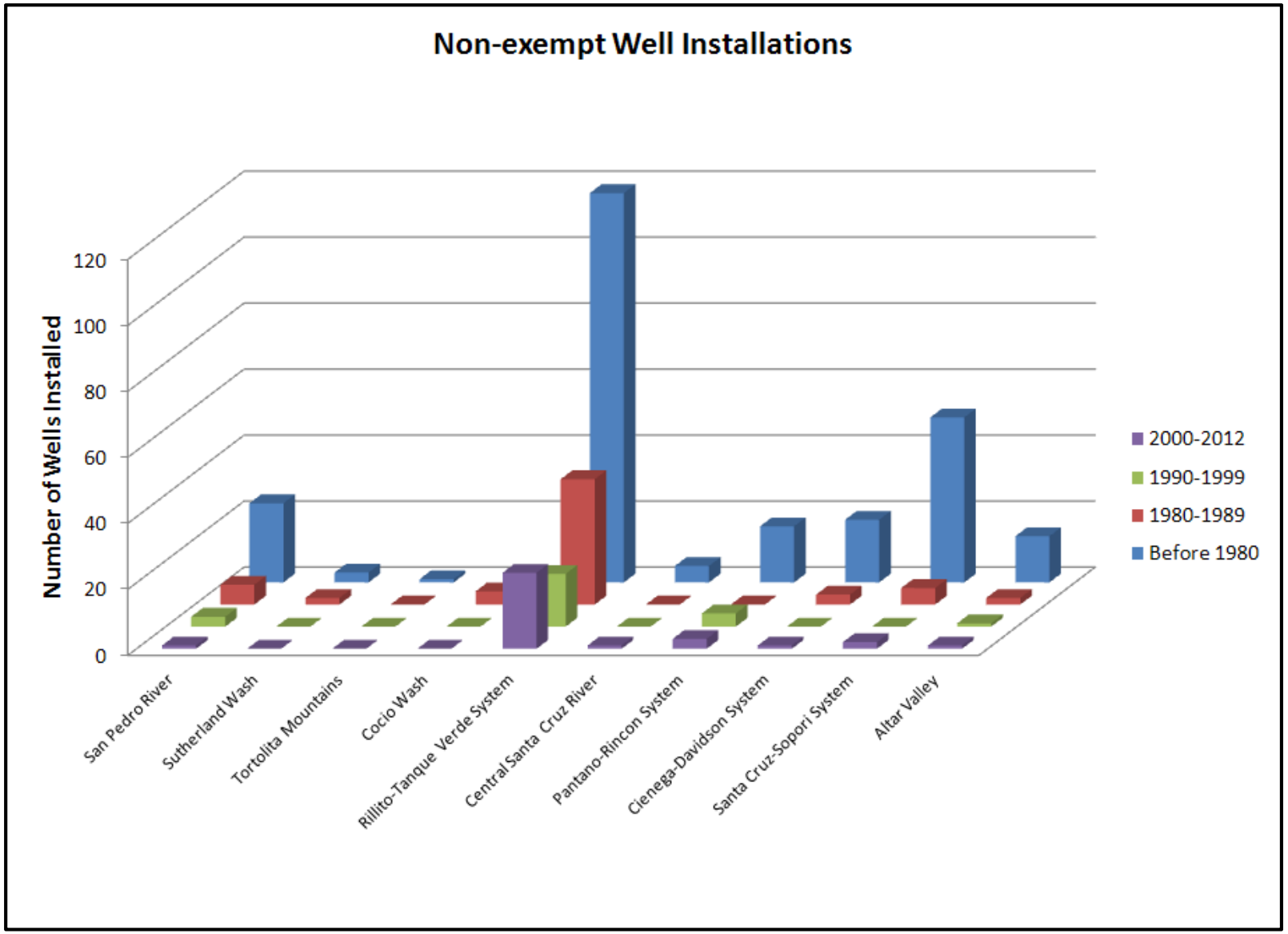


Figure 6. Drilling trends of non-exempt wells.



Water Withdrawals

The total amount of water withdrawn from all shallow groundwater regions in 2010 (the most recent year from which data were available) was estimated to be 27,820.5 acre-feet. This amount was calculated by summing water withdrawals from exempt wells, assumed to be 1.0 acre-feet/year/well, with water produced by non-exempt wells in 2010 as reported to the State. This amount does not include withdrawals from non-exempt wells that did not report data to ADWR. As discussed in the *"Data Sources"* section, owners of non-exempt wells outside of AMAs are not required to report their withdrawals to the State. In addition, owners of 139 non-exempt wells within AMAs did not report water withdrawals in 2010 for unknown reasons. Thus, the estimates presented here and in subsequent sections should be considered erring on the low side.

Water withdrawals varied greatly by region, with more than 90 percent of total withdrawals in 2010 coming from just two regions, the Santa Cruz-Sopori System and the Rillito-Tanque Verde System (Table 7). Furthermore, estimates suggested that non-exempt wells accounted for at least 92.6percent of the total water pumped in 2010. Determining the potential impacts of these water withdrawals on their aquifers is beyond the scope of this report and requires further work. A table listing the water withdrawals of each non-exempt well in 2010 is given in Appendix B.

Historic water withdrawal data from non-exempt wells are provided for eight of the 10 regions from 1984 to 2010 (Figure 7). Due to large differences in scale, further detail for water withdrawals for six of the regions producing less than 2,000 acre-feet of water per year is given in Figure 8. Non-exempt water withdrawal data were unavailable for the San Pedro River and Cocio Wash.

Since 1984, the Santa Cruz-Sopori System and the Rillito-Tanque Verde System produced the most water among any of the regions. From 1984 to 2010, water withdrawals trended upward in the Santa Cruz-Sopori System, while trending downward in the Rillito-Tanque Verde System. In comparison, withdrawals from the other regions were minor, though recent increases were observed in the Cienega-Davidson System.

Because water level trends in each shallow groundwater area are based on very site-specific information, results are presented within the regional sub-sections rather than in this overview. In addition, a discussion of potential shallow groundwater sites in eastern Pima County concludes the "*Results of Data Analysis"* section.

Table 7. Estimated water withdrawals in 2010 by region in acre-feet (AF).

Region	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)[1]	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)[2]	Total Withdrawn from All Wells (AF)	% of Total
San Pedro River	72	72.0	41	0	No Data	72.0	0.3%
Sutherland Wash	29	29.0	5	5	9.3	38.3	0.1%
Tortolita Mtns.	123	123.0	2	2	0.0	123.0	0.4%
Cocio Wash	1	1.0	4	0	No Data	1.0	0.0%
Rillito-Tanque Verde System	718	718.0	257	173	6,254.5	6,972.5	25.1%
Central Santa Cruz River	35	35.0	23	5	3.4	38.4	0.1%
Pantano-Rincon System	213	213.0	29	21	472.7	685.7	2.5%
Cienega-Davidson System	353	353.0	29	4	501.2	854.2	3.1%
Santa Cruz-Sopori System	254	254.0	64	52	18,446.2	18,700.2	67.2%
Altar Valley	262	262.0	28	17	73.2	335.2	1.2%
TOTAL	**2,060**	**2,060.0 AF**	**482**	**279**	**25,760.5 AF**	**27,820.5 AF**	**100.0%**

[1] *Annual withdrawals from exempt wells are assumed to be 1 AF per year.*

[2] *Totals from non-exempt wells only include amounts that were reported to ADWR by well owners.*

Figure 7. Water production from non-exempt wells reporting from 1984-2010.

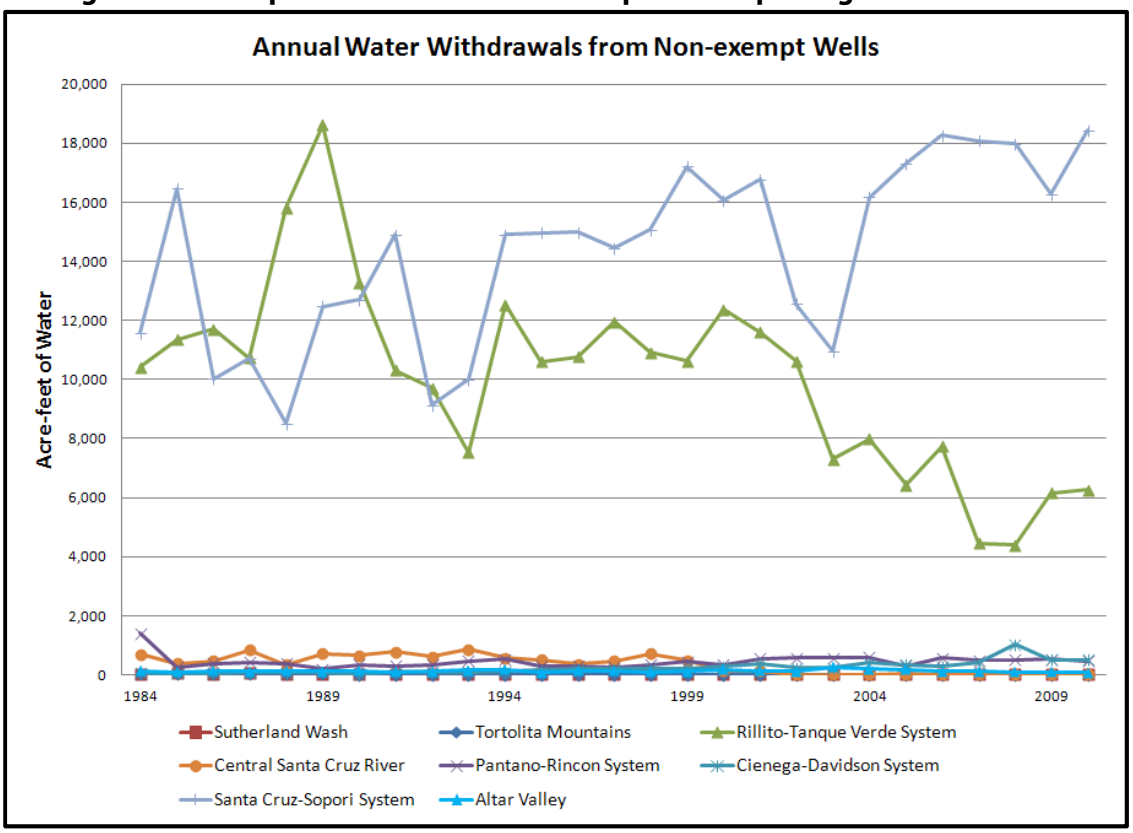
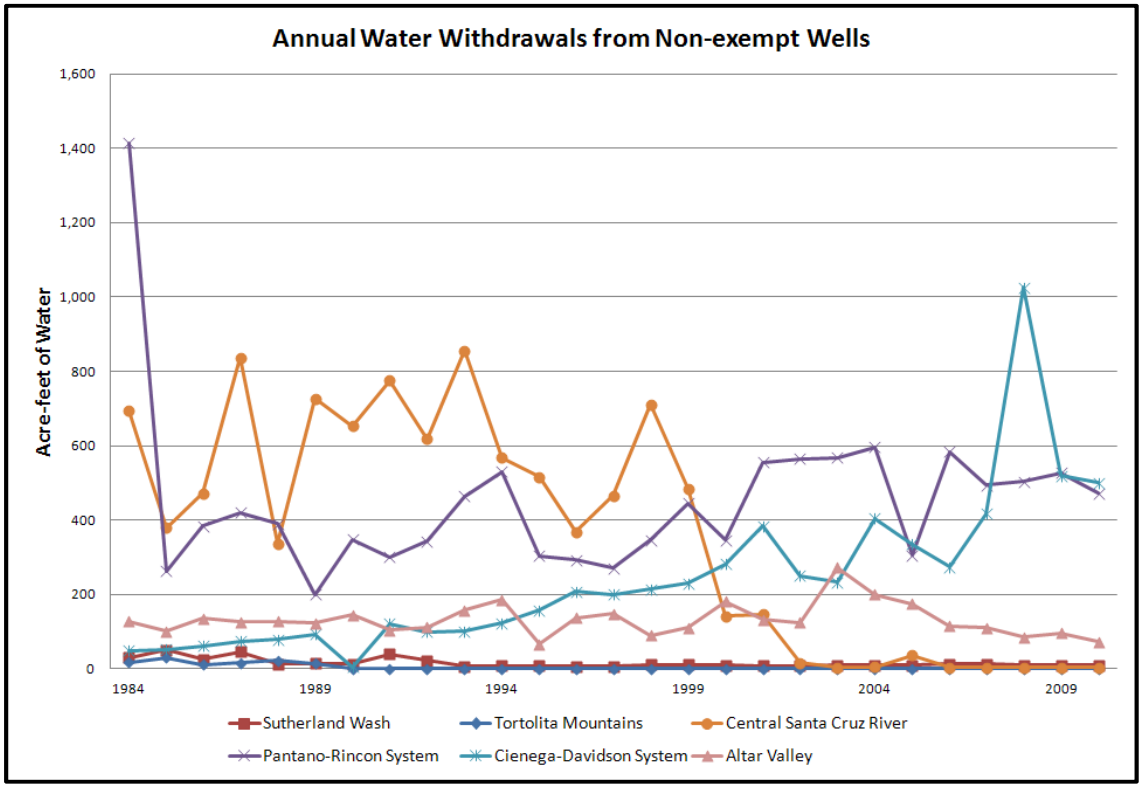


Figure 8. Water production from non-exempt wells in six regions.



Region-Specific Results

The following sub-sections provide detailed information on well inventories, well densities, drilling trends, water withdrawals and water levels for each of the 10 regions. In general, the regions are sorted according to their geographic location, progressing from north to south.

For regions that include several shallow groundwater areas, additional detailed tables and figures are provided. Extra charts regarding water levels are presented in Appendix C as noted.

San Pedro River

Description

The San Pedro River region, located in northeastern Pima County, contains one shallow groundwater area, San Pedro River (Bingham Cienega) (Figure 9). Although surface water is only intermittent throughout most of the area, perennial water is present in Bingham Cienega (City of Tucson and Pima County, 2009; PAG, 2001). Assemblages of velvet mesquite, Goodding willow and ash are found in Bingham Cienega (PAG, 2000a; Pima County, 2011), immediately downstream (i.e., north) of agricultural fields.

Well Inventory

As of 2012, the San Pedro River (Bingham Cienega) area contained a total of 72 exempt and 41 non-exempt water-producing wells. The area had a moderate well density of 6.1 wells/sq. mile.

Drilling Trends

Drilling dates are unknown for 15 of the wells. However, for those with known dates, 57 were drilled before 1980, 15 were drilled from 1980-1989, five were drilled from 1990-1999 and 21 (1.7 wells/year) were drilled since 2000. Of the 21 wells drilled since 2000, only two were non-exempt. Figure 10 shows the drilling history of these wells.

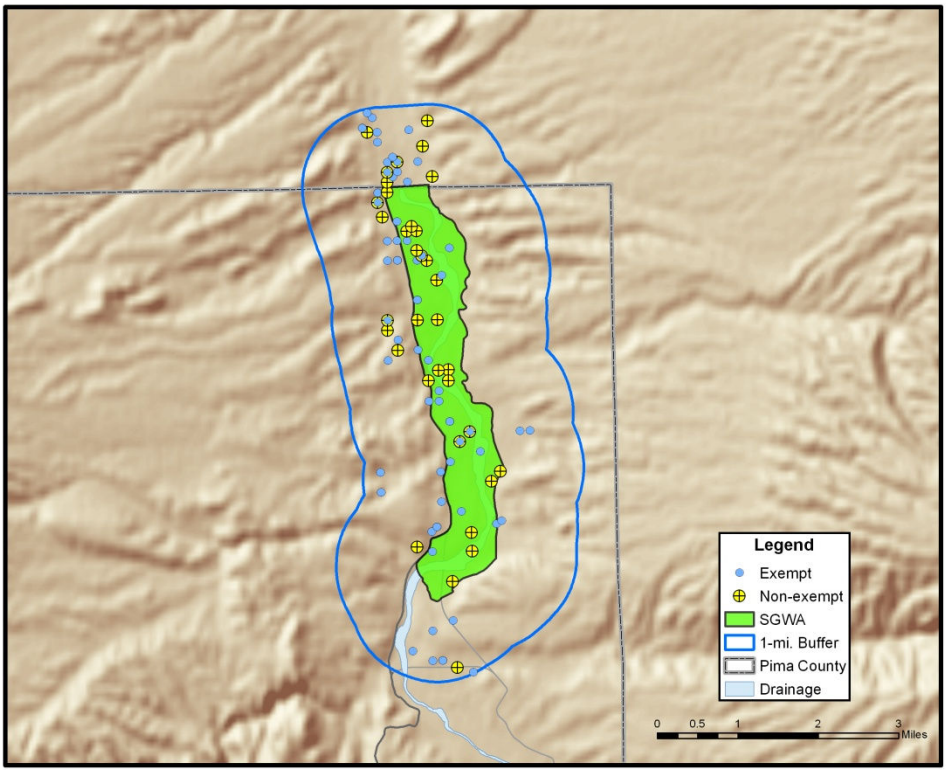
Water Withdrawals

As none of the wells are located inside any AMA, no water withdrawal data are available for the non-exempt wells. However, it is estimated that at least 72.0 acre-feet of water was withdrawn in 2010 based on the number of exempt wells alone.

Water Levels

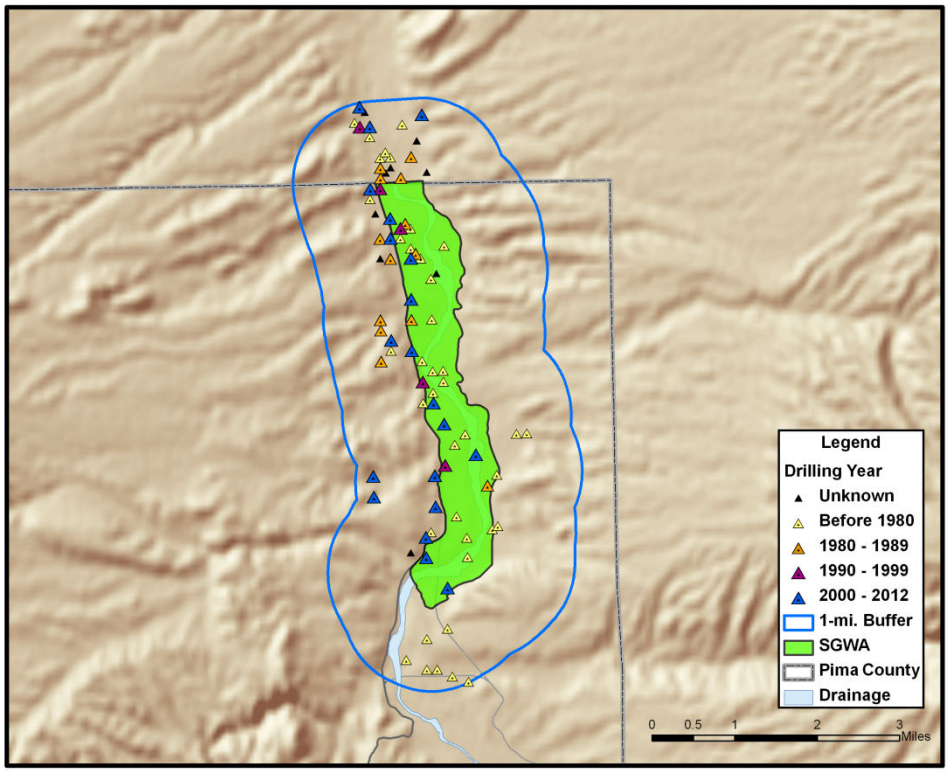
Repeated water level measurements were made for nine wells between 1950 and 2006 (Figure 11). Though water levels fluctuated from year to year, no long-term change in water level was evident.

Figure 9. Wells in the San Pedro River region.



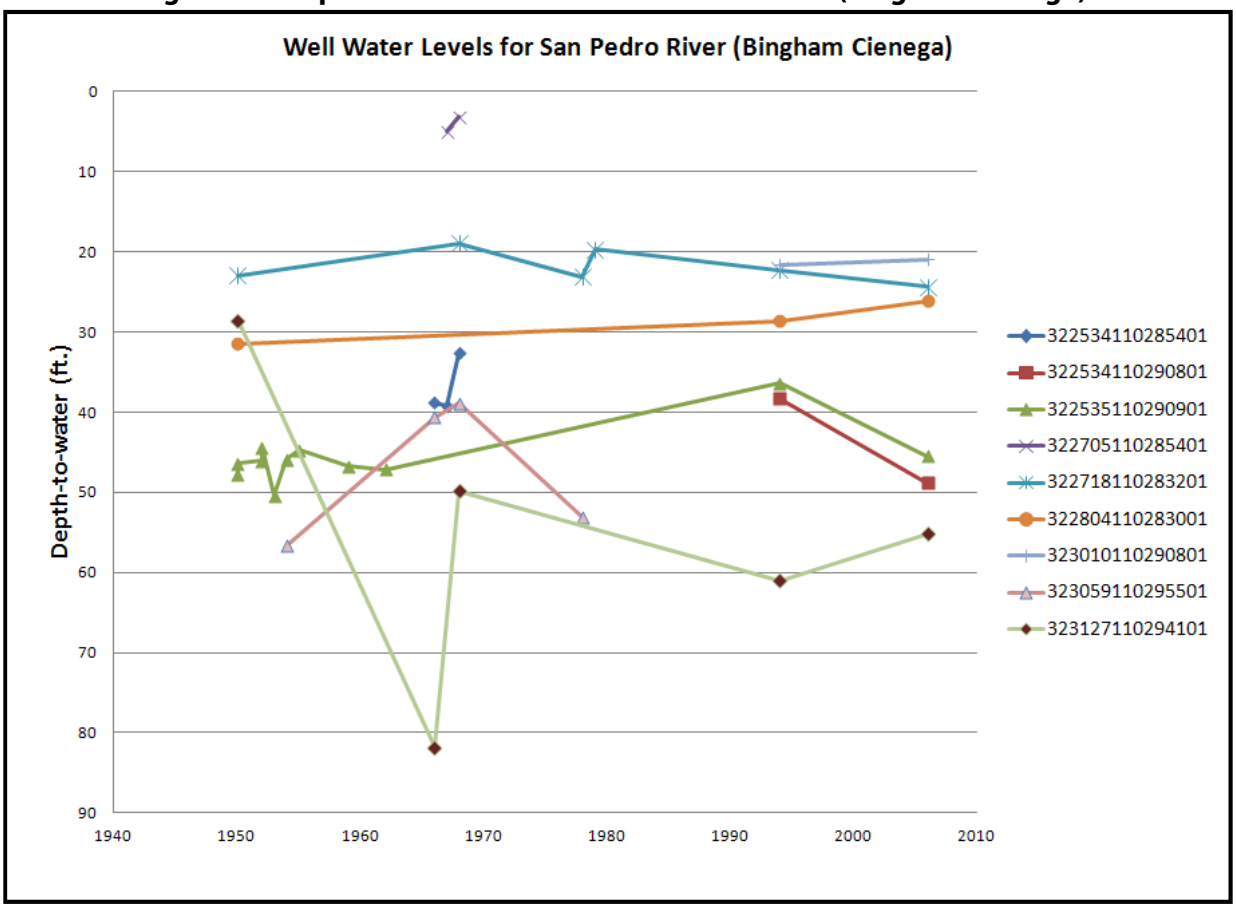
Note: SGWA = Shallow groundwater area

Figure 10. Drilling history in San Pedro River (Bingham Cienega).



Note: SGWA = Shallow groundwater area

Figure 11. Depth-to-water in wells in San Pedro River (Bingham Cienega).



Note: Only wells with multiple readings are shown. Legend lists GWSI site-IDs.

Sutherland Wash

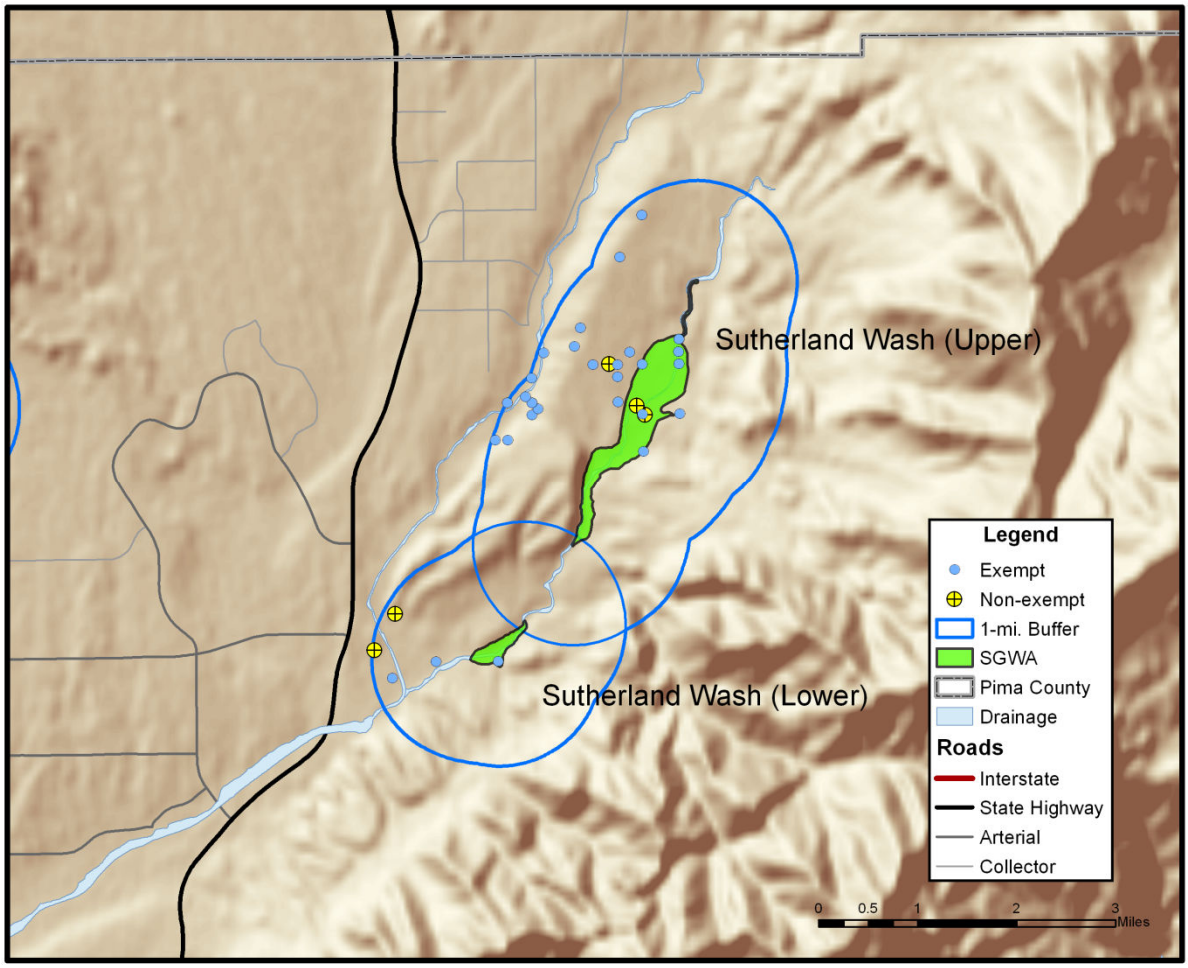
Description

The Sutherland Wash region contains two shallow groundwater areas, Sutherland Wash (Lower) and Sutherland Wash (Upper), in far northern Pima County (Figure 12). These two areas flow into Cañada del Oro, which drains into the Santa Cruz River. Both of these areas have stands of Fremont cottonwood, Arizona ash, velvet mesquite and hackberry trees (PAG, 2000a).

Well Inventory

As of 2012, the Sutherland Wash region had a total of 30 exempt and five non-exempt water-producing wells with a low well density of 2.6 wells/sq. mile. The well inventory and density of each area is given in Table 8. Of the two areas, Sutherland Wash (Upper) contains the majority of wells. Overall, 14.3 percent of the wells in this region are non-exempt.

Figure 12. Wells in Sutherland Wash.



Note: SGWA = Shallow groundwater area

Table 8. Inventory and density of wells in the Sutherland Wash region.

Shallow Groundwater Area	Total # of Wells	# of Exempt Wells	# of Non-exempt Wells	Wells/Sq. Mi.
Sutherland Wash (Lower)	5	3	2	1.0
Sutherland Wash (Upper)	30	27	3	2.9
REGION	**35**	**30**	**5**	**2.6**

Drilling Trends

Drilling dates are unknown for six of the wells, however, for those with known dates, 12 were drilled before 1980, seven were drilled from 1980-1989, five were drilled from 1990-1999 and five (0.4 wells/year) were drilled since 2000 (Table 9). Of the five wells drilled since 2000, all were exempt and all were installed in Sutherland Wash (Upper). Figure 13 shows the drilling history of these wells.

Water Withdrawals

All wells in the Sutherland Wash region are located within the Tucson AMA, and all non-exempt well owners had reported their water withdrawal reports for 1984-2010 to ADWR. Water withdrawal information for the two areas is given in Table 10, and totaled 38.3 acre-feet in 2010. Overall, 24.2 percent of the water withdrawn from this region came from non-exempt wells. Approximately 75 percent of the total water came from Sutherland Wash (Upper).

Figure 14 shows total water withdrawals from non-exempt wells in each shallow groundwater area from 1984 to 2010. Since 1992, water withdrawals from the non-exempt wells declined sharply, though there was some resurgence in pumping in Sutherland Wash (Lower) within the last decade.

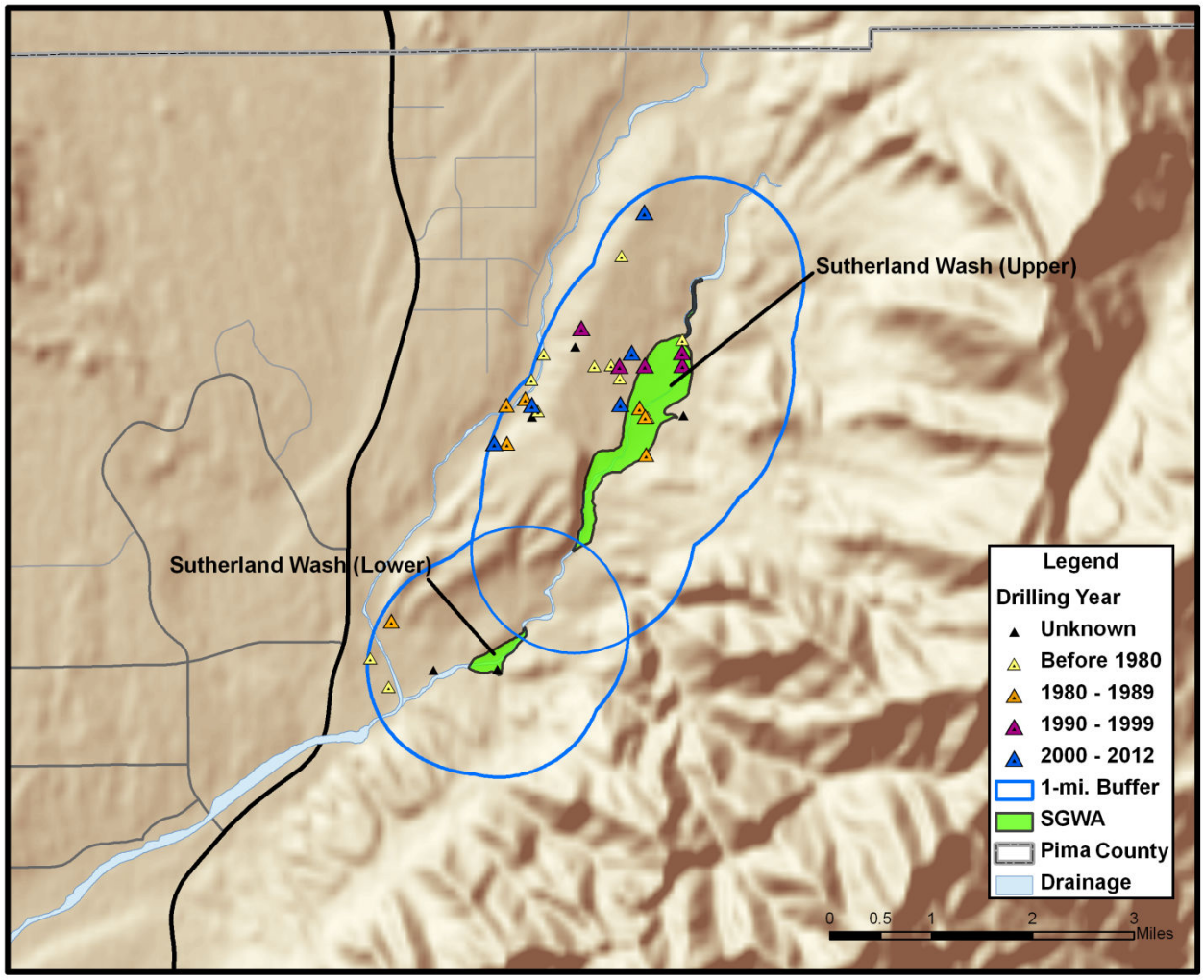
Water Levels

As multiple water level measurements were not available for any wells in the Sutherland Wash (Upper) area, it was not possible to analyze water level trends at this site. The Sutherland Wash (Lower) area had three wells in which water level measurements were repeatedly made between 1953 and 2005 (Figure 15). Results from these three wells are somewhat inconclusive, however there was an indication that water levels in one well (Site-ID# 322549110553501) dropped 30-35 ft. between 1995 and 2005. As all three measurements in this well were taken during the winter months, the decline was not attributable to seasonal effects.

Table 9. Drilling history in Sutherland Wash.

Shallow Groundwater Area	# Wells Drilled in Time Period					# Non-exempt Wells Drilled 2000-2012
	Date Unknown	Before 1980	1980-1989	1990-1999	2000-2012	
Sutherland Wash (Lower)	2	2	1	0	0	0
Sutherland Wash (Upper)	4	10	6	5	5	0
REGION	**6**	**12**	**7**	**5**	**5**	**0**

Figure 13. Drilling history in Sutherland Wash.



Note: SGWA = Shallow groundwater area

Table 10. Water withdrawals in 2010 from Sutherland Wash in acre-feet (AF).

SGWA	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Sutherland Wash (Lower)	3	3.0	2	2	6.4	9.4	68.1%
Sutherland Wash (Upper)	26	26.0	3	3	2.9	28.9	10.0%
REGION	**29**	**29.0 AF**	**5**	**5**	**9.3 AF**	**38.3 AF**	**24.2%**

Figure 14. Water withdrawals from non-exempt wells in Sutherland Wash.

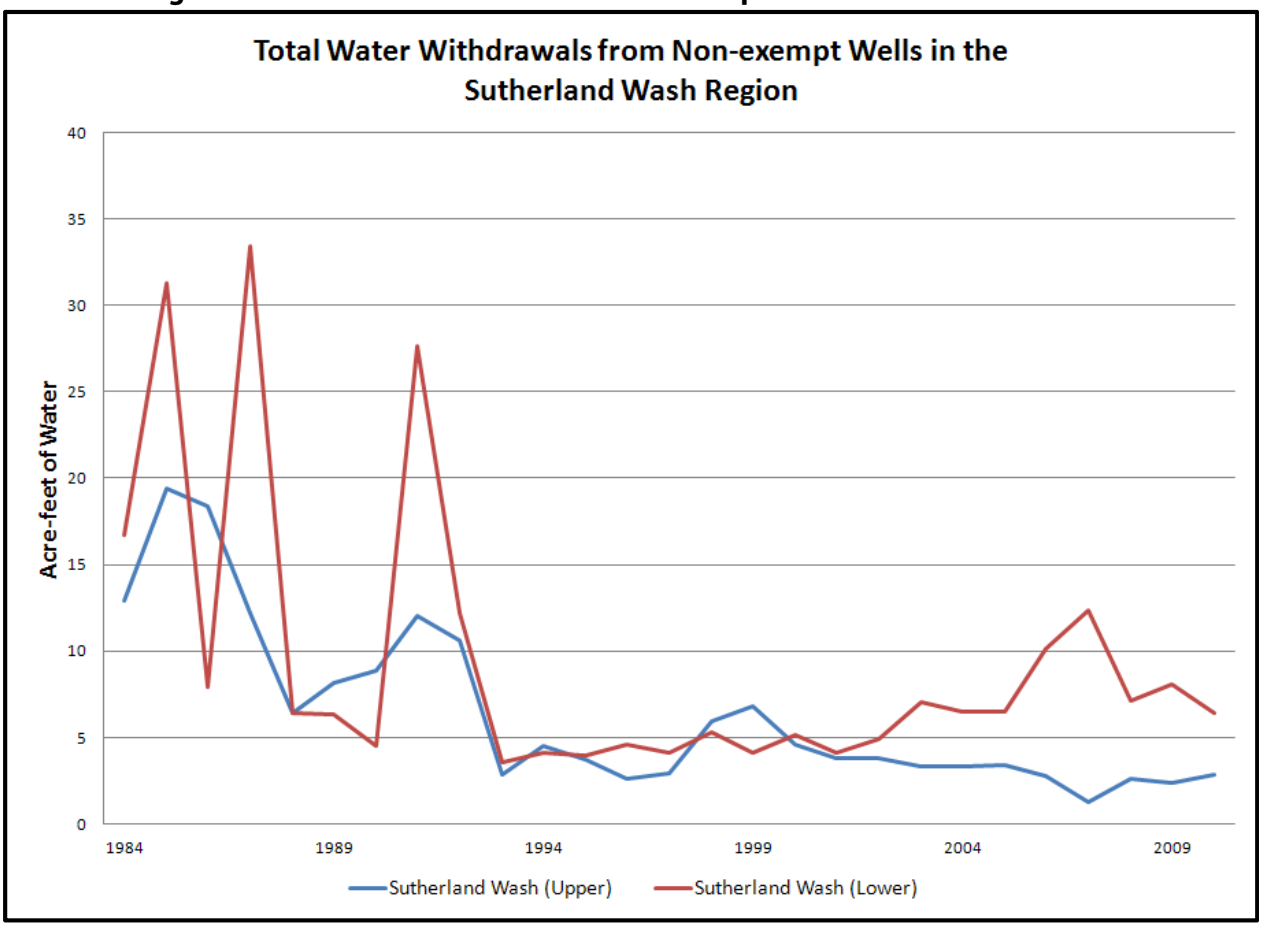
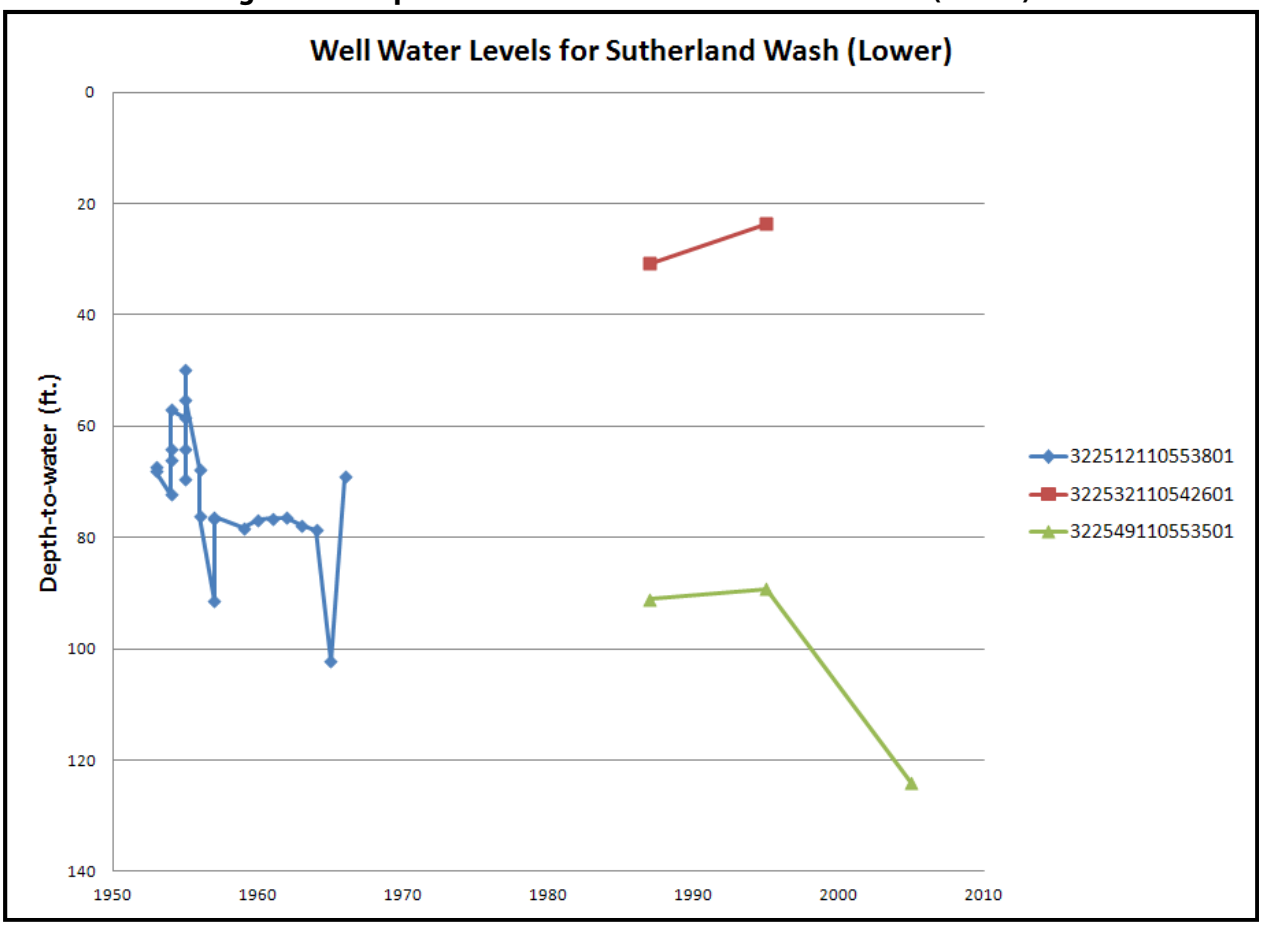


Figure 15. Depth-to-water in wells of Sutherland Wash (Lower).



Note: Legend lists GWSI site-IDs.

Tortolita Mountains

Description

The Tortolita Mountains region contains one shallow groundwater area, the Tortolita Mountains area, in far northern Pima County (Figure 16). The area is located on the south side of the Tortolita Mountains and drains through a series of minor washes toward the Santa Cruz River.

Well Inventory

As of 2012, the Tortolita Mountains area had a total of 125 exempt and two non-exempt water-producing wells. The area had one of the highest well densities of any of the study sites at 26.5 wells/sq. mile. However, only 1.6 percent of the wells were non-exempt.

Drilling Trends

Drilling dates are unknown for 14 of the wells. However, for those with known dates, 17 were drilled before 1980, 27 were drilled from 1980-1989, 27 were drilled from 1990-1999 and 42 (3.4 wells/year) were drilled since 2000. Of the 42 wells drilled since 2000, all were exempt. Figure 17 shows the drilling history of these wells. Since 2000, drillers installed wells in the Tortolita Mountain at a greater rate for its size than at any other site.

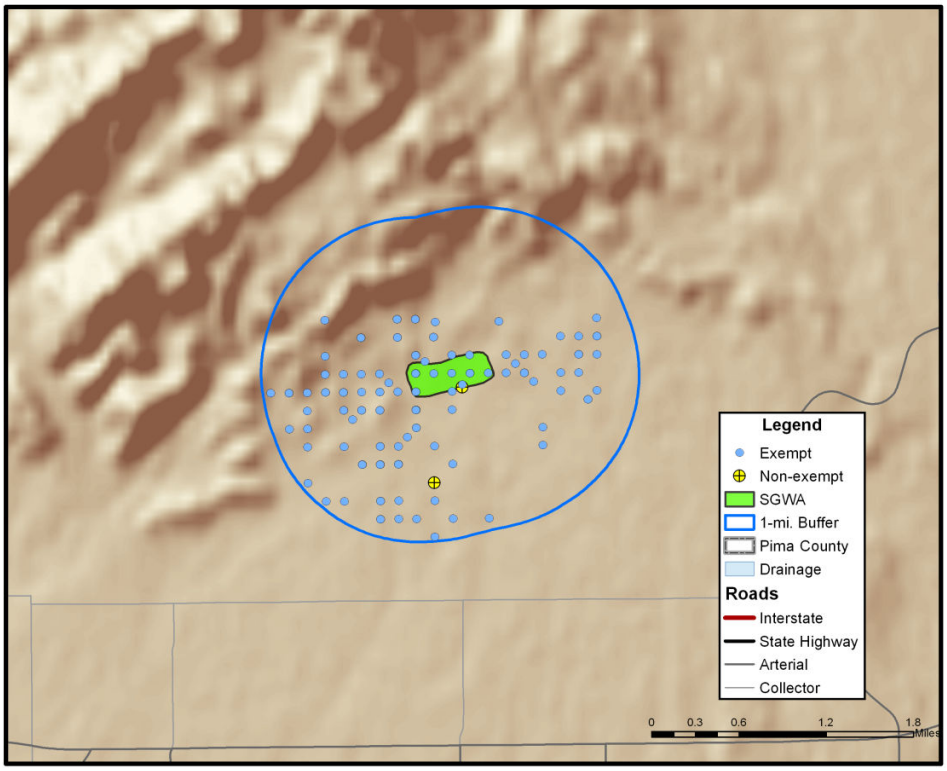
Water Withdrawals

All wells in the Tortolita Mountains area are located within the Tucson AMA. Although the owner of the two non-exempt wells reported water withdrawals to ADWR as required, neither well produced water since the early 1990s (Figure 18). Therefore, total water withdrawals for 2010 were based solely on exempt wells with an estimated withdrawal of 123.0 acre-feet.

Water Levels

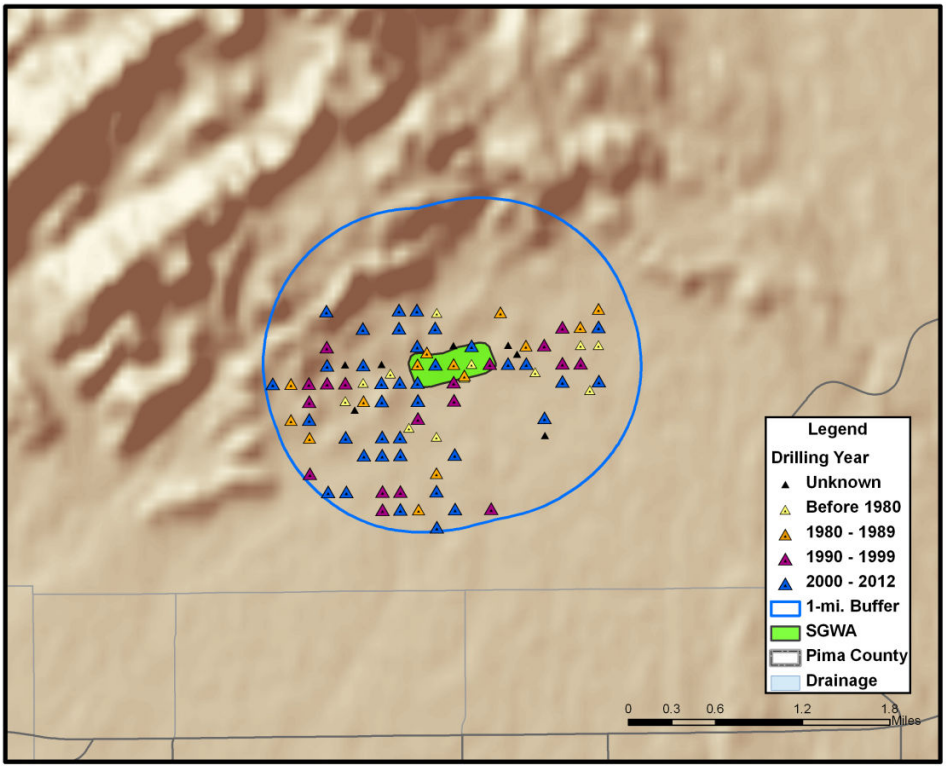
Four wells in this area had repeated water level measurements performed between 1981 and 2010. Given the paucity of data it is difficult to make any conclusive statements regarding water level trends, though there is some evidence of declining water levels over time (Figure 19).

Figure 16. Wells in the Tortolita Mountains region.



Note: SGWA = Shallow groundwater area

Figure 17. Drilling history in the Tortolita Mountains region.



Note: SGWA = Shallow groundwater area

Figure 18. Water withdrawals from non-exempt wells in the Tortolita Mountains region.

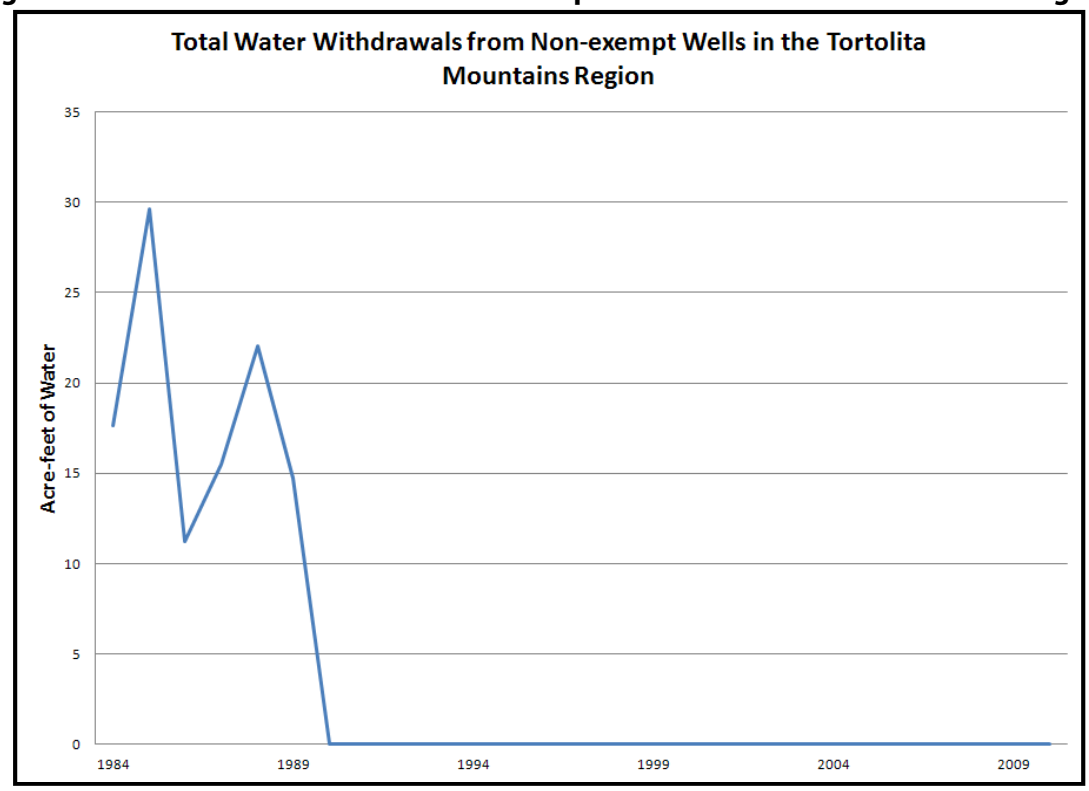
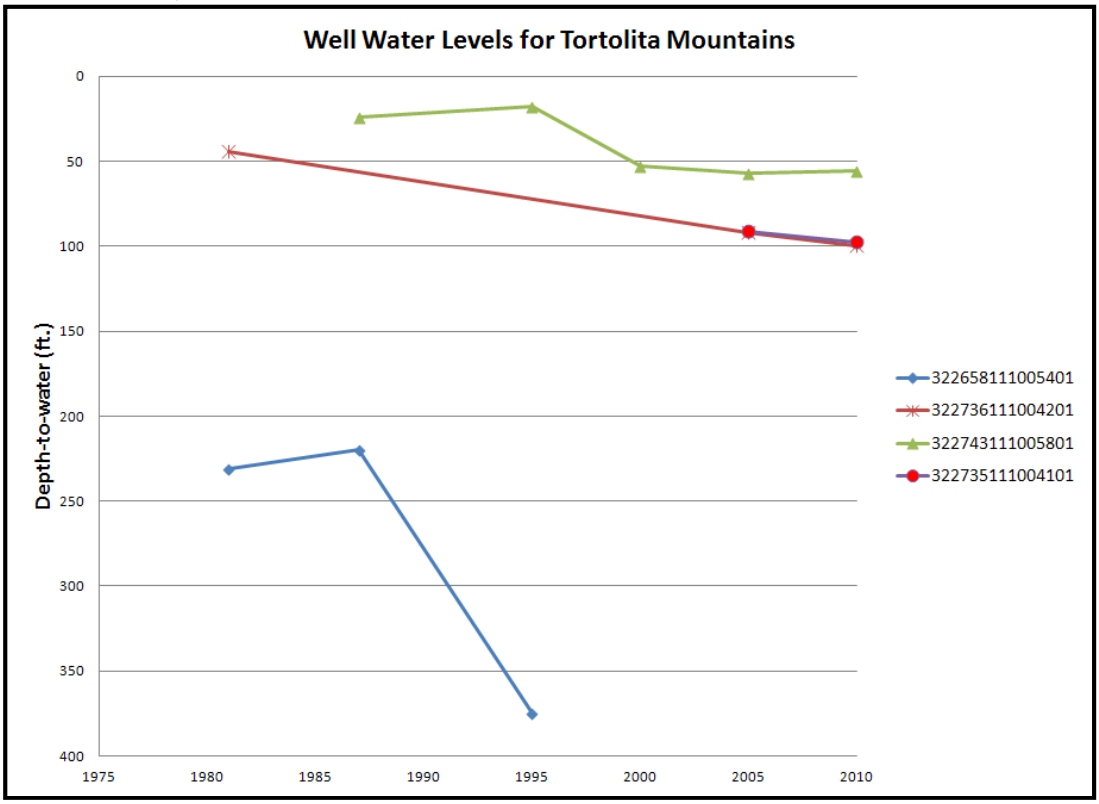


Figure 19. Depth-to-water in wells of the Tortolita Mountains.



Note: Legend lists GWSI site-IDs.

Cocio Wash Region

Description

The Cocio Wash region contains one shallow groundwater area, the Cocio Wash Area, west of Marana and southeast of the Silverbell Mountains (Figure 20). Cocio Wash is a former site of the Gila topminnow (Pima County, 2011). However, nearby mining activities may have impacted this site. Runoff from this site flows eastward toward Brawley Wash and eventually into the Santa Cruz River.

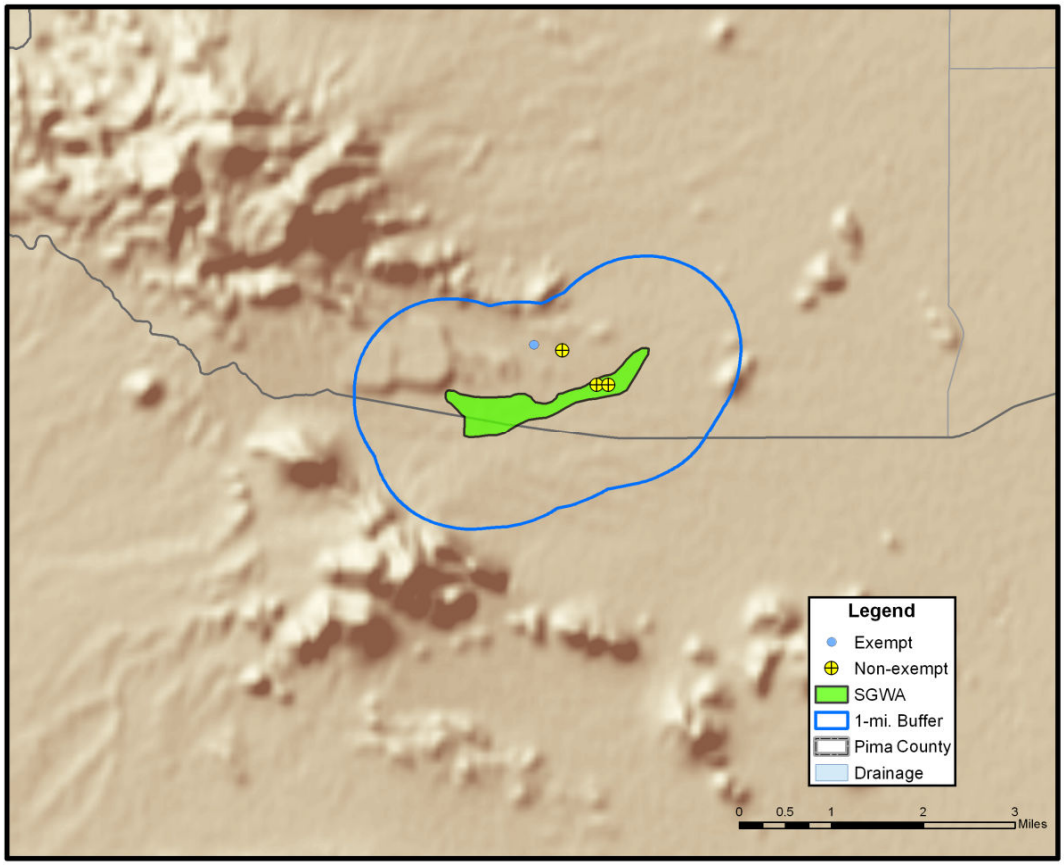
Well Inventory

As of 2012, Cocio Wash had a total of one exempt and four non-exempt water-producing wells, having a very low well density of 0.5 wells/sq. mile. Although this site has the highest proportion of non-exempt wells (80%) of any region, the small sample size makes comparisons of this metric with other regions questionable.

Drilling Trends

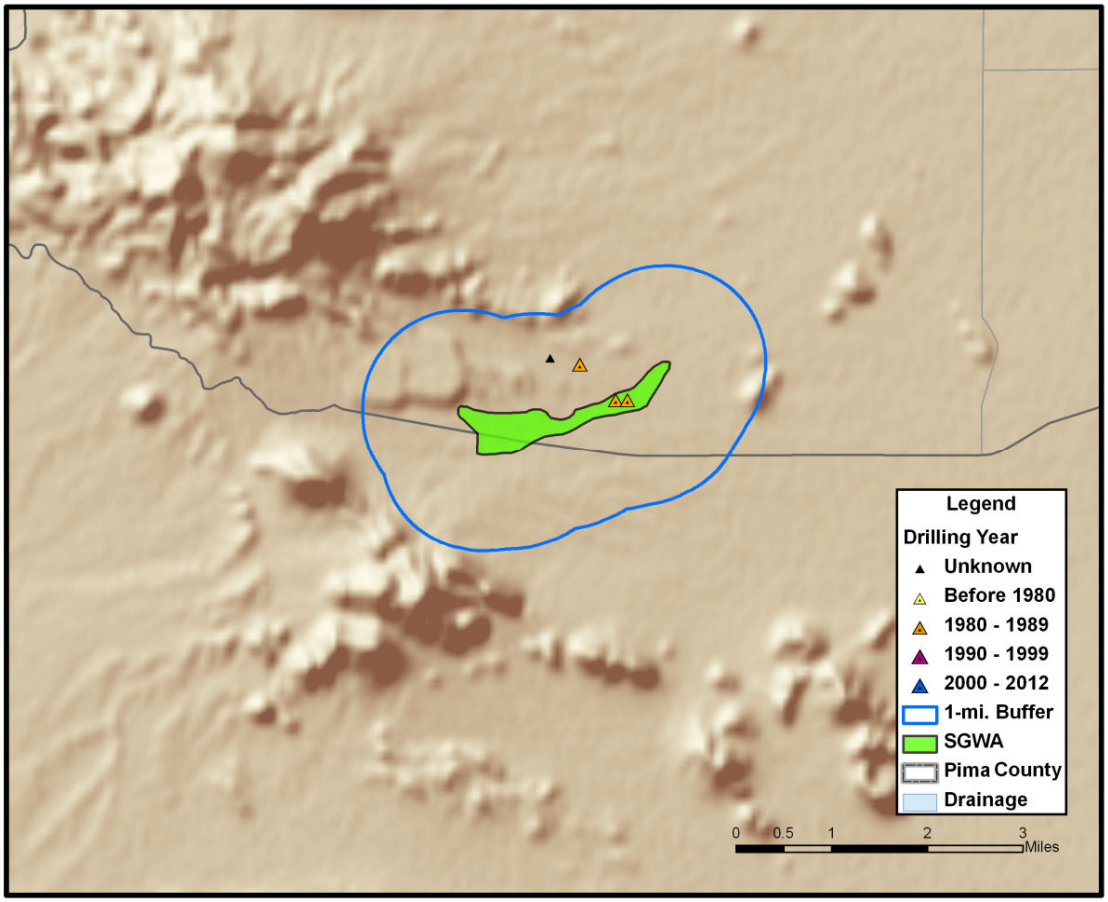
The drilling date of the exempt well is unknown. However, all four non-exempt wells were drilled in 1984. Since then, drillers have not installed any new water-producing wells in this area. Figure 21 shows the drilling history of these wells.

Figure 20. Wells in the Cocio Wash region.



Note: SGWA = Shallow groundwater area. Due to overlapping locations of two non-exempt wells, only four wells are visible in this map.

Figure 21. Drilling history in Cocio Wash.



Note: SGWA = Shallow groundwater area. Due to overlapping locations of two non-exempt wells, only four wells are visible in this map.

Water Withdrawals

All of the wells were located inside the Tucson AMA; however, the owner of the four non-exempt wells did not report withdrawals to ADWR. Thus, the total water withdrawals from this area were based solely on the one exempt well with an estimated withdrawal of 1.0 acre-feet per year.

Water Levels

No wells in this area showed multiple water level measurements. At the time of installation in 1984, the depth-to-water in the non-exempt wells ranged from 14 to 22 feet. However, no newer data are available. No water level information was available for the one exempt well.

Rillito-Tanque Verde System

Description

The Rillito-Tanque Verde System is the most developed well field in this study, and contains seven shallow groundwater areas (Figures 22 and 23). The Sabino Canyon (Summerhaven) area, at an elevation of 8,200 ft., is located at the headwaters of Sabino Creek near the summit of the Santa Catalina Mountains. The six remaining areas are located in Tucson's northeastern foothills. After the drainages converge at Rillito Creek, water flows westward to the Santa Cruz River. Sabino Canyon features perennial water for most of its course, whereas the other drainages are classified as intermittent (Pima County, 2009).

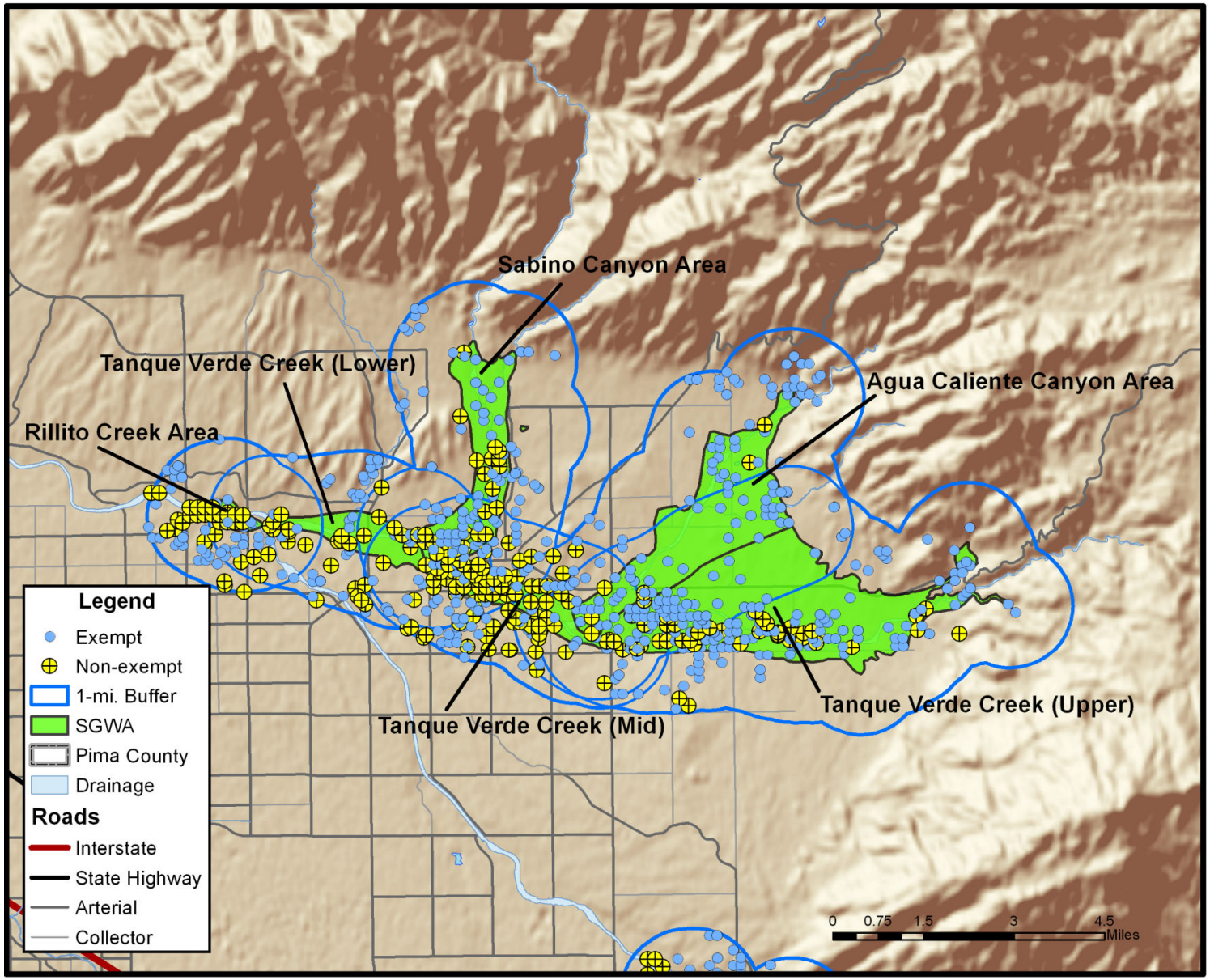
This region supports a wide diversity of vegetation types due to its considerable range in elevation. The Sabino Canyon (Summerhaven) area features assemblages of ponderosa pine, white fir, Douglas-fir, Arizona ash and a variety of oak species, typical of higher elevations in the Santa Catalina Mountains (PAG, 2000a). The Agua Caliente Canyon Area supports Arizona ash, hackberry tree and mesquite (Pima County, 2011). Velvet mesquite, mixed broadleaf woodlands, Fremont cottonwood, Arizona sycamore, Arizona walnut and willow are found in the Sabino Canyon Area (PAG, 2000a). In Tanque Verde Creek (Upper) there is Arizona ash, velvet mesquite and Fremont cottonwood (PAG, 2000a). In addition, the Rillito-Tanque Verde System includes a number of popular sites where visitors are drawn to surface water, riparian vegetation and recreational opportunities.

Because of the close proximity of many of the shallow groundwater areas within this region the one-mile buffers surrounding the areas commonly overlap. Consequently, some wells coincide with more than one shallow groundwater area. This data replication affects tables and figures related to well inventories, drilling histories and water withdrawals, so that summing values of the individual areas leads to overinflated numbers. In each table, the row labeled "REGION" represents the correct sums of well numbers or water volumes without duplicates.

Well Inventory

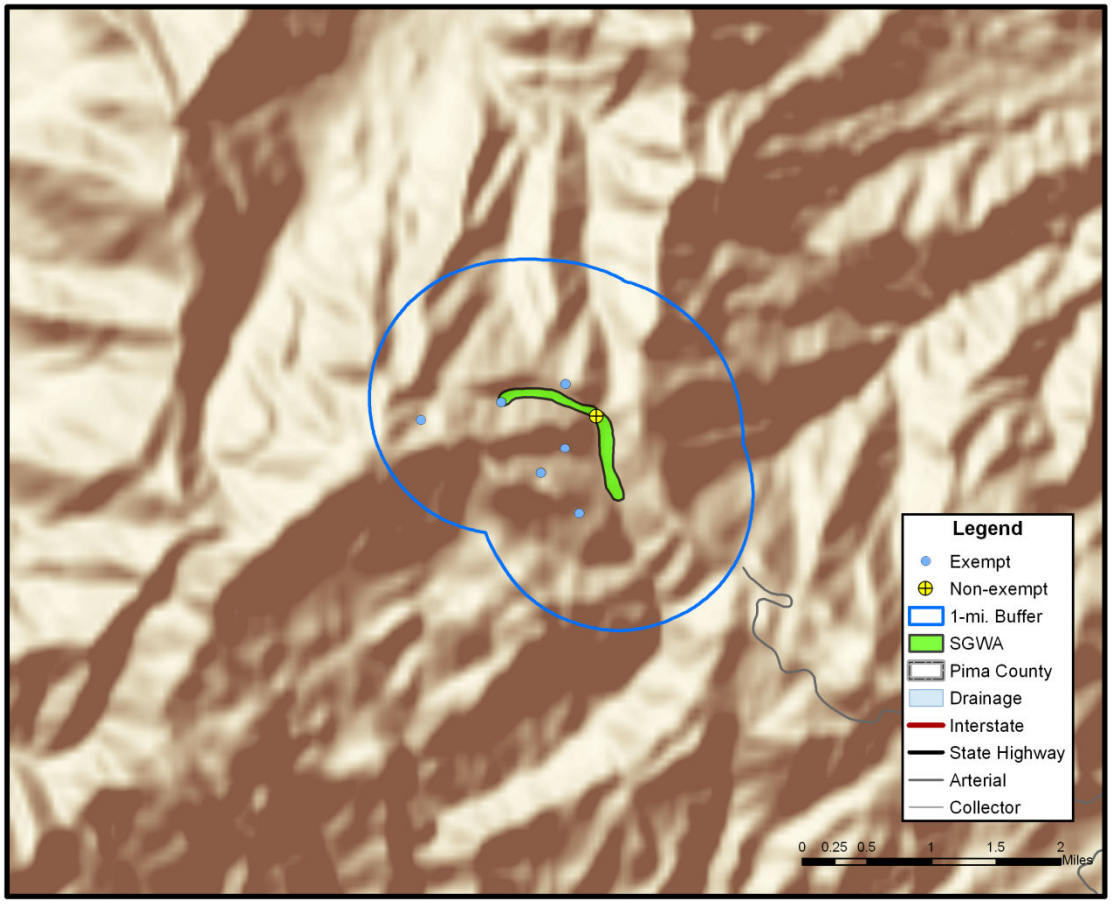
As of 2012, the Rillito-Tanque Verde System had a total of 722 exempt and 257 non-exempt water-producing wells, by far the most wells of any of the regions. Likewise, this area had a high well density of 14.1 wells/sq. mile, with most of its areas showing even higher densities.

Figure 22. Wells in the Rillito-Tanque Verde System, excluding Sabino Canyon (Summerhaven).



Note: SGWA = Shallow groundwater area

Figure 23. Wells in Sabino Canyon (Summerhaven).



Note: SGWA = Shallow groundwater area

Table 11 shows the well inventory and density of each area. For reasons explained previously, the row labeled "REGION" eliminates duplicate well counts due to overlapping shallow groundwater buffers and represents the correct sums for the region. The areas with the most wells were Tanque Verde Creek (Mid) and Tanque Verde Creek (Upper), whereas the fewest wells were in Sabino Canyon (Summerhaven). Overall, 26.3 percent of the wells in this region were non-exempt.

Drilling Trends

Drilling dates are unknown for 219 of the wells in this region. However, for those with known dates, 361 were drilled before 1980, 106 were drilled from 1980-1989, 114 were drilled from 1990-1999 and 179 (14.5 wells/year) were drilled since 2000 (Table 12). Of the 179 wells drilled since 2000, 23 were non-exempt, the most of any region. The recent drilling rate of 14.5 wells/year was also the greatest of any region.

Figures 24 and 25 show the drilling history of these wells. Agua Caliente Canyon Area and Tanque Verde Creek (Upper) were the two most active areas for drilling since 2000, each having rates of 6.1 wells/year, mostly exempt wells. Drilling activity since 2000 was lowest for the Rillito Creek Area and Sabino Canyon (Summerhaven), with 11 and three new wells, respectively. The two areas with the greatest numbers of new non-exempt wells were Sabino Canyon Area and Tanque Verde Creek (Mid), with a combined total of 19 wells (duplicates eliminated).

Table 11. Inventory and density of wells in the Rillito-Tanque Verde System in 2012.

Shallow Groundwater Area	Total # of Wells	# of Exempt Wells	# of Non-exempt Wells	Wells/Sq. Mi.
Agua Caliente Canyon Area	342	275	67	16.6
Rillito Creek Area	108	61	47	18.9
Sabino Canyon Area	286	188	98	17.9
Sabino Canyon (Summerhaven)	13	12	1	2.1
Tanque Verde Creek (Lower)	276	172	104	26.3
Tanque Verde Creek (Mid)	394	255	139	34.3
Tanque Verde Creek (Upper)	394	326	68	14.4
REGION[1]	**979**	**722**	**257**	**14.1**

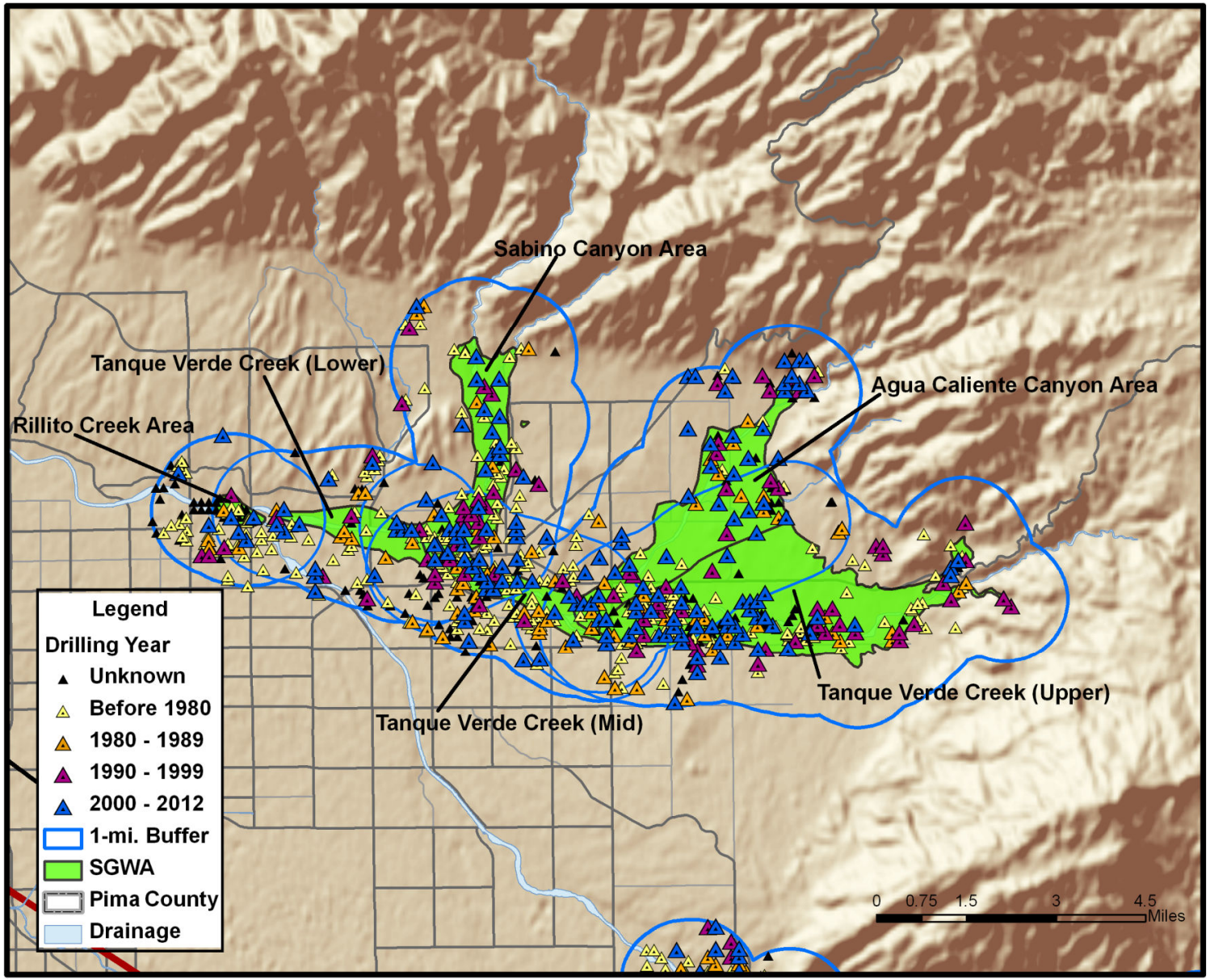
[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Table 12. Drilling history in the Rillito-Tanque Verde System.

Shallow Groundwater Area	# Wells Drilled in Time Period					# Non-exempt Wells Drilled 2000-2012
	Date Unknown	Before 1980	1980-1989	1990-1999	2000-2012	
Agua Caliente Canyon Area	70	120	43	34	75	5
Rillito Creek Area	37	49	5	6	11	1
Sabino Canyon Area	52	109	27	40	58	15
Sabino Canyon (Summerhaven)	1	8	1	0	3	1
Tanque Verde Creek (Lower)	68	102	28	36	42	8
Tanque Verde Creek (Mid)	83	153	48	41	69	15
Tanque Verde Creek (Upper)	77		52	49	75	4
REGION[1]	**219**	**361**	**106**	**114**	**179**	**23**

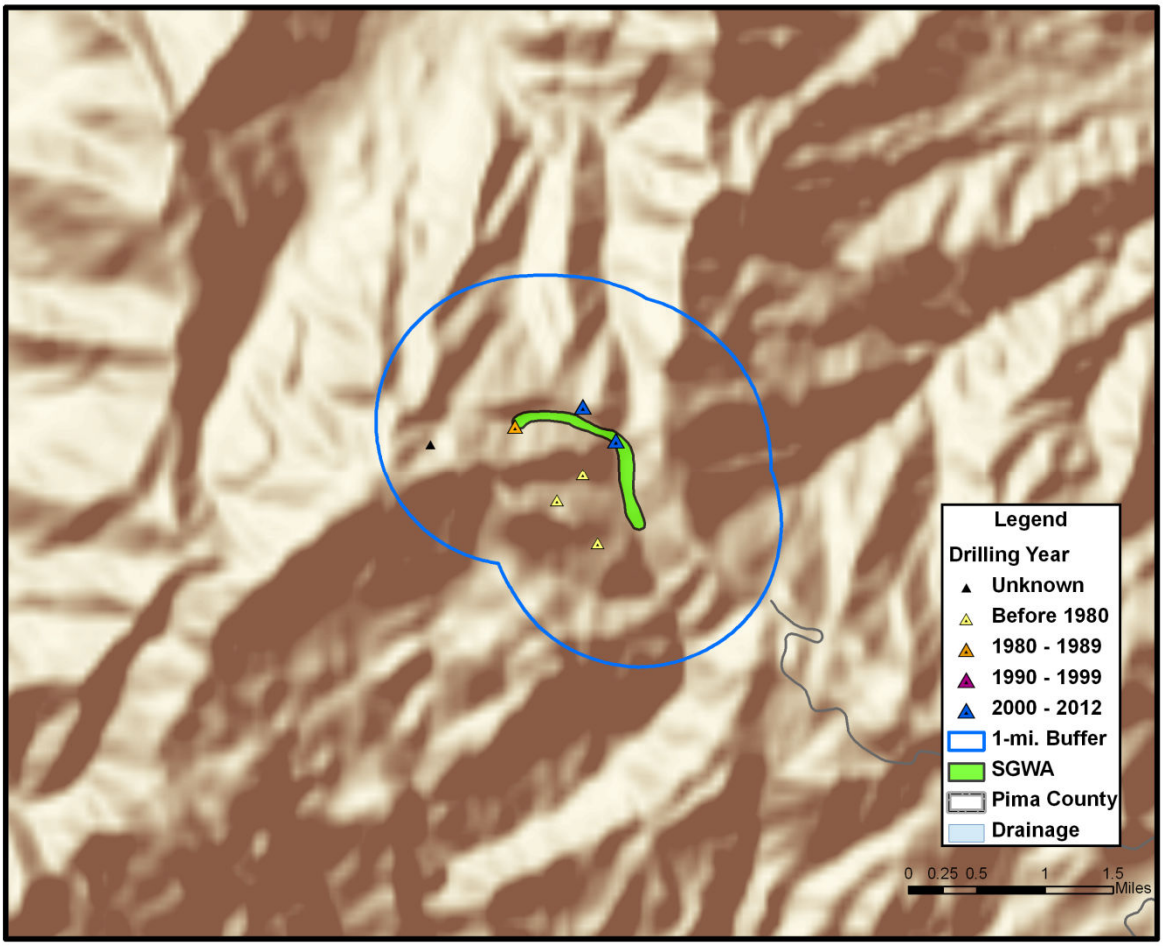
[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Figure 24. Drilling history in the Rillito-Tanque Verde System, excluding Sabino Canyon (Summerhaven).



Note: SGWA = Shallow groundwater area

Figure 25. Drilling history in Sabino Canyon (Summerhaven).



Note: SGWA = Shallow groundwater area

Water Withdrawals

All wells in the Rillito-Tanque Verde System are located within the Tucson AMA. Owners of 173 of the 257 non-exempt wells reported their water withdrawal reports for 1984-2010 to ADWR. Water withdrawal information for the each of the areas is given in Table 13, and totaled 6,972.5 acre-feet in 2010, second only to the Santa Cruz-Sopori System. Among the areas in this region, Tanque Verde Creek (Mid) produced the most water and Sabino Canyon (Summerhaven) produced the least. The vast majority (89.7%) of water withdrawn in this region came from non-exempt wells.

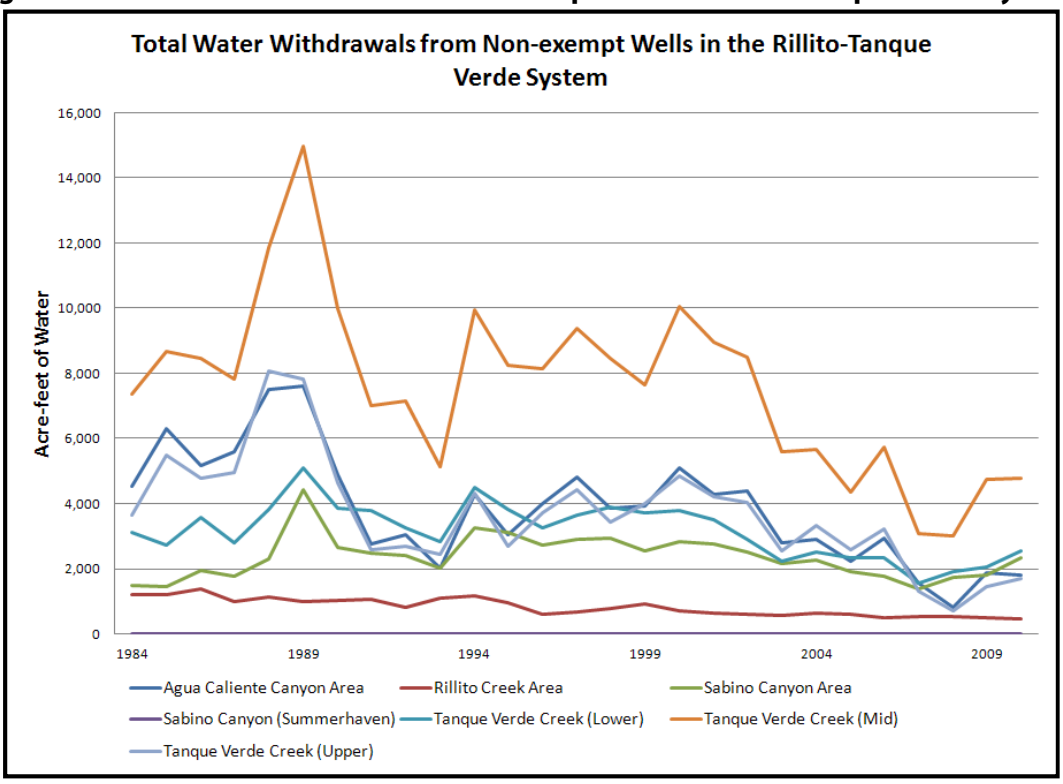
Figure 26 shows the total water withdrawals from non-exempt wells for each of the seven areas from 1984 through 2010. Historically, a general decline in water withdrawals was apparent for the areas, excluding Sabino Canyon (Summerhaven), with withdrawals reaching their lowest levels in 2007-2008, shortly after water from the Central Arizona Project (CAP) became widely used in Tucson (City of Tucson and Pima County, 2009). In every year from 1984 to 2010, the greatest amount of water was withdrawn from Tanque Verde Creek (Mid).

Table 13. Water withdrawals in 2010 from Rillito-Tanque Verde System in acre-feet (AF).

Shallow Groundwater Area	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Agua Caliente Canyon Area	273	273.0	67	50	1,814.6	2,087.6	86.9%
Rillito Creek Area	61	61.0	47	25	475.0	536.0	88.6%
Sabino Canyon Area	188	188.0	98	66	2,335.4	2,523.4	92.5%
Sabino Canyon (Summerhaven)	12	12.0	1	1	0.03	12.0	0.2%
Tanque Verde Creek (Lower)	172	172.0	104	69	2,549.6	2,721.6	93.7%
Tanque Verde Creek (Mid)	254	254.0	139	104	4,766.5	5,020.5	94.9%
Tanque Verde Creek (Upper)	322	322.0	68	51	1,687.3	2,009.3	84.0%
REGION[1]	**718**	**718.0 AF**	**257**	**173**	**6,254.5 AF**	**6,972.5 AF**	**89.7%**

[1] Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.

Figure 26. Water withdrawals from non-exempt wells in Rillito-Tanque Verde System.



Water Levels

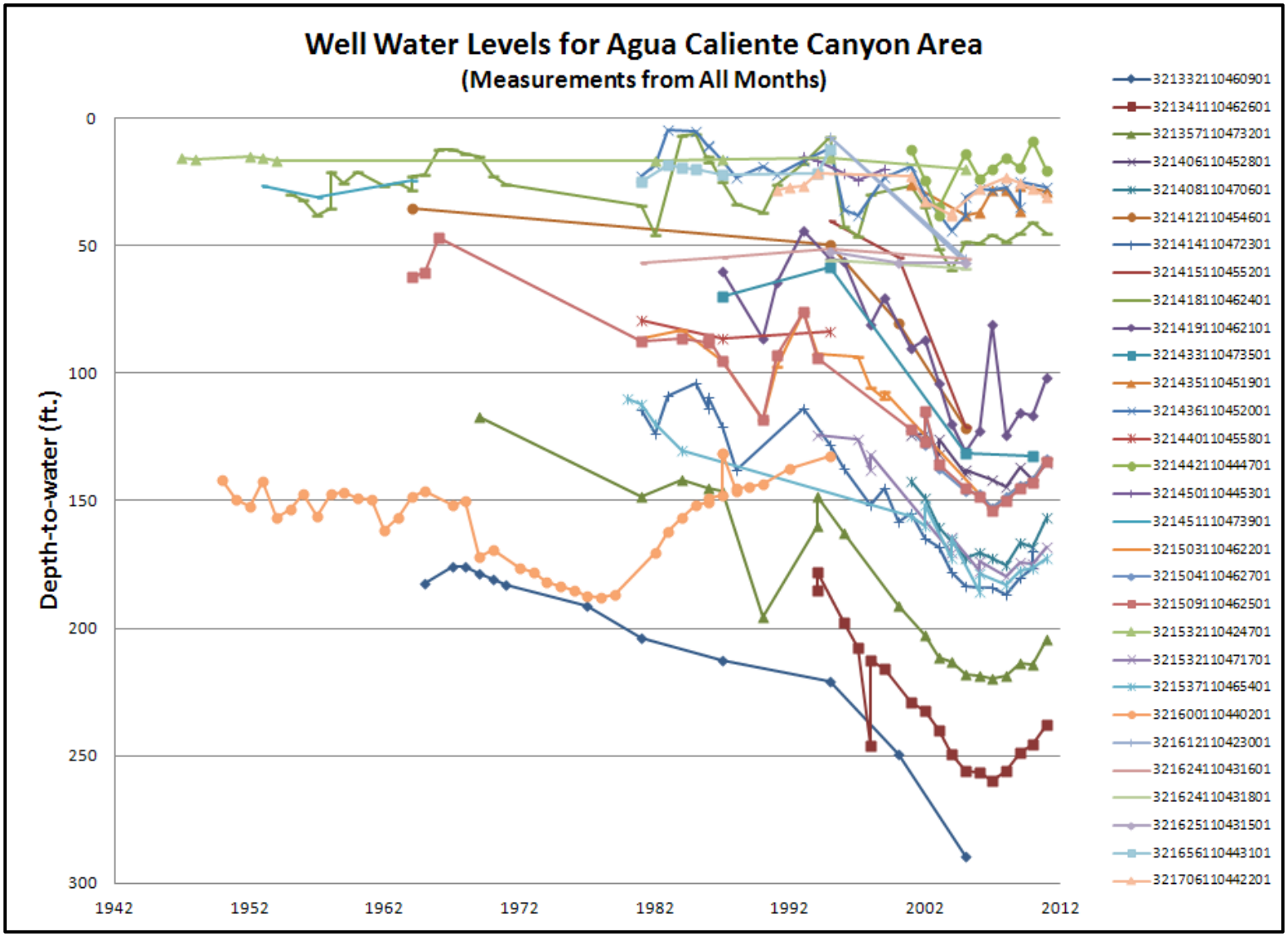
Field personnel have collected hundreds of water level readings in dozens of wells in the Rillito-Tanque Verde System since 1939. Plots of water levels for the Agua Caliente Canyon Area are given in Figures 27 and 28. As in previous depth-to-water charts in this report, Figure 27 shows all measurements for the site. Because of strong seasonal influences on depth-to-water, year-to-year trends are difficult to discern, especially among the numerous shallow wells. To minimize seasonal influences, only measurements recorded in the months of January and February were plotted in Figure 28. This is a time of year when groundwater pumping and evapotranspiration from vegetation is minimized, and groundwater levels would be expected to be their highest. Also, note that the figure only plots measurements collected since 1980 to enhance the chart further.

In the Agua Caliente Canyon Area, most shallow wells showed a decline in water levels until 2003 or 2004 and then began a slow recovery. In order to quantify the changes in water levels over time, the slopes of regression lines were calculated for shallow wells during three time periods, 1980 to 1995, 1995 to 2005 and 2005 to 2012. Only wells in which water levels were within 100 ft. of the land surface in 1980, or later, were included. Table 14 shows the annual water level changes for each well during each time period. In addition, the right-most column shows the overall annual change in water levels for five shallow wells in which depth-to-water data were recorded from 1981 to 2011. The results indicate that water levels were approximately constant from 1980 to 1995, declined at a rate of 2.5 ft./yr. from 1995 to 2005, and then increased at a rate of 1.6 ft./yr. since 2005. Overall, the mean water level decline between 1981 and 2011 was 1.4 ft./yr. for the five selected wells.

Note that the recoveries in water levels closely followed sharp reductions in water withdrawals in this region during the early 2000s (Figure 26). Water level increases may continue if pumping rates remain low.

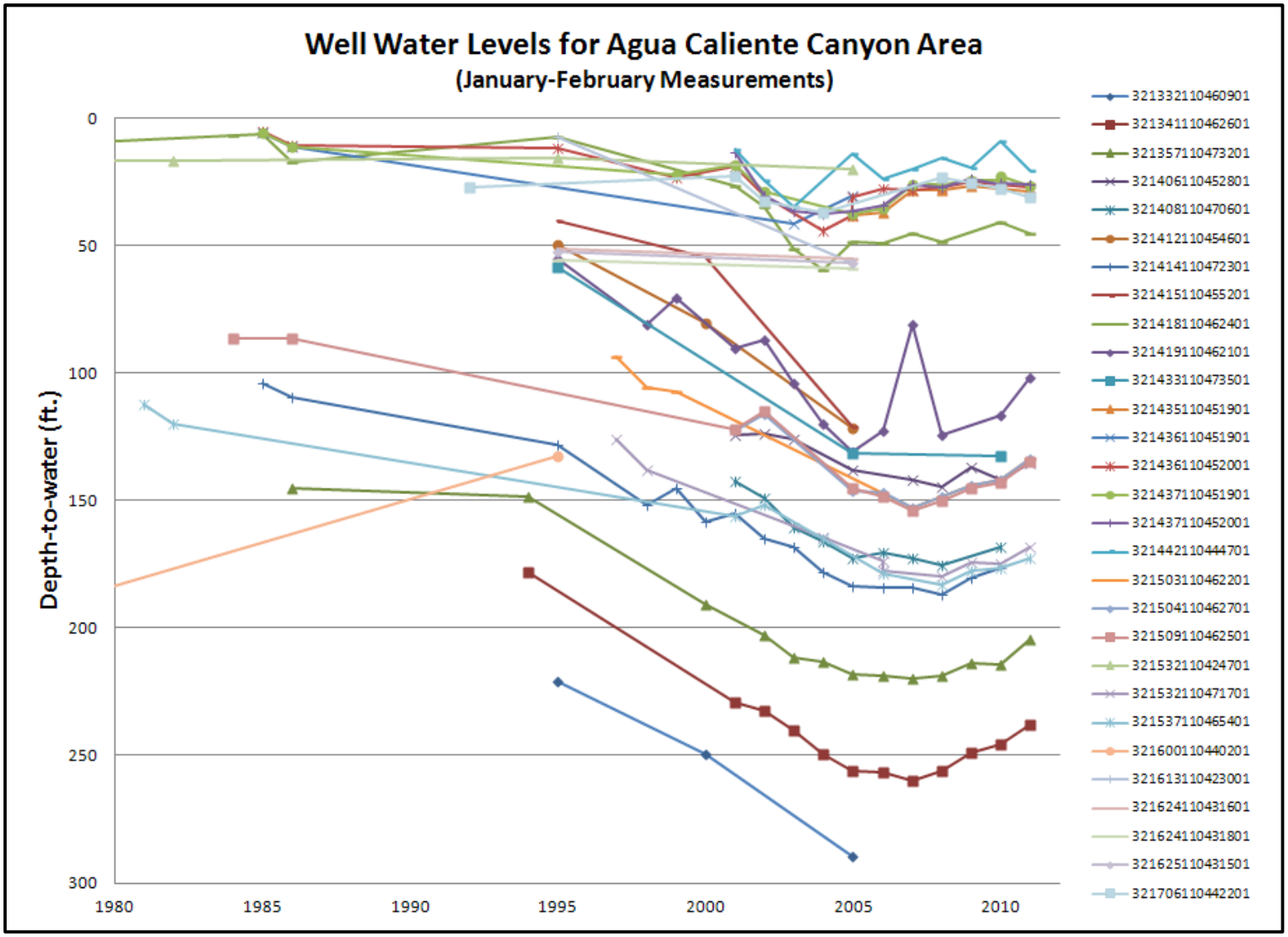
Additional depth-to-water plots for the Rillito Creek Area, the Sabino Canyon Area and the three Tanque Verde Creek sites (Lower, Mid, and Upper) are given in Appendix C. As with the Agua Caliente Canyon Area, these areas showed similar patterns of decline and recovery for deeper wells, with minima occurring around 2004 to 2007. Water level declines since 1995 were noticeable in several shallow wells in the Sabino Canyon and Tanque Verde Creek (Mid) areas.

Figure 27. Depth-to-water in wells in the Agua Caliente Canyon Area.



Note: See Appendix C for other study sites.

Figure 28. Depth-to-water in wells in the Agua Caliente Canyon Area since 1980.



Note: Only measurements acquired in January and February are plotted.

Table 14. Groundwater level changes in shallow wells of Agua Caliente Canyon Area.

Site ID	Groundwater Level Change (ft./yr.)[1]			
	1980-1995	1995-2005	2005-2012	1981-2011
321418110462401	0.9	-2.6	1.0	-1.0
321419110462101	2.1	-7.1	2.3	
321435110451901	Insufficient data	-3.0	1.4	
321436110451901	-0.8	5.4	Insufficient data	
321436110452001	-0.2	-1.1	0.9	-0.7
321437110451901	-0.2	-0.3	2.1	-0.6
321437110452001	Insufficient data	-5.3	1.7	
321442110444701	Insufficient data	-0.4	0.4	
321450110445301	-1.5	0.7	Insufficient data	
321503110462201	-0.5	-7.1	4.6	-2.2
321509110462501	-0.4	-6.8	1.8	-2.4
321532110424701	0.1	-0.5	Insufficient data	
321613110423001	Insufficient data	-4.9	Insufficient data	
321624110431601	0.4	-0.4	Insufficient data	
321656110443101	0.4	Insufficient data	Insufficient data	
321706110442201	2.0	-4.3	-0.8	
Mean	**0.2**	**-2.5**	**1.6**	**-1.4**

[1] *Positive change indicates increase in water level; negative change indicates declining water level.*

Central Santa Cruz River

Description

The Central Santa Cruz River region contains one shallow groundwater area, the Santa Cruz River (Tucson) site (Figure 29). Though this is a small area, its long-term history and central location make it one of the most significant study sites in this report.

The Santa Cruz River (Tucson) shallow groundwater area is located immediately southwest of downtown Tucson and upstream from the confluence with Rillito Creek. Once perennial, this urban stretch of the river is currently dry (City of Tucson and Pima County, 2009). It now supports scattered mesquite and tamarisk trees (pers. obs.).

Well Inventory

As of 2012, the Santa Cruz River (Tucson) area had a total of 35 exempt and 23 non-exempt water-producing wells with a high well density of 10.7 wells/sq. mile. With 39.7 percent of the wells being non-exempt, this region is second only to Cocio Wash in its proportion of non-exempt wells.

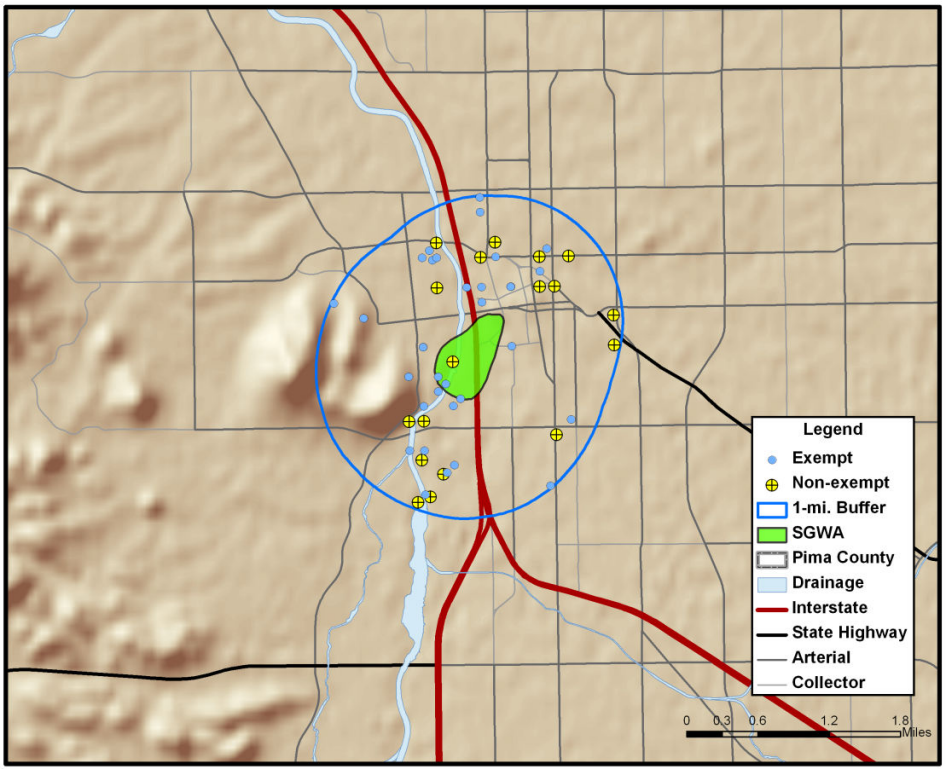
Drilling Trends

The drilling dates for 43 out of the 58 wells are unknown, and could indicate that they are very old. Of the remaining 15 wells with known drilling dates, 10 were drilled before 1980, none was drilled from 1980-1989, one was drilled from 1990-1999 and four (0.3 wells/year) were drilled since 2000. Of the four wells drilled since 2000, one was non-exempt. The rate at which wells were drilled since 2000 was the one of the lowest of any region. Figure 30 shows the distribution of wells in the area by drilling year.

Water Withdrawals

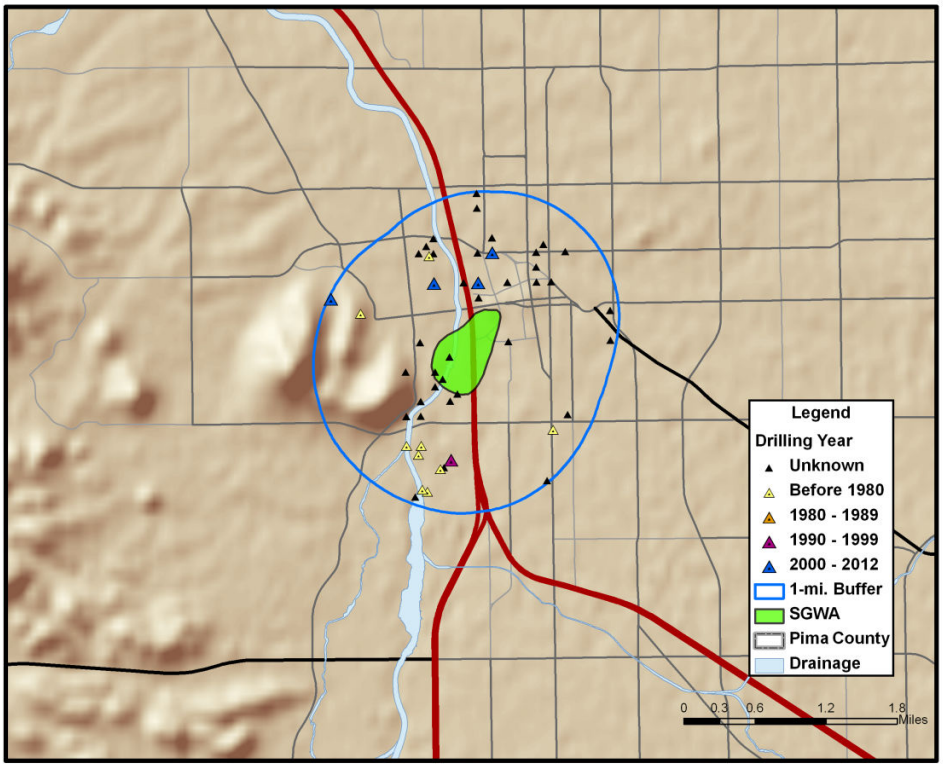
All wells in the Santa Cruz River (Tucson) area are located within the Tucson AMA. Owners of 5 of the 23 non-exempt wells reported their water withdrawal reports for 1984-2010 to ADWR. Water withdrawal information for the area is given in Table 15, and totaled 38.4 acre-feet in 2010, though as noted, data were unavailable for most non-exempt wells. Historically, this area produced large quantities of water, mostly due to one productive non-exempt well, but beginning around 2002 water withdrawals from the reporting non-exempt wells dropped to near-zero values (Figure 31).

Figure 29. Wells in the Central Santa Cruz River region.



Note: SGWA = Shallow groundwater area

Figure 30. Drilling history in the Central Santa Cruz River region.

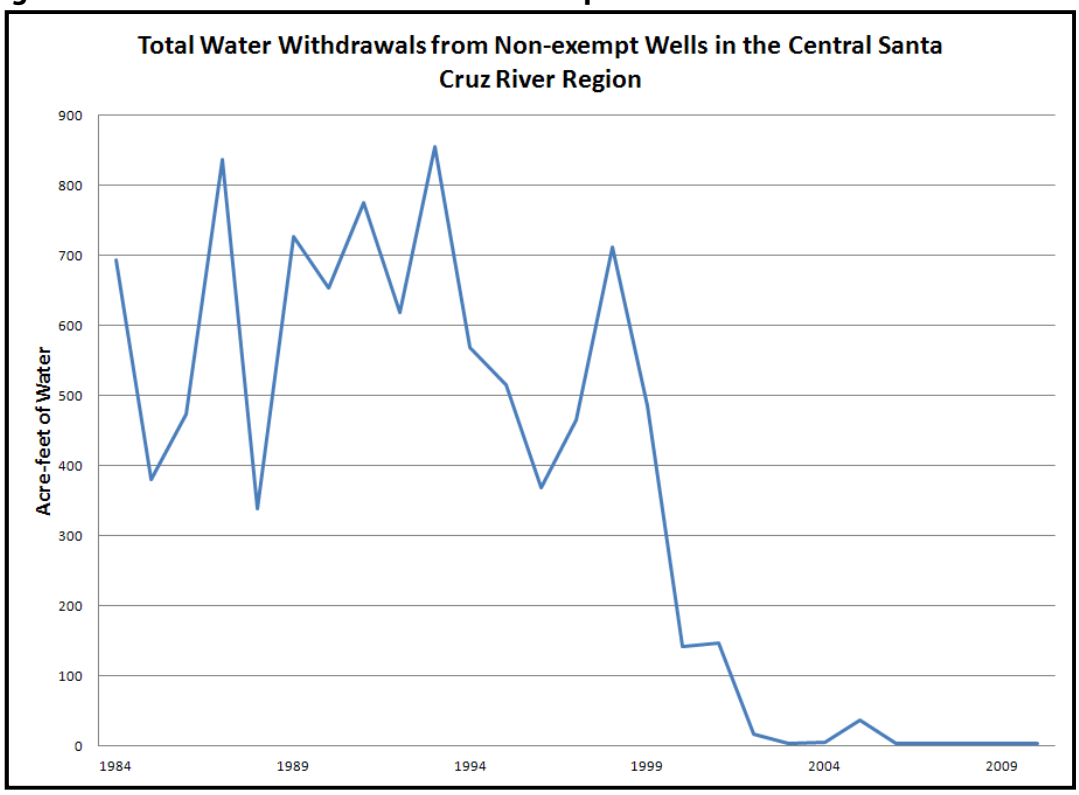


Note: SGWA = Shallow groundwater area

Table 15. Water withdrawals in 2010 from the Central Santa Cruz River in acre-feet (AF).

Shallow Groundwater Area	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Santa Cruz River (Tucson)	35	35.0 AF	23	5	3.4 AF	38.4 AF	8.9%

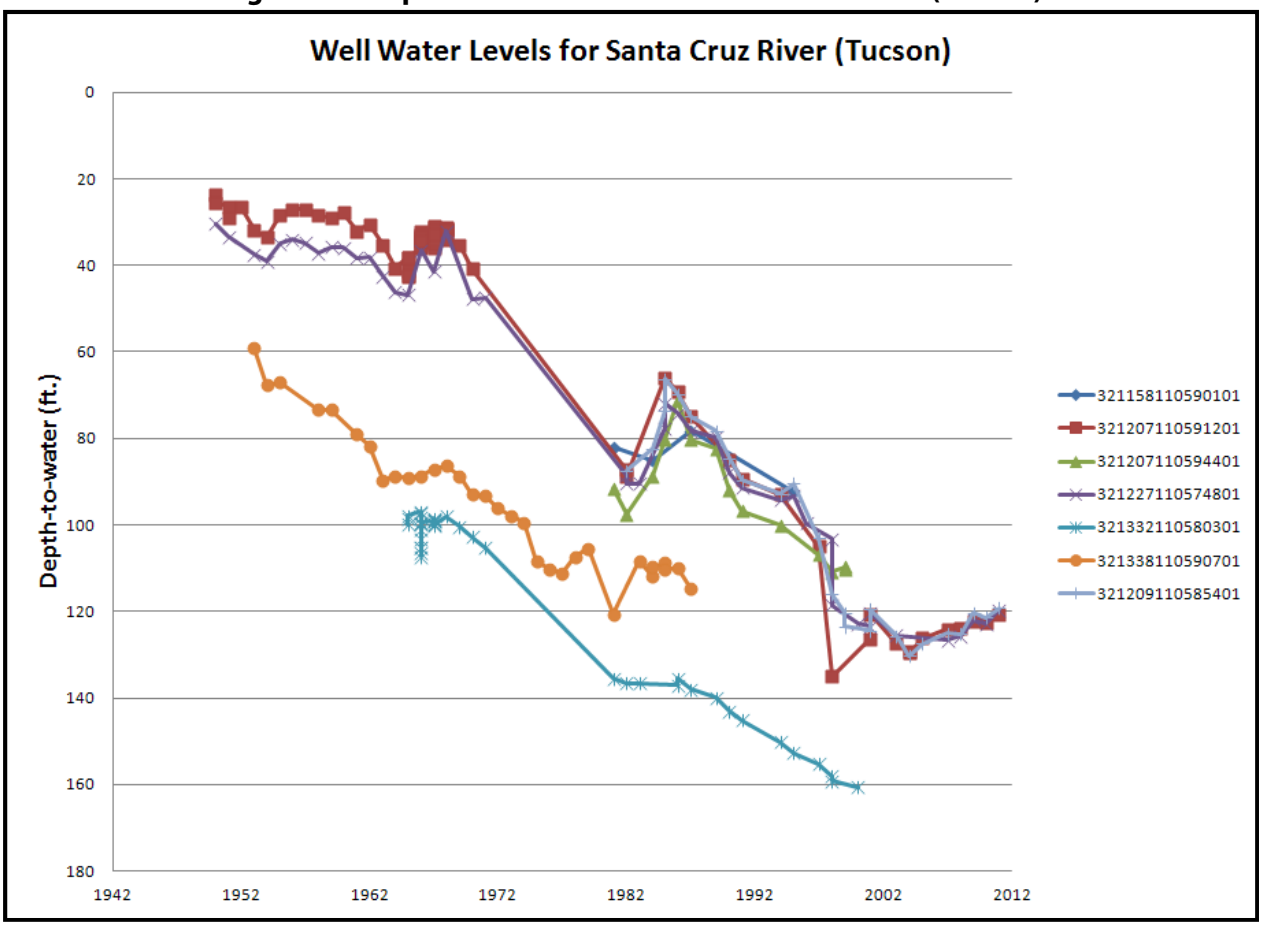
Figure 31. Water withdrawals from non-exempt wells in the Central Santa Cruz River.



Water Levels

The Santa Cruz River (Tucson) site illustrates one of the clearest examples of water level declines among all areas in this study (Figure 32). Water levels dropped by ~100 ft. between 1950 and 2003 in two shallow wells. Other wells show similar rates of decline of about two feet per year. One encouraging sign is that water level declines stabilized or even reversed slightly since 2003-2004. As with the Rillito-Tanque Verde System, this could be the consequence of sharp curtailments in water withdrawals.

Figure 32. Depth-to-water in wells of Santa Cruz River (Tucson).



Note: Legend lists GWSI site-IDs.

Pantano-Rincon System

Description

The Pantano-Rincon System contains three shallow groundwater areas: Pantano Wash, Box Canyon (Rincon) and the Rincon Creek Area (Figure 33). As previously noted, the Rincon Creek Area was extended farther upstream for this report to capture additional riparian vegetation and several new wells.

Box Canyon (Rincon) and Rincon Creek receive runoff from the west side of the Rincon Mountains between Tanque Verde Ridge and Rincon Peak. From there, water flows into Pantano Wash, which courses northward to Rillito Creek. All drainages are non-perennial (City of Tucson and Pima County, 2009).

The three areas support a mix of riparian vegetation within their drainages. Box Canyon (Rincon) has stands of mesquite (Pima County, 2011). Pantano Wash has willow and cattail present (Pima County, 2011). Rincon Creek has assemblages of Fremont cottonwood, Goodding willow, mesquite, Arizona walnut and mesquite (PAG, 2000a; Pima County, 2011).

Because of the close proximity of many of the shallow groundwater areas within this region the one-mile buffers surrounding the areas commonly overlap. Consequently, some wells coincide with more than one shallow groundwater area. This data replication affects tables and figures related to well inventories, drilling histories and water withdrawals, so that summing values of the individual areas leads to overinflated numbers. In each table, the row labeled "REGION" represents the correct sums of well numbers or water volumes without duplicates.

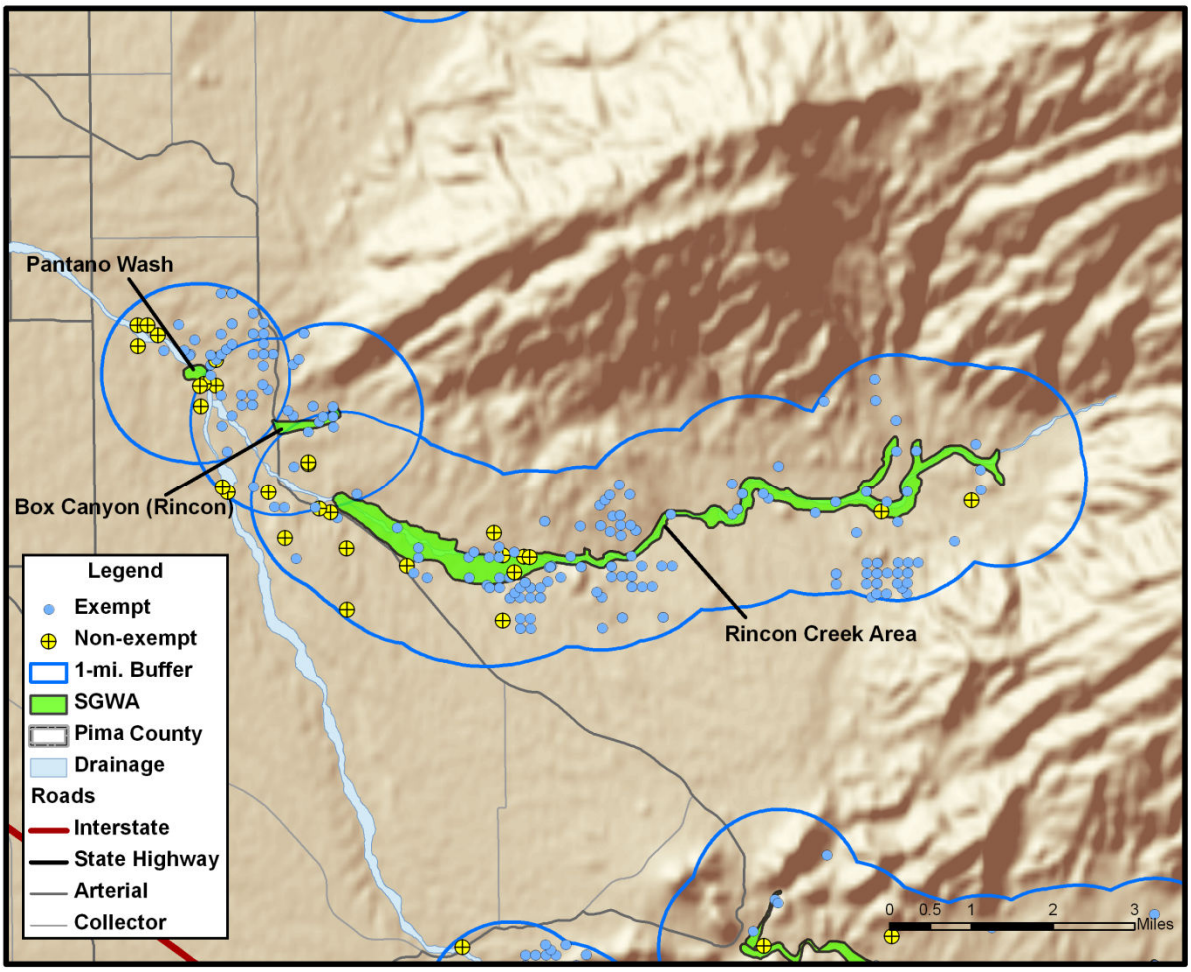
Well Inventory

As of 2012, the Pantano-Rincon System had a total of 215 exempt and 29 non-exempt water-producing wells with a moderate well density of 8.0 wells/sq. mile. The well inventory and density of each area is given in Table 16. For reasons explained previously, the row labeled "REGION" eliminates duplicate well counts due to overlapping shallow groundwater buffers and represents the correct sums for the region. As can be seen in Table 16, the Rincon Creek Area contains the most water-producing wells in this region; however, Pantano Wash has the highest well density.

Drilling Trends

Drilling dates are unknown for 41 of the wells in the region; however, for those with known dates, 68 were drilled before 1980, 22 were drilled from 1980-1989, 56 were drilled from 1990-1999 and 57 (4.6 wells/year) were drilled since 2000 (Table 17). Of the 57 wells drilled since 2000, only three were non-exempt. Most of these new wells were installed in the Rincon Creek Area. Figure 34 shows the drilling history of these wells.

Figure 33. Wells in the Pantano-Rincon System.



Note: SGWA = Shallow groundwater area

Table 16. Inventory and density of wells in the Pantano-Rincon System in 2012.

Shallow Groundwater Area	Total # of Wells	# of Exempt Wells	# of Non-exempt Wells	Wells/Sq. Mi.
Box Canyon (Rincon)	51	41	10	9.8
Pantano Wash	56	47	9	14.0
Rincon Creek Area	177	159	18	7.2
REGION[1]	**244**	**215**	**29**	**8.0**

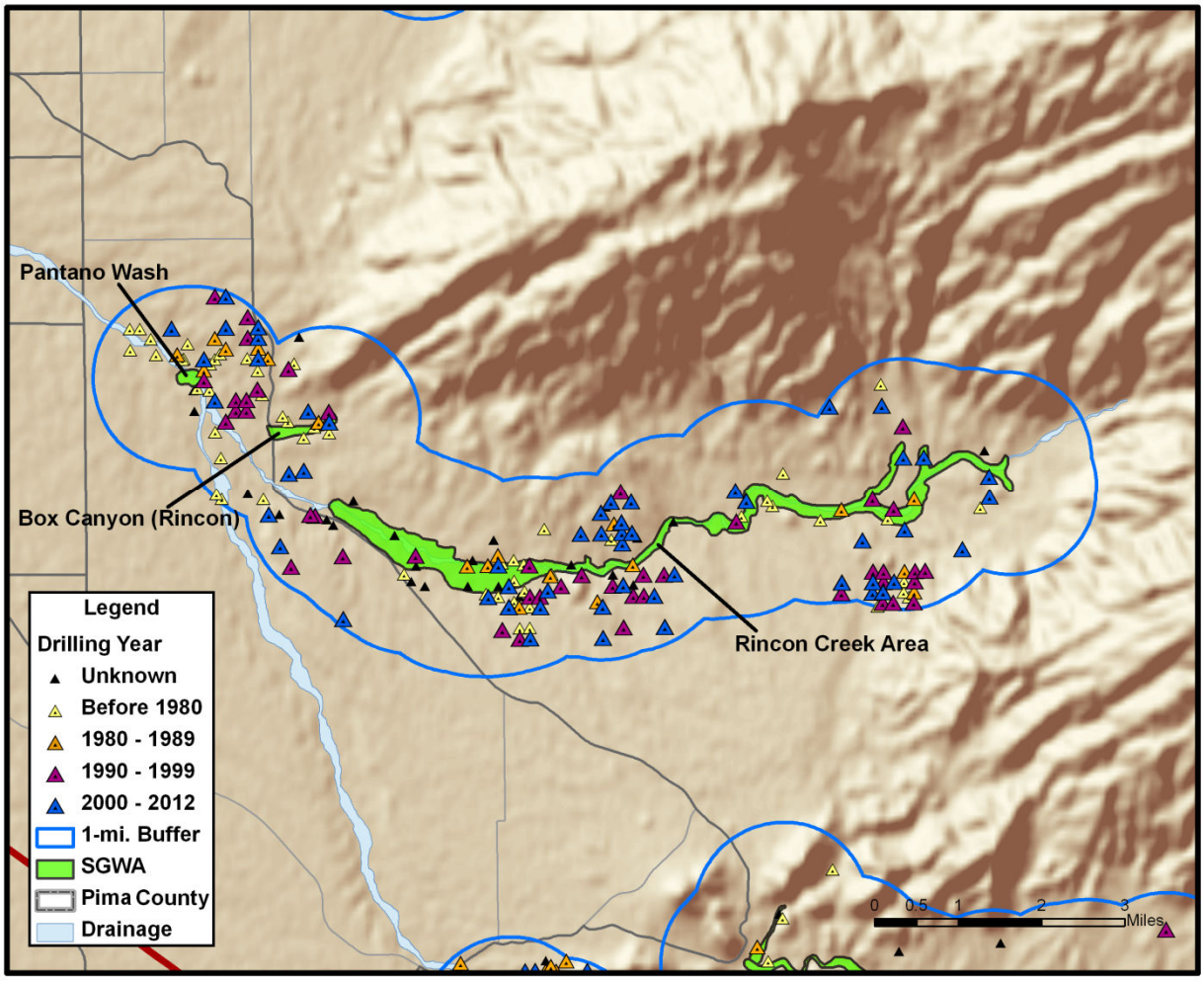
[1] Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.

Table 17. Drilling history in the Pantano-Rincon System.

SGWA	# Wells Drilled in Time Period					# Non-exempt Wells Drilled 2000-2012
	Date Unknown	Before 1980	1980-1989	1990-1999	2000-2012	
Box Canyon (Rincon)	8	19	4	12	8	1
Pantano Wash	6	22	7	13	8	0
Rincon Creek Area	33	40	15	41	48	3
REGION[1]	**41**	**68**	**22**	**56**	**57**	**3**

[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Figure 34. Drilling history in the Pantano-Rincon System.



Note: SGWA = Shallow groundwater area

Water Withdrawals

All wells in the Pantano-Rincon System are located within the Tucson AMA. Owners of 21 of the 29 non-exempt wells reported their water withdrawal reports for 1984-2010 to ADWR. Water withdrawal information for the each of the shallow groundwater areas is given in Table 18, and totaled 685.7 acre-feet in 2010. Of the areas in this region, the Rincon Creek Area produced the most water and Pantano Wash produced the least. The majority (68.9%) of water being withdrawn in this region came from non-exempt wells despite the fact that only 11.9 percent of the wells in this region are non-exempt.

From 1984 through 2010 water withdrawals from non-exempt wells declined to negligible amounts for Pantano Wash yet increased more than twofold for Box Canyon (Rincon) and the Rincon Creek Area beginning around 2001 (Figure 35).

Water Levels

Numerous water level measurements from wells were available for Box Canyon (Rincon) and the Rincon Creek Area (Figures 36 and 37). Depth-to-water measurements in Pantano Wash were duplicates of those found in Box Canyon (Rincon), as all were from their areas of overlap; therefore, no separate plot is given for Pantano Wash. Both charts indicated steady or increasing water levels until 1995. After 1995 water levels for most wells trended downward, though the data were somewhat sparse. This decline could be related to greater groundwater withdrawals as reported in Figure 35.

Table 18. Water withdrawals in 2010 from the Pantano-Rincon System in acre-feet (AF).

Shallow Groundwater Area	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Box Canyon (Rincon)	41	41.0	10	8	338.6	379.6	89.2%
Pantano Wash	47	47.0	9	8	1.3	48.3	2.7%
Rincon Creek Area	157	157.0	18	12	465.5	622.5	74.8%
REGION[1]	**213**	**213.0 AF**	**29**	**21**	**472.7 AF**	**685.7 AF**	**68.9%**

[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Figure 35. Water withdrawals from non-exempt wells in the Pantano-Rincon System.

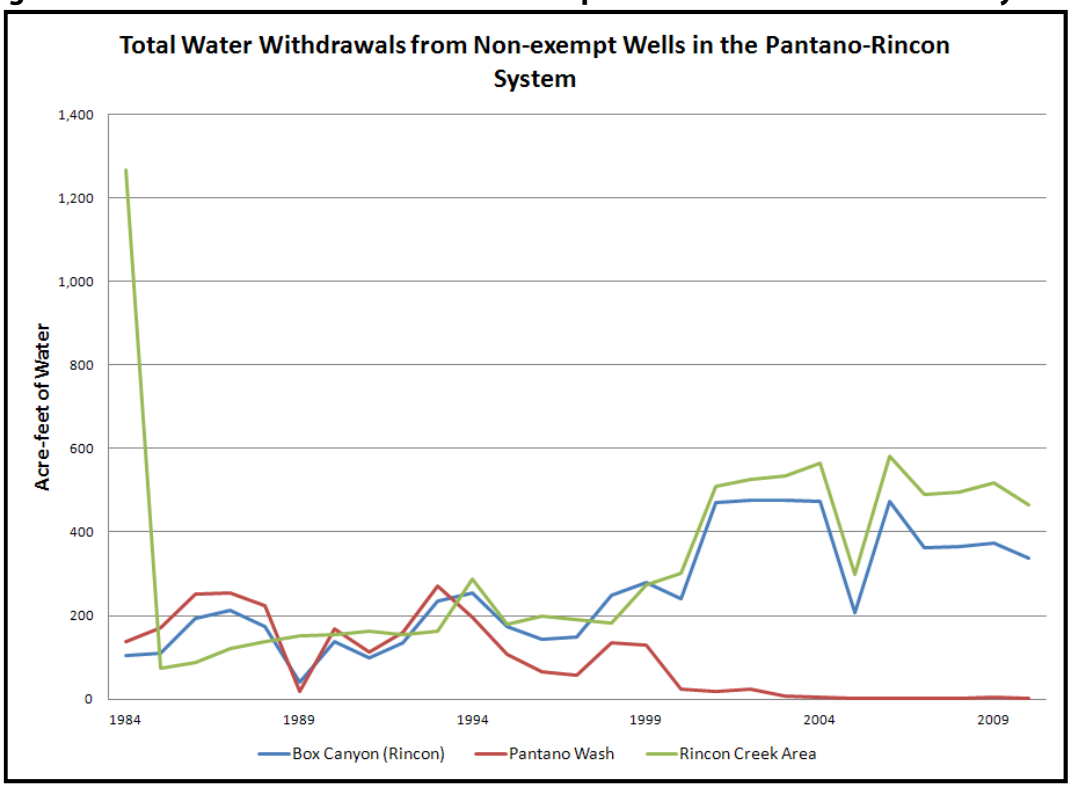
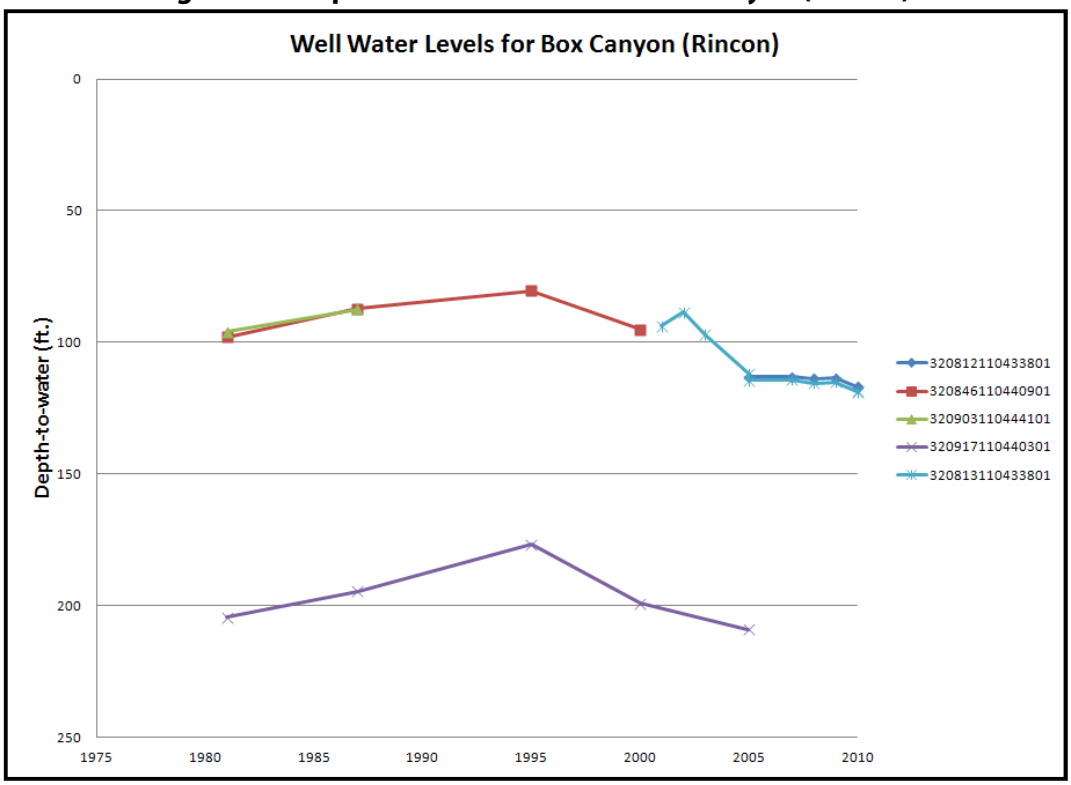
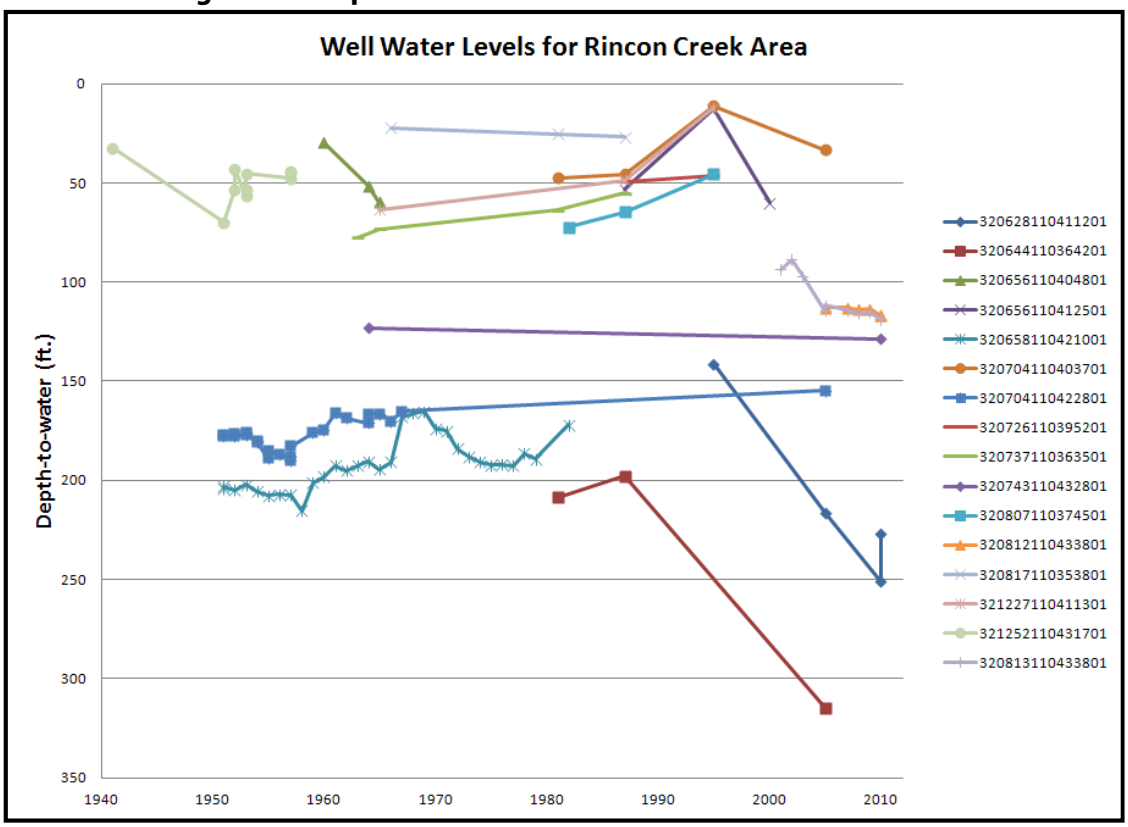


Figure 36. Depth-to-water of wells in Box Canyon (Rincon).



Note: Legend lists GWSI site-IDs.

Figure 37. Depth-to-water of wells in the Rincon Creek Area.



Note: Legend lists GWSI site-IDs.

Cienega-Davidson System

Description

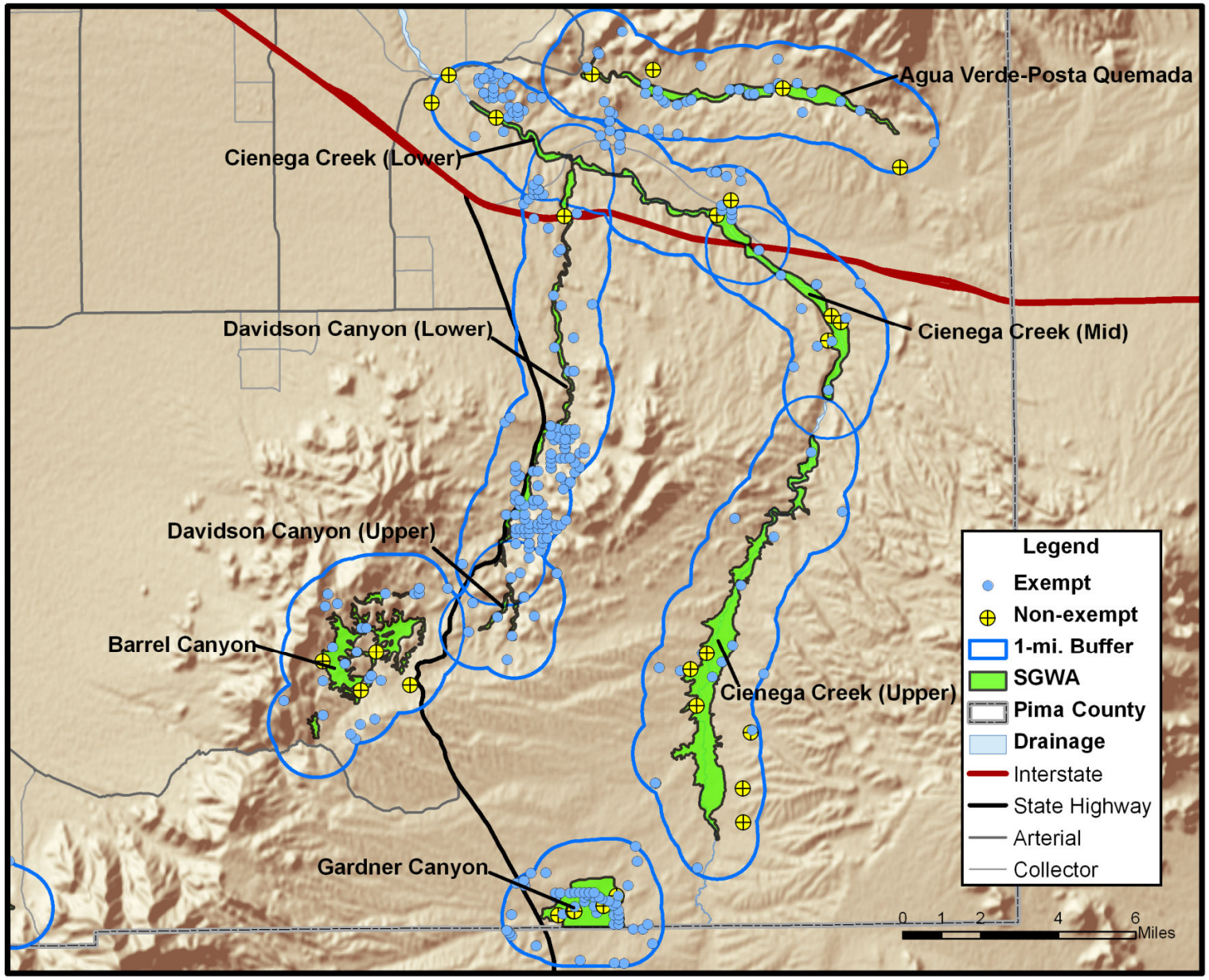
The Cienega-Davidson System contains eight shallow groundwater areas making it one of the most complex regions in this study (Figure 38). Agua Verde-Posta Quemada collects water from the south slopes of the Rincon Mountains. The other seven areas drain the north slope of the Santa Rita Mountains. The region exhibits a mix of perennial and intermittent reaches. All drainages ultimately flow into Pantano Wash, which courses northward to Rillito Creek.

Agua Verde-Posta Quemada supports riparian vegetation, such as Arizona ash, Goodding willow, Fremont cottonwood and velvet mesquite (PAG, 2000a; Pima County, 2011). The Cienega Creek sites feature Fremont Cottonwood, Goodding willow, seep willow, Arizona ash and mesquite (PAG, 2000a; Pima County, 2011). Similarly, Davidson Canyon supports cottonwood, ash, Goodding willow, seep willow, hackberry and mesquite (PAG, 2000a; Pima County, 2011).

This region includes several noteworthy environmental features. Cienega Creek and Davidson Canyon are each designated as Outstanding Arizona Waters (OAW), which protects their high quality, free-flowing surface water under the U.S. Clean Water Act. The Cienega Creek (Lower) site and parts of Cienega Creek (Mid) are protected by the Cienega Creek Natural Preserve administered by Pima County. Most of Cienega Creek (Upper) falls within the Las Cienegas National Conservation Area administered by the Bureau of Land Management. Perennial reaches in Cienega Creek support populations of the Gila chub and the Gila topminnow, both listed as Threatened and Endangered Species (City of Tucson and Pima County, 2009). Finally, it should be noted that Barrel Canyon is within the proposed Rosemont Copper project site.

Because of the close proximity of many of the shallow groundwater areas within this region the one-mile buffers surrounding the areas commonly overlap. Consequently, some wells coincide with more than one shallow groundwater area. This data replication affects tables and figures related to well inventories, drilling histories and water withdrawals, so that summing values of the individual areas leads to overinflated numbers. In each table, the row labeled "REGION" represents the correct sums of well numbers or water volumes without duplicates.

Figure 38. Wells in Cienega-Davidson System.



Note: SGWA = Shallow groundwater area

Well Inventory

As of 2012, the Cienega-Davidson System had a total of 355 exempt and 29 non-exempt water-producing wells with a well density of 2.6 wells/sq. mile, a lower density than most other areas. Overall, only 7.6 percent of the wells in this region are non-exempt. The well inventory and density of each area is given in Table 19. For reasons explained previously, the row labeled "REGION" eliminates duplicate well counts due to overlapping shallow groundwater buffers and represents the correct sums for the region. As can be seen in Table 19, Davidson Canyon (Lower) contains the greatest number of wells in this region, whereas Davidson Canyon (Upper) has the fewest. The highest densities are in Davidson Canyon (Lower) and Gardner Canyon, which are outside the land preserves and conservation areas.

Drilling Trends

Drilling dates are unknown for 72 of the wells in the region; however, for those with known dates, 96 were drilled before 1980, 53 were drilled from 1980-1989, 72 were drilled from 1990-1999 and 91 (7.4 wells/year) were drilled since 2000 (Table 20). Of the 91 wells drilled since 2000, only one was non-exempt. The drilling rate in this region since 2000 was second only to the Rillito-Tanque Verde System. Figure 39 displays geographically the drilling history of these wells.

Well drilling since 2000 was most prevalent in Cienega Creek (Lower) and in Davidson Canyon (Lower) with 35 and 28 new wells, respectively. The only new non-exempt well to be drilled since 2000 was installed in Agua Verde-Posta Quemada; all other non-exempt wells (28) in the region were drilled before 2000. The last well to be drilled in Davidson Canyon (Upper) was installed in1996.

Table 19. Inventory and density of wells in the Cienega-Davidson System in 2012.

Shallow Groundwater Area	Total # of Wells	# of Exempt Wells	# of Non-exempt Wells	Wells/Sq. Mi.
Agua Verde-Posta Quemada	47	43	4	2.0
Barrel Canyon	29	25	4	1.5
Cienega Creek (Lower)	79	74	5	3.5
Cienega Creek (Mid)	22	18	4	1.4
Cienega Creek (Upper)	23	17	6	0.7
Davidson Canyon (Lower)	135	134	1	4.9
Davidson Canyon (Upper)	15	15	0	1.8
Gardner Canyon	62	57	5	5.6
REGION[1]	**384**	**355**	**29**	**2.6**

[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Table 20. Drilling history in the Cienega-Davidson System.

Shallow Groundwater Area	# Wells Drilled in Time Period					Non-exempt Wells Drilled 2000-2012
	Date Unknown	Before 1980	1980-1989	1990-1999	2000-2012	
Agua Verde-Posta Quemada	5	17	5	7	13	1
Barrel Canyon	14	9	2	2	2	0
Cienega Creek (Lower)	4	9	15	16	35	0
Cienega Creek (Mid)	5	8	2	4	3	0
Cienega Creek (Upper)	14	6	0	1	2	0
Davidson Canyon (Lower)	21	28	21	37	28	0
Davidson Canyon (Upper)	4	4	2	5	0	0
Gardner Canyon	8	20	9	8	17	0
REGION[1]	**72**	**96**	**53**	**72**	**91**	**1**

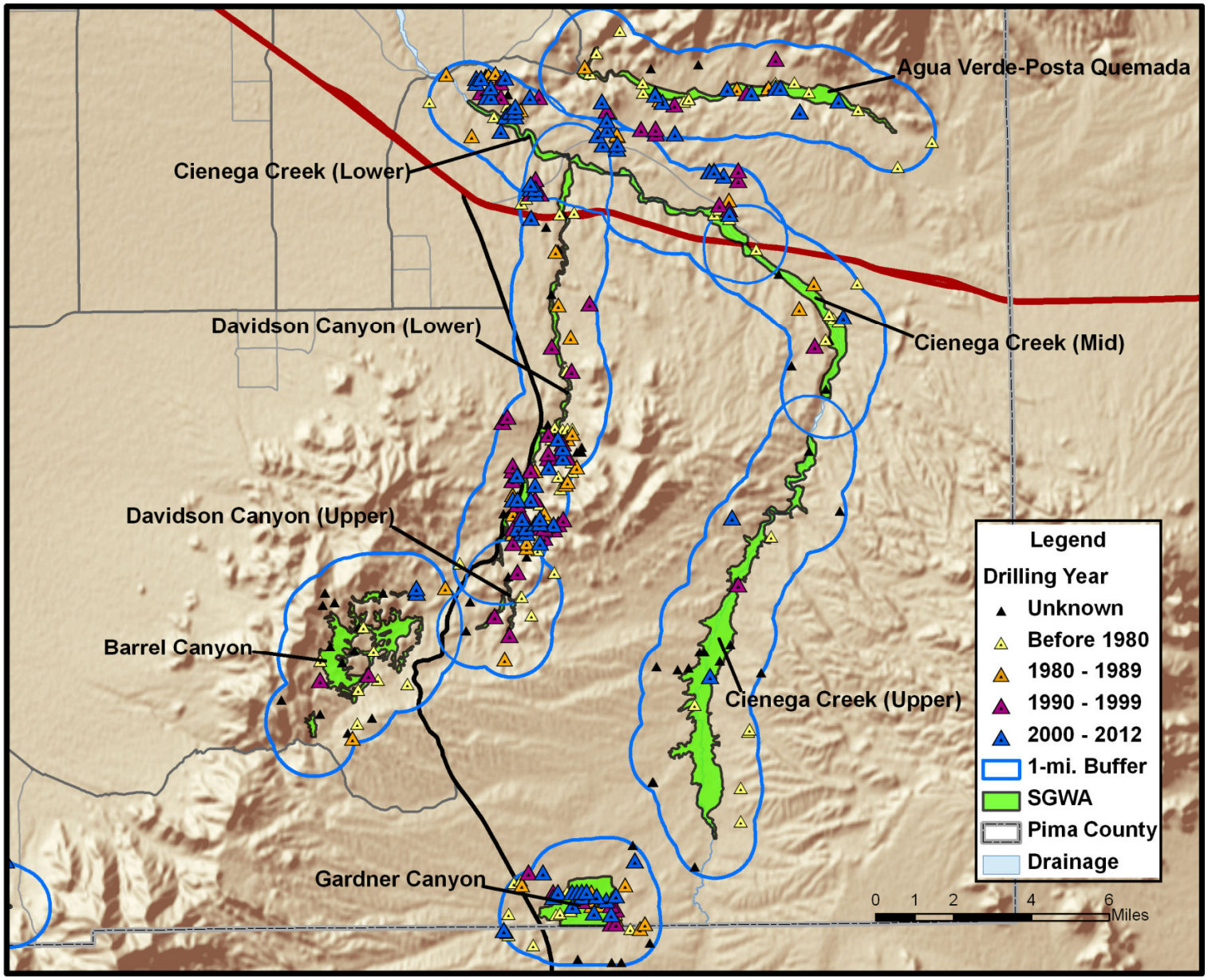
[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Water Withdrawals

Approximately half of the wells in the Cienega-Davidson System are within the Tucson AMA, while the others are outside of any AMA. As such, historic water withdrawal data were only available for four non-exempt wells out of the 29 present in the region, and actual withdrawals could be considerably more than estimated here. Water withdrawal information for the each of the shallow groundwater areas is given in Table 21, and totaled 854.2 acre-feet in 2010. Even with only four non-exempt wells reporting data, the majority (58.7%) of water being withdrawn in this region came from non-exempt wells. Of the eight shallow groundwater areas in this region, Cienega Creek (Lower) produced the most water, chiefly due to two productive non-exempt wells. Davidson Canyon (Upper) produced the least amount of water.

For the two areas in which annual water pumping data were reported to ADWR, water withdrawal trends are given in Figure 40 for the period 1984-2010. While water production from non-exempt wells was consistently low in Agua Verde-Posta Quemada, water production in Cienega Creek (Lower) went from 39.2 acre-feet in 1984 to a peak of 1,020.4 acre-feet in 2008.

Figure 39. Drilling history in the Cienega-Davidson System.



Note: SGWA = Shallow groundwater area

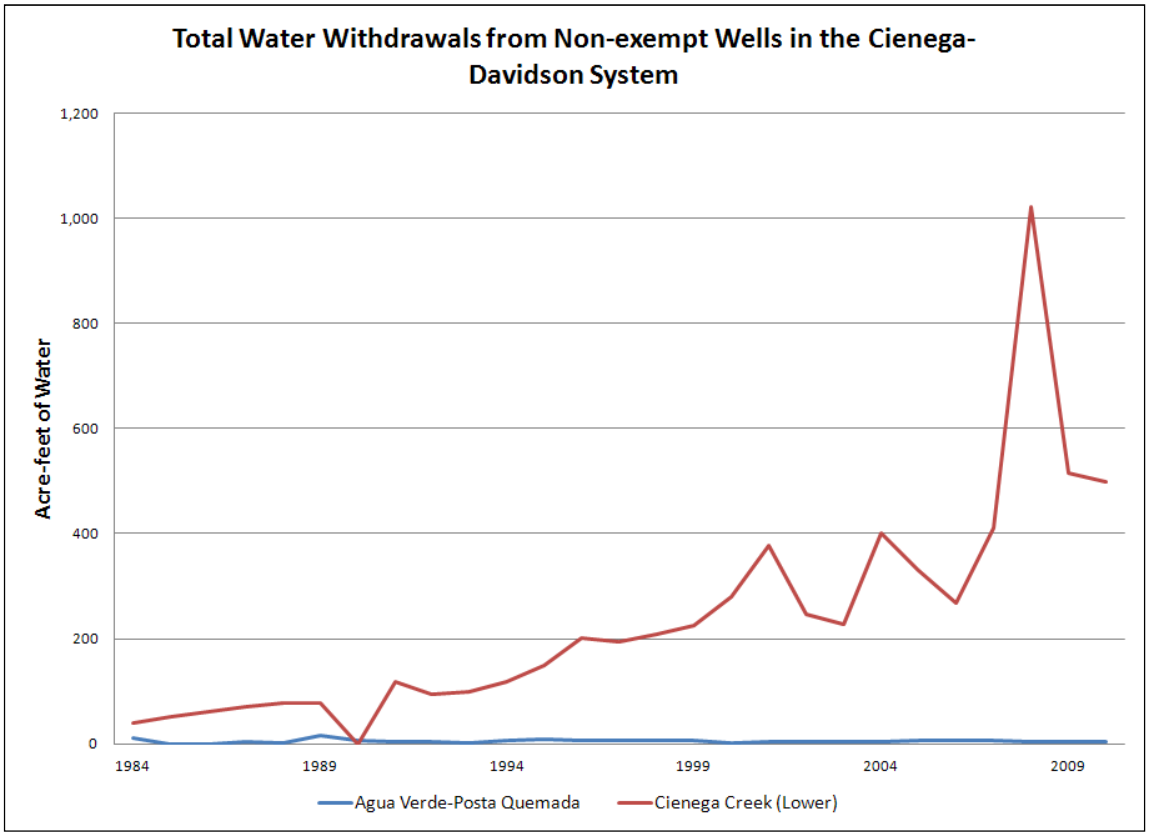
Table 21. Water withdrawals in 2010 from the Cienega-Davidson System in acre-feet (AF).

SGWA	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)[1]	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Agua Verde-Posta Quemada	42	42.0	4	2	3.2	45.2	7.0%
Barrel Canyon	25	25.0	4	0	No Data	25.0	0.0%
Cienega Creek (Lower)	73	73.0	5	2	498.0	571.0	87.2%
Cienega Creek (Mid)	22	22.0	4	0	No Data	18.0	0.0%
Cienega Creek (Upper)	17	17.0	6	0	No Data	17.0	0.0%
Davidson Canyon (Lower)	134	134.0	1	0	0.0	134.0	0.0%
Davidson Canyon (Upper)	15	15.0	0	0	0.0	15.0	0.0%
Gardner Canyon	57	57.0	5	0	No Data	57.0	0.0%
REGION[2]	**353**	**353.0 AF**	**29**	**4**	**501.2 AF**	**854.2 AF**	**58.7%**

[1] Only four out of 29 non-exempt wells reported pumping data for 2010; actual withdrawals could be considerably more than estimated here.

[2] Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.

Figure 40. Water withdrawals from non-exempt wells in the Cienega-Davidson System.



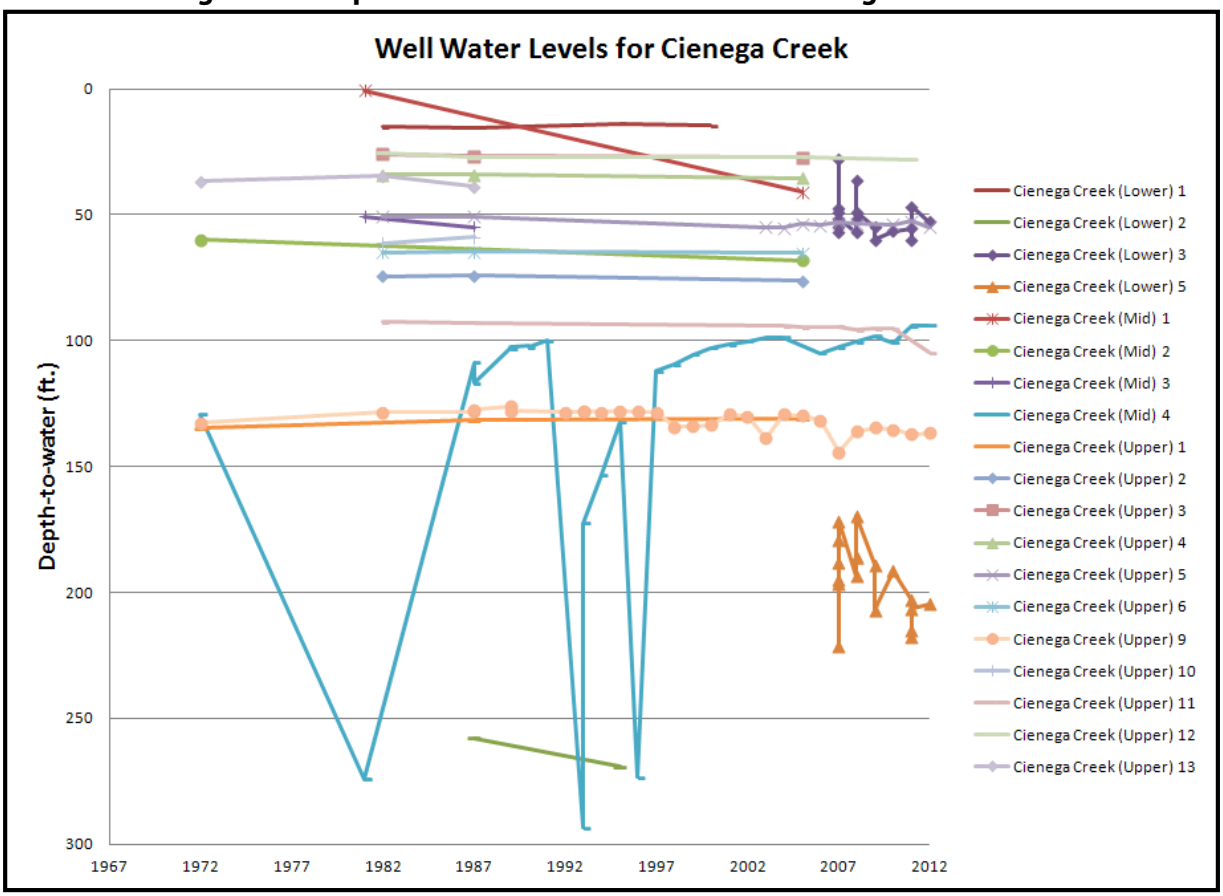
Water Levels

Water level information for this region was available from two sources, (1) ADWR's GWSI database and (2) PAG's water monitoring program. The GWSI data for seven of the areas are shown in Figures 41, 42 and 43. For clarification, the names of the wells in Figures 41 and 42 are based on shallow groundwater area rather than GWSI site IDs. A look-up table is provided in Appendix D, which gives their respective GWSI site IDs. Davidson Canyon (Upper) only had one well with multiple depth measurements, a well that was also within the buffer of Davidson Canyon (Lower). As such, this well is named "Davidson Canyon (Lower) 1" in Figure 42.

Although the figures derived from GWSI data show considerable variation in the depth-to-water of a few wells, long-term water levels were near stable. Variation may be accounted for, in part, due to seasonal fluctuation.

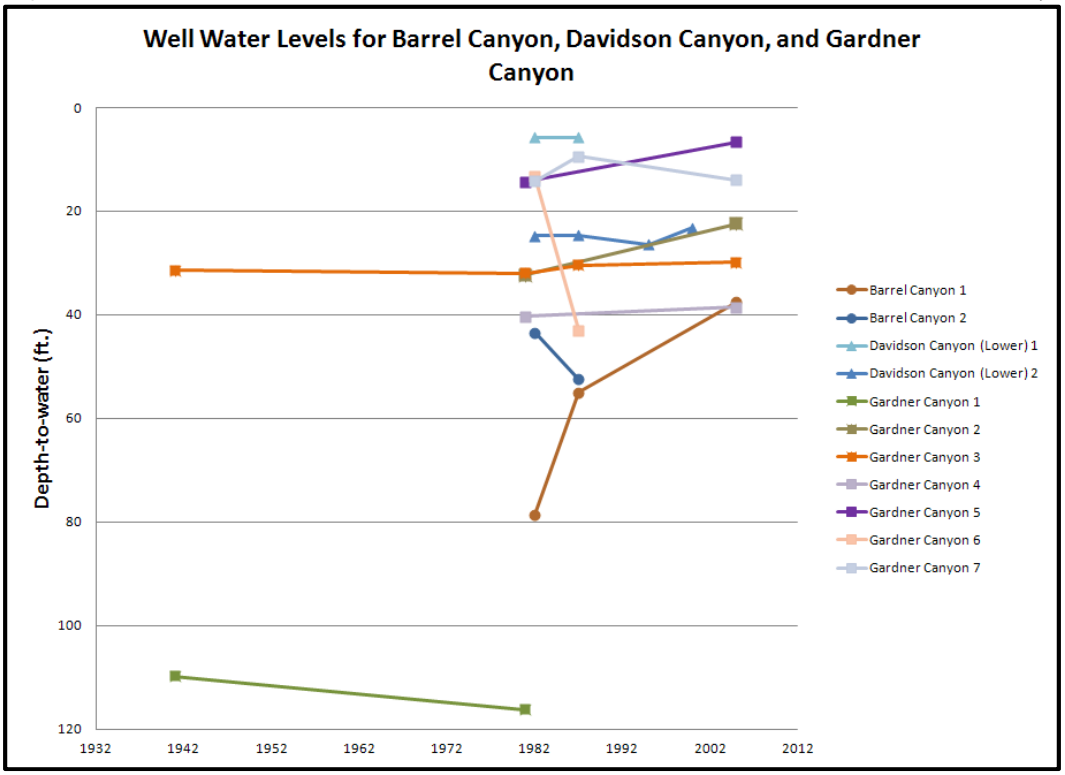
PAG has monitored water level information in the Cienega-Davidson System and has collected additional detailed data from a variety of sources since the late 1980s. One advantage of this dataset over the GWSI measurements was that the PAG data were available on a monthly basis, providing much more detail for detecting seasonal variation as well as comparing to year-to-year trends. Figure 44 shows water levels for nine wells from June 1994 through May 2012. The Davidson #2 well is located in Davidson Canyon (Lower), whereas the remaining eight wells are in Cienega Creek (Lower). Several of the wells, including Cienega and PS-1, showed regular seasonal variation in water levels. At least two wells, Jungle and Empirita #2, showed long-term water level declines of 10-15 feet over the 18-year study period, whereas the other wells were relatively stable from year to year or had inadequate data for establishing a trend.

Figure 41. Depth-to-water in wells of the three Cienega Creek sites.



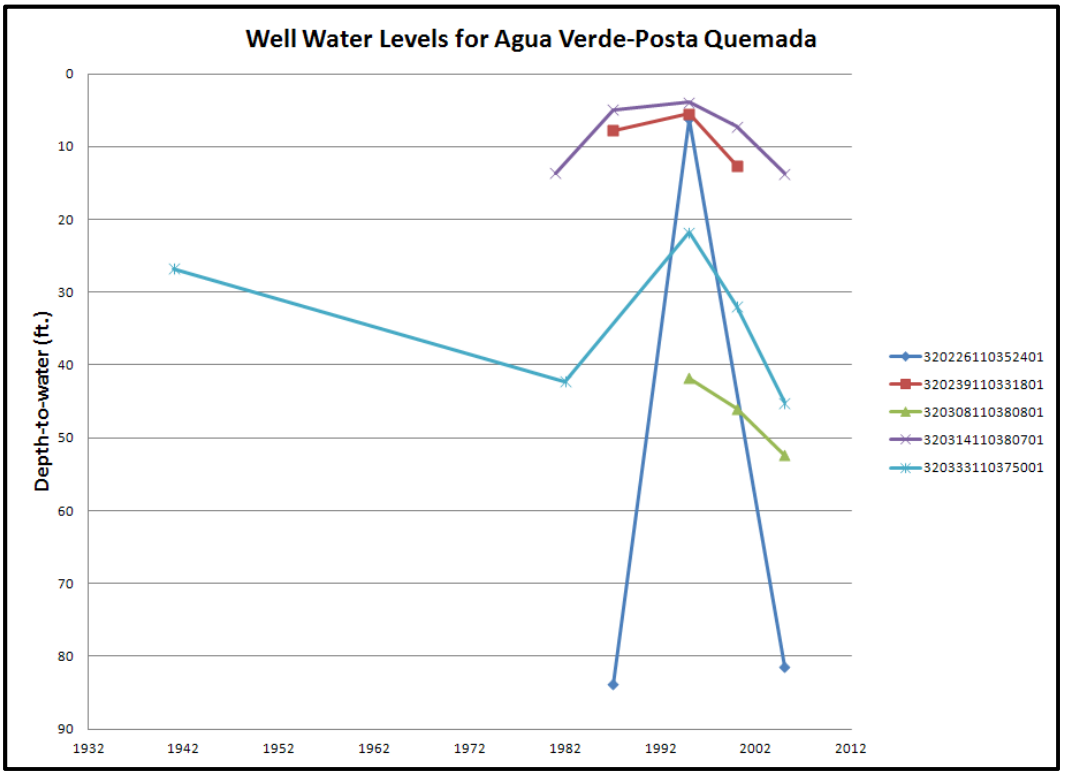
Note: Two wells with measurements entirely below 300 ft. are not plotted. See Appendix D for GWSI site-IDs.

Figure 42. Depth-to-water in wells of Barrel, Davidson (Lower) and Gardner Canyons.



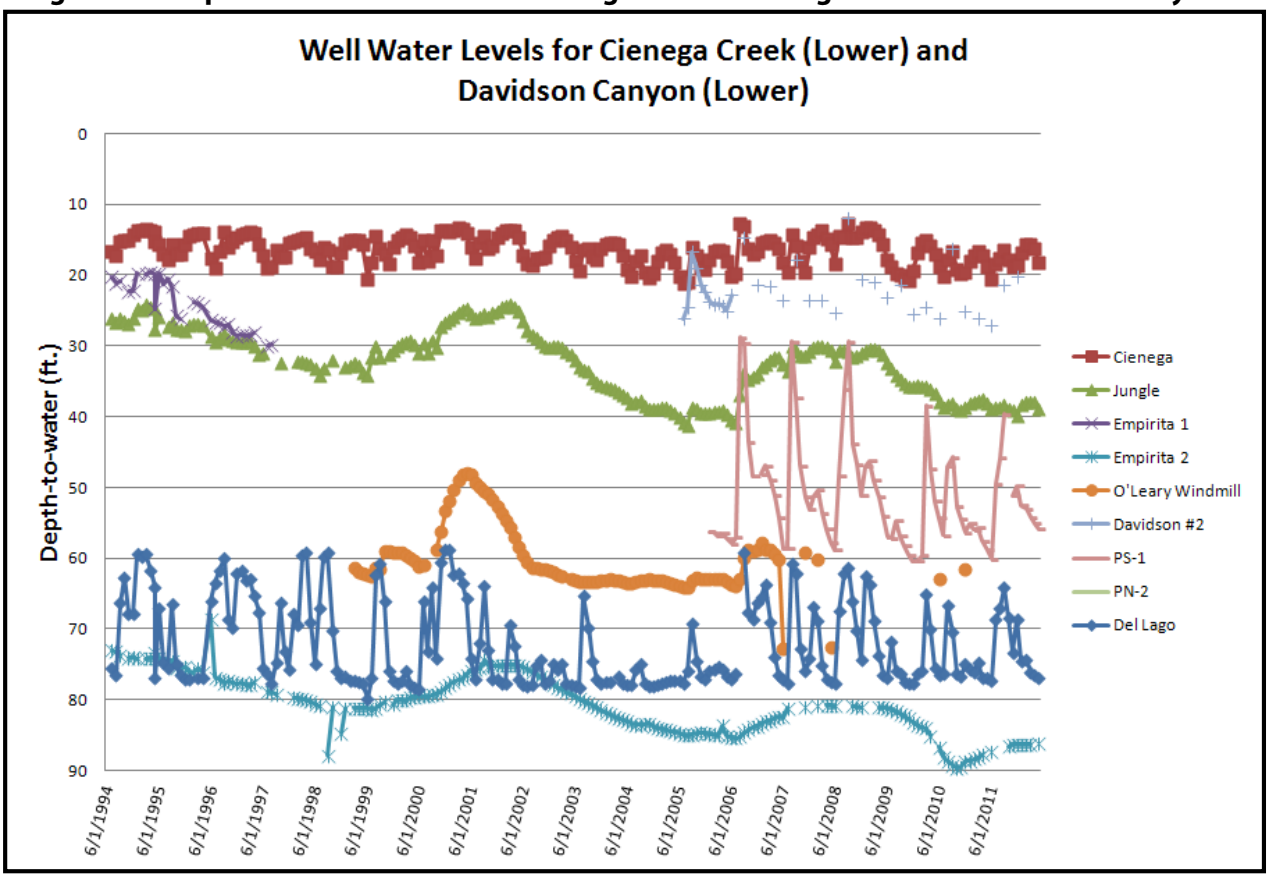
Note: See Appendix D for GWSI site-IDs.

Figure 43. Depth-to-water in wells of Agua Verde-Posta Quemada.



Note: Legend lists GWSI site-IDs.

Figure 44. Depth-to-water in PAG monitoring wells for Cienega Creek and Davidson Canyon.



Note: Well names in legend from PAG's well monitoring program.

Santa Cruz-Sopori System

Description

The Santa Cruz-Sopori System contains three shallow groundwater areas: Madera Canyon, Santa Cruz River (Canoa) and Sopori Wash (Figure 45). Madera Canyon drains a portion of the northwest slopes of the Santa Rita Mountains and flows westward to the Santa Cruz River. Sopori Wash originates in hills west of Tubac and also flows into the Santa Cruz River. Portions of this wash are located in Santa Cruz County. The Santa Cruz River (Canoa) site is located immediately downstream (north) of the confluence of Sopori Wash with the Santa Cruz River.

Sopori Wash is the largest of the three areas and contains stands of cottonwood and mesquite (Pima County, 2011). Madera Canyon is highly valued for its biodiversity and recreational opportunities. The Santa Cruz River (Canoa) area has stands of cottonwood, and is the site of Pima County's first major acquisition under the Sonoran Desert Conservation Plan (City of Tucson and Pima County, 2009).

Because of the close proximity of Santa Cruz River (Canoa) and Sopori Wash, the one-mile buffers surrounding these areas overlap. Consequently, some wells coincide with more than one shallow groundwater area. This data replication affects tables and figures related to well inventories, drilling histories and water withdrawals, so that summing values of the individual areas leads to overinflated numbers. In each table, the row labeled "REGION" represents the correct sums of well numbers or water volumes without duplicates.

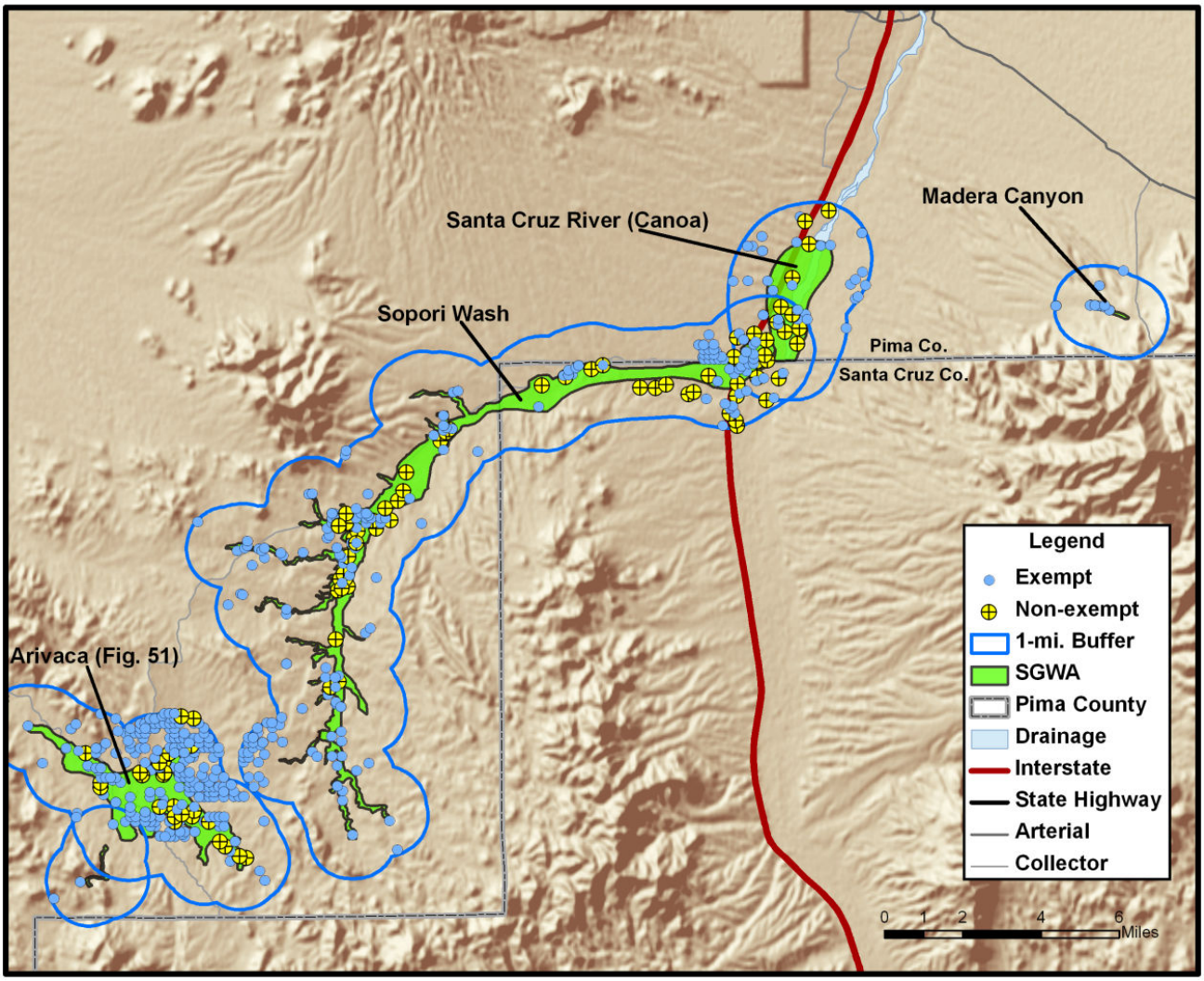
Well Inventory

As of 2012, the Santa Cruz-Sopori System had a total of 255 exempt and 64 non-exempt water-producing wells with a low well density of 3.6 wells/sq. mile. The well inventory and density of each area is given in Table 22. For reasons explained previously, the row labeled "REGION" eliminates duplicate well counts due to overlapping shallow groundwater buffers and represents the correct sums for the region. As can be seen in Table 22, Sopori Wash contains the greatest number of water-producing wells in this region. Also note that there are no non-exempt wells in Madera Canyon.

Drilling Trends

Drilling dates are unknown for 45 of the wells in the region; however, for those with known dates, 145 were drilled before 1980, 63 were drilled from 1980-1989, 27 were drilled from 1990-1999 and 39 (3.2 wells/year) were drilled since 2000 (Table 23). Of the 39 wells drilled since 2000, only two were non-exempt (Table 23). Most of these new wells were installed in the Sopori Wash area. Figure 46 shows the drilling history of these wells.

Figure 45. Wells in the Santa Cruz-Sopori System.



Note: SGWA = Shallow groundwater area

Table 22. Inventory and density of wells in the Santa Cruz-Sopori System.

Shallow Groundwater Area	Total # of Wells	# of Exempt Wells	# of Non-exempt Wells	Wells/Sq. Mi.
Madera Canyon	15	15	0	2.8
Santa Cruz River (Canoa)	69	49	20	4.9
Sopori Wash	275	215	60	3.7
REGION[1]	**319**	**255**	**64**	**3.6**

[1] Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.

Table 23. Drilling history in the Santa Cruz-Sopori System.

Shallow Groundwater Area	# Wells Drilled in Time Period					# Non-exempt Wells Drilled 2000-2012
	Date Unknown	Before 1980	1980-1989	1990-1999	2000-2012	
Madera Canyon	0	11	0	0	4	0
Santa Cruz River (Canoa)	10	40	7	6	6	0
Sopori Wash	41	120	58	24	32	2
REGION[1]	**45**	**145**	**63**	**27**	**39**	**2**

[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Water Withdrawals

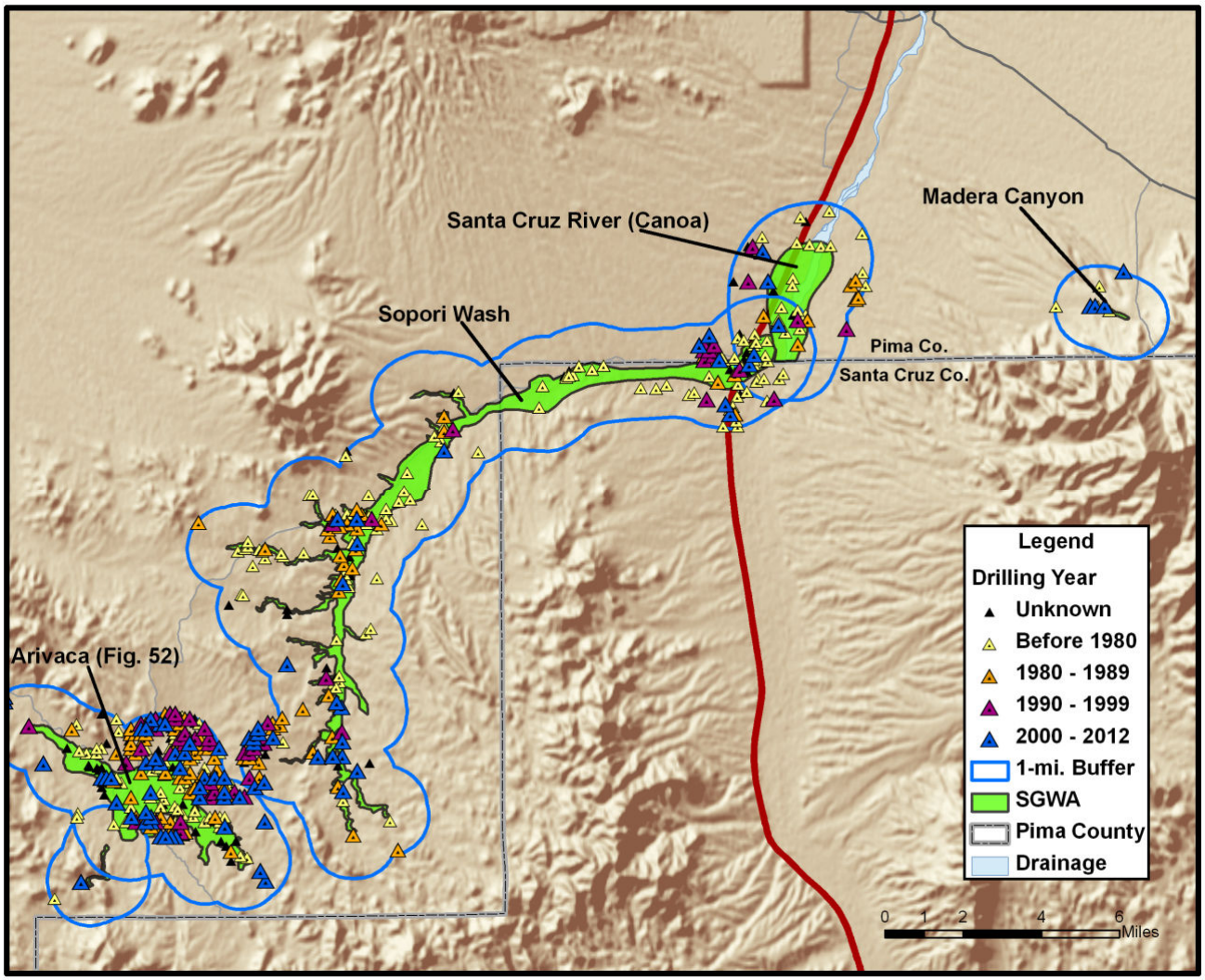
Of the 319 wells in this region, 254 are located in the Santa Cruz AMA and 65 are in the Tucson AMA. No wells are found outside of an AMA. Of the 64 non-exempt wells, owners of 52 wells reported water withdrawals for 1984-2010 to ADWR. Water withdrawal information for each of the areas is given in Table 24, and totaled 18,700.2 acre-feet in 2010, or 67.2 percent of water extracted by the 10 regions. With water withdrawals totaling 17,536.1 acre-feet/year, Santa Cruz River (Canoa) ranked first in water production among the 32 shallow groundwater areas in this study. In fact, four non-exempt wells owned by Freeport-McMoran Sierrita Inc. in the area produced more water than all other wells in this study combined.

Water production from non-exempt wells in both Santa Cruz River (Canoa) and the Sopori Wash areas trended upward since 1984, although Sopori Wash showed a slight decline in water production since 2007 (Figure 47). (Note: the Sopori Wash buffer shares one of the highly productive Freeport-McMoran wells with the Santa Cruz River (Canoa) buffer.) Given the absence of non-exempt wells in Madera Canyon, water withdrawal trends for that area are unknown.

Water Levels

Numerous water level measurements from wells were available for Santa Cruz River (Canoa) and Sopori Wash, whereas only a few depth readings were recorded in Madera Canyon (Figure 48). Due to the large number of wells measured in the Santa Cruz River (Canoa) and Sopori Wash areas, only wells that had at least 20 measurements were plotted (Figures 49 and 50). In all three plots, water levels were generally steady or increasing until the mid-1990s, at which time they declined, especially in the Santa Cruz River (Canoa) site.

Figure 46. Drilling history in the Santa Cruz-Sopori System.



Note: SGWA = Shallow groundwater area

Table 24. Water withdrawals in 2010 from the Santa Cruz-Sopori System in acre-feet (AF).

Shallow Groundwater Area	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Madera Canyon	15	15.0	0	0	0.0	15.0	0.0%
Santa Cruz River (Canoa)	48	48.0	20	15	17,488.1	17,536.1	99.7%
Sopori Wash	215	215.0	60	49	6,511.2	6,726.2	96.8%
REGION[1]	**254**	**254.0 AF**	**64**	**52**	**18,446.2 AF**	**18,700.2 AF**	**98.6%**

[1] Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.

Figure 47. Water withdrawals from non-exempt wells in the Santa Cruz-Sopori System.

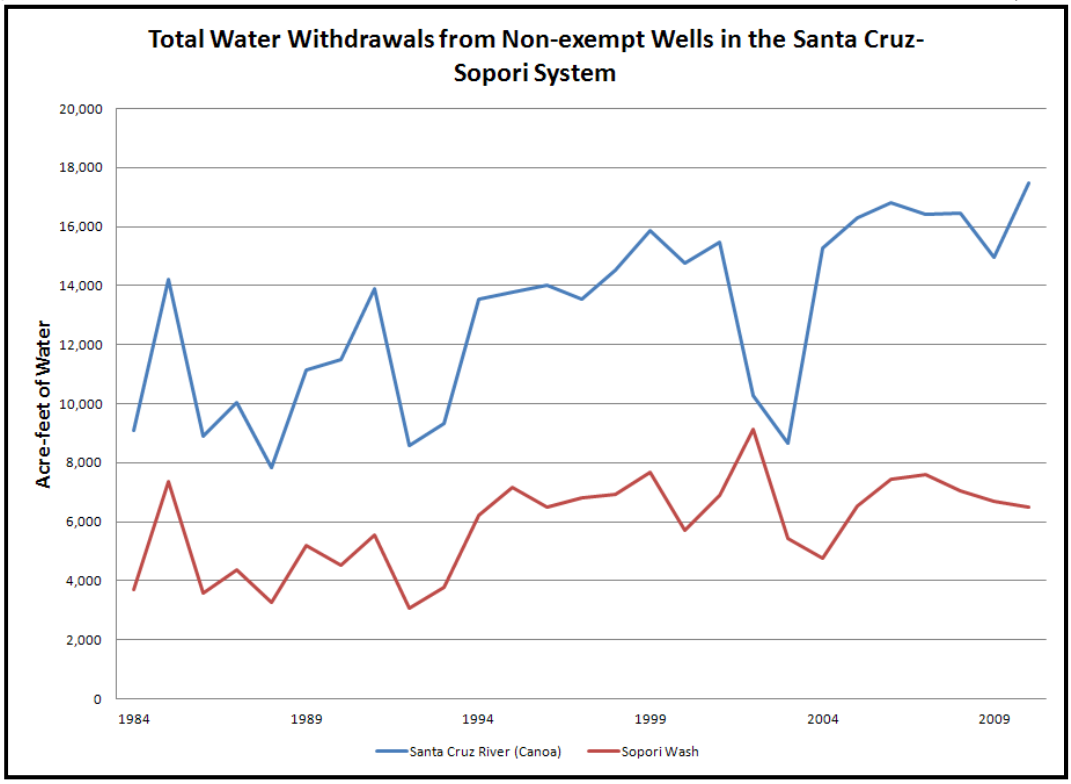
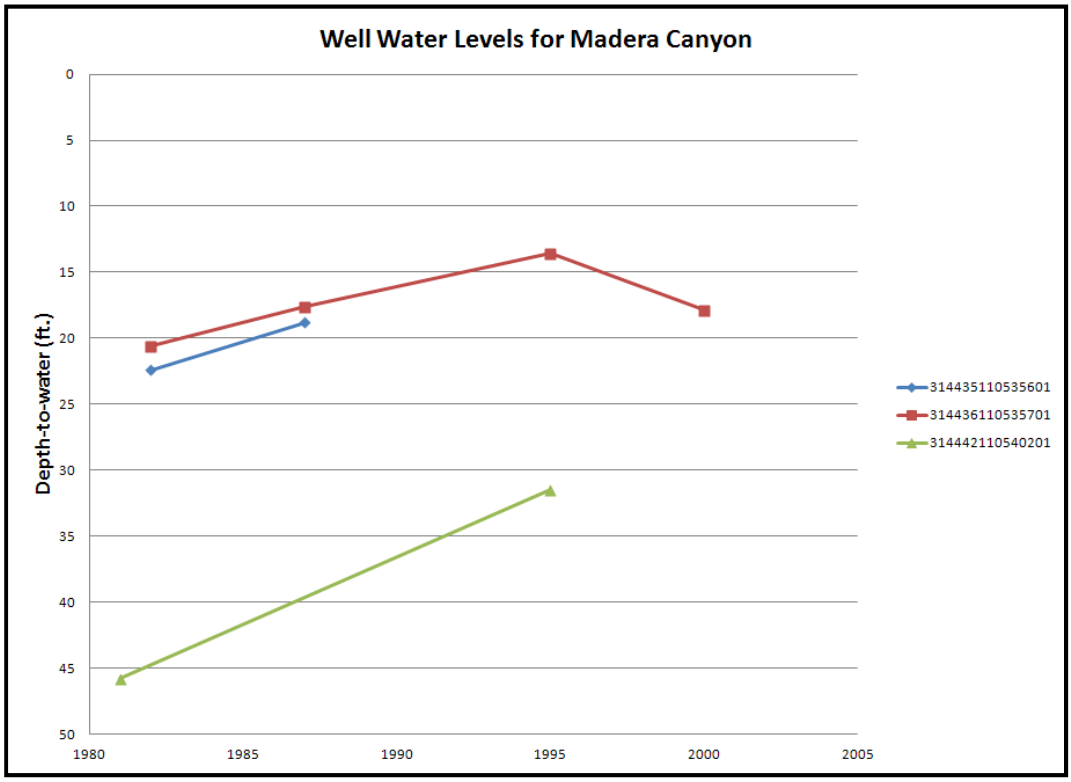
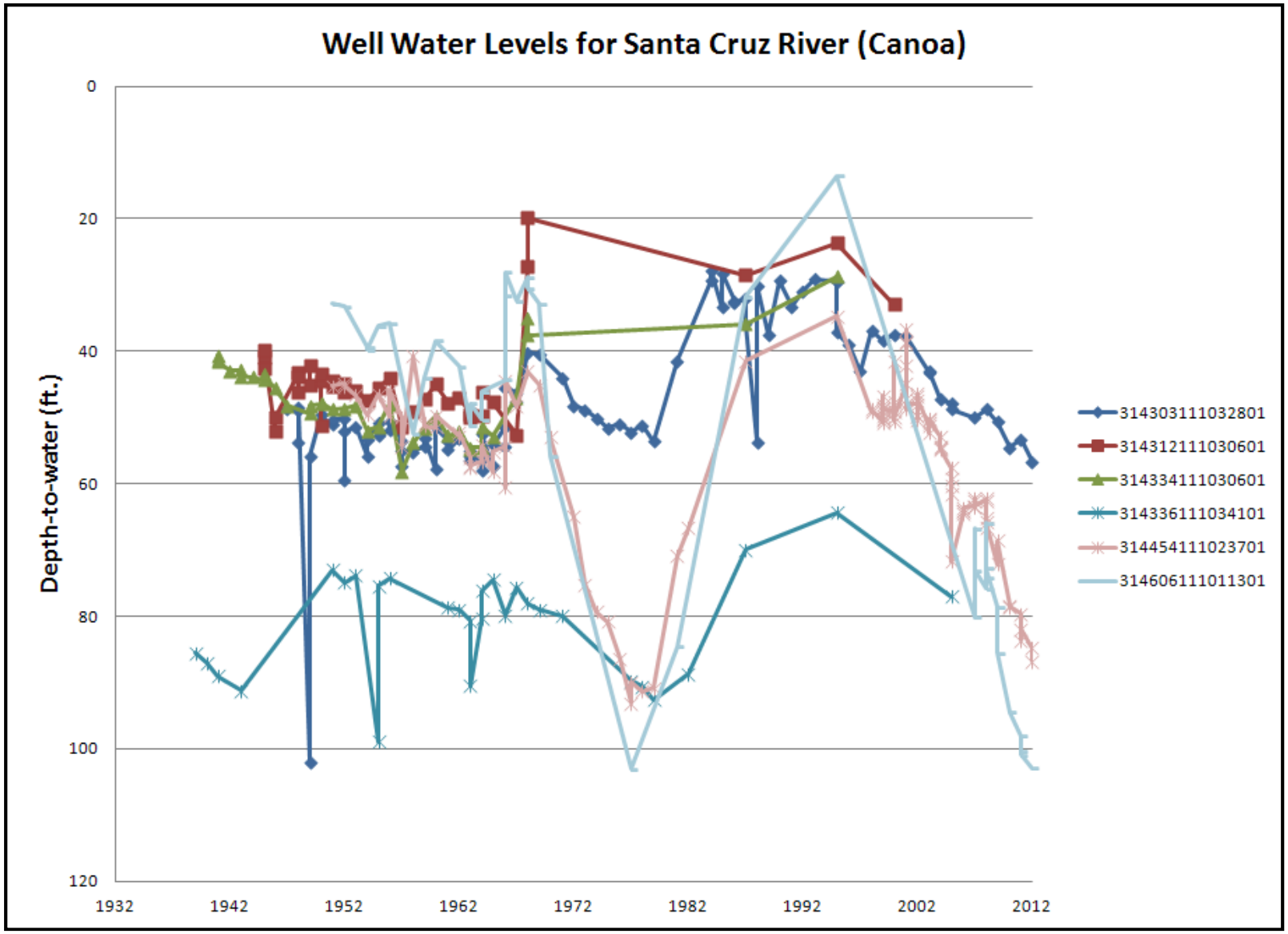


Figure 48. Depth-to-water in wells of Madera Canyon.



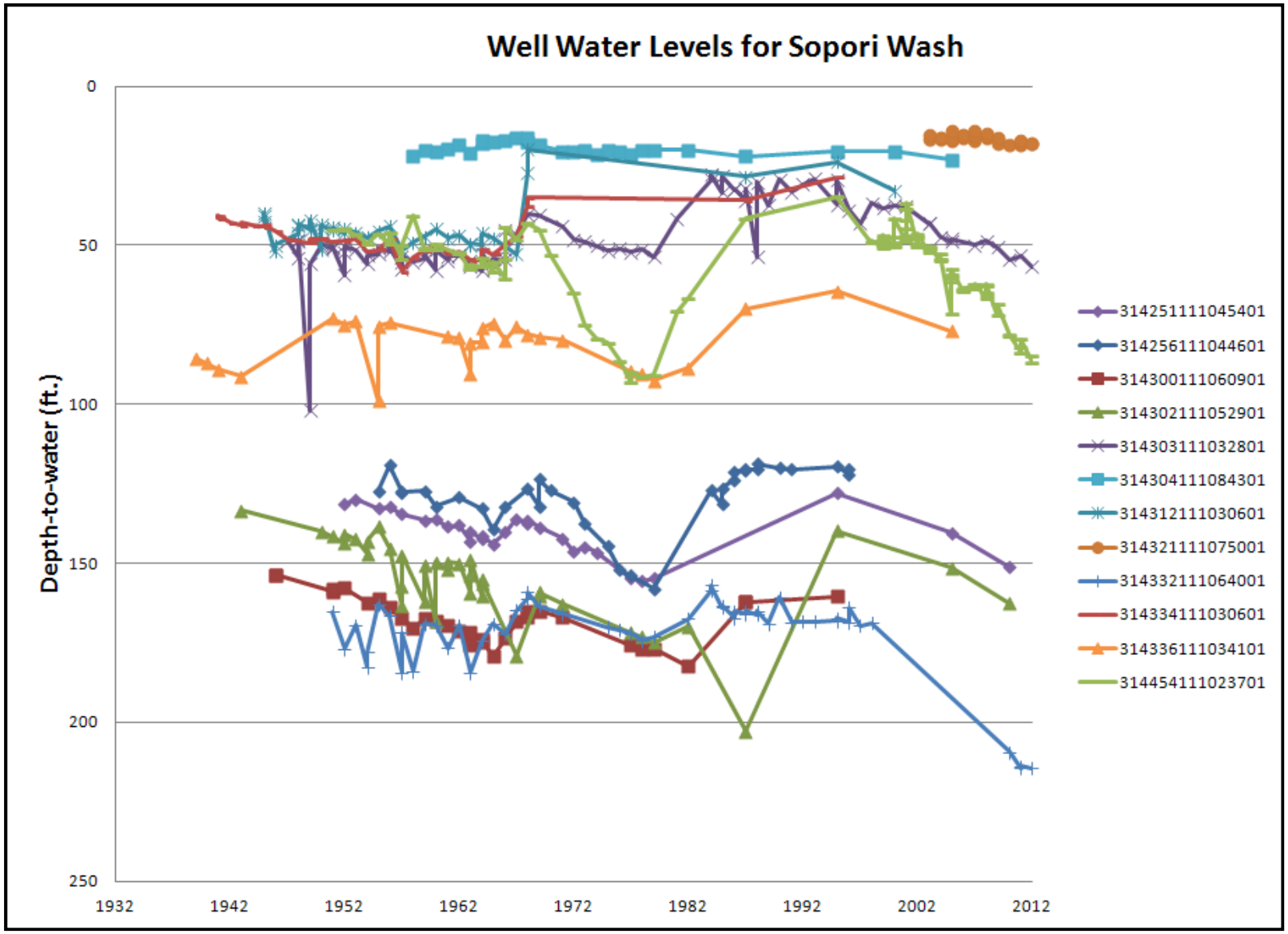
Note: Legend lists GWSI site-IDs.

Figure 49. Depth-to-water in wells of Santa Cruz River (Canoa).



Note: Legend lists GWSI site-IDs; only wells with 20+ samples are plotted.

Figure 50. Depth-to-water in wells of Sopori Wash.



Note: Legend lists GWSI site-IDs; only wells with 20+ samples are plotted.

Altar Valley

Description

The Altar Valley region contains five shallow groundwater areas: Arivaca Area, Brown Canyon, Fraguita Wash, Sabino Canyon (Baboquivari) and Thomas Canyon (Figure 51). The five areas can be divided into two subgroups based on their locations. Arivaca Area and Fraguita Wash are on the east side of the Altar Valley, whereas Brown Canyon, Sabino Canyon (Baboquivari) and Thomas Canyon are on the west side of the valley where they drain the east-facing slopes of the Baboquivari Mountains. Water from all five areas flows into Altar Wash and the Buenos Aires National Wildlife Refuge (NWR).

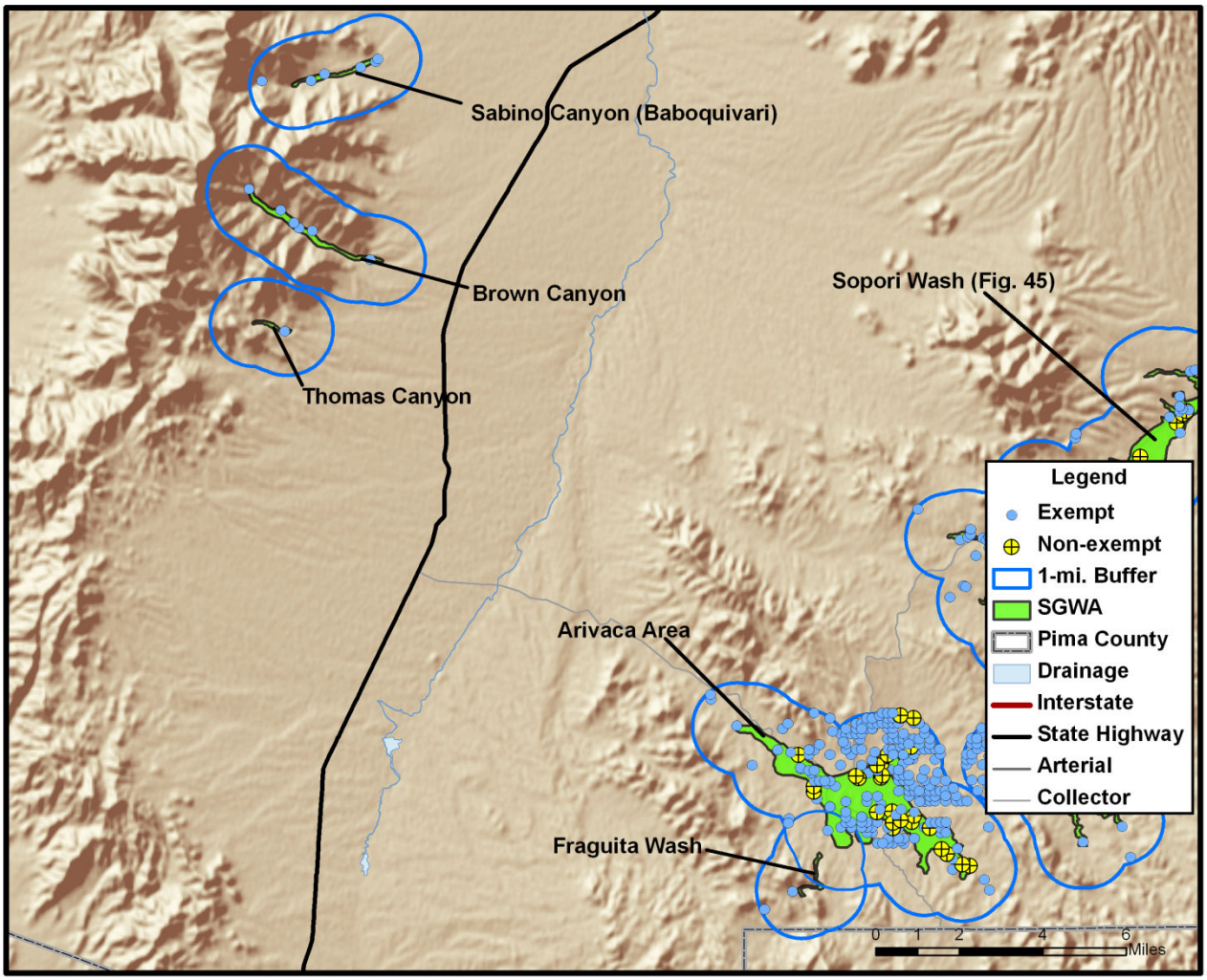
The Arivaca Area is by far the largest of the five areas in this region, and exhibits both perennial and intermittent surface water. The area has stands of cottonwood and mesquite (PAG, 2000a), and is well known for the Arivaca Cienega, a part of Buenos Aires NWR, which is rich in bird life. Brown Canyon features Arizona sycamore and mesquite (PAG, 2000a), and is the site of guided walks by Buenos Aires NWR (USFWS, 2012). Brown Canyon and Thomas Canyon exhibit intermittent surface water (City of Tucson and Pima County, 2009).

Because of the close proximity of Arivaca Area and Fraguita Wash, the one-mile buffers surrounding these areas overlap. Consequently, some wells coincide with more than one shallow groundwater area. This data replication affects tables and figures related to well inventories, drilling histories and water withdrawals, so that summing values of the individual areas leads to overinflated numbers. In each table, the row labeled "REGION" represents the correct sums of well numbers or water volumes without duplicates.

Well Inventory

As of 2012, the Altar Valley region had a total of 268 exempt and 28 non-exempt water-producing wells with a moderate well density of 5.5 wells/sq. mile, mostly due to the large number of wells in the Arivaca Area. The well inventory and density of each area is given in Table 25. For reasons explained previously, the row labeled "REGION" eliminates duplicate well counts due to overlapping shallow groundwater buffers and represents the correct sums for the region. As can be seen in Table 25, the Arivaca Area contains the greatest number of the wells in this region, including all of the non-exempt wells.

Figure 51. Wells in the Altar Valley region.



Note: SGWA = Shallow groundwater area

Table 25. Inventory and density of wells in the Altar Valley region in 2012.

Shallow Groundwater Area	Total # of Wells	# of Exempt Wells	# of Non-exempt Wells	Wells/Sq. Mi.
Arivaca Area	279	251	28	10.9
Brown Canyon	6	6	0	0.5
Fraguita Wash	8	8	0	1.3
Sabino Canyon (Baboquivari)	8	8	0	1.0
Thomas Canyon	1	1	0	0.2
REGION[1]	**296**	**268**	**28**	**5.5**

[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Drilling Trends

Drilling dates are unknown for 44 of the wells in the region; however, for those with known dates, 94 were drilled before 1980, 74 were drilled from 1980-1989, 36 were drilled from 1990-1999 and 48 (3.9 wells/year) were drilled since 2000 (Table 26). Of the 48 wells drilled since 2000, only one was non-exempt (Table 26). Most of the new wells were installed in Arivaca Area. Figure 52 shows the drilling history of these wells.

Water Withdrawals

Of the 296 wells in this region, all are located in the Tucson AMA. Of the 28 non-exempt wells, owners of 17 wells reported water withdrawals for 1984-2010 to ADWR. Water withdrawal information for each of the areas is given in Table 27, and totaled 335.2 acre-feet in 2010.

Of the study sites in this region, the Arivaca Area produced the most water, while the other four areas produced relatively little water. The majority (78.2%) of water being withdrawn in this region came from exempt wells.

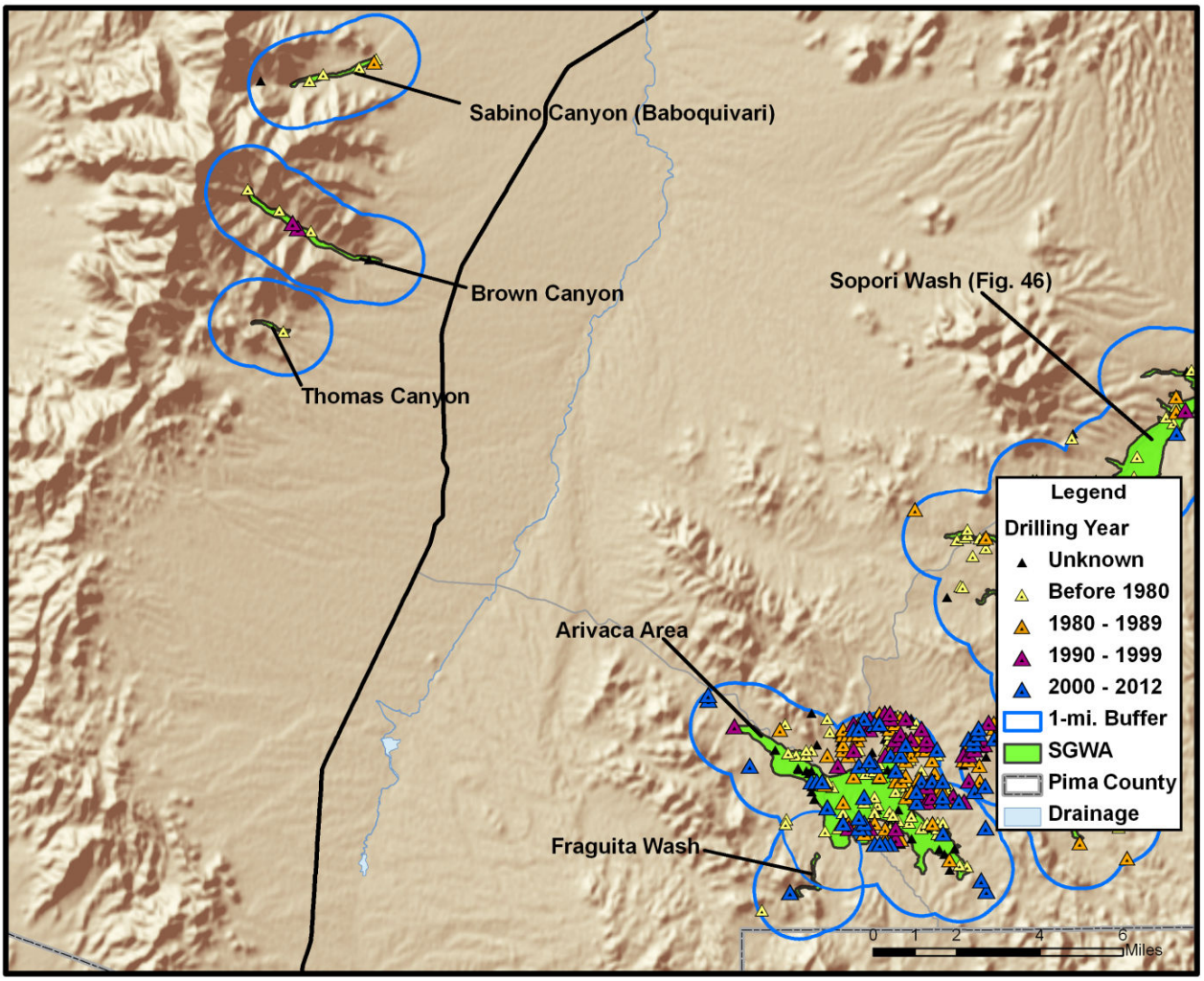
As the Arivaca Area was the only site in this region with non-exempt wells, water withdrawal data from 1984 to 2010 were limited to that area. As can be seen in Figure 53, water withdrawals from the Arivaca Area peaked in 2003, then declined sharply afterward.

Table 26. Drilling history in the Altar Valley region.

Shallow Groundwater Area	# Wells Drilled in Time Period					# Non-exempt Wells Drilled 2000-2012
	Date Unknown	Before 1980	1980-1989	1990-1999	2000-2012	
Arivaca Area	42	83	73	34	47	1
Brown Canyon	1	3	0	2	0	0
Fraguita Wash	0	4	1	1	2	0
Sabino Canyon (Baboquivari)	1	6	1	0	0	0
Thomas Canyon	0	1	0	0	0	0
REGION[1]	**44**	**94**	**74**	**36**	**48**	**1**

[1] *Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.*

Figure 52. Drilling history in the Altar Valley region.



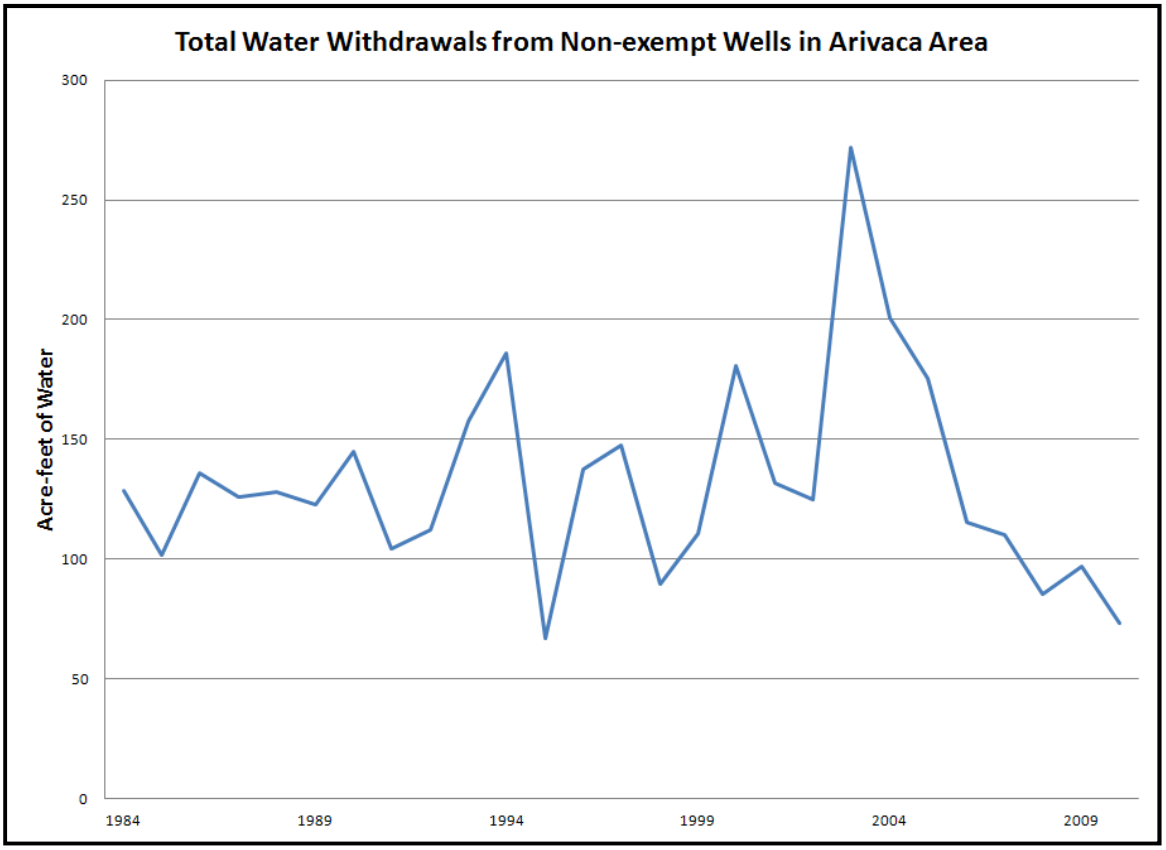
Note: SGWA = Shallow groundwater area

Table 27. Water withdrawals in 2010 from the Altar Valley region in acre-feet (AF).

Shallow Groundwater Area	# of Exempt Wells	Total Withdrawn from Exempt Wells (AF)	Total # of Non-exempt Wells	# of Non-exempt Wells Reporting	Total Withdrawn from Non-exempt Wells (AF)	Total Withdrawn from All Wells (AF)	Percentage Withdrawn from Non-exempt Wells
Arivaca Area	245	245.0	28	17	4.3	318.2	23.0%
Brown Canyon	6	6.0	0	0	0.0	6.0	0.0%
Fraguita Wash	8	8.0	0	0	0.0	8.0	0.0%
Sabino Canyon (Baboquivari)	8	8.0	0	0	0.0	8.0	0.0%
Thomas Canyon	1	1.0	0	0	0.0	1.0	0.0%
REGION[1]	**262**	**262.0 AF**	**28**	**17**	**73.2 AF**	**335.2 AF**	**21.8%**

[1] Due to data duplication among some of the shallow groundwater areas, refer to "REGION" row for actual sums.

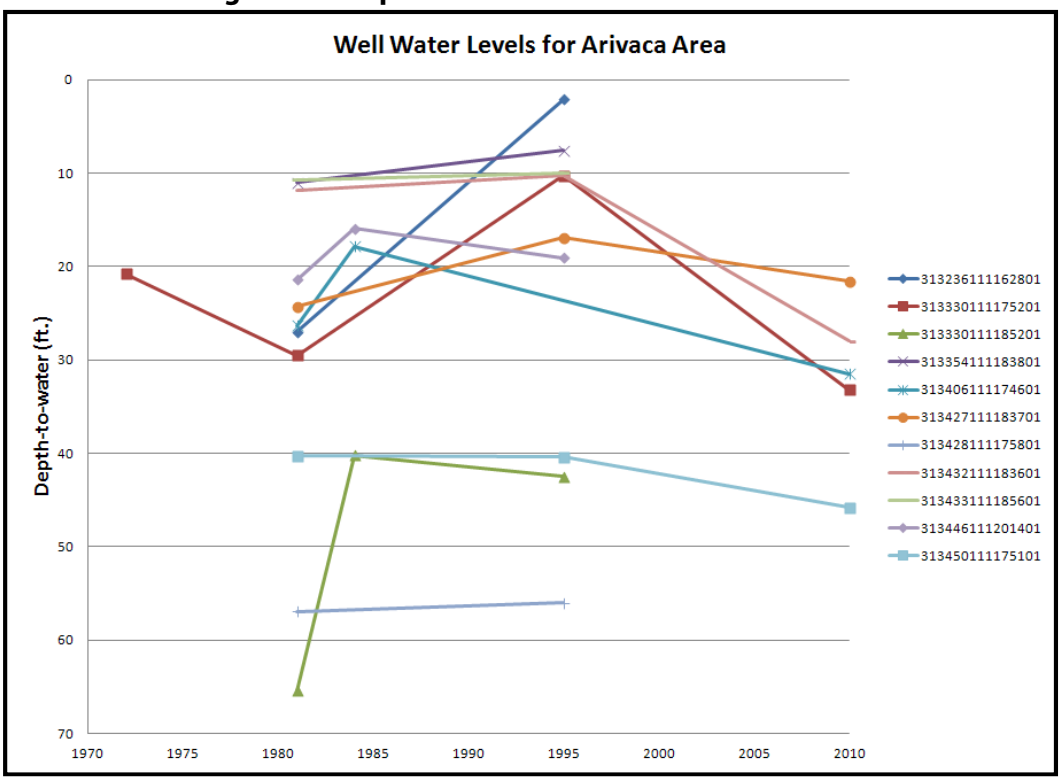
Figure 53. Water withdrawals from non-exempt wells in the Altar Valley region.



Water Levels

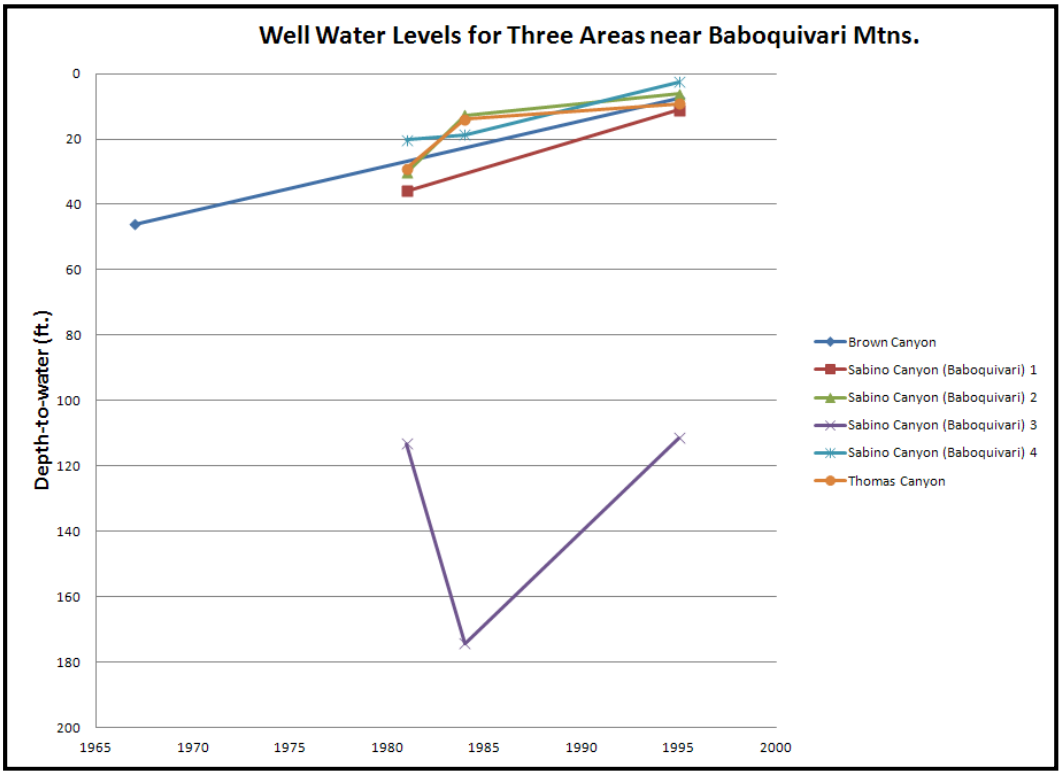
Numerous water level measurements from wells were available for Arivaca Area (Figure 54); however, none was available for Fraguita Wash, and only a few were available for the three areas at the base of the Baboquivari Mountains: Brown Canyon, Sabino Canyon (Baboquivari) and Thomas Canyon (Figure 55). For clarification, the names of the wells in Figure 55 are based on shallow groundwater area rather than GWSI site ID. A look-up table is provided in Appendix D, which gives their respective GWSI site IDs. Both of these plots suggest that water levels were generally stable, or even rising, until 1995. From 1995 until 2010, well water levels in the Arivaca Area declined five to 23 feet. As no data were available for the other shallow groundwater areas after 1995, it is not known whether the declines shown in the Arivaca Area are representative of the Altar Valley.

Figure 54. Depth-to-water in wells of Arivaca Area.



Note: Legend lists GWSI site-IDs.

Figure 55. Depth-to-water in wells near Baboquivari Mountains.

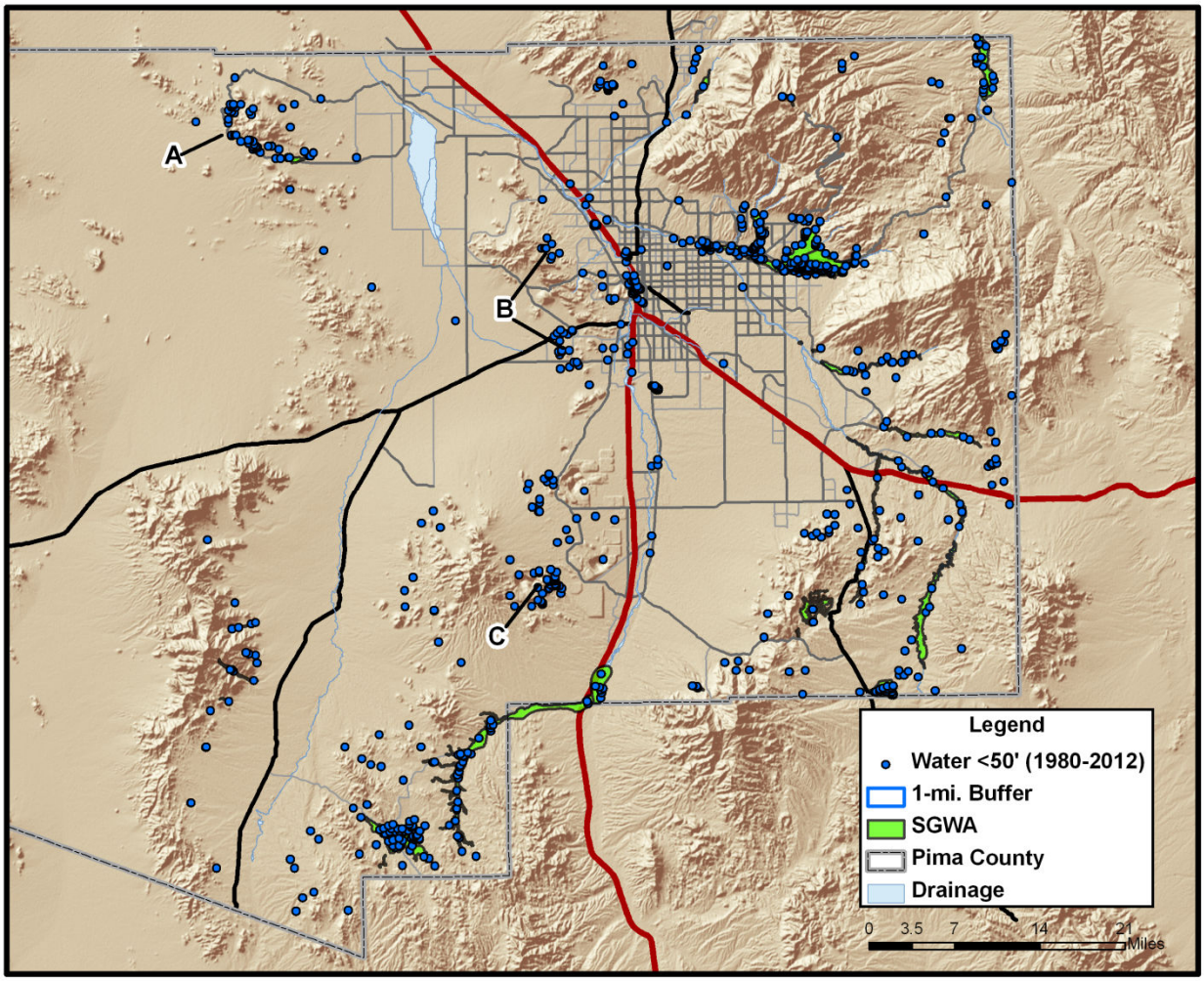


Note: See Appendix D for GWSI site-IDs.

Other Shallow Groundwater Sites of Interest

By selecting all post-1980 wells having water level measurements within 50 ft. of the land surface, PAG found that only about half of the wells (481 out of 963) fall within the study site buffer areas. The other 482 wells are scattered throughout eastern Pima County, most often associated with the foothills of mountain ranges. Concentrations of shallow wells were found in the Silverbell Mountains (A), west of Tucson (B) and west of Green Valley (C) (Figure 56).

Figure 56. Survey of shallow wells in eastern Pima County.



Note: SGWA = Shallow groundwater area

SUMMARY

The purpose of this project was to collect and analyze available water well data in order to better understand shallow groundwater areas in eastern Pima County. PAG began conducting this type of analysis in 2000, when shallow groundwater areas were first identified as part of the Pima County Sonoran Desert Conservation Plan.

This report includes information from 32 shallow groundwater areas that are distributed throughout eastern Pima County. For clarity, these areas were aggregated into 10 shallow groundwater regions and are described below in relationship to major urban centers or landmarks.

Three large shallow groundwater regions (the Rillito-Tanque Verde System, the Pantano-Rincon System and the Cienega-Davidson System) ring the east side of the Tucson basin bordering the Santa Catalina Mountains, Rincon Mountains and the Santa Rita Mountains. These systems flow into streams that cross the populated urban core, contribute to recharge of the Tucson Basin aquifer, and provide highly valued riparian benefits to the Tucson region as a whole. Northeast of the Santa Catalina Mountains, Pima County also includes part of the San Pedro River and its associated shallow groundwater area. Two significant, but fairly small shallow groundwater areas lie north of the Tucson basin near the towns of Oro Valley and Marana. The Tortolita shallow groundwater area is located northwest of Oro Valley on the southern slope of the Tortolita Mountains, whereas the Southerland Wash shallow groundwater area is located along the western slope of the Catalina Mountains.

South of Green Valley, the very large Santa Cruz-Sopori System (including Madera Canyon) feeds into the southern part of the Santa Cruz River near the county line, providing aquifer recharge to the Green Valley area. Just west, the Altar Valley region, which includes the Arivaca Area, drains into Altar Valley and provides water to the town of Arivaca.

Finally, three fairly isolated shallow groundwater areas, including the Altar Valley west area, the Cocio Wash Area located just east of Silverbell Mine and the Santa Cruz River (Tucson) area, which is located along the Santa Cruz River near Starr Pass Road. None of these areas contain significant pumping records or very many active wells.

A total of 2,650 wells were identified within shallow groundwater areas and their one-mile buffers. PAG evaluated the drilling trends, pumping information and water levels for each area. Because wells are required to be permitted in the State of Arizona, drilling trend data are readily available. However, it is notable that many well locations are approximated in the records. For most wells, depth-to-water is measured only once, at the time of well installation, a limitation for evaluating water levels. As a result, water level trends reported in this study are entirely based on records from wells that were repeatedly measured. Finally, because exempt wells, and those non-exempt wells that lie outside the Active Management Area, are not required to report water withdrawals, water withdrawal amounts are approximate and are likely underestimated.

Information provided in this report can be used to improve understanding of shallow groundwater areas in eastern Pima County and to help make management and monitoring decisions for the areas. However, many other factors such as the aquifer depth and characteristics, aerial extent of headwaters, availability of precipitation and the extent and nature of the riparian system are also integral to the long-term viability of each shallow groundwater area and should be considered when making water management decisions.

Findings

New Drilling Activity

Well drilling continues to be active in eastern Pima County. Since 2000, numerous wells were drilled either in shallow groundwater areas or in their associated buffer areas. Well drilling during this time was most active in the Rillito-Tanque Verde System, followed by the Cienega-Davidson System and the Pantano-Rincon System. Regions with relatively low drilling activity since 2000 included the San Pedro River, Cocio Wash, Sutherland Wash and Central Santa Cruz River.

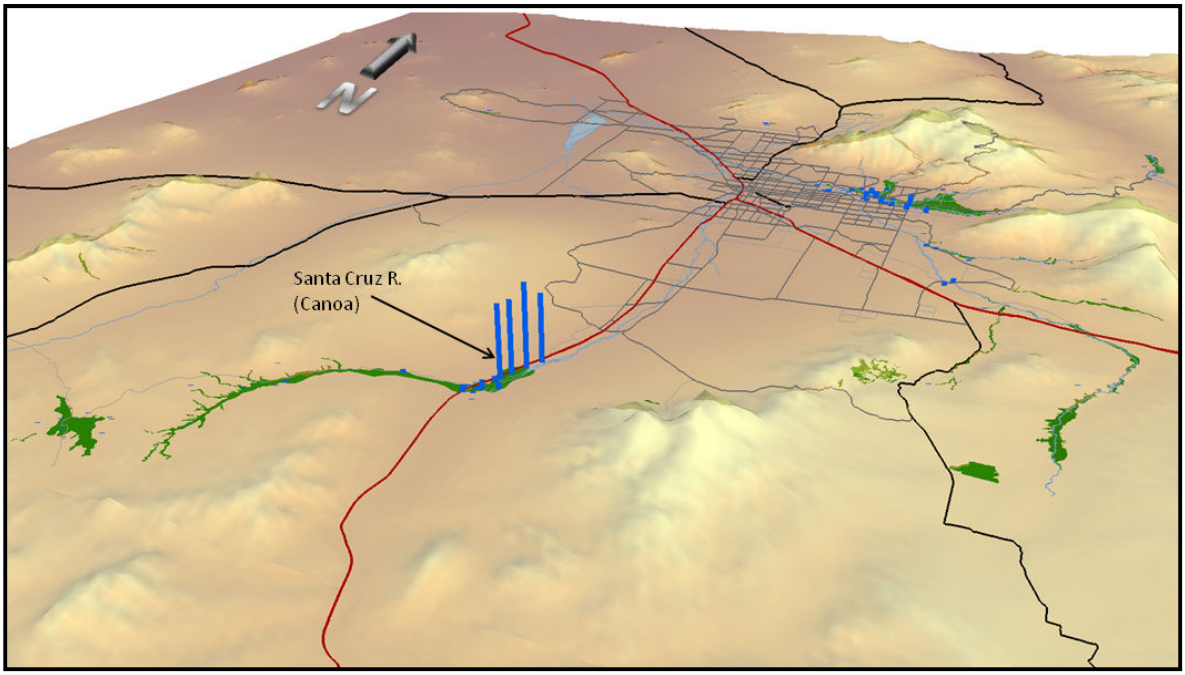
Water Withdrawals

An estimate of water withdrawals in 2010 indicated that the Rillito-Tanque Verde System and the Santa Cruz-Sopori System are large water-producing regions that together pumped an estimated 92.3 percent of the water extracted by the 10 regions. The remaining eight regions pumped only 7.7 percent of the total withdrawals. A 3-D perspective view of the 2010 pumping volumes by well is provided in Figure 57. Historic water withdrawal data from non-exempt wells show that since 1984 pumping increased in the Santa Cruz-Sopori System but declined sharply in the Rillito-Tanque Verde System. Increased pumping also was observed in the Pantano-Rincon System and the Cienega-Davidson System, though these are relatively low-producing regions.

Water Levels

Water level trends are one of the most difficult parameters to analyze, yet are one of the most critical indicators to consider. In 14 of the 32 areas examined in this report, depth-to-water data were absent or inadequate for evaluating water level trends. Of the remaining 18 areas, only three were stable over several decades of measurements.

Figure 57. Water withdrawals in 2010 by well (blue).



Note: Bar height is proportional to water volume; shallow groundwater areas are shown in green.

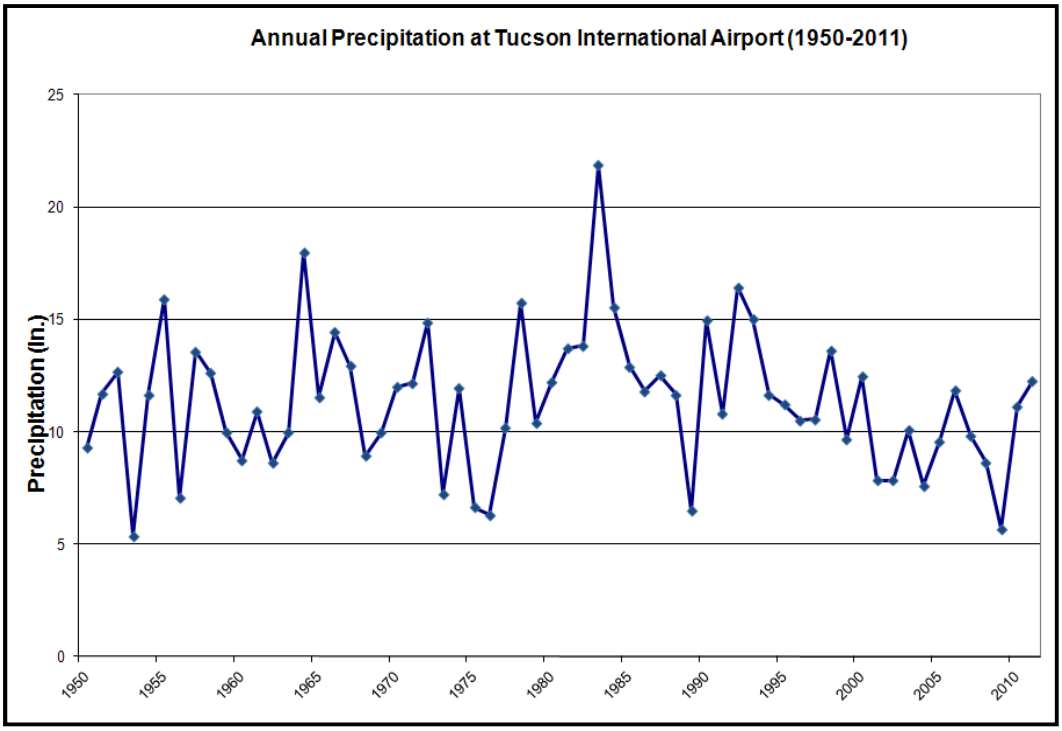
The Central Santa Cruz River region and the Rillito-Tanque Verde System showed similar long-term water level declines of 100-150ft. since 1950. Water levels that were less than 40 ft. from the surface in the 1950s are now more than 120 ft. deep. Since the early 2000s, however, water levels among the deeper wells of these regions partially rebounded, possibly due to a reduction in water withdrawals.

Of special interest is the Santa Cruz-Sopori System, which has experienced substantial water level declines since the 1995. Recent water level declines were apparent to a lesser extent in some of the shallow groundwater areas in the Tortolita Mountains, the Pantano-Rincon System, the Cienega-Davidson System and the Altar Valley.

Although water withdrawals may be responsible for declining water levels in some of these areas, the issue is confounded by other factors, such temporal variation in precipitation. Figure 58 shows annual precipitation amounts at Tucson International Airport since 1950, illustrating the great year-to-year variability that may occur at one site. PAG's detailed water level dataset from the Cienega-Davidson System (Figure 44) clearly showed seasonal and annual variations in the water levels of shallow wells. Water level data from shallower wells in the Rillito-Tanque Verde System also demonstrated annual fluctuations corresponding to heavy precipitation in the mid 1980s. Therefore, persistently dry conditions in eastern Pima County for most of the time since 2002 (UNL, 2012) could explain some of the recent groundwater level declines in some of the regions.

Further study using more comprehensive datasets of precipitation could help us understand the impact of droughts on groundwater levels. Numerous sources of detailed precipitation data are available for such an analysis, including the Pima County Regional Flood Control District Automated Local Evaluation in Real Time (ALERT) System (PCFRD, 2012).

Figure 58. Precipitation at Tucson International Airport (NOAA, 2012).



Status of Shallow Groundwater Areas

Given the recent trends in well drilling, water withdrawals and water levels, PAG identified those shallow groundwater areas that warrant additional study (Table 28). The following categories of well density, drilling activity, water withdrawals and water level trends are defined for use in Table 28:

Well Density (2012) -- Very low: 0.1-1 wells/mi^2; Low: 1.1-5 wells/mi^2; Moderate: 5.1-10 wells/mi^2; High: 10.1-20 wells/mi^2; Very high: >20 wells/mi^2

Drilling Activity (2000-2012) -- None: No new wells drilled; Low: 0.1-1 wells/yr; Moderate: 1.1-4 wells/yr; High: > 4 wells/yr

Water Withdrawals (2010) -- Very low: 0-10 AF/yr; Low: 10.1-100 AF/yr; Moderate: 100.1-1,000 AF/yr; High: 1,000.1-10,000 AF/yr; Very high: >10,000 AF/yr

Water Level Trends (2000-2012) -- Unknown: No data; Inconclusive: Insufficient data to establish trend; Stable, declining or increasing: Predominant trend of measurements

Areas that had one or more characteristic rated at least at the "moderate" level, or higher, were marked for further evaluation. Those having two or more "high" characteristics, or a combination of a "high" characteristic and a declining water level, were rated as "High Priority" for further evaluation.

Table 28. Status summary of all shallow groundwater areas.
(☼= Medium priority; ☼☼= High priority)

Shallow Groundwater Area	Well Density	Drilling Activity	Water Withdrawals	Water Level Trends	Further Evaluation Recommended
San Pedro River Region					
San Pedro River (Bingham Cienega)	Moderate	Low	Low[1]	Stable	☼
Sutherland Wash Region					
Sutherland Wash (Lower)	Very low	None	Very low	Inconclusive	
Sutherland Wash (Upper)	Low	Low	Low	Unknown	
Tortolita Mountains Region					
Tortolita Mountains	Very high	Moderate	Moderate	Declining	☼☼
Cocio Wash Region					
Cocio Wash Area	Very low	None	Very low[1]	Unknown	
Rillito-Tanque Verde System					
Agua Caliente Canyon Area	High	High	High	Increasing[2]	☼☼
Rillito Creek Area	High	Low	Moderate	Increasing[2]	☼
Sabino Canyon Area	High	High	High	Increasing[2]	☼☼
Sabino Canyon (Summerhaven)	Low	Low	Low	Unknown	

Shallow Groundwater Area	Well Density	Drilling Activity	Water Withdrawals	Water Level Trends	Further Evaluation Recommended
Tanque Verde Creek (Lower)	Very high	Moderate	High	Increasing[2]	☼☼
Tanque Verde Creek (Mid)	Very high	High	High	Increasing[2]	☼☼
Tanque Verde Creek (Upper)	High	High	High	Increasing[2]	☼☼
Central Santa Cruz River Region					
Santa Cruz River (Tucson)	High	Low	Low	Increasing[2]	☼
Pantano-Rincon System					
Box Canyon (Rincon)	Moderate	Low	Moderate	Declining	☼
Pantano Wash	High	Low	Low	Unknown	☼
Rincon Creek Area	Moderate	Moderate	Moderate	Declining	☼
Cienega-Davidson System					
Agua Verde-Posta Quemada	Low	Moderate	Low	Declining	☼
Barrel Canyon	Low	Low	Low	Inconclusive	
Cienega Creek (Lower)	Moderate	Moderate	Moderate	Declining	☼
Cienega Creek (Mid)	Low	Low	Low	Inconclusive	
Cienega Creek (Upper)	Very low	Low	Low	Stable	
Davidson Canyon (Lower)	Low	Moderate	Moderate	Inconclusive	☼
Davidson Canyon (Upper)	Low	None	Low	Unknown	
Gardner Canyon	Moderate	Moderate	Low	Stable	☼
Santa Cruz-Sopori System					
Madera Canyon	Low	Low	Low	Inconclusive	
Santa Cruz River (Canoa)	Low	Low	Very high	Declining	☼☼
Sopori Wash	Low	Moderate	High	Declining	☼☼
Altar Valley Region					
Arivaca Area	High	Moderate	Moderate	Declining	☼☼
Brown Canyon	Very low	None	Very low	Unknown	
Fraguita Wash	Low	Low	Very low	Unknown	
Sabino Canyon (Baboquivari)	Very low	None	Very low	Unknown	
Thomas Canyon	Very low	None	Very low	Unknown	

[1] *Data from non-exempt wells unavailable.*

[2] *Increasing since ~2005; long history of decline prior to 2000.*

Other Potential Shallow Groundwater Sites

In Pima County, numerous wells, even outside the designated shallow groundwater areas, intersect groundwater in at less than 50-foot depth. Several of these shallow wells are located in mountain front canyons and may indicate bedrock highs or artesian conditions, but they are outside of a major shallow groundwater area. Strong seasonal fluctuations in water levels are often noted in shallow wells near their recharge source (e.g., mountain fronts and washes) so water levels in these wells may reflect precipitation events rather than being persistently shallow (Artiola and Uhlman, 2009). Figure 56 in the report shows the full coverage of shallow wells and could serve as a guide for further study. Vegetation characterizations could be conducted during on-site evaluations or with remote sensing technologies, such as LIDAR or high-resolution imagery. If these areas meet the criteria for shallow groundwater sites set forth in the *Sonoran Desert Conservation Plan* (PAG, 2000a), they could be added at a future date.

RECOMMENDATIONS

This report provides baseline groundwater and well information within shallow groundwater areas in eastern Pima County. Well locations, drilling histories, water withdrawals and water levels are shown for each area allowing the reader to make comparisons, to gain a broad perspective and sense of trends. As groundwater resources receive more attention due to growth in the region, the need to understand water withdrawals from these sensitive groundwater areas will become more of a priority. Evaluations, such as the one presented in this report are helpful to land managers, water providers, municipal and private well owners as we work to maintain a balance between ecological and human water use.

It is important to recognize that the data presented did not undergo additional quality control at PAG and were not used for an in-depth hydrogeologic evaluation, which might include such information as aquifer dimensions and hydrologic characteristics, pumping impact from neighboring wells, drilling logs, etc. Data limitations are always a concern with this type of analysis, and every effort was made to describe these limitations or to limit the analysis so that conclusions were appropriate. The following supplemental investigations would advance our understanding of the basins, improving our ability to protect water resources and habitat.

Hydrologic Investigations

More robust hydrologic investigations are recommended for areas that exhibit long-term changes in water level. Such an investigation could include identifying wells with declining water levels, plotting them geographically, evaluating pumping histories for surrounding wells, and investigating aquifer and well characteristics at the well site. The potential impact of continued declines and recommendations for reversing these trends should also be studied. In addition, relating the findings back to the ecological elements would be key to the best possible management of the basins in the future. Groundwater declines were found in five of the 10 regions included in this study; the Tortolita Mountains, the Pantano-Rincon System, the Cienega-Davidson System, the Santa Cruz-Sopori System and Altar Valley. Two additional regions, the Rillito-Tanque Verde System and the Central Santa Cruz River, showed several decades of decline, but more recently exhibited water level increases.

Habitat Assessments

Habitat value assessments are recommended for all the areas, but especially for the eight regions where water level trends were either inconclusive or unknown. If the habitat value is high, an evaluation of land use trends, exempt well use and potential population growth in the areas could be undertaken to determine if additional management is warranted. We also recommend additional water level monitoring in these areas, if possible. Habitat assessments could be conducted using aerial imagery and LIDAR data, to evaluate vegetation composition, structure and canopy. Field work would be critical to verify the remote sensing data and to assess vegetation health.

Private Well Owner Engagement

Engagement and education of private exempt well owners is recommended. Many of these well owners are likely unaware about the interaction between the aquifer and the viability of habitat on their property or nearby washes and riparian areas. They also may be unaware of local drought severity since drought alert systems are constructed to cover broad geographic areas and in some cases are triggered by large municipal supply levels such as CAP. It is important to engage this population as much as possible so that they can assume responsibility for management of water withdrawals and habitat health in their areas.

Exempt Well Pumping Study
Better data on exempt well pumping are needed in order to understand the water balance within shallow groundwater areas. This is particularly important for areas with declining water levels. Currently, the Arizona Department of Water Resources estimates that exempt wells are pumped at a rate of 1 AF/year, yet they are legally allowed to pump significantly more. Since the state does not have production reporting requirements for these well owners, one option would be to conduct a water use study based on greening or crops visible on aerial imagery.

Changes to State Reporting Requirements
Efforts should be undertaken to change state policy so that all non-exempt well owners, even those outside the AMAs, report pumping. Information on non-exempt well pumping is needed for areas outside the Active Management Areas (AMA), especially in the San Pedro River region and in the Cienega-Davidson System, which have non-exempt wells located just outside the AMA boundary.

Surface Flow Evaluations
A more rigorous appraisal of surface flows and precipitation is needed to determine year-round surface water availability to the riparian vegetation within shallow groundwater areas. Water level data for those wells tapping the shallowest parts of the aquifers showed considerable variation, often with contrasting trends. These wells may be strongly influenced by surface flows and precipitation.

Statistical Analyses
Applying statistical and water level trend analyses could provide additional insight on water level trends within individual shallow groundwater areas. As an example, a simple averaging analysis was conducted in the Agua Caliente Canyon area within the Rillito-Tanque Verde System and is provided in the report. Similar examinations could be conducted in areas with a large number of wells that have been measured over an extended period of time. Information such as the time of year for the measurements, nearby pumping information and the geographic location of the wells would be important supplemental data for an accurate trend analysis.

Repeated Evaluations
Repeating this study every five-years would help the region stay informed about new drilling, groundwater use and water level trends. Ideally, this work would be combined with an evaluation of habitat and vegetation extent and health.

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APPENDIX A

Historical Name Cross-Reference List of Shallow Groundwater Areas

Current Report	2008 Report
Agua Caliente Canyon Area	Agua Caliente Canyon Area
Agua Verde-Posta Quemada	Agua Verde Creek Area, Posta Quemada Area, Posta Quemada
Arivaca Area	Arivaca Area
Barrel Canyon	Not included
Box Canyon (Rincon)	Box Canyon, Rincon
Brown Canyon	Brown Canyon
Cienega Creek (Lower)	Cienega Creek, Lower A
Cienega Creek (Mid)	Cienega Creek, Lower B
Cienega Creek (Upper)	Cienega Creek, Upper
Cocio Wash Area	Cocio Wash Area
Davidson Canyon (Lower)	Davidson Canyon
Davidson Canyon (Upper)	Davidson Canyon, Upper
Fraguita Wash	Fraguita Wash
Gardner Canyon	Gardner Canyon
Madera Canyon	Madera Canyon
Pantano Wash	Pantano Wash
Rillito Creek Area	Rillito Creek Area
Rincon Creek Area	Rincon Creek Area
Sabino Canyon Area	Sabino Canyon Area
Sabino Canyon (Baboquivari)	Sabino Canyon, Baboquivari
Sabino Canyon (Summerhaven)	Sabino Canyon, Summerhaven
San Pedro River (Bingham Cienega)	San Pedro River, Bingham Cienega
Santa Cruz River (Canoa)	Santa Cruz River, Canoa
Santa Cruz River (Tucson)	Santa Cruz River, Tucson
Sopori Wash	Sopori Wash
Sutherland Wash (Lower)	Sutherland Wash 1
Sutherland Wash (Upper)	Sutherland Wash 2
Tanque Verde Creek (Lower)	Tanque Verde Creek
Tanque Verde Creek (Mid)	Not included
Tanque Verde Creek (Upper)	Tanque Verde Creek Area
Thomas Canyon	Thomas Canyon
Tortolita Mountains	Tortolita Mountains

APPENDIX B

Water Withdrawn in 2010 from Non-exempt Wells in Acre-Feet

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Altar Valley	507390	PIMA	TUCSON	JARRE,G A	No Data
Altar Valley	507609	PIMA	TUCSON	ARIVACA TOWNSITEWTR,	0.00
Altar Valley	535630	PIMA	TUCSON	WILLIAMS, ROBERT,D	No Data
Altar Valley	601189	PIMA	TUCSON	MARY ELIZABETH WRKS	No Data
Altar Valley	602918	PIMA	TUCSON	SHEILA WALLEN	0.00
Altar Valley	603306	PIMA	TUCSON	LAWRENCE BECKELMAN	2.16
Altar Valley	604454	PIMA	TUCSON	LAWRENCE BECKELMAN	0.00
Altar Valley	606507	PIMA	TUCSON	PINEYARD,A W	No Data
Altar Valley	606508	PIMA	TUCSON	PINEYARD,A W	No Data
Altar Valley	610201	PIMA	TUCSON	SMITH,D D	No Data
Altar Valley	610202	PIMA	TUCSON	ARIVACA RANCH LLC	0.00
Altar Valley	610203	PIMA	TUCSON	SMITH,D D	No Data
Altar Valley	610204	PIMA	TUCSON	ARIVACA RANCH LLC	0.00
Altar Valley	610390	PIMA	TUCSON	DAFFRON, WILLIAM,J	23.17
Altar Valley	610391	PIMA	TUCSON	DAFFRON, WILLIAM,J	0.89
Altar Valley	616979	PIMA	TUCSON	ARIVACA WTR COOP INC,	10.28
Altar Valley	616980	PIMA	TUCSON	ARIVACA WTR COOP INC,	11.05
Altar Valley	618601	PIMA	TUCSON	JACK Q REES	0.00
Altar Valley	618750	PIMA	TUCSON	SMITH, DALE,D	0.00
Altar Valley	621595	PIMA	TUCSON	GIBBS,P J	No Data
Altar Valley	626386	PIMA	TUCSON	MARIAN L. MIKESELL ADMINISTRATIVE TRUST	1.00
Altar Valley	626387	PIMA	TUCSON	MARIAN L. MIKESELL ADMINISTRATIVE TRUST	1.00
Altar Valley	629426	PIMA	TUCSON	SWARD,M	No Data
Altar Valley	801315	PIMA	TUCSON	CHILTON, JAMES,K	23.62
Altar Valley	801316	PIMA	TUCSON	CHILTON, JAMES,K	0.00
Altar Valley	801426	PIMA	TUCSON	BRUCE BARKER	No Data
Altar Valley	803357	PIMA	TUCSON	DIAZ, FRED,	0.00
Altar Valley	805354	PIMA	TUCSON	STURDEVANT, C K & J,	No Data
Central Santa Cruz River	218214	PIMA	TUCSON	UNION PACIFIC RAILROAD	No Data
Central Santa Cruz River	219149	PIMA	TUCSON	QLD WACC LLC	No Data
Central Santa Cruz River	616496	PIMA	TUCSON	YUNT,D H	0.00
Central Santa Cruz River	616497	PIMA	TUCSON	YUNT,D H	0.00
Central Santa Cruz River	619925	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Central Santa Cruz River	629637	PIMA	TUCSON	GARCIA,R	No Data
Central Santa Cruz River	700406	PIMA	TUCSON		No Data
Central Santa Cruz River	700408	PIMA	TUCSON		No Data
Central Santa Cruz River	700409	PIMA	TUCSON		No Data
Central Santa Cruz River	700410	PIMA	TUCSON		No Data
Central Santa Cruz River	700411	PIMA	TUCSON		No Data
Central Santa Cruz River	700412	PIMA	TUCSON		No Data
Central Santa Cruz River	700413	PIMA	TUCSON		No Data
Central Santa Cruz River	700414	PIMA	TUCSON		No Data
Central Santa Cruz River	700415	PIMA	TUCSON		No Data
Central Santa Cruz River	700416	PIMA	TUCSON		No Data
Central Santa Cruz River	700417	PIMA	TUCSON		No Data
Central Santa Cruz River	700418	PIMA	TUCSON		No Data
Central Santa Cruz River	700419	PIMA	TUCSON		No Data
Central Santa Cruz River	700424	PIMA	TUCSON		No Data
Central Santa Cruz River	700425	PIMA	TUCSON		No Data
Central Santa Cruz River	800629	PIMA	TUCSON	RICHARD B. & DELIA L. VIDAL	3.40

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Central Santa Cruz River	801003	PIMA	TUCSON	PIMA CO. REGIONAL FLOOD CONTROL DISTRICT	0.00
Cienega-Davidson System	086632	PIMA	OUTSIDE AMA	ARTHUR C & HELENE A WHITE	No Data
Cienega-Davidson System	087817	PIMA	TUCSON	VAIL WATER COMPANY	257.00
Cienega-Davidson System	216620	PIMA	TUCSON	ROCKFORD CORPORATION	0.00
Cienega-Davidson System	518543	PIMA	OUTSIDE AMA	WHITE, JOHNNY,	No Data
Cienega-Davidson System	602949	PIMA	TUCSON	VAIL WATER COMPANY	0.00
Cienega-Davidson System	606763	PIMA	OUTSIDE AMA	RAY & CATHY HARM	No Data
Cienega-Davidson System	608186	PIMA	OUTSIDE AMA	SALCIDO,M M	No Data
Cienega-Davidson System	608615	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	608616	PIMA	OUTSIDE AMA	BLM-PHOENIX DISTRICT,	No Data
Cienega-Davidson System	608619	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	608621	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	608623	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	608624	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	608626	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	608627	PIMA	OUTSIDE AMA	ROSEMONT COPPER COMPANY	No Data
Cienega-Davidson System	608630	PIMA	OUTSIDE AMA	ROSEMONT COPPER COMPANY	No Data
Cienega-Davidson System	608631	PIMA	OUTSIDE AMA	ROSEMONT COPPER COMPANY	No Data
Cienega-Davidson System	608632	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	625703	PIMA	TUCSON	VAIL WATER COMPANY	241.00
Cienega-Davidson System	627560	PIMA	TUCSON	PIMA COUNTY NATURAL RESOURCES, PARKS AND RECREATION DEPT.	3.17
Cienega-Davidson System	627562	PIMA	TUCSON	PIMA COUNTY NATURAL RESOURCES, PARKS AND RECREATION DEPT.	0.00
Cienega-Davidson System	627729	PIMA	OUTSIDE AMA	PIMA COUNTY FLOOD,	No Data
Cienega-Davidson System	627730	PIMA	OUTSIDE AMA	EMPIRITA RANCH INC,	No Data
Cienega-Davidson System	627731	PIMA	OUTSIDE AMA	EMPIRITA RANCH INC,	No Data
Cienega-Davidson System	627732	PIMA	OUTSIDE AMA	EMPIRITA RANCH INC,	No Data
Cienega-Davidson System	636223	PIMA	OUTSIDE AMA	BLM-SAFFORD DISTRICT,	No Data
Cienega-Davidson System	801774	PIMA	OUTSIDE AMA	EMPIRITA RANCH INC,	No Data
Cienega-Davidson System	804912	PIMA	OUTSIDE AMA	ROSEMONT COPPER COMPANY	No Data
Cienega-Davidson System	908973	PIMA	OUTSIDE AMA	HUGH M. & ARDITH E. FOX	No Data
Cocio Wash	508607	PIMA	TUCSON	ASARCO INC,	No Data
Cocio Wash	508608	PIMA	TUCSON	ASARCO INC,	No Data
Cocio Wash	508609	PIMA	TUCSON	ASARCO INC,	No Data
Cocio Wash	508610	PIMA	TUCSON	ASARCO INC,	No Data
Pantano-Rincon System	217020	PIMA	TUCSON	SPANISH TRAIL WATER COMPANY	No Data
Pantano-Rincon System	536560	PIMA	TUCSON	SPANISH TRAIL WATER,	127.88
Pantano-Rincon System	540941	PIMA	TUCSON	SAGUARO WATER CO,	85.12
Pantano-Rincon System	550957	PIMA	TUCSON	SCHULTZ, MICHAEL,W	No Data
Pantano-Rincon System	564331	PIMA	TUCSON	FIDELITY NATIONAL TITLE	No Data
Pantano-Rincon System	589498	PIMA	TUCSON	CITY OF TUCSON ENVIRONMENTAL SERVICES	16.70
Pantano-Rincon System	591952	PIMA	TUCSON	SPANISH TRAIL WATER COMPANY	No Data
Pantano-Rincon System	603304	PIMA	TUCSON	DOWNEY,L A	5.87
Pantano-Rincon System	607532	PIMA	TUCSON	RINCON WATER CO,	29.57
Pantano-Rincon System	611135	PIMA	TUCSON	RINCON VALLEY HOLDINGS LTD PARTNERSHIP	180.00

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Pantano-Rincon System	611136	PIMA	TUCSON	RINCON VALLEY HOLDINGS LIMITED PARTNERSHIP	No Data
Pantano-Rincon System	613823	PIMA	TUCSON	WILLIAM & MARY PRYDE	0.00
Pantano-Rincon System	618002	PIMA	TUCSON	BURRUEL,J G	0.00
Pantano-Rincon System	620931	PIMA	TUCSON	ACOSTA,G	8.32
Pantano-Rincon System	622098	PIMA	TUCSON	AZ STATE LAND DEPT,	0.00
Pantano-Rincon System	622249	PIMA	TUCSON	SPANISH TRAIL WATER,	5.02
Pantano-Rincon System	622256	PIMA	TUCSON	SPANISH TRAIL WATER,	5.80
Pantano-Rincon System	622258	PIMA	TUCSON	FIDELITY NATIONAL TITLE AGENCY, TR #10773	No Data
Pantano-Rincon System	622259	PIMA	TUCSON	ROCKING K HOLDINGS LTD PARTNERSHIP	0.00
Pantano-Rincon System	623002	PIMA	TUCSON	JAMES & PAULA HENLEY	1.00
Pantano-Rincon System	628077	PIMA	TUCSON	TUCSON, CITY OF,	7.10
Pantano-Rincon System	628924	PIMA	TUCSON	CARL & DOROTHY MOYER	0.00
Pantano-Rincon System	635791	PIMA	TUCSON	SHETLAND PROPERTIES CO, LLC	0.00
Pantano-Rincon System	635792	PIMA	TUCSON	SHETLAND PROPERTIES CO, LLC	No Data
Pantano-Rincon System	651076	PIMA	TUCSON	KLEINE,A	0.00
Pantano-Rincon System	801158	PIMA	TUCSON	HUERTA, RICHARD P &,	0.00
Pantano-Rincon System	801174	PIMA	TUCSON	VALLEY ROCK & SAND,	0.30
Pantano-Rincon System	801193	PIMA	TUCSON	CROSS,R E	No Data
Pantano-Rincon System	801299	PIMA	TUCSON	CELINA RUIZ	0.00
Rillito-Tanque Verde System	086335	PIMA	TUCSON	HEALING IN HARMONY	0.00
Rillito-Tanque Verde System	200410	PIMA	TUCSON	PIMA COUNTY NATURAL RESOURCES, PARKS AND RECREATION DEPT.	11.62
Rillito-Tanque Verde System	212489	PIMA	TUCSON	DONALD L. ROGERS	44.28
Rillito-Tanque Verde System	219156	PIMA	TUCSON		No Data
Rillito-Tanque Verde System	219591	PIMA	TUCSON	METROPOLITAN DOMESTIC WATER IMPROVEMENT DISTRICT	No Data
Rillito-Tanque Verde System	221382	PIMA	TUCSON	MITCHELL AND ROBIN POZEZ	No Data
Rillito-Tanque Verde System	501108	PIMA	TUCSON	VISTA DE SIERRAS ASSOCIATES	0.00
Rillito-Tanque Verde System	501152	PIMA	TUCSON	TUCSON COUNTRY CLUB,	0.00
Rillito-Tanque Verde System	501580	PIMA	TUCSON	ALLAN & JANE HAMILTON	75.36
Rillito-Tanque Verde System	502179	PIMA	TUCSON	CITY OF TUCSON ENVIRONMENTAL SERVICES	304.70
Rillito-Tanque Verde System	502740	PIMA	TUCSON	GAMBURG,M	2.80
Rillito-Tanque Verde System	502836	PIMA	TUCSON	TACK ROOM LTD, THE	0.00
Rillito-Tanque Verde System	503670	PIMA	TUCSON	THE CLUB AT LA MARIPOSA, L.C.	0.00
Rillito-Tanque Verde System	503963	PIMA	TUCSON	FORTY NINERS WATER CO	0.00
Rillito-Tanque Verde System	506124	PIMA	TUCSON	MARK MEYER	0.50
Rillito-Tanque Verde System	508096	PIMA	TUCSON	KAREN MURPHY	0.00
Rillito-Tanque Verde System	510879	PIMA	TUCSON	TUCSON WATER	0.00
Rillito-Tanque Verde System	511305	PIMA	TUCSON	TUCSON WATER	334.20
Rillito-Tanque Verde System	513567	PIMA	TUCSON	TUCSON WATER	410.40
Rillito-Tanque Verde System	513674	PIMA	TUCSON	TUCSON WATER	506.30
Rillito-Tanque Verde System	513675	PIMA	TUCSON	TUCSON WATER	297.40
Rillito-Tanque Verde System	517255	PIMA	TUCSON	R.E. MILLER PAVING,	0.00
Rillito-Tanque Verde System	517256	PIMA	TUCSON	R.E. MILLER PAVING,	0.00
Rillito-Tanque Verde System	517257	PIMA	TUCSON	R.E. MILLER PAVING,	0.00
Rillito-Tanque Verde System	517258	PIMA	TUCSON	R.E. MILLER PAVING,	0.00

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Rillito-Tanque Verde System	517259	PIMA	TUCSON	R.E. MILLER PAVING,	0.00
Rillito-Tanque Verde System	520583	PIMA	TUCSON	CELLA, PAUL,W	No Data
Rillito-Tanque Verde System	521442	PIMA	TUCSON	SHEPHERD, PAUL,R	0.00
Rillito-Tanque Verde System	523906	PIMA	TUCSON	CITY OF TUCSON - TUCSON WATER	164.40
Rillito-Tanque Verde System	524177	PIMA	TUCSON	EL RANCHO MERLITA LLC	0.00
Rillito-Tanque Verde System	524372	PIMA	TUCSON	TANKERSLEY, RUTH,M	No Data
Rillito-Tanque Verde System	524460	PIMA	TUCSON	MATHEWS, WILLIAM JR,	No Data
Rillito-Tanque Verde System	524534	PIMA	TUCSON	PROTELL, ROBERT,	No Data
Rillito-Tanque Verde System	524543	PIMA	TUCSON	TUCSON COUNTRY CLUB,	30.71
Rillito-Tanque Verde System	524769	PIMA	TUCSON	ALLAN J. HAMILTON C/O RANCHO BOSQUE, LLC	0.00
Rillito-Tanque Verde System	526006	PIMA	TUCSON	DENIS GRIGGS	0.00
Rillito-Tanque Verde System	526049	PIMA	TUCSON	KURT & AMY DENNINGHOFF	No Data
Rillito-Tanque Verde System	527101	PIMA	TUCSON	GEORGE S YOUNGERMAN	No Data
Rillito-Tanque Verde System	527986	PIMA	TUCSON		No Data
Rillito-Tanque Verde System	529650	PIMA	TUCSON	RUSTAND, CARSON,B	No Data
Rillito-Tanque Verde System	530916	PIMA	TUCSON	BENNETT, JAMES,H	No Data
Rillito-Tanque Verde System	530988	PIMA	TUCSON	TUCSON WATER	0.00
Rillito-Tanque Verde System	530989	PIMA	TUCSON	TUCSON WATER	0.00
Rillito-Tanque Verde System	531986	PIMA	TUCSON	MALONEY, CHRISTOPHER,T	No Data
Rillito-Tanque Verde System	532441	PIMA	TUCSON	DARREN LOWRY	No Data
Rillito-Tanque Verde System	544884	PIMA	TUCSON	TANQUE VERDE GUEST,	No Data
Rillito-Tanque Verde System	548666	PIMA	TUCSON	MITCHELL AND ROBIN POZEZ	4.70
Rillito-Tanque Verde System	550282	PIMA	TUCSON	PIMA COUNTY TRANS &,	0.00
Rillito-Tanque Verde System	550283	PIMA	TUCSON	PIMA COUNTY TRANS &,	0.00
Rillito-Tanque Verde System	550284	PIMA	TUCSON	PIMA COUNTY TRANS &,	0.00
Rillito-Tanque Verde System	550377	PIMA	TUCSON	PIMA COUNTY TRANS &,	0.00
Rillito-Tanque Verde System	550378	PIMA	TUCSON	PIMA COUNTY TRANS &,	0.00
Rillito-Tanque Verde System	550379	PIMA	TUCSON	PIMA COUNTY TRANS &,	No Data
Rillito-Tanque Verde System	550380	PIMA	TUCSON	PIMA COUNTY TRANS &,	No Data
Rillito-Tanque Verde System	551616	PIMA	TUCSON	PIMA COUNTY WASTEWAT,E R	0.00
Rillito-Tanque Verde System	554054	PIMA	TUCSON	SUNDT CORPORATION,	0.00
Rillito-Tanque Verde System	554055	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554056	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554057	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554058	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554059	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554060	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554061	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554062	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554063	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554064	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554065	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554066	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554067	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554068	PIMA	TUCSON	SUNDT CORPORATION,	No Data
Rillito-Tanque Verde System	554069	PIMA	TUCSON	SUNDT CORPORATION,	No Data

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Rillito-Tanque Verde System	557971	PIMA	TUCSON	DONALD L. ROGERS	9.79
Rillito-Tanque Verde System	575575	PIMA	TUCSON	DAVID GARDNER	No Data
Rillito-Tanque Verde System	580900	PIMA	TUCSON	CHARLES & MARGARET CRARY	No Data
Rillito-Tanque Verde System	581131	PIMA	TUCSON	PLATOSA LLC	No Data
Rillito-Tanque Verde System	581364	PIMA	TUCSON	FORTY NINER WATER CO.	No Data
Rillito-Tanque Verde System	581365	PIMA	TUCSON	B.J. & EARLE MOONEY	3.00
Rillito-Tanque Verde System	582429	PIMA	TUCSON	SHERYL L. NORTH	No Data
Rillito-Tanque Verde System	582690	PIMA	TUCSON	JOE N. PIERSON	No Data
Rillito-Tanque Verde System	583637	PIMA	TUCSON	RUTH M TANKERSLEY	No Data
Rillito-Tanque Verde System	583638	PIMA	TUCSON	RUTH M TANKERSLEY	No Data
Rillito-Tanque Verde System	583639	PIMA	TUCSON	RUTH M TANKERSLEY	No Data
Rillito-Tanque Verde System	583775	PIMA	TUCSON	MT LEMMON DOMESTIC WATER IMPROV DIST	0.03
Rillito-Tanque Verde System	588206	PIMA	TUCSON	SANTA PAULA RANCH LLC	No Data
Rillito-Tanque Verde System	589496	PIMA	TUCSON	LAC 1987 TRUST	No Data
Rillito-Tanque Verde System	591927	PIMA	TUCSON	CASTLE ROCK HOME OWNERS ASSOCIATION	No Data
Rillito-Tanque Verde System	594075	PIMA	TUCSON	METROPOLITAN DOMESTIC WATER IMPROVEMENT DISTRICT	163.46
Rillito-Tanque Verde System	595280	PIMA	TUCSON	WALTER L PALSER	No Data
Rillito-Tanque Verde System	600039	PIMA	TUCSON	GEREN THURSTON, ET AL	No Data
Rillito-Tanque Verde System	600087	PIMA	TUCSON	DONALD MARTIN	0.00
Rillito-Tanque Verde System	600345	PIMA	TUCSON	SPEAR,H D	1.00
Rillito-Tanque Verde System	600347	PIMA	TUCSON	TUCSON MEDICAL CNTR,	59.10
Rillito-Tanque Verde System	600348	PIMA	TUCSON	TUCSON MEDICAL CNTR,	45.10
Rillito-Tanque Verde System	600349	PIMA	TUCSON	TUCSON MEDICAL CNTR,	195.80
Rillito-Tanque Verde System	604250	PIMA	TUCSON	CROSBY, WILLIAM,	0.00
Rillito-Tanque Verde System	604343	PIMA	TUCSON	CITY OF TUCSON ENVIRONMENTAL SERVICES	0.00
Rillito-Tanque Verde System	604344	PIMA	TUCSON	CITY OF TUCSON ENVIRONMENTAL SERVICES	0.00
Rillito-Tanque Verde System	604910	PIMA	TUCSON	JAMES & GLENDA MERRY	7.00
Rillito-Tanque Verde System	604914	PIMA	TUCSON	STARK,R W	9.50
Rillito-Tanque Verde System	606494	PIMA	TUCSON	GEORGE S YOUNGERMAN	0.00
Rillito-Tanque Verde System	608183	PIMA	TUCSON	DRYDEN,S M	0.00
Rillito-Tanque Verde System	609323	PIMA	TUCSON	ARNELL,P C	24.50
Rillito-Tanque Verde System	609943	PIMA	TUCSON	WALT & CAROL TREAT CLARK	0.00
Rillito-Tanque Verde System	610266	PIMA	TUCSON	HOUSTON,J	0.00
Rillito-Tanque Verde System	610542	PIMA	TUCSON	DOUGLAS,P Z	0.37
Rillito-Tanque Verde System	610543	PIMA	TUCSON	DOUGLAS,P Z	10.74
Rillito-Tanque Verde System	611930	PIMA	TUCSON	BRAD AND RENA RANDALL	0.00
Rillito-Tanque Verde System	611931	PIMA	TUCSON	STEPHENS,C	0.00
Rillito-Tanque Verde System	611932	PIMA	TUCSON	STEPHENS, CECIL,	No Data
Rillito-Tanque Verde System	612268	PIMA	TUCSON	WILSON JR,L L	5.64
Rillito-Tanque Verde System	612269	PIMA	TUCSON	WILSON JR,L L	0.00
Rillito-Tanque Verde System	612270	PIMA	TUCSON	WILSON JR,L L	0.58
Rillito-Tanque Verde System	612466	PIMA	TUCSON	DOUGLAS, PETER,H	0.00
Rillito-Tanque Verde System	612491	PIMA	TUCSON	SWAN PARTNERS	0.00
Rillito-Tanque Verde System	612943	PIMA	TUCSON	GRIGGS,D C	0.00
Rillito-Tanque Verde System	613644	PIMA	TUCSON	METZ, RICHARD,E	0.00

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Rillito-Tanque Verde System	613764	PIMA	TUCSON	MENICK, FRED,	0.00
Rillito-Tanque Verde System	616902	PIMA	TUCSON	Metropolitan DWID-HUB	103.80
Rillito-Tanque Verde System	616903	PIMA	TUCSON	METROPOLITAN DWID - HUB	194.98
Rillito-Tanque Verde System	616904	PIMA	TUCSON	METROPOLITAN DOMESTIC WATER IMPROVEMENT DIST	403.07
Rillito-Tanque Verde System	616905	PIMA	TUCSON	METROPOLITAN DOMESTIC WATER IMPROVEMENT DIST	83.06
Rillito-Tanque Verde System	616928	PIMA	TUCSON	CR RESORTS, LLC	0.00
Rillito-Tanque Verde System	616963	PIMA	TUCSON	JOHN HENKEL	0.00
Rillito-Tanque Verde System	616965	PIMA	TUCSON	MCCORMICK TANKERSLEY,R	No Data
Rillito-Tanque Verde System	616966	PIMA	TUCSON	MCCORMICK TANKERSLEY,R	No Data
Rillito-Tanque Verde System	616967	PIMA	TUCSON	MCCORMICK TANKERSLEY,	No Data
Rillito-Tanque Verde System	616968	PIMA	TUCSON	TANKERSLEY, RUTH M,	No Data
Rillito-Tanque Verde System	617197	PIMA	TUCSON	J.T. & N.G. GREER TRUST	0.00
Rillito-Tanque Verde System	617300	PIMA	TUCSON	CITY OF TUCSON-TUCSON WATER	0.00
Rillito-Tanque Verde System	617984	PIMA	TUCSON	PALSER, WALTER DEAN,	0.00
Rillito-Tanque Verde System	618075	PIMA	TUCSON	CONNOR,P T	0.00
Rillito-Tanque Verde System	618412	PIMA	TUCSON	PORTER, WILLIAM,W	0.00
Rillito-Tanque Verde System	618919	PIMA	TUCSON	GAIL M SANDERS RICE	7.00
Rillito-Tanque Verde System	618934	PIMA	TUCSON	MCLEAN, JOHN,W	0.00
Rillito-Tanque Verde System	619256	PIMA	TUCSON	CONWAY,W E	0.00
Rillito-Tanque Verde System	619957	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	619968	PIMA	TUCSON	TUCSON, CITY OF	305.80
Rillito-Tanque Verde System	619972	PIMA	TUCSON	TUCSON, CITY OF	205.40
Rillito-Tanque Verde System	619974	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	619975	PIMA	TUCSON	TUCSON, CITY OF	187.80
Rillito-Tanque Verde System	619977	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	619978	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620025	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620072	PIMA	TUCSON	TUCSON, CITY OF	181.10
Rillito-Tanque Verde System	620079	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620080	PIMA	TUCSON	TUCSON, CITY OF	554.10
Rillito-Tanque Verde System	620090	PIMA	TUCSON	TUCSON, CITY OF,	No Data
Rillito-Tanque Verde System	620093	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620094	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620118	PIMA	TUCSON	TUCSON, CITY OF,	No Data
Rillito-Tanque Verde System	620119	PIMA	TUCSON	TUCSON, CITY OF,	No Data
Rillito-Tanque Verde System	620120	PIMA	TUCSON	TUCSON, CITY OF,	No Data
Rillito-Tanque Verde System	620121	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620194	PIMA	TUCSON	TUCSON, CITY OF,	0.00
Rillito-Tanque Verde System	620710	PIMA	TUCSON	FENSTER SCHOOL INC,	11.81
Rillito-Tanque Verde System	620736	PIMA	TUCSON	ALLAN & JANE HAMILTON	0.00
Rillito-Tanque Verde System	620857	PIMA	TUCSON	MARK & LAURIE BUTLER	0.00
Rillito-Tanque Verde System	621014	PIMA	TUCSON	PARK,W G	0.00
Rillito-Tanque Verde System	621041	PIMA	TUCSON	WALTER L PALSER	0.00
Rillito-Tanque Verde System	621346	PIMA	TUCSON	PARK,W G	0.00
Rillito-Tanque Verde System	621379	PIMA	TUCSON	PAM HASKELL	0.00

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Rillito-Tanque Verde System	621623	PIMA	TUCSON	MILLER, NOLA,E	29.40
Rillito-Tanque Verde System	621625	PIMA	TUCSON	ANTHONY W SWENSRUD	0.00
Rillito-Tanque Verde System	621657	PIMA	TUCSON	RIVER FOREST HOMEOWNERS' ASSOCIATION	No Data
Rillito-Tanque Verde System	623019	PIMA	TUCSON	HELLER,C J	0.00
Rillito-Tanque Verde System	623270	PIMA	TUCSON	SIMMONS,L M	0.00
Rillito-Tanque Verde System	624205	PIMA	TUCSON	TANQUE VERDE RANCH,	11.24
Rillito-Tanque Verde System	624208	PIMA	TUCSON	TANQUE VERDE RANCH,	0.00
Rillito-Tanque Verde System	624223	PIMA	TUCSON	BECKER,W R	0.00
Rillito-Tanque Verde System	625709	PIMA	TUCSON	PATRICK S EGAN	1.00
Rillito-Tanque Verde System	625819	PIMA	TUCSON	EL CORTIJO, LLC., AN ARIZONA LIMITED LIABILITY CO	10.29
Rillito-Tanque Verde System	625820	PIMA	TUCSON	EL CORTIJO, LLC., AN ARIZONA LIMITED LIABILITY CO	No Data
Rillito-Tanque Verde System	625821	PIMA	TUCSON	EL CORTIJO, LLC., AN ARIZONA LIMITED LIABILITY CO	No Data
Rillito-Tanque Verde System	625822	PIMA	TUCSON	EL CORTIJO, LLC., AN ARIZONA LIMITED LIABILITY CO	No Data
Rillito-Tanque Verde System	625958	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	625959	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	625960	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	625961	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	625962	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	625963	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	625967	PIMA	TUCSON	CIENEGA LTD,	No Data
Rillito-Tanque Verde System	626131	PIMA	TUCSON	TUCSON COUNTRY CLUB,	0.00
Rillito-Tanque Verde System	626132	PIMA	TUCSON	TUCSON COUNTRY CLUB,	55.62
Rillito-Tanque Verde System	626133	PIMA	TUCSON	TUCSON COUNTRY CLUB,	No Data
Rillito-Tanque Verde System	626134	PIMA	TUCSON	TUCSON COUNTRY CLUB,	131.90
Rillito-Tanque Verde System	626135	PIMA	TUCSON	TUCSON COUNTRY CLUB,	76.08
Rillito-Tanque Verde System	626136	PIMA	TUCSON	TUCSON COUNTRY CLUB,	88.76
Rillito-Tanque Verde System	626292	PIMA	TUCSON	CASTLE ROCK HOME OWNERS ASSOCIATION	92.20
Rillito-Tanque Verde System	626294	PIMA	TUCSON	CASTLE ROCK HOME OWNERS ASSOCIATION	0.00
Rillito-Tanque Verde System	626295	PIMA	TUCSON	PIONEER TRUST CO,	No Data
Rillito-Tanque Verde System	626297	PIMA	TUCSON	CASTLE ROCK HOME OWNERS ASSOCIATION	0.00
Rillito-Tanque Verde System	626298	PIMA	TUCSON	CASTLE ROCK HOME OWNERS ASSOCIATION	0.00
Rillito-Tanque Verde System	626299	PIMA	TUCSON	PIONEER TRUST CO,	No Data
Rillito-Tanque Verde System	626378	PIMA	TUCSON	BARTELS,P H	0.00
Rillito-Tanque Verde System	626405	PIMA	TUCSON	TUCSON WATER	179.80
Rillito-Tanque Verde System	626406	PIMA	TUCSON	TUCSON WATER CO	0.00
Rillito-Tanque Verde System	626407	PIMA	TUCSON	TUCSON WATER	127.00
Rillito-Tanque Verde System	627073	PIMA	TUCSON	PIMA COUNTY,	10.25
Rillito-Tanque Verde System	627581	PIMA	TUCSON	WELP 95 LLC	0.00
Rillito-Tanque Verde System	627915	PIMA	TUCSON	HELLER, ANITA,P	0.00
Rillito-Tanque Verde System	627947	PIMA	TUCSON	M P L CORP,	0.00
Rillito-Tanque Verde System	628080	PIMA	TUCSON	FORD,R	0.00
Rillito-Tanque Verde System	628505	PIMA	TUCSON	PARK,W G	0.00
Rillito-Tanque Verde System	628567	PIMA	TUCSON	STACY,R E	0.00
Rillito-Tanque Verde System	628874	PIMA	TUCSON	CURRIER JR,G	0.00

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Rillito-Tanque Verde System	628973	PIMA	TUCSON	SHEPHERD,P R	0.00
Rillito-Tanque Verde System	629213	PIMA	TUCSON	LASON,D L	0.00
Rillito-Tanque Verde System	629424	PIMA	TUCSON	KARTCHNER, MARK,	No Data
Rillito-Tanque Verde System	631270	PIMA	TUCSON	PETER & CINDY J REINTHAL & STACKHOUSE	0.00
Rillito-Tanque Verde System	631716	PIMA	TUCSON	CESARE, JOSEPH,R	No Data
Rillito-Tanque Verde System	634970	PIMA	TUCSON	SALZMAN,R E	0.00
Rillito-Tanque Verde System	635851	PIMA	TUCSON	COLUMBIA REALTY CORP,	No Data
Rillito-Tanque Verde System	636191	PIMA	TUCSON	SAHUARO GIRL SCOUT,	No Data
Rillito-Tanque Verde System	638875	PIMA	TUCSON	MAJESKY,R L	4.20
Rillito-Tanque Verde System	643146	PIMA	TUCSON	ED & RHONDA WADINGTON	No Data
Rillito-Tanque Verde System	643147	PIMA	TUCSON	MITCHELL AND ROBIN POZEZ	0.00
Rillito-Tanque Verde System	647106	PIMA	TUCSON	COLUMBIA REALTY CORP,	No Data
Rillito-Tanque Verde System	647107	PIMA	TUCSON	COLUMBIA REALTY CORP,	No Data
Rillito-Tanque Verde System	700684	PIMA	TUCSON		No Data
Rillito-Tanque Verde System	700695	PIMA	TUCSON		No Data
Rillito-Tanque Verde System	800356	PIMA	TUCSON	TUCSON WATER	424.70
Rillito-Tanque Verde System	800437	PIMA	TUCSON	CAMPBELL,L C	0.00
Rillito-Tanque Verde System	800736	PIMA	TUCSON	CELLA, PAUL,W	1.00
Rillito-Tanque Verde System	800803	PIMA	TUCSON	B.J. & EARLE MOONEY	0.00
Rillito-Tanque Verde System	800848	PIMA	TUCSON	CHRISTOPHER STREETER	3.00
Rillito-Tanque Verde System	800851	PIMA	TUCSON	KELM,R A	No Data
Rillito-Tanque Verde System	800922	PIMA	TUCSON	MAUREEN C HAWXHURST	0.00
Rillito-Tanque Verde System	801027	PIMA	TUCSON	SISTERS-IMMACULATE,	5.00
Rillito-Tanque Verde System	801036	PIMA	TUCSON	SWAIM,R J	0.00
Rillito-Tanque Verde System	801039	PIMA	TUCSON	MEAD,O O	9.00
Rillito-Tanque Verde System	801131	PIMA	TUCSON	CASA ONE HOLDING,	0.00
Rillito-Tanque Verde System	801134	PIMA	TUCSON	DYBVIG, DAVID,	0.00
Rillito-Tanque Verde System	801135	PIMA	TUCSON	BRIAN NEILSEN	0.00
Rillito-Tanque Verde System	801159	PIMA	TUCSON	HASSEY,N E	0.00
Rillito-Tanque Verde System	801170	PIMA	TUCSON	DESERT CHRISTIAN SCHOOLS, INC.	No Data
Rillito-Tanque Verde System	801176	PIMA	TUCSON	DORAN,T E	0.00
Rillito-Tanque Verde System	801182	PIMA	TUCSON	FERGANCHICK,B	No Data
Rillito-Tanque Verde System	801204	PIMA	TUCSON	STEVE & FRANCESCA BRENNAN	1.00
Rillito-Tanque Verde System	801241	PIMA	TUCSON	DAVID GARDNER	12.00
Rillito-Tanque Verde System	801293	PIMA	TUCSON	BOYLIN, BENJAMIN,	0.00
Rillito-Tanque Verde System	801298	PIMA	TUCSON	KAREN MURPHY	0.00
Rillito-Tanque Verde System	801373	PIMA	TUCSON	SHARER, KEVIN,	4.70
Rillito-Tanque Verde System	801394	PIMA	TUCSON	GREGORY HUTCHINSON	0.00
Rillito-Tanque Verde System	801395	PIMA	TUCSON	RUSTAND, WARREN,S	0.00
Rillito-Tanque Verde System	801497	PIMA	TUCSON	RANCH HOUSE INVESTORS, LLC	0.00
Rillito-Tanque Verde System	801498	PIMA	TUCSON	RANCH HOUSE INVESTORS, LLC	0.00
Rillito-Tanque Verde System	801627	PIMA	TUCSON	MATHEWS JR,W R	4.00
Rillito-Tanque Verde System	801906	PIMA	TUCSON	BARBARA MC NAUGHTON	0.00
Rillito-Tanque Verde System	801928	PIMA	TUCSON	GOEBEL,G M	0.00
Rillito-Tanque Verde System	801967	PIMA	TUCSON	BENNETT,J H	0.00
Rillito-Tanque Verde System	801968	PIMA	TUCSON	BENNETT,J H	0.00
Rillito-Tanque Verde System	803452	PIMA	TUCSON	ERWIN, ELDON,	0.00

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Rillito-Tanque Verde System	803463	PIMA	TUCSON	RUSTAND, WARREN,S	1.46
Rillito-Tanque Verde System	803490	PIMA	TUCSON	GONDA, GERALD,	No Data
Rillito-Tanque Verde System	803492	PIMA	TUCSON	TURNER, WILLIAM,H	0.00
Rillito-Tanque Verde System	805155	PIMA	TUCSON	BROOKS, ROBERT,J	10.00
Rillito-Tanque Verde System	805619	PIMA	TUCSON	MALONEY, CHRISTOPHER,T	0.00
San Pedro River	203759	PINAL	OUTSIDE AMA	JERRY BROWN	No Data
San Pedro River	502331	PIMA	OUTSIDE AMA	HILLIARD, RONNIE,L	No Data
San Pedro River	505070	PINAL	OUTSIDE AMA	JOSEPH & JULIE CARDELLA	No Data
San Pedro River	507227	PIMA	OUTSIDE AMA	BAYLESS & BERKALEW,	No Data
San Pedro River	533167	PIMA	OUTSIDE AMA	BINGHAM, FARON,	No Data
San Pedro River	536881	PIMA	OUTSIDE AMA	GONZALEZ, JESSE,	No Data
San Pedro River	561909	PINAL	OUTSIDE AMA	JERRY BROWN	No Data
San Pedro River	577588	PIMA	OUTSIDE AMA		No Data
San Pedro River	598121	PIMA	OUTSIDE AMA	BAYLESS & BERKALEW	No Data
San Pedro River	600077	PIMA	OUTSIDE AMA	BEAL,J E	No Data
San Pedro River	600350	PIMA	OUTSIDE AMA	HAWK,J W	No Data
San Pedro River	606852	PINAL	OUTSIDE AMA	BROWN,M W	No Data
San Pedro River	606875	PINAL	OUTSIDE AMA	MONTANO, JOSE,L	No Data
San Pedro River	608215	PIMA	OUTSIDE AMA	BAYLESS & BERKALEW,	No Data
San Pedro River	608217	PIMA	OUTSIDE AMA	BAYLESS & BERKALEW,	No Data
San Pedro River	608221	PIMA	OUTSIDE AMA	BAYLESS & BERKALEW,	No Data
San Pedro River	608222	PIMA	OUTSIDE AMA	BAYLESS & BERKALEW,	No Data
San Pedro River	608576	PINAL	OUTSIDE AMA	BLANK,C	No Data
San Pedro River	610362	PIMA	OUTSIDE AMA	WHITE, JOE ET AL,	No Data
San Pedro River	613386	PIMA	OUTSIDE AMA	DYKES,E H	No Data
San Pedro River	613387	PIMA	OUTSIDE AMA	DYKES,J H	No Data
San Pedro River	613516	PIMA	OUTSIDE AMA	MULLER,R F	No Data
San Pedro River	613661	PINAL	OUTSIDE AMA	VALENZUELA,E	No Data
San Pedro River	613756	PIMA	OUTSIDE AMA	BINGHAM,A N	No Data
San Pedro River	613758	PIMA	OUTSIDE AMA	BINGHAM,A N	No Data
San Pedro River	613760	PIMA	OUTSIDE AMA	HILLIARD, RONNIE,L	No Data
San Pedro River	613761	PIMA	OUTSIDE AMA	FLOYD,R	No Data
San Pedro River	620729	PIMA	OUTSIDE AMA	STRAUSSER, VALORY,	No Data
San Pedro River	624838	PIMA	OUTSIDE AMA	JUNUIS D. & LAVONA EVANS	No Data
San Pedro River	624839	PIMA	OUTSIDE AMA	JUNUIS D. & LAVONA EVANS	No Data
San Pedro River	624851	PIMA	OUTSIDE AMA	KELLY,J	No Data
San Pedro River	624852	PIMA	OUTSIDE AMA	KELLY,J	No Data
San Pedro River	624853	PIMA	OUTSIDE AMA	KELLY,J	No Data
San Pedro River	628437	PIMA	OUTSIDE AMA	STANFORD,J	No Data
San Pedro River	631702	PIMA	OUTSIDE AMA	ERNEST & CLENNA SPURGEON	No Data
San Pedro River	636251	PINAL	OUTSIDE AMA	LE GRAND,D	No Data
San Pedro River	642786	PIMA	OUTSIDE AMA	HAMMOND,J	No Data
San Pedro River	804805	PIMA	OUTSIDE AMA	STEVEN & TRULY NOLEN	No Data
San Pedro River	804806	PIMA	OUTSIDE AMA	STEVEN & TRULY NOLEN	No Data
San Pedro River	804807	PIMA	OUTSIDE AMA	STEVEN & TRULY NOLEN	No Data
San Pedro River	805318	PINAL	OUTSIDE AMA	OSCAR J KING	No Data
Santa Cruz-Sopori System	507285	PIMA	SANTA CRUZ	ED & NANCY KAY,	0.00

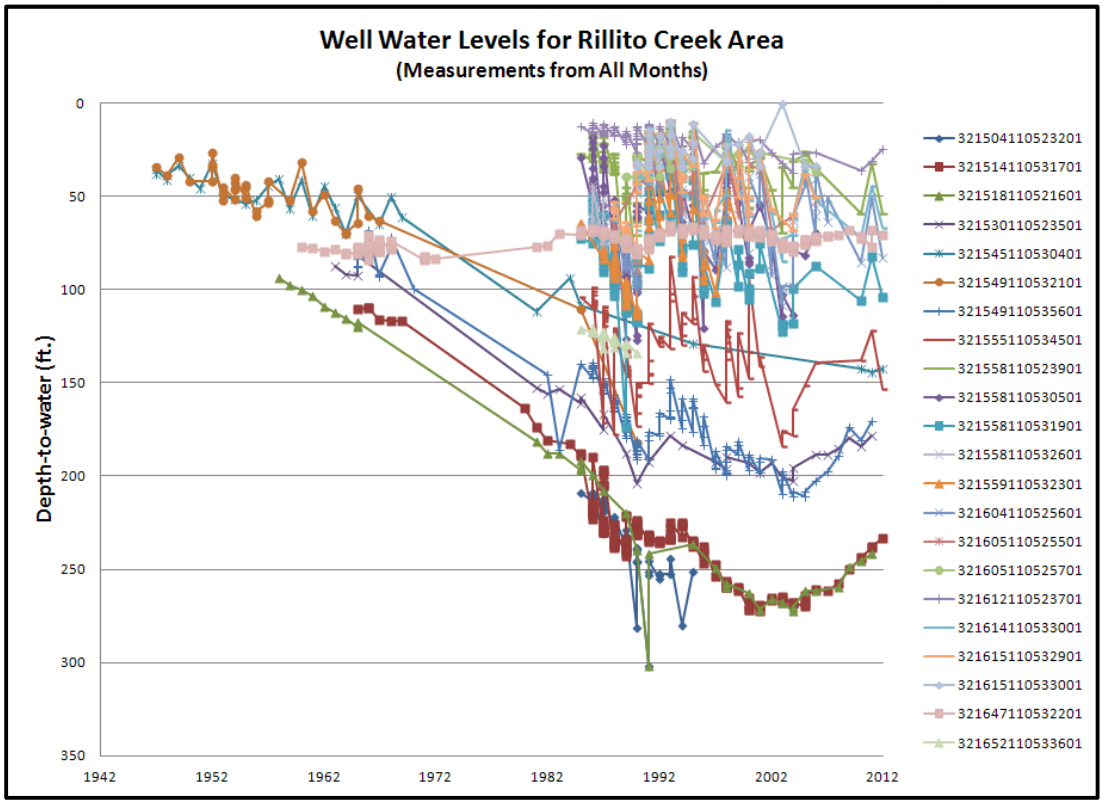
Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Santa Cruz-Sopori System	507495	PIMA	SANTA CRUZ	Rancho Sonado, LLC	365.50
Santa Cruz-Sopori System	507555	PIMA	SANTA CRUZ	B & M FARMS,	No Data
Santa Cruz-Sopori System	554070	PIMA	SANTA CRUZ	PIMA COUNTY DEPT OF,T R	0.00
Santa Cruz-Sopori System	564156	PIMA	SANTA CRUZ	O. ZIEG WARNER	No Data
Santa Cruz-Sopori System	578736	SANTA CRUZ	SANTA CRUZ	DE ANZA RESORT LLC - DE ANZA TRAILS RV	3.00
Santa Cruz-Sopori System	587035	PIMA	TUCSON	GREEN VALLEY WATER COMPANY	No Data
Santa Cruz-Sopori System	591959	PIMA	SANTA CRUZ	TOOLE III,H T	No Data
Santa Cruz-Sopori System	606133	PIMA	SANTA CRUZ	PIMA COUNTY NATURAL RESOURCES, PARKS AND RECREATION DEPT.	0.13
Santa Cruz-Sopori System	606136	PIMA	SANTA CRUZ	CARROW CO,	0.00
Santa Cruz-Sopori System	606138	PIMA	SANTA CRUZ	PIMA COUNTY NATURAL RESOURCES, PARKS AND RECREATION DEPT.	No Data
Santa Cruz-Sopori System	606139	PIMA	SANTA CRUZ	CARROW CO,	36.28
Santa Cruz-Sopori System	606140	PIMA	SANTA CRUZ	CARROW CO,	118.61
Santa Cruz-Sopori System	606448	SANTA CRUZ	SANTA CRUZ	NEUBANER, JEAN,E	0.00
Santa Cruz-Sopori System	609931	SANTA CRUZ	SANTA CRUZ	MICHAEL EWING	19.20
Santa Cruz-Sopori System	612064	PIMA	SANTA CRUZ	Sopori 12500 Investors, LLC, etal	68.05
Santa Cruz-Sopori System	612065	SANTA CRUZ	SANTA CRUZ	INSCRIPTION CANYON,	194.49
Santa Cruz-Sopori System	612067	SANTA CRUZ	SANTA CRUZ	FIRST AMERICAN TITLE INSURANCE COMPANY, TRUST 8626	15.42
Santa Cruz-Sopori System	612068	SANTA CRUZ	SANTA CRUZ	FIRST AMERICAN TITLE INSURANCE COMPANY, TRUST 8626	0.00
Santa Cruz-Sopori System	612069	SANTA CRUZ	SANTA CRUZ	FIRST AMERICAN TITLE INSURANCE COMPANY, TRUST 8626	10.70
Santa Cruz-Sopori System	612070	SANTA CRUZ	SANTA CRUZ	FIRST AMERICAN TITLE INSURANCE COMPANY, TRUST 8626	0.00
Santa Cruz-Sopori System	612071	SANTA CRUZ	SANTA CRUZ	FIRST AMERICAN TITLE INSURANCE COMPANY, TRUST 8626	0.00
Santa Cruz-Sopori System	612072	PIMA	SANTA CRUZ		0.30
Santa Cruz-Sopori System	612073	SANTA CRUZ	SANTA CRUZ	INSCRIPTION CANYON,	0.00
Santa Cruz-Sopori System	612074	SANTA CRUZ	SANTA CRUZ	INSCRIPTION CANYON,	8.68
Santa Cruz-Sopori System	612928	PIMA	SANTA CRUZ	NUSBAUM,D R	0.00
Santa Cruz-Sopori System	612929	PIMA	SANTA CRUZ	FRANK M. BAUCOM	0.00
Santa Cruz-Sopori System	613921	PIMA	SANTA CRUZ	LEM,W O	0.00
Santa Cruz-Sopori System	619387	PIMA	SANTA CRUZ	OBLENDER ET AL,T W	No Data
Santa Cruz-Sopori System	622881	SANTA CRUZ	SANTA CRUZ	DE ANZA RESORT LLC - DE ANZA TRAILS RV	1.60
Santa Cruz-Sopori System	623113	PIMA	TUCSON	FREEPORT-MCMORAN SIERRITA INC.	3,660.00
Santa Cruz-Sopori System	623114	PIMA	TUCSON	FREEPORT-MCMORAN SIERRITA INC.	4,428.00
Santa Cruz-Sopori System	623115	PIMA	TUCSON	FREEPORT-MCMORAN SIERRITA INC.	3,847.00
Santa Cruz-Sopori System	623116	PIMA	SANTA CRUZ	FREEPORT-MCMORAN SIERRITA INC.	3,876.00
Santa Cruz-Sopori System	623888	PIMA	SANTA CRUZ	STEWART TITLE & TRUST #2725	331.51
Santa Cruz-Sopori System	624047	PIMA	SANTA CRUZ	RIFENBARK, DAVID,M	8.76
Santa Cruz-Sopori System	625121	SANTA CRUZ	SANTA CRUZ	MIDDLETON RANCH CO,	22.40

Region	Registry ID	County	AMA	Owner Name	Water With-drawn (AF)
Santa Cruz-Sopori System	625122	SANTA CRUZ	SANTA CRUZ	MIDDLETON RANCH CO,	82.00
Santa Cruz-Sopori System	625123	PIMA	SANTA CRUZ	MIDDLETON RANCH CO,	141.54
Santa Cruz-Sopori System	625124	PIMA	SANTA CRUZ	MIDDLETON RANCH CO,	338.45
Santa Cruz-Sopori System	625125	PIMA	SANTA CRUZ	MIDDLETON RANCH CO,	122.00
Santa Cruz-Sopori System	625126	PIMA	SANTA CRUZ	MIDDLETON RANCH CO,	141.53
Santa Cruz-Sopori System	625127	SANTA CRUZ	SANTA CRUZ	MIDDLETON RANCH CO,	No Data
Santa Cruz-Sopori System	625246	SANTA CRUZ	SANTA CRUZ	MARLEY CATTLE CO,	0.00
Santa Cruz-Sopori System	625247	SANTA CRUZ	SANTA CRUZ	MARLEY CATTLE CO,	0.00
Santa Cruz-Sopori System	625248	PIMA	SANTA CRUZ	MARLEY CATTLE CO,	No Data
Santa Cruz-Sopori System	625422	PIMA	SANTA CRUZ	JUDI BRYAN	0.00
Santa Cruz-Sopori System	625423	PIMA	SANTA CRUZ	PIMA COUNTY NATURAL RESOURCES, PARKS AND RECREATION DEPT.	0.00
Santa Cruz-Sopori System	626063	PIMA	SANTA CRUZ	Rancho Sonado, LLC	12.08
Santa Cruz-Sopori System	626064	PIMA	SANTA CRUZ	Rancho Sonado, LLC	No Data
Santa Cruz-Sopori System	627939	SANTA CRUZ	SANTA CRUZ	HENSON FARMS,	415.50
Santa Cruz-Sopori System	628146	PIMA	SANTA CRUZ	B & M FARMS,	0.00
Santa Cruz-Sopori System	628147	PIMA	SANTA CRUZ	B & M FARMS,	0.00
Santa Cruz-Sopori System	628934	PIMA	SANTA CRUZ	LAURINDA OSWALD	No Data
Santa Cruz-Sopori System	628935	PIMA	SANTA CRUZ	LAURINDA OSWALD	48.85
Santa Cruz-Sopori System	629430	PIMA	SANTA CRUZ	LAKEWOOD WTR CO,	93.65
Santa Cruz-Sopori System	629431	PIMA	SANTA CRUZ	LAKEWOOD WTR CO,	28.82
Santa Cruz-Sopori System	634078	PIMA	SANTA CRUZ	JAMES GITTINGS	0.00
Santa Cruz-Sopori System	800625	PIMA	SANTA CRUZ	BRACAMONTE RANCH,	6.13
Santa Cruz-Sopori System	801305	PIMA	SANTA CRUZ	BARBARA BECKER	0.00
Santa Cruz-Sopori System	801306	PIMA	SANTA CRUZ	SAN RAFAEL VALLEY FAMILY PARTNERSHIP LLLP	No Data
Santa Cruz-Sopori System	801414	PIMA	SANTA CRUZ	THOMAS & SIGRUN SMORRA	No Data
Santa Cruz-Sopori System	801454	PIMA	SANTA CRUZ	DUNBAR,E P	0.00
Santa Cruz-Sopori System	801470	PIMA	SANTA CRUZ	BUCKEYE RANCH	0.00
Sutherland Wash	503021	PIMA	TUCSON	CORONADO NATL FOREST,	6.40
Sutherland Wash	613458	PIMA	TUCSON	LAGO DEL ORO WATER,	2.08
Sutherland Wash	613459	PIMA	TUCSON	LAGO DEL ORO WATER,	0.28
Sutherland Wash	615782	PIMA	TUCSON	WILLIAM MATTHEWS	0.52
Sutherland Wash	626681	PIMA	TUCSON	CHICAGO TITLE INS CO,	0.00
Tortolita Mountains	634164	PIMA	TUCSON	LA CHOLLA AIRPARK,	0.00
Tortolita Mountains	801105	PIMA	TUCSON	LA CHOLLA AIRPARK,	0.00

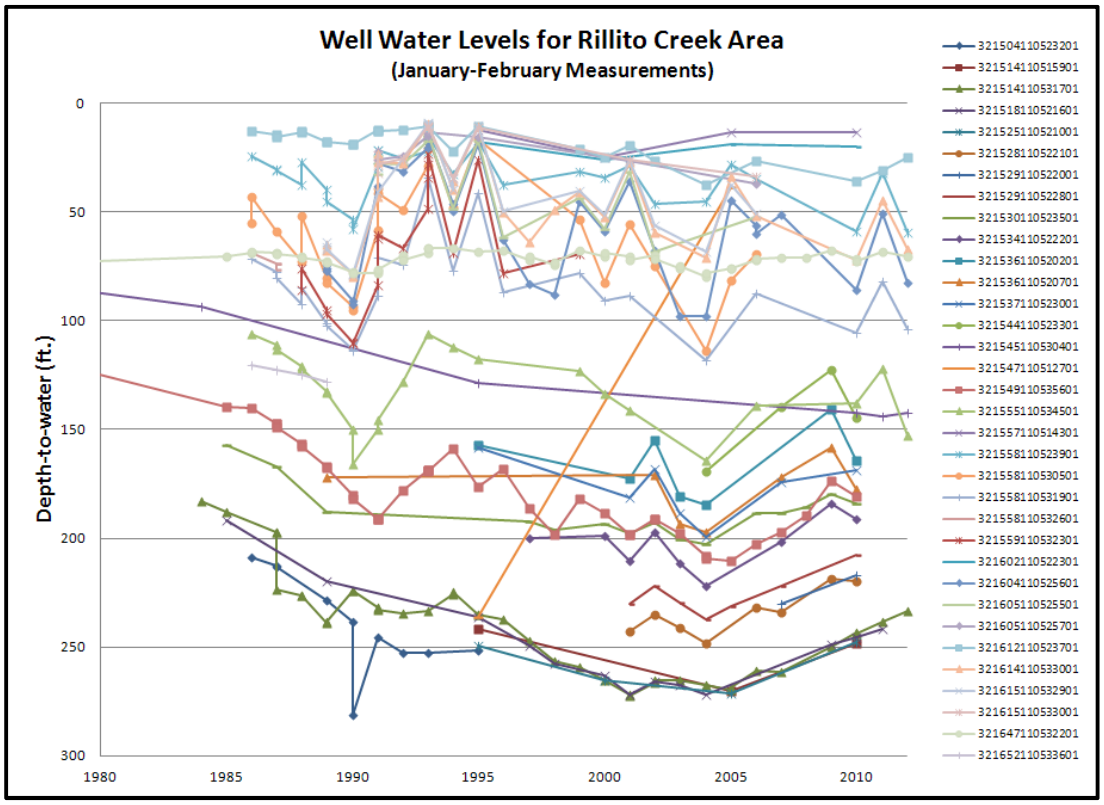
Note: Owner names reproduced exactly as given in ADWR Well Registry.

APPENDIX C

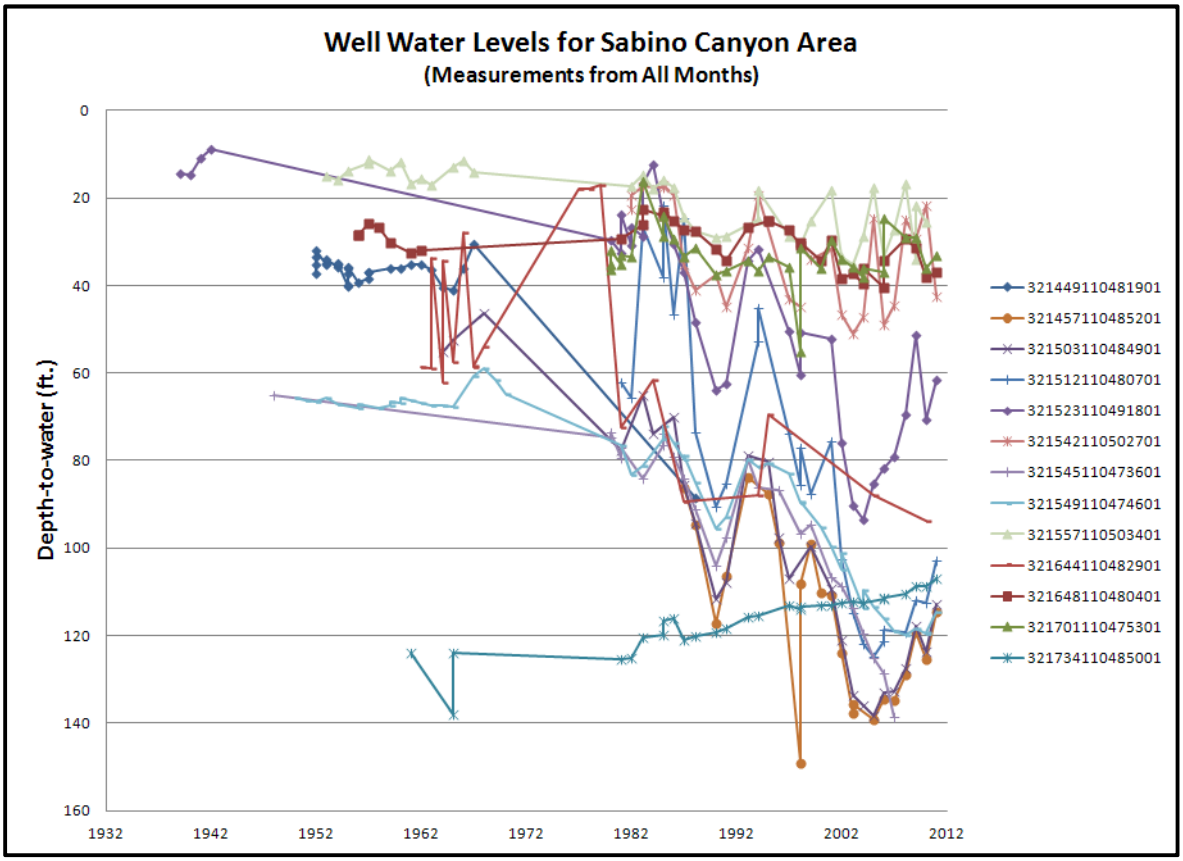
Additional Water Level Charts for the Rillito-Tanque Verde System



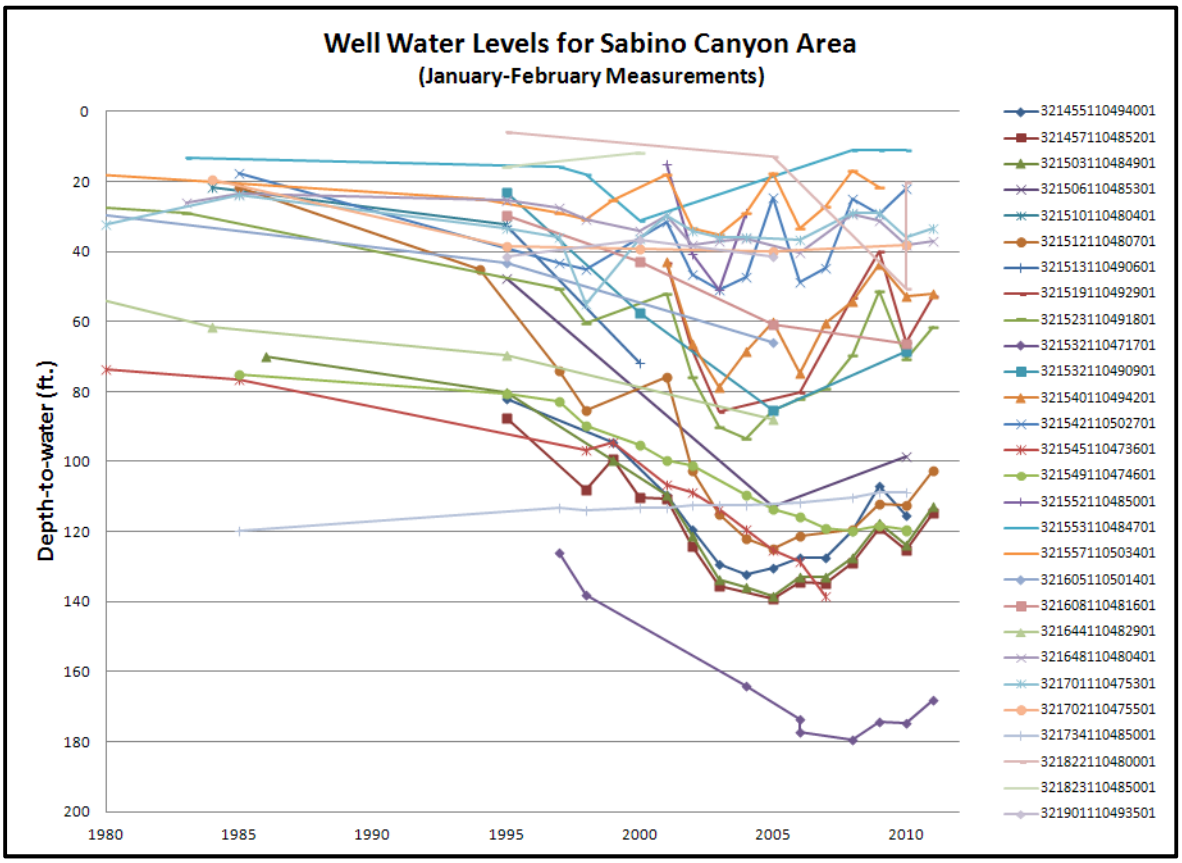
Note: Legend lists GWSI site-IDs; only wells with 20+ samples are plotted.



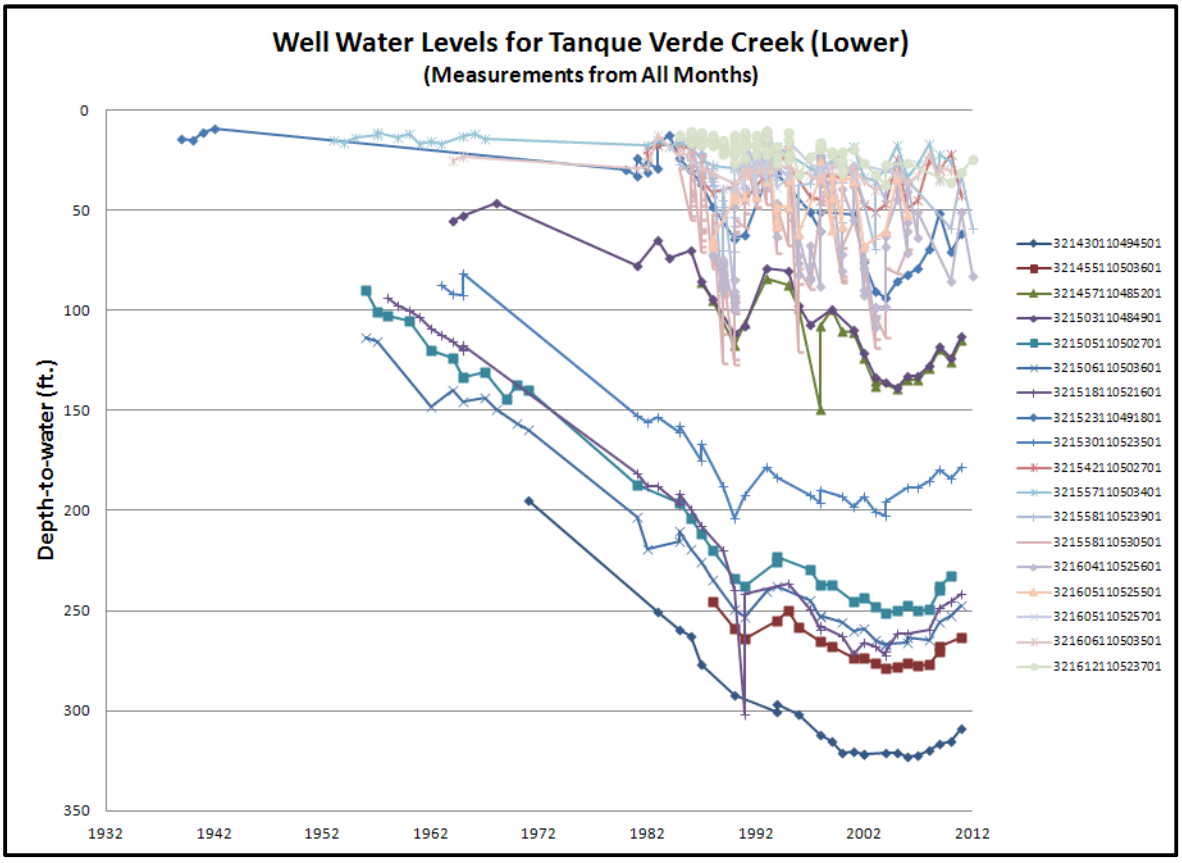
Note: Legend lists GWSI site-IDs.



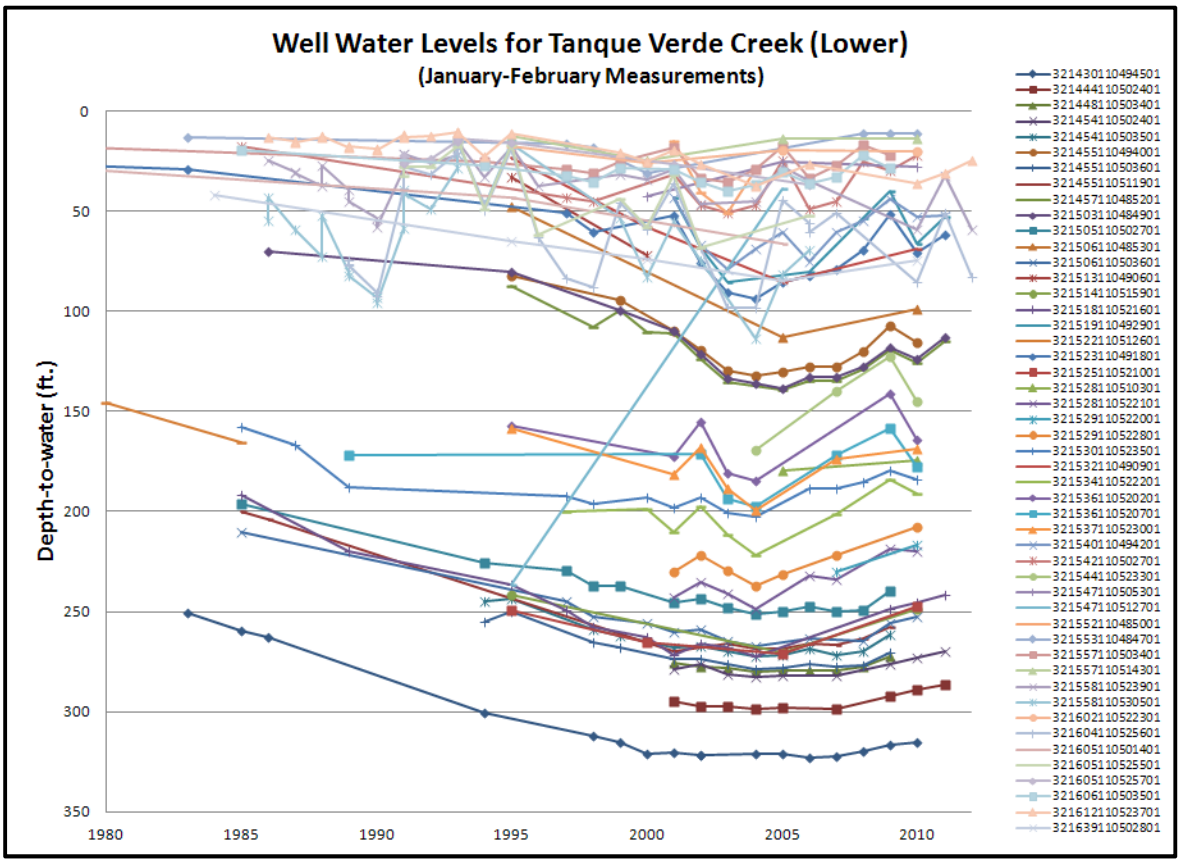
Note: Legend lists GWSI site-IDs; only wells with 20+ samples are plotted.



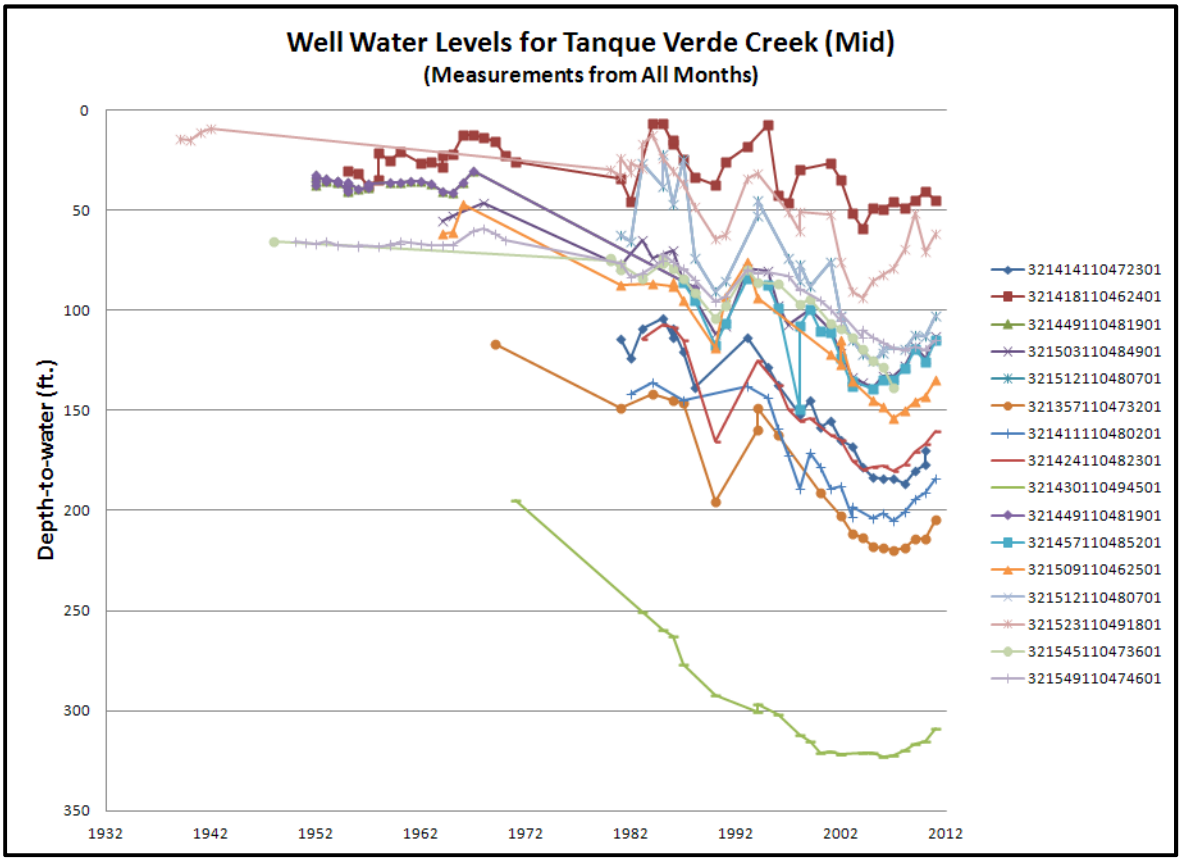
Note: Legend lists GWSI site-IDs.



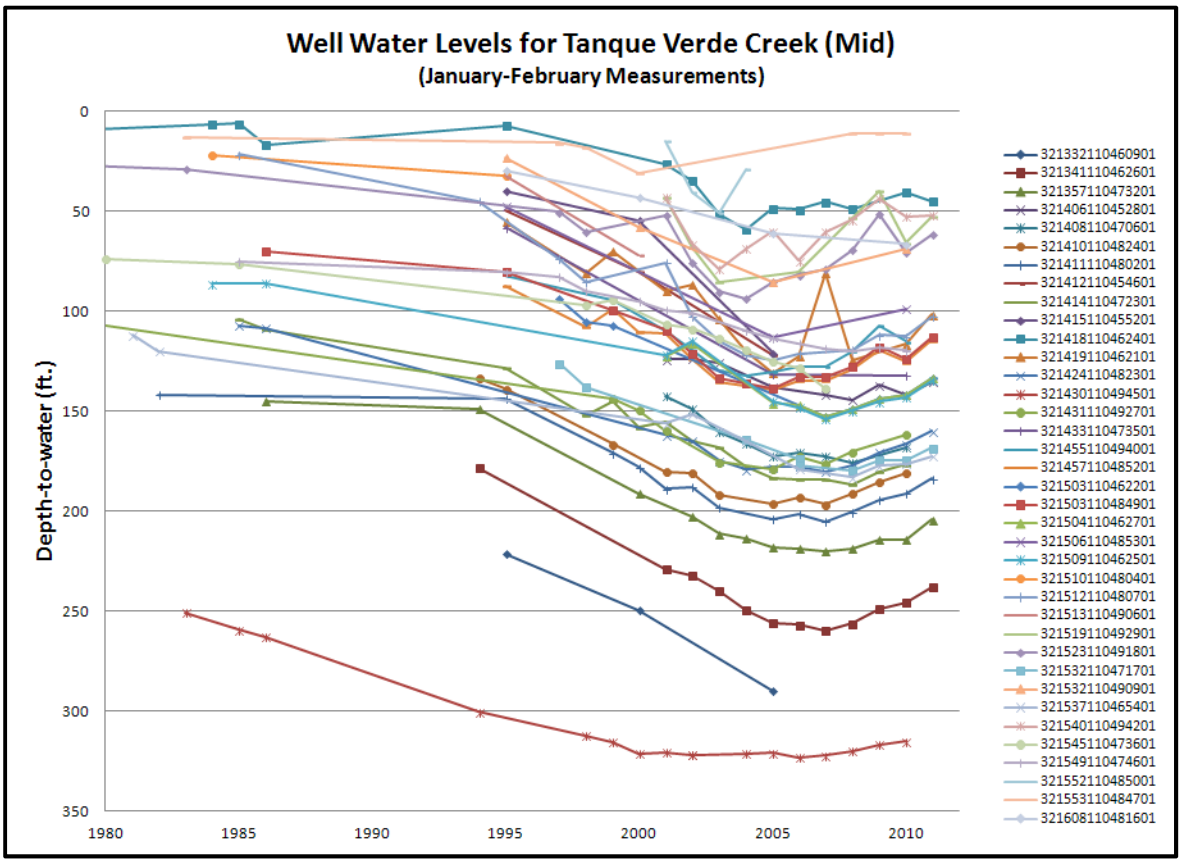
Note: Legend lists GWSI site-IDs; only wells with 20+ samples are plotted.



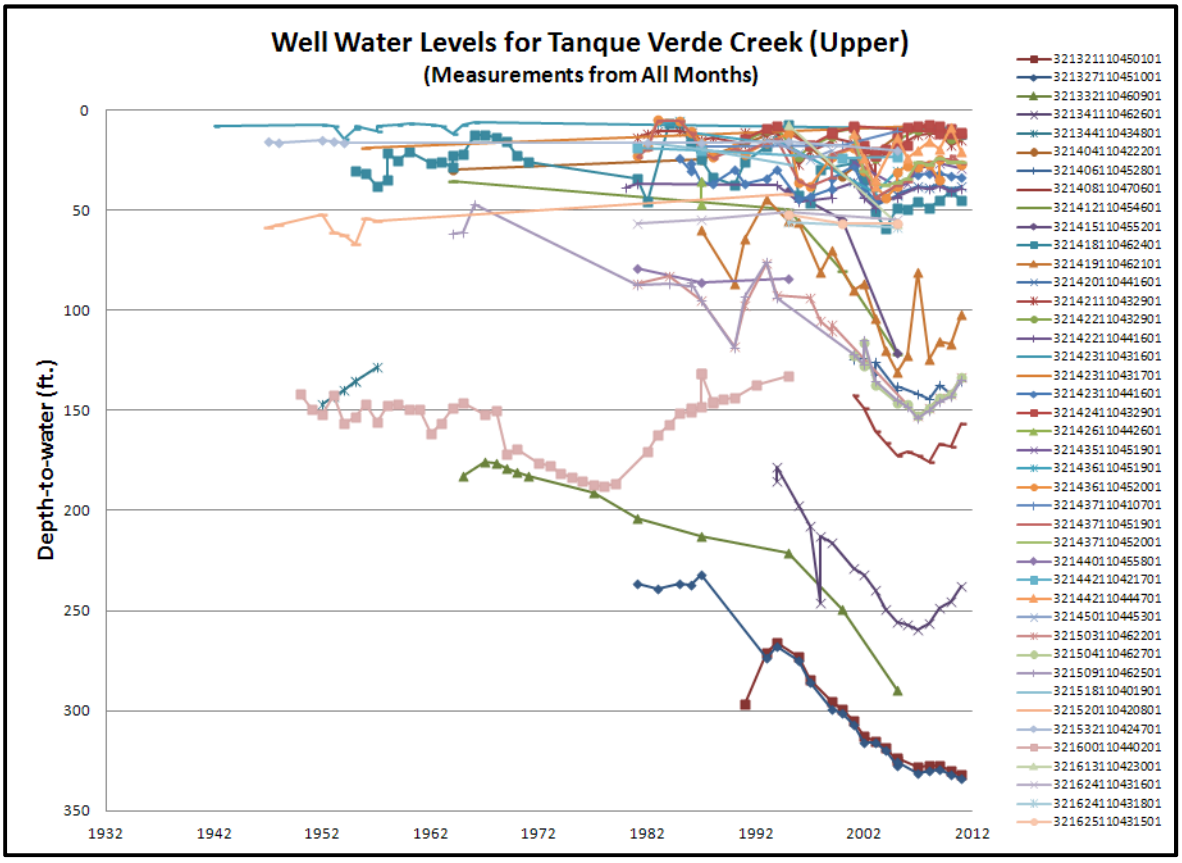
Note: Legend lists GWSI site-IDs.



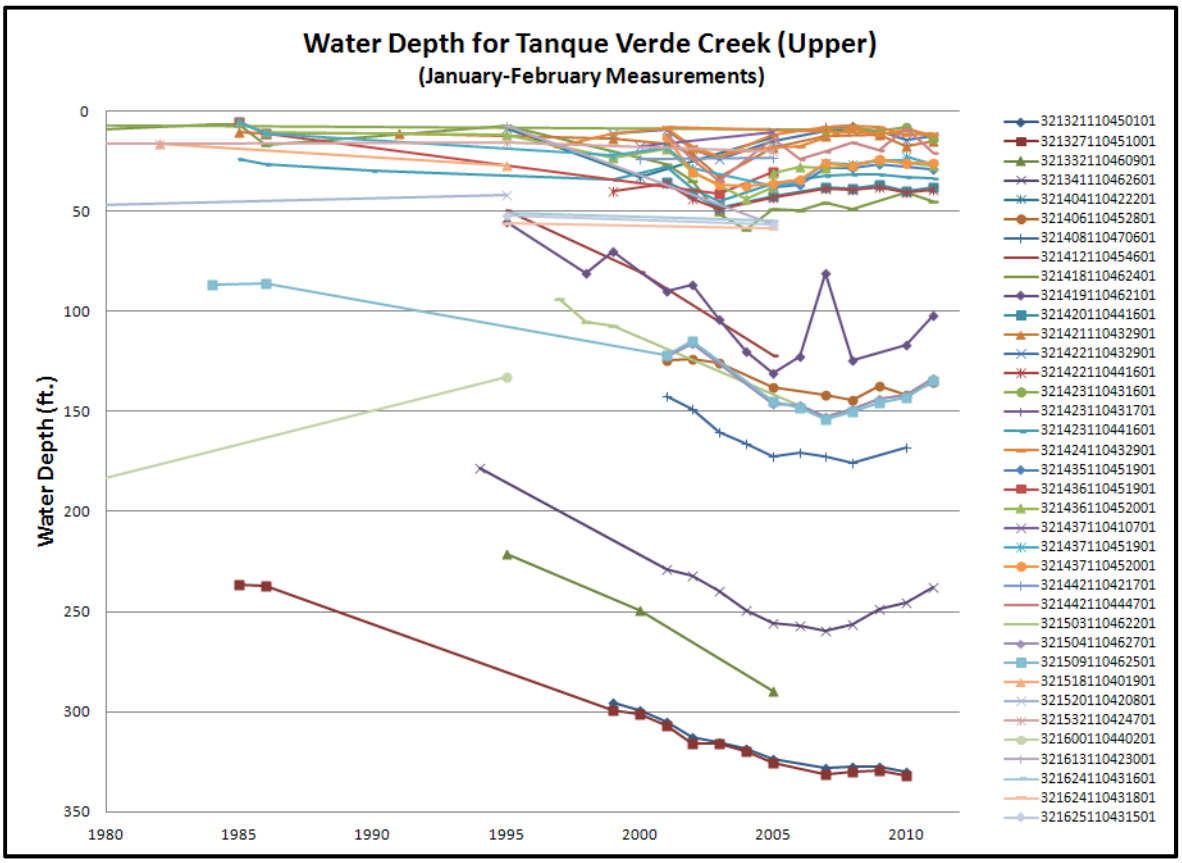
Note: Legend lists GWSI site-IDs; only wells with 20+ samples are plotted.



Note: Legend lists GWSI site-IDs.



Note: Legend lists GWSI site-IDs.



Note: Legend lists GWSI site-IDs.

APPENDIX D

Look-up Table for GWSI Site IDs

Legend Name	GWSI Site ID
GWSI Site IDs for Figure 41	
Cienega Creek (Lower) 1	320014110363901
Cienega Creek (Lower) 2	320137110371701
Cienega Creek (Lower) 3	320216110405901
Cienega Creek (Lower) 5	320249110413501
Cienega Creek (Mid) 1	315552110315401
Cienega Creek (Mid) 2	315730110313701
Cienega Creek (Mid) 3	315732110314701
Cienega Creek (Mid) 4	315816110310601
Cienega Creek (Upper) 1	314658110340701
Cienega Creek (Upper) 2	314704110360301
Cienega Creek (Upper) 3	314707110363401
Cienega Creek (Upper) 4	314756110360601
Cienega Creek (Upper) 5	314808110363901
Cienega Creek (Upper) 6	314814110340301
Cienega Creek (Upper) 9	314916110340401
Cienega Creek (Upper) 10	314936110355301
Cienega Creek (Upper) 11	314937110362301
Cienega Creek (Upper) 12	314947110344701
Cienega Creek (Upper) 13	314958110343901
GWSI Site IDs for Figure 42	
Barrel Canyon 1	314913110441201
Barrel Canyon 2	315124110424601
Davidson Canyon (Lower) 1	315118110395701
Davidson Canyon (Lower) 2	315504110390201
Gardner Canyon 1	314341110402801
Gardner Canyon 2	314410110390901
Gardner Canyon 3	314410110402101
Gardner Canyon 4	314412110390301
Gardner Canyon 5	314414110384601
Gardner Canyon 6	314435110374401
Gardner Canyon 7	314540110370601
GWSI Site IDs for Figure 55	
Brown Canyon	314520111310101
Sabino Canyon (Baboquivari) 1	314844111321201
Sabino Canyon (Baboquivari) 2	314902111325101
Sabino Canyon (Baboquivari) 3	314913111320701
Sabino Canyon (Baboquivari) 4	314921111311401
Thomas Canyon	314351111330701