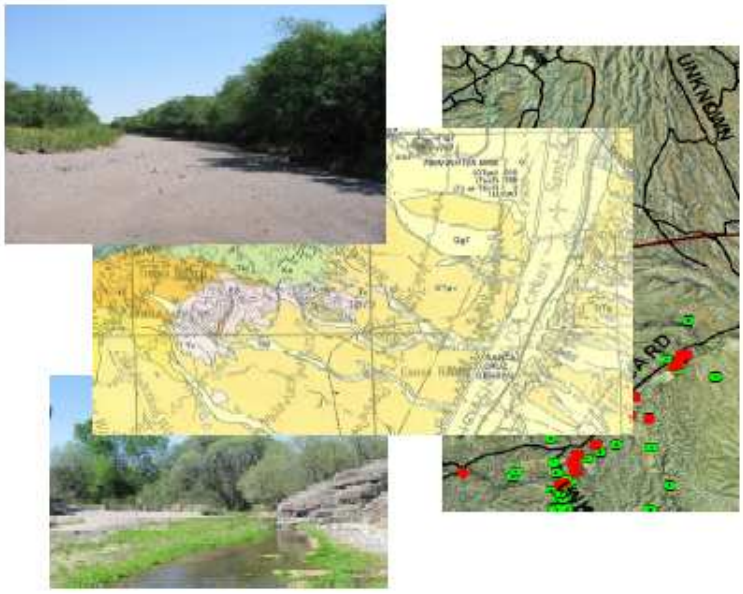
Groundwater Withdrawals in Shallow Groundwater Areas

EASTERN PIMA COUNTY, ARIZONA

1984-2006



Pima Association of Governments

Prepared for Pima County Regional Flood Control District by Pima Association of Governments

September 2008

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INTRODUCTION

The Tucson region has historically depended largely on groundwater to meet its water requirements. Rapid population growth has caused increased water consumption, and likewise, increased groundwater pumping over the years. Future growth will further challenge our limited water resources. As our region's population expands and our groundwater aquifers become developed, it becomes increasingly important to understand pumping trends for sensitive areas, such as shallow groundwater areas, so that riparian habitats are not compromised. Eastern Pima County is a semi-arid landscape that receives approximately 12 inches of rainfall annually, making the presence of water and riparian habitats especially rare and valued by the community (National Weather Service Forecast Office, 2008).

Groundwater aquifers are generally deep in eastern Pima County, except where they intersect natural recharge areas, such as streams 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. Shallow groundwater areas are commonly associated with perennial and intermittent stream reaches, as well as rare riparian environments. In our region, many riparian habitats are supported along intermittently flowing streams because tree roots reach down and tap into subsurface water.

In 2000, Pima Association of Governments (PAG) produced a study on groundwater withdrawals and surface water diversions near perennial and intermittent streams and shallow groundwater areas entitled *Water Usage Along Selected Streams in Pima County, AZ*. This document was prepared for Pima County in 2000 as part of the supporting documentation for the Sonoran Desert Conservation Plan (SDCP). In 2006, PAG prepared a follow-up document, which summarized groundwater withdrawals from shallow groundwater areas in eastern Pima County. This report was prepared by Pima Association of Governments' Watershed Planning Program to present pumping trends from 1984-2006, in the shallow groundwater areas of Eastern Pima County (Refer to Appendix A for maps of shallow groundwater areas and for wells located in these areas).

In the State of Arizona, all wells are required to be registered through the Arizona Department of Water Resources (ADWR). Data downloads based on ADWR well registrations and supplemental

investigations by ADWR were used to prepare this report. In Arizona, wells may be registered as either non-exempt or exempt. Pumping rates must be reported for non-exempt wells, but this requirement does not extend to exempt wells, making it very difficult to estimate how much water is being pumped annually from exempt wells and, therefore, from the aquifer as a whole. Exempt wells may pump as the well owner sees fit, as long as they don't exceed a pumping capacity of 35 gpm[1]. Because many exempt wells are located in shallow groundwater areas, this creates problems for estimating annual pumpage from these areas. This report documents the total number of exempt and non-exempt wells for each shallow groundwater area and the total water pumped from each area, based on an assumption that one acre-foot per year (AF/Y) is withdrawn from each exempt well. Appendix B includes pumping trends and total volume of water pumped via non-exempt wells for selected shallow groundwater areas.

DATA SOURCES

For this project, PAG collected data from two well databases maintained and updated by the Arizona Department of Water Resources (ADWR): *the* ***Wells-55*** and *the* ***Ground Water Site Inventory (GWSI)*** databases, to create the database used for this report. The Wells-55 database, presented on the Wells-55 Web site, 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. The GWSI database is ADWR's most up-to-date repository for statewide well information. It contains field data that were collected by the ADWR Hydrology Division's Basic Data Section or 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. Since there is no single database that can provide a complete list of wells in Arizona, both these databases were used to compile the final database used for this shallow groundwater area report.

Disclaimers:

The following disclaimers are provided by ADWR.

Wells-55 Data

The information contained in the Wells-55 Web site has not been verified by the State of Arizona, and the ADWR is unable to guarantee the accuracy of this information. ADWR will not assume any liability for damages resulting from use or misuse of this information. ADWR does not provide software training, support or application development with this information.

[1] An exempt well that pumps water at the rate of 35 gallons per minute will pump 50,400 gallons of water per day. This is much higher than per capita water consumption in Tucson (177 gallons per day) as has been documented by Tucson Water (Water Plan 2000-2050).

GWSI Data

Every new well is required by law to be registered with the state. This information may be incomplete because well registration, while required, is voluntary. The well owner or the well driller reports all of the well information to ADWR. The well locations in this database will not match the actual well locations on the ground. 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 has been 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. Some wells do not have corresponding location points. Non-located wells account for only about 0.05% of the entire Well Registry database. Annual reported well pumping amounts are reported only for wells within groundwater basins that have been designated as Acitve Management Areas (AMAs) or Irrigation Non-expansion Areas (INA) with a pump capacity greater than 35 gallons per minute. Annual reports are required to be submitted by the well owners by March 31 of the following year.

Exempt and Non-Exempt Wells

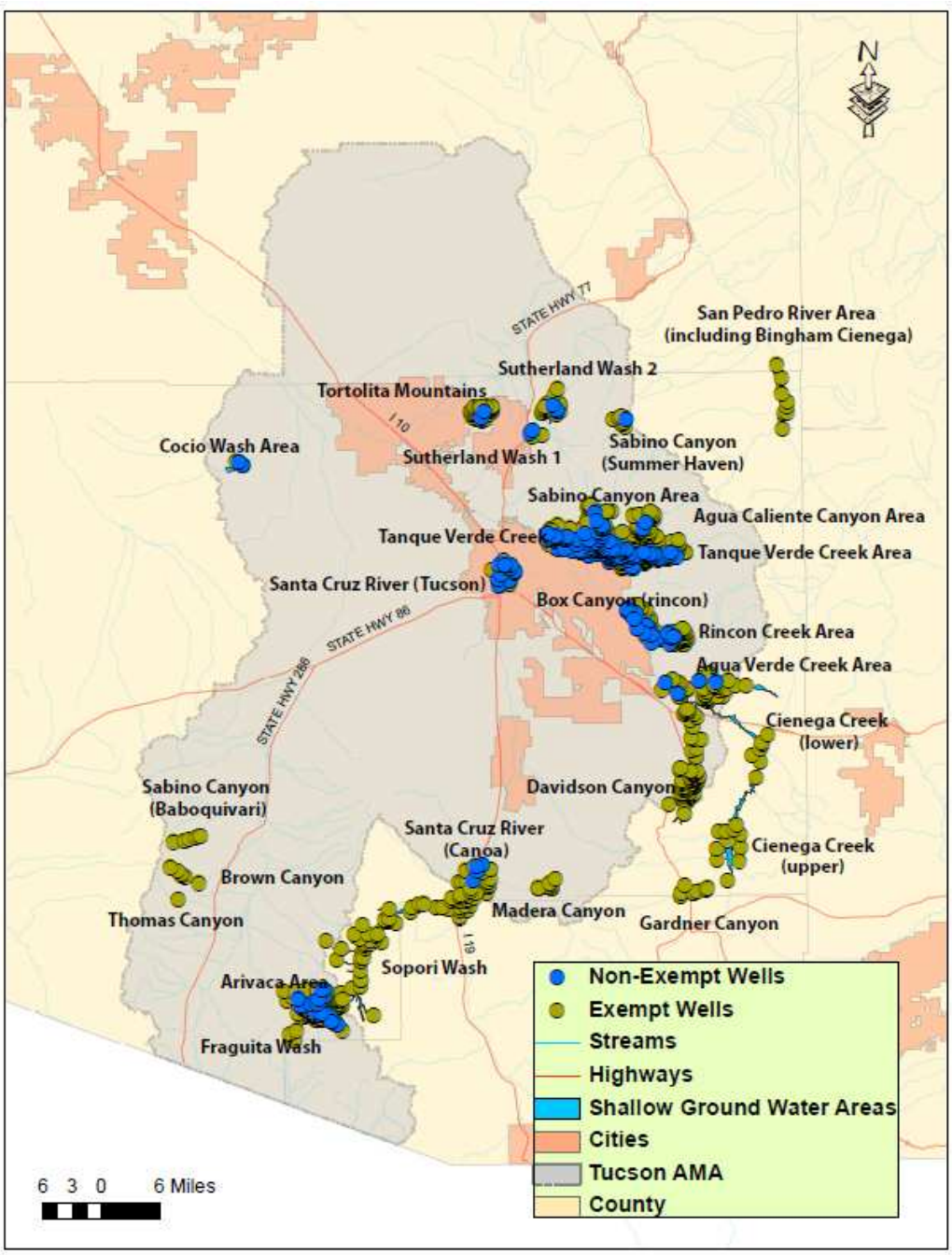
The shallow groundwater wells were categorized based on their characteristics as exempt and non-exempt wells. Based on ADWR documents:

> "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)."
>
> "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)."

STUDY AREA

This study focuses on 31 shallow groundwater areas located in eastern Pima County (Figure 1). Although only 18 shallow groundwater areas were studied for temporal trend analysis purposes. The rest of the shallow groundwater areas were excluded from the trend analysis calculation because either they did not have a non-exempt well or had non-exempt wells but did not have and pumping information for those wells. Most of these areas were previously identified by Pima Association of Governments and the Pima County Regional Flood Control District (PCRFCD) for the 2000 study, *Water Usage Along Selected Streams in Pima County, AZ*, but some changes and additions were made since that time. Many of these areas are either contiguous or are located very close to another shallow groundwater area.

Figure 1. Shallow Groundwater Areas of Eastern Pima County

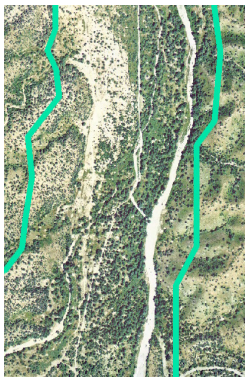


Map Disclaimer: "The information included on this map has been compiled from a variety of sources and is subject to change without notice. Pima Association of Governments makes no representation or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information." Map prepared in March 2008.

While comprehensive, this may not include all the shallow groundwater areas in eastern Pima County. Additional areas could be identified with further investigation of the region.

Demarcation of Shallow Groundwater Areas:

Shallow groundwater areas were defined as places where the water table is less than 50 feet below the ground surface. For areas where well depth information was not available, shallow groundwater areas were demarcated based on plants that are known to thrive in shallow groundwater areas. Mesquite Bosques and Cottonwood trees were often used as indicator species for demarcating shallow groundwater areas.

A.  B.  C. 

A. Shallow groundwater area with dense mesquite canopy (*PAG: Sopori Wash Report*)

B. Mesquite Bosque (*Pro-Mesquite*)

C. Cottonwood (*Environment News Service*)

PAG included 22 shallow groundwater areas in the 2000 report, and identified Rincon Valley as an area of special interest in the 2007 report. For this 2008 report, 31 shallow groundwater areas (nine new areas were added to the list) were studied and they are listed on Table 1 and shown in Figure 1.

Table 1 List of Shallow Groundwater Areas (2008)

1. Agua Caliente	9. Cocio Wash	17. Rillito Creek	25. Sopori Wash
2. Agua Verde Creek	10. Davidson Canyon	18. Rincon Creek	26. Sutherland Wash 1
3. Arivaca	11. Davidson Canyon (Upper)	19. Sabino Canyon	27. Sutherland Wash 2
4. Box Canyon (Rincon)	12. Fraguita Wash	20. Sabino Canyon (Baboquivari)	28. Tanque Verde Creek
5. Brown Canyon	13. Gardner Canyon	21. Sabino Canyon (Summerhaven)	29. Tanque Verde Creek Area
6. Cienega Creek (Lower A)	14. Madera Canyon	22. San Pedro River	30. Thomas Canyon
7. Cienega Creek (Lower B)	15. Pantano Wash	23. Santa Cruz River(Canoa)	31. Tortolita Mountains
8. Cienega Creek (Upper)	16. Posta Quemada	24. Santa Cruz River(Tucson)	

DATA MINING AND METHODOLOGY

Data mining is also 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 was the basis of all calculations and findings used in this report. 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. Also, there was some overlap between the GWSI and the Wells-55 databases, which had to be corrected during the data mining process. After merging the two databases, wells located outside the one-mile buffer of shallow groundwater areas in eastern Pima County were deleted. After that, duplicate well records, wells that were used for scientific exploration or cleaning and wells that had been capped or destroyed were removed from the database. A few other wells were removed based on their attributes, as shown in Table 2. The remaining data fields used for this investigation are shown in Table 3.

Table 2. Attributes used for well record removal from the merged database

Attribute Name in the "Merged" Database	Criteria used for deleting data
Registration Number	Duplicate records
Welltype	Cathodic, recovery, soil vapor extraction, mineral exploration, geotechnical, injection, exploration, monitor, or piezometer
Siteuse	Unused, anode, heat res, observation, recharge, test, water-quality monitoring, or well destroyed
Wateruse	Unused or Observation
Wateruse 1	Remediation or Monitoring
Wateruse 2	Test, other - mineral explore, or monitoring
Canceled	Yes
Welluse 1	Abandoned, capped, destroyed, mineral exploration, geotechnical, cathodic, test, monitor, piezometer or observation
Welluse2	Abandoned, capped, destroyed, monitor, observation, recharge, or recovery

Table 3. Data Fields Used: 2008 Databases of Wells

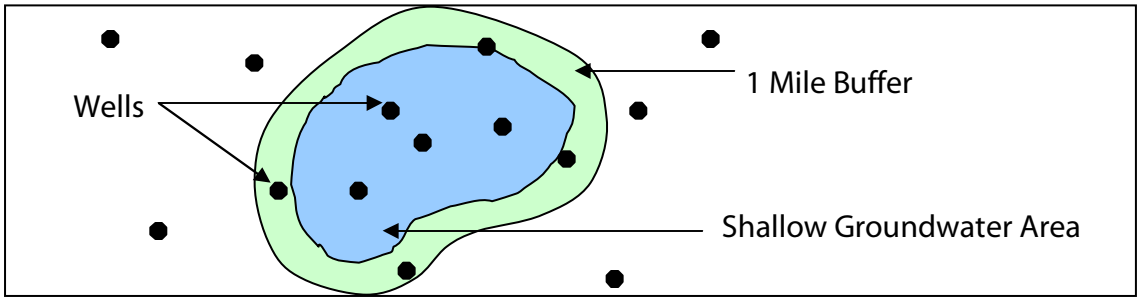
Field Names	Definition	Source
DEPTH_TO_W	Depth to Water in Well	ADWR GWSI
HOLE_DEPTH	Hole Depth	ADWR GWSI
LATITUDE	Well Latitude	ADWR GWSI
LONGITUDE	Well Longitude	ADWR GWSI
SITEUSE	Site Use	ADWR GWSI
WATERUSE	Water Use	ADWR GWSI
WELL_ALTIT	Well Altitude	ADWR GWSI
WL_ELEVATI	Water Level Elevation	ADWR GWSI
WL_MEAS_DA	Date of Well Measurement	ADWR GWSI
WELL_DEPTH, WELLDEPTH	Well Depth	ADWR GWSI and Wells-55
REGISTRATI, REGISTRY_1	Registry #	ADWR GWSI and Wells-55
UTM_EASTNA, UTM_NORTHN, UTMY, UTMX	Well UTM	ADWR GWSI and Wells-55
LASTNAME, FIRSTNAME, OWNER	Well Owner Name	ADWR GWSI and Wells-55
ADDRESS	Owner Address	ADWR Wells-55
APPROVED	Approval Date	ADWR Wells-55
BASIN	Basin	ADWR Wells-55
CANCELLED	Cancellation Status of Well	ADWR Wells-55
CASINGDEEP	Casing Depth	ADWR Wells-55
CASINGTYPE	Casing Type	ADWR Wells-55
CASINGWIDE	Casing Width	ADWR Wells-55
CITY	City of Owner	ADWR Wells-55
COMPANY	Company Owner Name	ADWR Wells-55
COUNTY	County	ADWR Wells-55
DRAWDOWN	Draw-Down in Well	ADWR Wells-55
DRILLER	Driller	ADWR Wells-55
DRILLLOG	Drill Log	ADWR Wells-55
INSTALLED	Installed Date	ADWR Wells-55
PROGRAM	Program	ADWR Wells-55
PUMPPOWER	Power of Pump	ADWR Wells-55
PUMPRATE	Pump Rate	ADWR Wells-55
PUMPTOTAL	Total Withdrawal Amount (AF) (1984-2006)	ADWR Wells-55
PUMPTYPE	Pump Type	ADWR Wells-55
STATE	State of Owner	ADWR Wells-55
SUBBASIN	Sub-basin	ADWR Wells-55
TESTRATE	Tested Rate of Pump	ADWR Wells-55
TOWNSHIP, NORTHSOUTH, RANGE, EASTWEST, SECTION, ACRE160, ACRE40, ACRE10	Well Cadastral Location (Public Land Survey System) with Quarter Sections	ADWR Wells-55
WATERLEVEL	Water Level	ADWR Wells-55
WATERSHED	Watershed	ADWR Wells-55
WATERUSE1 , WATERUSE2, WATERUSE3	Water Use	ADWR Wells-55
WELLTYPE	Exempt/Non-Exempt	ADWR Wells-55 and GWSI Combined(PAG)
WELLUSE1, WELLUSE2	Well Use	ADWR Wells-55
ZIPCODE	ZIP Code of Owner	ADWR Wells-55
Reg_No.	Registration Number of all Wells	PAG

The following data mining steps were used to sort and clean the data. These steps are also graphically represented in a flow chart in Figure 3.

Step 1: Two GIS data files provided by ADWR were merged using the merge function of ArcGIS. Wells that did not have a registration number were deleted from the database. Only wells with a registration number were considered for the next step.

Step 2: Wells that were situated inside a one-mile buffer for shallow groundwater areas were included in the database. Figure 2 shows a schematic drawing of a blue zone representing the shallow groundwater area and a green zone representing a one-mile buffer around the shallow groundwater area, both of which were included for the well inventory. The one-mile buffer was considered to be closely connected with the central shallow groundwater area (blue) and thus included in the final shallow groundwater area. Many shallow groundwater areas shared boundaries and had overlapping buffer zones. Wells located in the overlapping buffer zones were included in both shallow groundwater areas.

Figure 2. Sketch of a Shallow Groundwater Area and one-mile buffer used for selecting shallow groundwater wells from the database



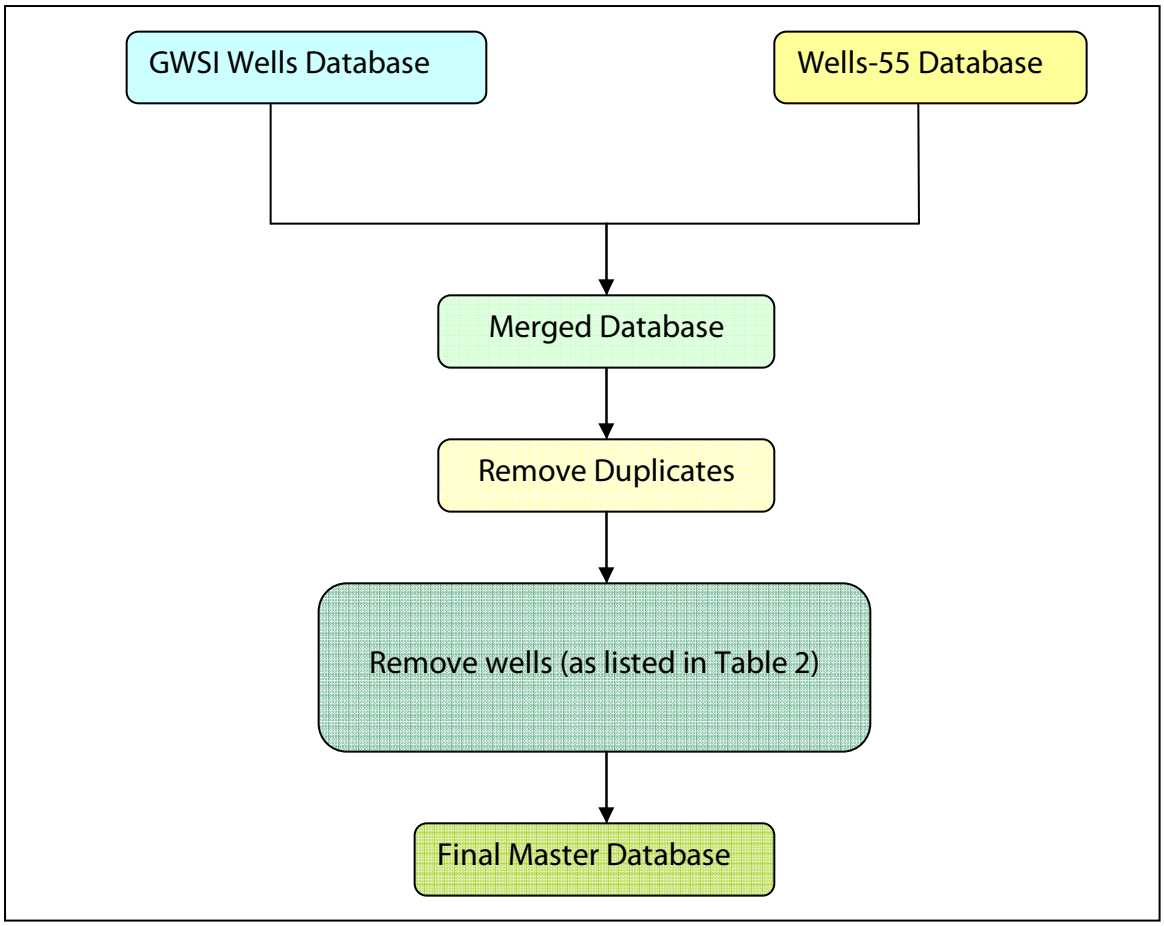
Step 3: All duplicate records (as identified by comparing registration numbers) were deleted. Since every well has a unique registration number, any repetition of the registration number indicated the presence of a duplicate record.

Step 4: All wells that were used for exploration, monitoring, cleaning-up purposes or had been destroyed or capped were deleted from the database. Table 2 provides a detailed list of criteria that were used to remove unnecessary well records.

Step 5: The remaining wells were either exempt or non-exempt based on their pumping characteristics. ADWR-GWSI databases categorized most of the wells as either exempt or non-exempt. Some wells that did not have a category name were categorized as exempt or non-

exempt by PAG based on their well type or water use. Wells in the Wells-55 database were assumed to be exempt if they did not have any pumping rates reported. Once all wells were categorized as exempt or non-exempt, further data analysis was conducted.

Figure 3. Steps involved in data mining



DATA ANALYSIS

***Non-exempt wells*:** Average and total annual water withdrawal volumes were calculated for each shallow groundwater area, based on the withdrawal amounts reported. Both average and total annual volume of water withdrawn were plotted against time (in years). A linear trend line was fitted for each plot to observe the trend over the last 22 years. Information is presented for the 31 shallow groundwater areas that have non-exempt wells with pumping data in the form of graphs in Appendix B of this report. The trend lines indicate increased or decreased water withdrawal over the last 22 years within each shallow groundwater area.

Exempt wells: As mentioned earlier, exempt wells are only permitted to withdraw a maximum of 35 gallons per minute. Because exempt well owners are not required to report water withdrawals from their wells to ADWR, pumping volumes can only be estimated. As a result, neither the GWSI database nor the Wells-55 database has any annual withdrawal data for exempt wells. Because there are many more exempt wells than non-exempt wells, lack of information on exempt wells leads to poor estimates for total water withdrawn in shallow groundwater areas. ADWR staff indicated that 0.5 - 1 Acre Feet (AF) would be a safe assumption of annual withdrawal made by exempt wells in the Tucson AMA (Kenneth Seasholes, personal communication). In keeping with this suggestion, we assumed that each exempt well withdrew 1 AF per year for the purposes of this study.

RESULTS AND DISCUSSION

Number of Wells Located in Shallow Groundwater Areas:

Shallow groundwater areas vary in size and location. In addition, the number of wells per shallow groundwater area also varies (Figure 4, Table 4). For example, the Thomas Canyon Shallow Groundwater Area had only one well, whereas, the Tanque Verde Shallow Groundwater Area contained 498 wells. The largest number of wells (exempt and non-exempt) per shallow groundwater area was found in the following areas:

- Arivaca Area
- Agua Caliente Area
- Davidson Canyon Area
- Tanque Verde Area
- Sabino Canyon Area

The smallest number of wells per shallow groundwater area was found in:

- Thomas Canyon
- Cocio Wash

Non-Exempt Wells:

A total of 347 non-exempt wells were located in the shallow groundwater areas included in this study. Out of the 31 areas, 12 had no non-exempt wells, nine had less than five non-exempt wells and seven of them had more than 20 exempt wells. In all cases but one, the areas had a greater

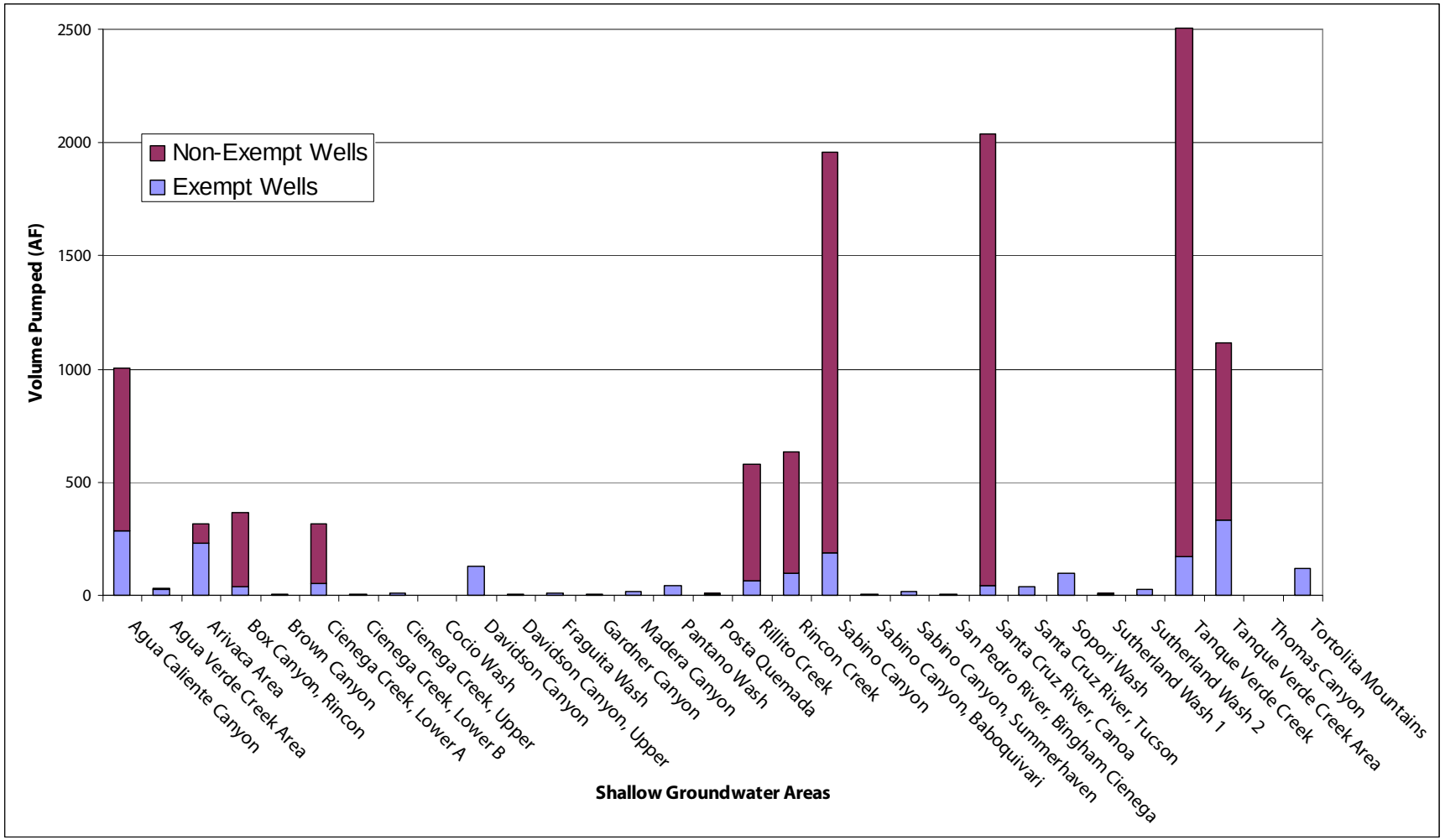
number of exempt wells than non-exempt wells. The areas with more than 20 non-exempt wells included:

- Agua Caliente Canyon
- Arivaca Area
- Rillito Creek
- Sabino Canyon Area
- Santa Cruz River (Tucson)
- Tanque Verde Creek
- Tanque Verde Creek Area

Exempt Wells:

A total of 1,656 exempt wells were found to be located in the shallow groundwater areas included in the study, as compared to 1,757 exempt wells reported in the 2007 report. The number of exempt wells was highest in the Tanque Verde Shallow Groundwater Area, followed by the Agua Caliente Area and Arivaca Area. Numbers of exempt wells were lowest in Cocio Wash and the Thomas Canyon Area. In some of the shallow groundwater areas, there were as many as 58 times more exempt wells than non-exempt wells, but over the entire study area, there were slightly fewer than five times more exempt wells than non-exempt wells. Even though in numbers, exempt wells far exceeded non-exempt wells, in terms of water withdrawal, non-exempt wells far exceeded exempt wells, if the assumption of 1 AF/Y withdrawal is correct. However, this trend would reverse if each exempt well were pumped at its permitted capacity of 35 gpm.

Figure 4. Number of wells located in Shallow Groundwater Areas



Values given in this figure were calculated based on 2006 well data.

Table 4. Tabulation of Shallow Groundwater Wells and Well Pumping Information

	EXEMPT WELLS			NON-EXEMPT WELLS			SUMMARY		
	# of Exempt Wells	Average Amount Withdrawn in 2006	Total Amount Withdrawn in 2006	# Non-Exempt Wells	Average Amount Withdrawn in 2006	Total Amount Withdrawn in 2006	Total of Exempt and Non-Exempt Well Withdrawal in 2006	Ratio of Exempt Wells to Non-Exempt Wells	Ratio of Total Withdrawn by Exempt to Non-Exempt Wells
Agua Caliente Canyon	284	1.00	284.00	65	42.32	719.36	1003.36	4.37	0.39
Agua Verde Creek Area	26	1.00	26.00	2	6.61	6.61	32.61	13.00	3.93
Arivaca Area	229	1.00	229.00	28	12.485	87.395	316.40	8.18	2.62
Box Canyon, Rincon	40	1.00	40.00	9	81.75	327	367.00	4.44	0.12
Brown Canyon	6	1.00	6.00	0	0	0	6.00		
Cienega Creek, Lower A	51	1.00	51.00	2	268	268	319.00	25.50	0.19
Cienega Creek, Lower B	6	1.00	6.00	0	0	0	6.00		
Cienega Creek, Upper	13	1.00	13.00	0	0	0	13.00		
Cocio Wash	1	1.00	1.00	4	0	0	1.00	0.25	
Davidson Canyon	128	1.00	128.00	0	0	0	128.00		
Davidson Canyon, Upper	4	1.00	4.00	0	0	0	4.00		
Fraguita Wash	11	1.00	11.00	0	0	0	11.00		
Gardner Canyon	8	1.00	8.00	0	0	0	8.00		
Madera Canyon	14	1.00	14.00	0	0	0	14.00		
Pantano Wash	44	1.00	44.00	9	0.66	1.31	45.31	4.89	33.59
Posta Quemada	4	1.00	4.00	1	6.61	6.61	10.61	4.00	0.61
Rillito Creek	64	1.00	64.00	50	32.34	517.38	581.38	1.28	0.12
Rincon Creek	95	1.00	95.00	16	89.76	538.57	633.57	5.94	0.18
Sabino Canyon	189	1.00	189.00	98	70.75	1768.72	1957.72	1.93	0.11
Sabino Canyon, Baboquivari	8	1.00	8.00	0	0	0	8.00		
Sabino Canyon, Summerhaven	15	1.00	15.00	1	0.12	0.12	15.12	15.00	125.00
San Pedro River, Bingham Cienega	8	1.00	8.00	0	0	0	8.00		
Santa Cruz River, Canoa	41	1.00	41.00	4	3609	10827	10868.00	10.25	0.00
Santa Cruz River, Tucson	37	1.00	37.00	21	0.1	0.1	37.10	1.76	370.00
Sopori Wash	95	1.00	95.00	0	0	0	95.00		
Sutherland Wash 1	4	1.00	4.00	2	4.14	4.14	8.14	2.00	0.97
Sutherland Wash 2	26	1.00	26.00	3	0.93	2.8	28.80	8.67	9.29
Tanque Verde Creek	171	1.00	171.00	107	75.24	2332.54	2503.54	1.60	0.07
Tanque Verde Creek Area	332	1.00	332.00	66	55.99	783.92	1115.92	5.03	0.42
Thomas Canyon	1	1.00	1.00	0	0	0	1.00		
Tortolita Mountains	116	1.00	116.00	2	0	0	116.00	58.00	
Summary	**1656**	**1.00**	**1656**	**347**	**269.45**	**93500**	**95156**	**4.77**	**0.02**

Note: Each shallow groundwater area includes wells within its boundaries plus those within one mile buffer zone. Some buffer zones overlap in the study area. The summary row indicates the totals for all the shallow groundwater areas combined.

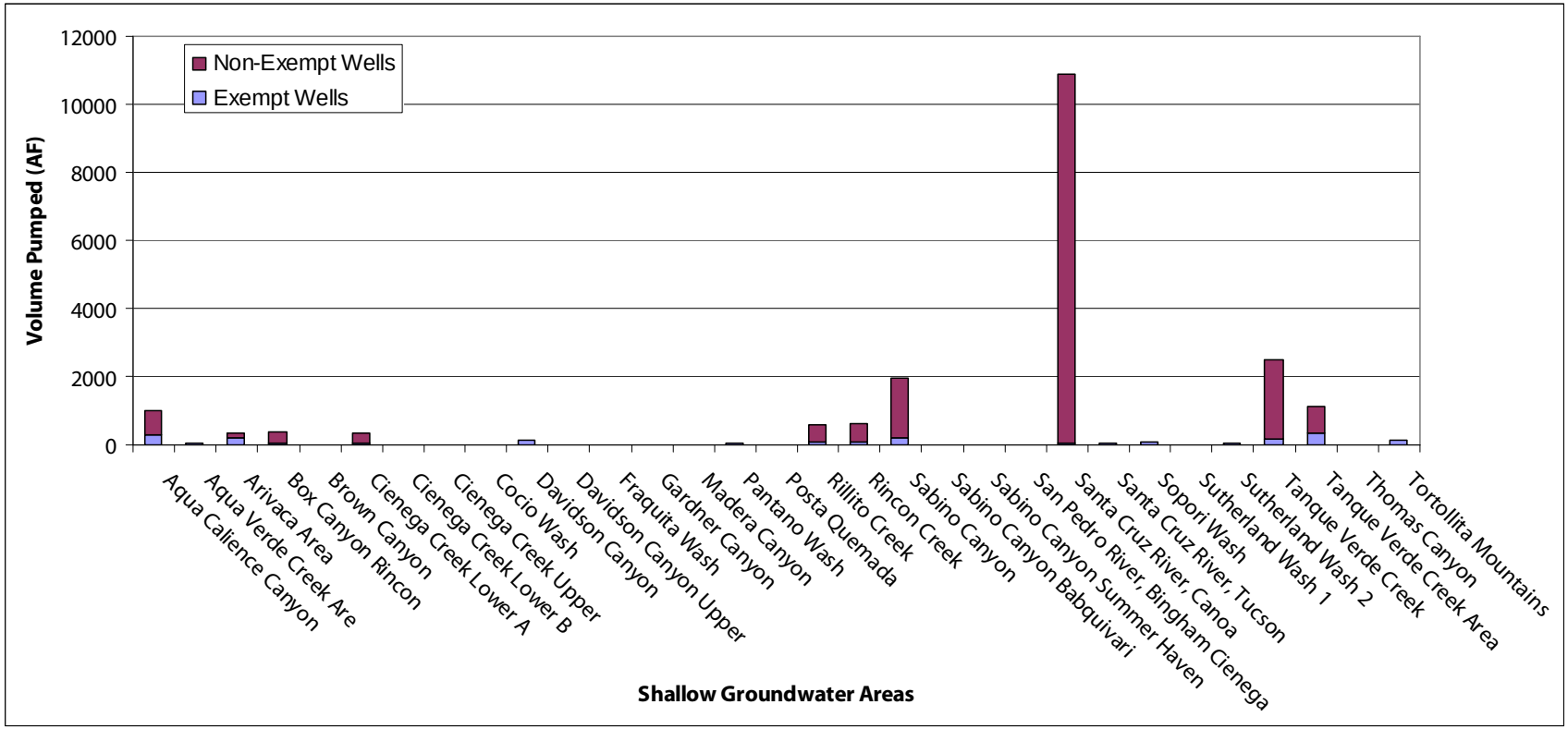
Groundwater Withdrawal from Shallow Groundwater Areas:

Non-exempt wells collectively withdrew several times more water annually compared to the exempt wells (with the assumption that exempt wells withdraw 1 AF per year) (Figure 5). Santa Cruz River at Canoa withdrew more than 10,000 AF per year in 2006, which was several times higher than most of the other shallow groundwater areas. Tanque Verde Creek, Sabino Canyon, and Tanque Verde Creek Area withdrew between 1,000 and 2,000 AF per year in 2006. Cocio Wash and Thomas Canyon withdrew the least amount of water in 2006 (1AF each). Other than a few shallow groundwater areas, the rest of the areas withdrew less than 30 AF per year in 2006.

Due to a few outliers like Santa Cruz and Tanque Verde Creek, the average groundwater withdrawal per year was 654 AF, whereas the median groundwater withdrawal was only 32 AF per year. Based on our assumptions, it can be concluded that non-exempt wells account for most of the groundwater withdrawal in most shallow groundwater areas. Also, there is a significant spatial variation in groundwater withdrawal among different shallow groundwater areas.

Twelve shallow groundwater areas: Brown Canyon, Cienega Creek Lower B, Cienega Creek Upper, Fraguita Wash, Gardner Canyon, Madera Canyon, Sabino Canyon (Baboquivari), San Pedro River (Bingham Cienega), Sopori Wash, and Thomas Canyon did not have any non-exempt wells. So, no trend analysis for these shallow groundwater areas could be performed.

Figure 5. Water pumped by Exempt and Non-Exempt wells



Values given in this figure were calculated based on 2006 well data.

Pumping Trends for Non-Exempt Wells in Each Shallow Groundwater Area:

Graphs 1 and 2 in Appendix B show the total volume pumped and average annual pumping rate for all non-exempt wells included in this study. Graph 1 shows that the amount of groundwater withdrawn from all the study areas combined remained relatively consistent over the years, although relatively more groundwater was pumped in 1989, while less was pumped in 1993 and 2002-2003. The fact that the average annual pumping rate increased over that time indicates that, in general, fewer wells are being used to withdraw the same amount of water.

Inspection of the graphs showing trends for individual shallow groundwater areas (Appendix B) indicates that seven of the individual areas have undergone increased groundwater pumping from non-exempt wells, while seven have shown decreased groundwater pumping and three have stayed the same. These results mimic the combined findings for all the basins continued (Appendix B, Graphs 1 and 2). Six individual areas show both an increased groundwater production and also contain more than 40 exempt wells. Further investigation of these areas might be warranted because the coupling of increased volumes produced from non-exempt wells and the possibility that exempt wells may be pumping more than 1 AF/year might make these areas at risk for overpumping and excessive draw down. These areas include:

Arivaca Area	Rincon Creek
Box Canyon Rincon	Santa Cruz River Canoa
Cienega Creek Lower	Tanque Verde Creek

However, data from both Arivaca and Tanque Verde show that the volume of groundwater pumped from non-exempt wells has significantly decreased since 2003 and 1999 respectively.

Agua Caliente Area

A total of 65 non-exempt wells and 284 exempt wells were located in this shallow groundwater area in 2006. Non-exempt wells pumped approximately 720 AF of groundwater in 2006, as compared to 2,000 AF withdrawn in 1984. Overall, both annual total withdrawal and annual average pumping rates declined since 1984 in the Agua Caliente area, although a period of increased pumping occurred in the mid and late1980s (1985-89) (Appendix B: Graphs 3 and 4). The year 1993 represented a very low period of pumping.

Agua Verde Area

A total of two non-exempt and 26 exempt wells were located in this shallow groundwater area in 2006. Non-exempt wells pumped 6.61 AF of groundwater in 2006, as compared to 5.8 AF

withdrawn in 1984 (Appendix B: Graph 5). Pumping rates slightly increased since 1984, with significant peaks occurring in 1989 and slightly increased pumping in 1995.

Arivaca Area

A total of 28 non-exempt and 229 exempt wells were located in this shallow groundwater area in 2006. Non-exempt wells pumped slightly less than 90 AF of groundwater in 2006 compared to 150 AF withdrawn in 1984 (Appendix B: Graphs 6 and 7). Overall, both annual total withdrawal and annual average pumping rates increase since 1984 in the Arivaca area. Increased total water pumped was most evident in 2003.

Box Canyon

A total of nine non-exempt and 40 exempt wells were located in this shallow groundwater area in 2006. Non-exempt wells pumped approximately 340 AF of groundwater in 2006 compared to 100 AF in 1984. There were 40 exempt wells located in this area. Annual total withdrawal and annual average pumping rates slightly increased, but varied significantly over the 22 year study period. Periods of increased pumping were found in 1985-87, 1993, and 2001-04 and 2006. Periods showing low pumping rates include 1995-2000 and 2005 (Appendix B: Graphs 8 and 9).

Cienega Creek Lower A

A total of two non-exempt and 51exempt wells were located in this shallow groundwater area in 2006. Pumping volumes were reported for only one of the non-exempt wells and this well has only been active since 1991. It pumped approximately 275 AF of groundwater in 2006 compared to 5 AF in early 1991 (Appendix B: Graphs 10 and 11). The trendline shows a sharp increase in pumping rate over the last 10 years, with a peak in 2005.

Pantano Wash

A total of nine non-exempt and 44 exempt wells were located in this shallow groundwater area in 2006. Non-exempt wells pumped approximately 1.31 AF of groundwater in 2006 compared to 140 AF in 1984 (Appendix B: Graphs 12 and 13). Annual total withdrawal and annual average pumping rates declined over the last two decades. However, pumping rates were highly variable until 2000. Pumping rates were high in 1985-87, 1993 and 1998-89. Low pumping rates were observed in 1989 and 2000-06.

Posta Quemada Area

A total of one non-exempt well and 4 exempt wells were located in this shallow groundwater area in 2006. One non-exempt well pumped out 6.61 AF of water in 2006 compared to 9 AF in 1984. Annual average pumping and annual total withdrawal declined over the last two decades (Appendix B: Graph 14). High pumping rates were observed in 1989 and 1995.

Rillito Creek Area

A total of 50 non-exempt and 64 exempt wells were located in this shallow groundwater area in 2006. Fifty non-exempt wells pumped out 517 AF of water in 2006 as compared to 1,000 AF in 1984. Annual total withdrawal and annual average pumping rates declined over the last two decades (Appendix B: Graphs 15 and 16).

Rincon Creek Area

A total of 16 non-exempt and 95 exempt wells were located in this shallow groundwater area in 2006. Sixteen non-exempt wells pumped out 540 AF of water in 2006 compared to almost nothing in 1984. Annual total withdrawal and annual average pumping rates have increased in the last two decades (Appendix B: Graphs 17 and 18).

Sabino Canyon (Summerhaven)

A total of one non-exempt and 15 exempt wells were located in this shallow groundwater area in 2006. One non-exempt well pumped out 0.1 AF of water in 2006 compared to 0.6 AF in 2002. Unlike many other shallow groundwater areas, this shallow groundwater area only had one non-exempt well that was active since 2002, thus a 22 year trend could not be analyzed here. Annual total withdrawal and annual average pumping rates have declined over the last five years in this shallow groundwater area (Appendix B: Graph 19).

Sabino Canyon

A total of 98 non-exempt wells and 189 exempt wells were located in this shallow groundwater area in 2006. Ninety-eight non-exempt wells pumped out 75 AF in 2006 compared to 45 AF in 1984. Annual total withdrawal and annual average pumping rates increased in the last two decades in this shallow groundwater area (Appendix B: Graph 20 and 21). There was a sharp increase in pumping in 1989.

Santa Cruz River (Canoa)

A total of four non-exempt and 41 exempt wells were located in this shallow groundwater area in 2006. Four non-exempt wells pumped out 10,000 AF of water in 2006 compared to 7,000 AF in 1984. Annual total withdrawal and annual average pumping rates have increased in the last two decades (Appendix B: Graphs 22 and 23). There was a sharp decline in water pumping in 2002.

Santa Cruz River (Tucson)

A total of 21 non-exempt wells and 37 exempt wells were located in this area in 2006. Twenty-one non-exempt wells pumped out almost zero AF of water in 2006 compared to 700 AF in 1984. Annual total withdrawal and annual average pumping rates have declined sharply over the last two decades (Appendix B: Graphs 24 and 25).

Sutherland Wash 1

A total of two non-exempt and four exempt wells were located in this area in 2006. Two non-exempt wells pumped out 4.14 AF of water in 2006 compared to 17 AF in 1984. Annual total withdrawal and annual average pumping rates have declined over the last two decades (Appendix B: Graphs 26 and 27). There were a few upward spikes in late 1980s and early 1990s, but beyond that time frame water pumping in this shallow groundwater area has been generally stable.

Sutherland Wash 2

A total of three non-exempt and 26 exempt wells were located in this area in 2006. Three non-exempt wells pumped out 2.8 AF of water in 2006 compared to 10 AF in 1984. Annual total withdrawal and annual average pumping rates have declined over the last two decades (Appendix B: Graphs 28 and 29).

Tanque Verde Creek Area

A total of 66 non-exempt and 332 exempt wells were located in this area in 2006. Sixty six non-exempt wells pumped out 783 AF of water in 2006 compared to 1,000 AF in 1984. Annual total withdrawal and annual average pumping rates have declined over the last two decades (Appendix B: Graphs 30 and 31).

Tanque Verde Creek

A total of 107 non-exempt and 171 exempt wells were located in this area in 2006. One-hundred and seven non-exempt wells pumped out 2,333 AF of water in 2006 compared to 3,000 AF in 1984. Annual total withdrawal and annual average pumping rates have declined over the last two decades (Appendix B: Graphs 32 and 33).

Tortolita Mountains

A total of two non-exempt and 116 exempt wells were located in this area in 2006. Two non-exempt wells pumped out zero AF of water in 2006 compared to 17 AF in 1984. Annual total withdrawal and annual average pumping rates have declined over the last two decades (Appendix B: Graphs 34 and 35).

Data Limitations:

Several data and methodology limitations were encountered when conducting this investigation. Data was often inconsistent in the various databases used for the study and sometimes the water withdrawal information was unavailable from ADWR. In addition, it may not be possible to directly compare this investigation with previous studies conducted by PAG in 2000 and 2006. This is because the methodology changed slightly, more shallow groundwater areas were added

and, in many cases, boundaries of the existing shallow groundwater areas were modified. For this report, non-exempt well volumes were not available for outside the Tucson AMA because they are not required to report pumping volumes to ADWR. For shallow groundwater areas located entirely outside the Tucson AMA (e.g. Sopori Wash), does not have any well volume reported for its non-exempt wells which limits data analysis for this shallow groundwater area. Such unavailability of data on some shallow groundwater areas limits our conclusions.

Data Inconsistency and Cross-Listing Comparisons

Not all well records provided in the databases contained completed attribute fields. This occurred because the sources of information varied significantly for the Wells-55 and the GWSI databases (See Data Sources section above). Inconsistent data availability was seen for every field of data including registration number, location, exempt status, pumping volumes, cancellation date, installation date, well depth etc. If the registration number was not available, other data were cross referenced to determine if duplicate well records were listed. The few wells with no location information were excluded from this report. Non-located wells account for only about 0.05% of the entire ADWR database, which probably had minimal impact on the results of this study.

Unavailability of Pumping Information

Pumping information was not available for all the wells included in this study. ADWR relies on non-exempt well owners to submit their annual withdrawal amounts for the Wells-55 database by March 31 each year. Therefore, when a well record lists zero as an annual pumping volume, it is assumed that is not an absence of reported pumpage. Many wells in the GWSI database could not be cross-listed in the Wells-55 database, and since the Wells-55 database provided pumping volumes and status of wells as either exempt or non-exempt, some assumptions were made. Since non-exempt wells are required to report withdrawal rates to the state, wells listed only in the GWSI database were assumed to be exempt. For non-exempt wells with no pumping information, the pumping volume was assumed to be zero. For this report, non-exempt volume estimates were not included for wells outside of the TAMA since those areas did not report pumping volumes to ADWR.

Trend lines used in the graphs are based on linear regression equation that was prepared using Microsoft Excel. All trend lines represent simple linear regression prepared based on 22 data points (for 22 years). The significance levels for the trend lines were not calculated or presented in this report. The trend lines were used as a visual tool to observe and study linear trends for different shallow groundwater areas.

Changes Incorporated into this Report

As mentioned earlier, nine new shallow groundwater areas were added in this report. Some of the old shallow groundwater areas were divided into two separate shallow groundwater areas. Due

to such changes, comparison between shallow groundwater areas of this report and shallow groundwater areas in the previous PAG reports is difficult. In some cases boundaries of old shallow groundwater areas were redefined like Sopori Wash area. As a result, the current Sopori wash area includes a larger area and more wells.

Data mining methods used in 2000 and 2007 were somewhat different from the methods used in 2008. None of the previous reports included any graphical trend analyses, which makes it harder to compare 2008 trends with those presented in previous reports. In additions, average well withdrawal rates were calculated using slightly different assumptions in previous studies, making temporal comparisons difficult.

CONCLUSIONS AND RECOMMENDATIONS

This report documents groundwater pumping trends for 31 shallow groundwater areas in eastern Pima County. Most of these areas are adjacent to the Catalina, Rincon and Santa Rita Mountains that ring the eastern side of the Tucson basin. These areas vary in size from 312,581 sq. ft. for Posta Quemada to 207,828,544 sq. ft. for Tanque Verde Creek Area and most of them contain both non-exempt wells and exempt wells. It is impossible to determine the total amount of groundwater withdrawn in these areas because no information is known about the actual amount of water that is being pumped from the 1,656 exempt wells that exist. Results presented in this report assume that exempt wells are pumping 1 acre foot of groundwater per year as recommended by ADWR.

As groundwater resources receive more attention due to growth in our region, the need to understand total pumping from sensitive groundwater areas will become more of a priority. Currently, the fact that exempt well owners do not have to report pumping rates makes a complete understanding of our groundwater usage impossible. Rule changes at the state level would be required to remedy this situation.

Data presented in this report indicate that total pumping in eastern Pima County has remained stable over the last 22 years, even though many individual shallow groundwater areas have experienced increases or decreases in total pumping. Six shallow groundwater areas experienced increases in total water pumping over the last 22 years, includes Arivaca, Agua Verde Creek, Box Canyon Rincon, Cienega Creek (Lower), Rincon Creek and Santa Cruz (Canoa). Further studies could evaluate the cause of such increases in water pumped from certain shallow groundwater areas. Total water pumping has gone down in nine shallow groundwater areas - Agua Caliente, Pantano Wash, Posta Quemada, Sutherland Wash (1 and 2), Tanque Verde, Tortolita, Rillito Creek and Santa Cruz (Tucson). Of these nine areas, Agua Caliente, Pantano Wash and Santa Cruz (Tucson) have experienced a steep decline in total water pumping over the last 22 years.

Recommendations for Future Investigations

Future investigations could improve our understanding about pumping trends and resource availability in individual shallow groundwater areas.

More robust spatial and temporal trend analysis could be added as part of future updates. Trend analysis in this report has brought forward some specific shallow groundwater areas that have either experienced a sharp increase or a sharp decrease in well pumping over the last 20 years. It was not within the scope of this report to conduct a detailed analysis for every shallow groundwater area, thus such areas of interest were left unexplored.

Water pumping is closely linked with economic and population growth of a region. It would be worthwhile to study water pumping in shallow groundwater areas in relation to economic change, population growth, land use change and policy change in the Tucson region. A cause and effect study might be able to provide a better explanation of the trends described in this report.

Additionally, future well investigations of this type may be simplified by work currently being conducted as part of the Arizona Wells project, by the University of Arizona (SAHRA) group. This project will merge the Wells-55 and GWSI databases and provide Web downloads to the public. The project will make basic water withdrawal analyses much more accessible; however, caution should be used because data mining techniques incorporated into the Arizona Wells project may not meet the needs of all users.

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APPENDIX A

Maps of shallow groundwater areas in eastern Pima County

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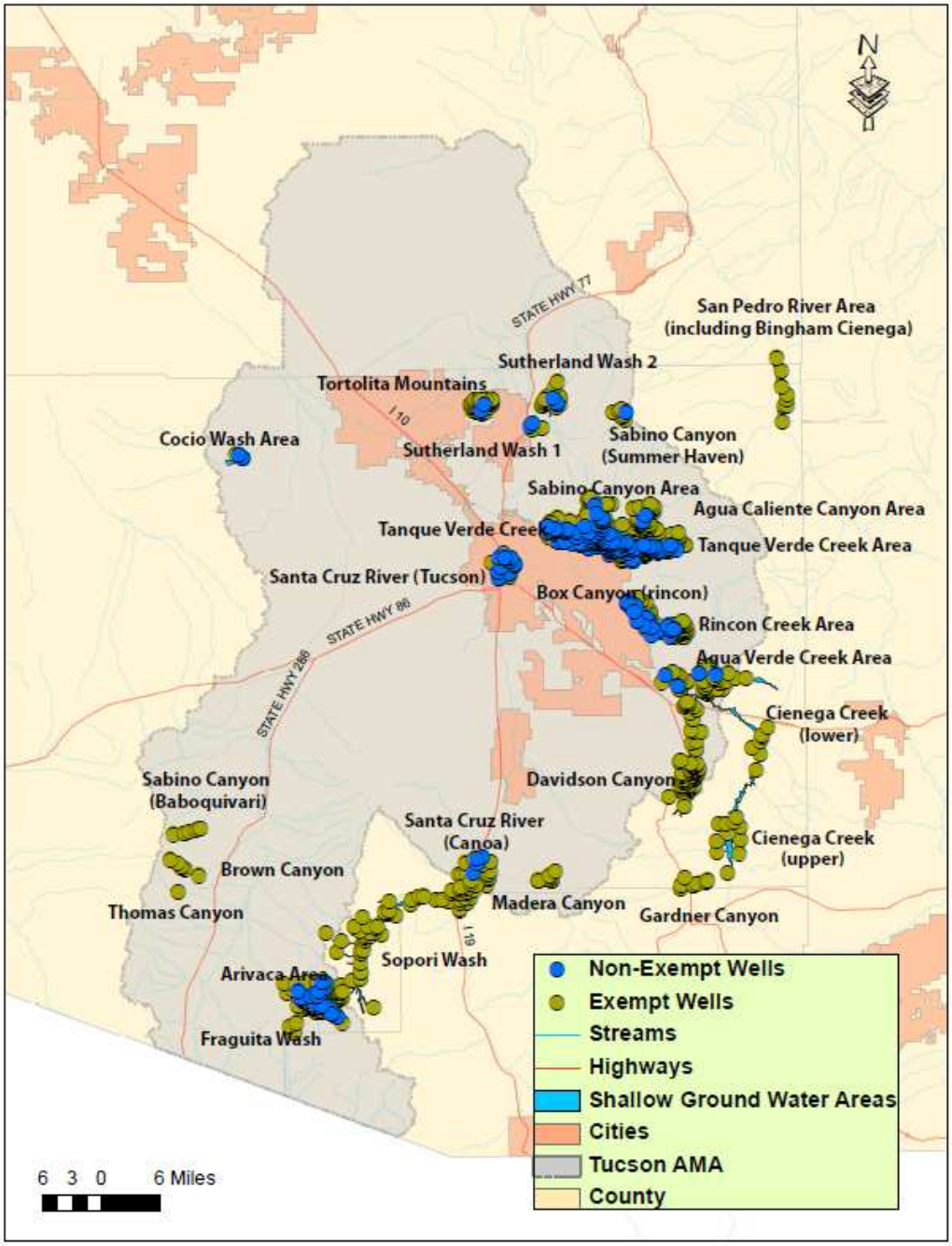
Maps showing exempt and non-exempt wells located in shallow groundwater areas of eastern Pima County

Map A

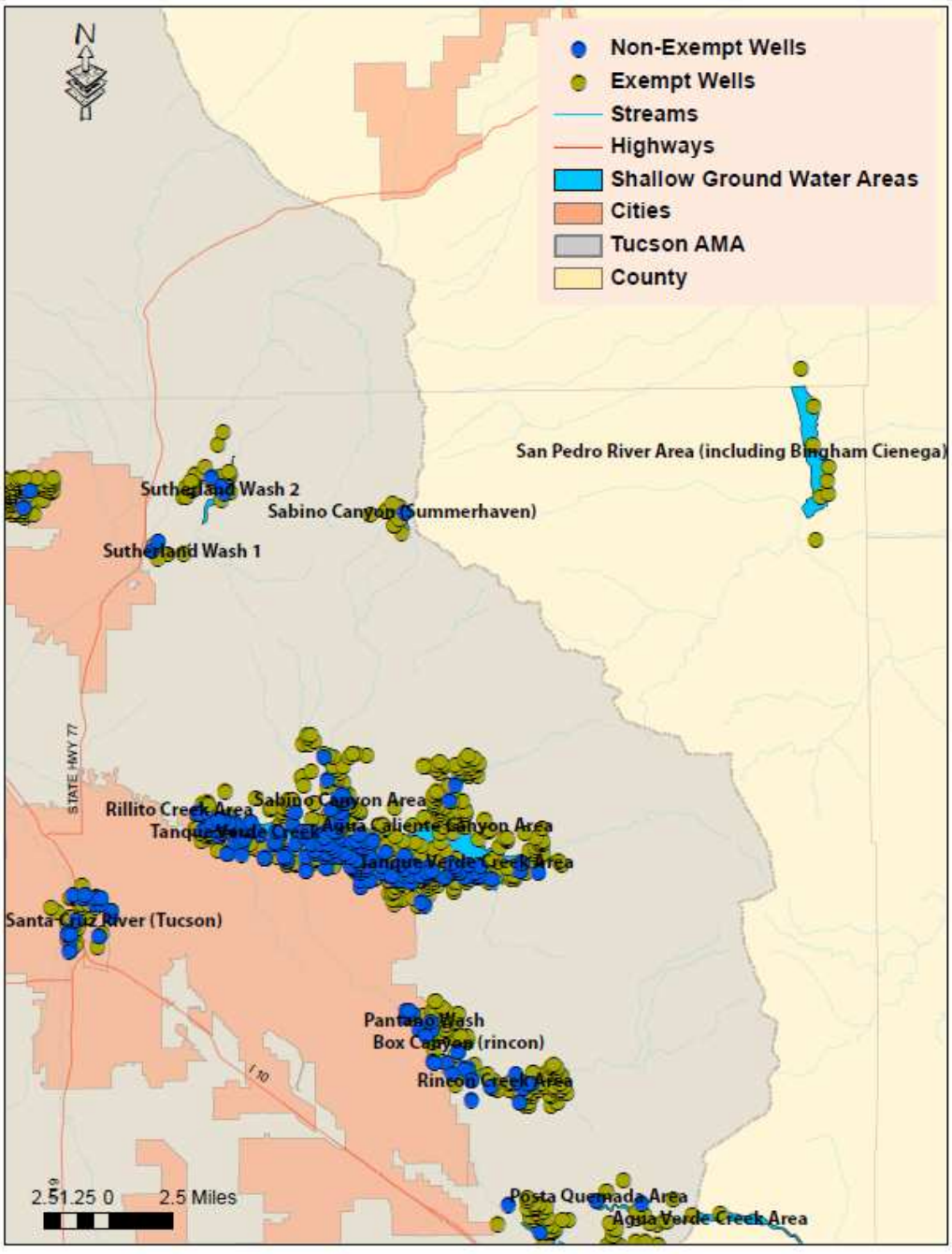
Exempt and Non-Exempt Wells in Shallow Groundwater Areas of Eastern Pima County



Map Disclaimer: "The information included on this map has been compiled from a variety of sources and is subject to change without notice. Pima Association of Governments makes no representation or warranties, express or implied, as to accuracy, completeness, timliness, or rights to the use of such information." Map prepared in March 2008.

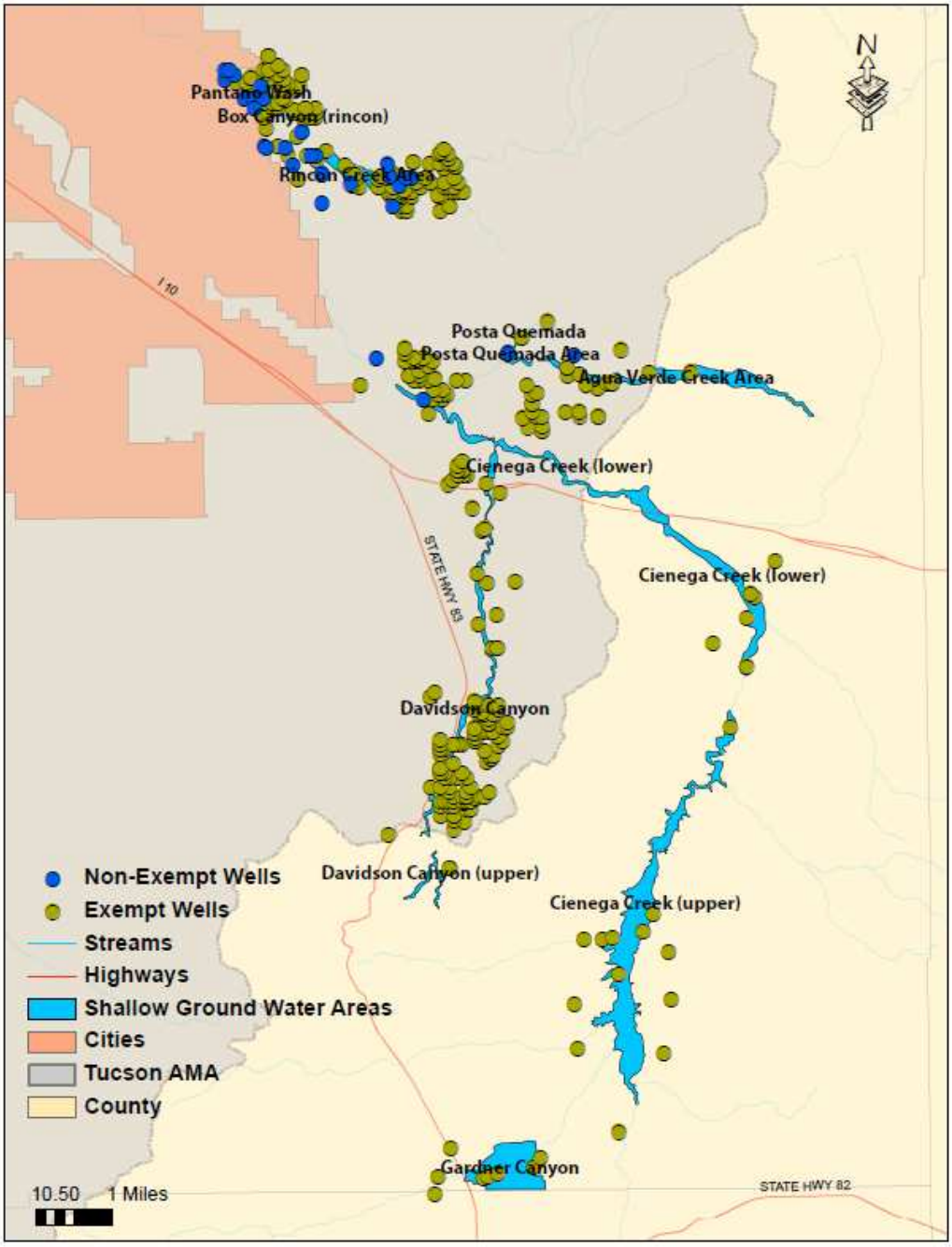
MAP B

Northeastern Shallow Groundwater Areas of Pima County



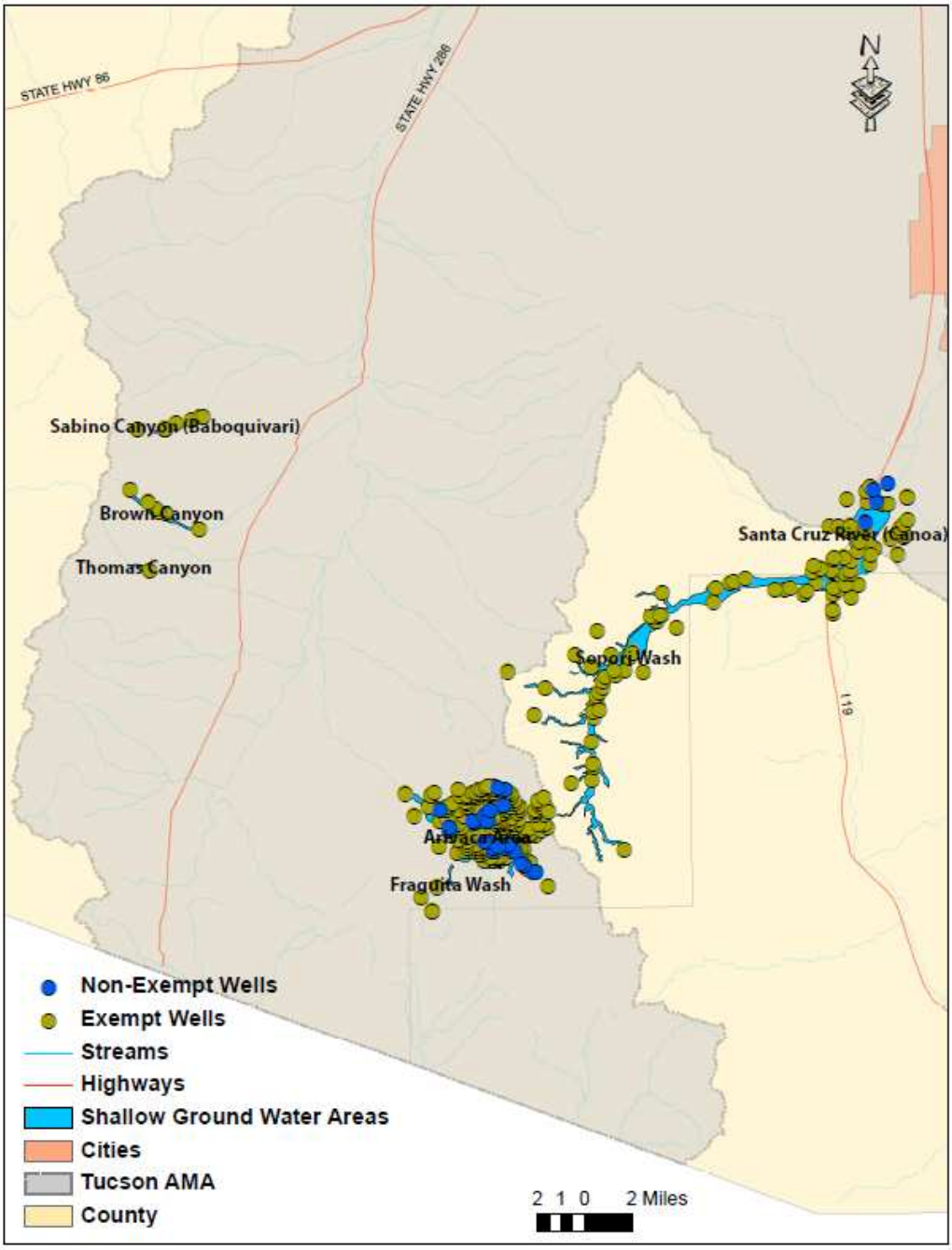
MAP C

Southeastern Shallow Groundwater Areas of Pima County



MAP D

Southwestern Shallow Groundwater Areas of Pima County



Appendix B

Graphical representations of pumping trends in shallow groundwater areas

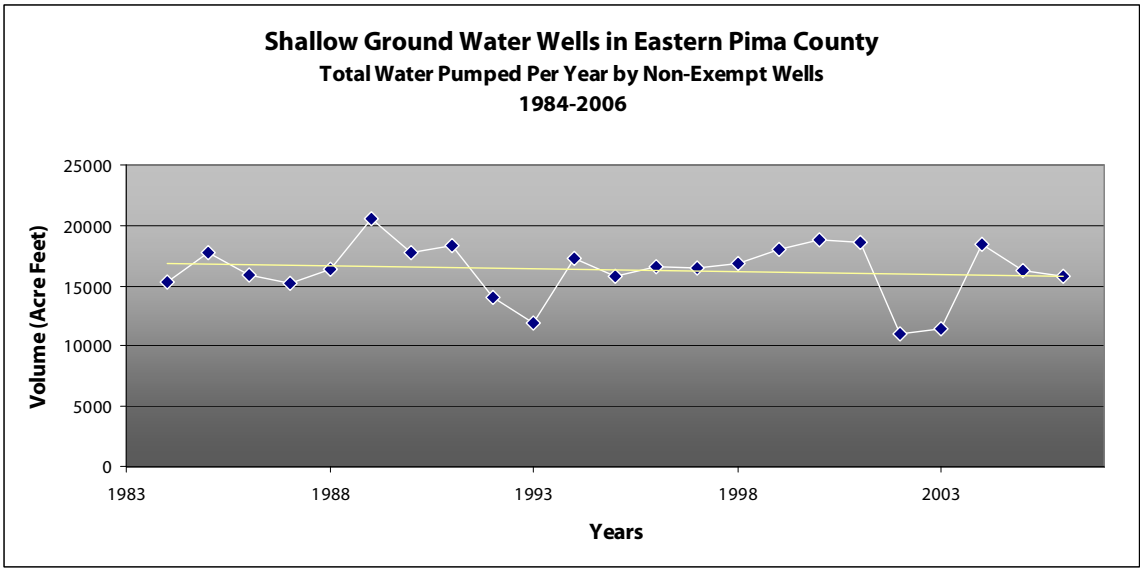
Graphs showing average annual pumping rates and total water pumped per year from non-exempt wells in various shallow groundwater areas of Eastern Pima County

Table of Contents

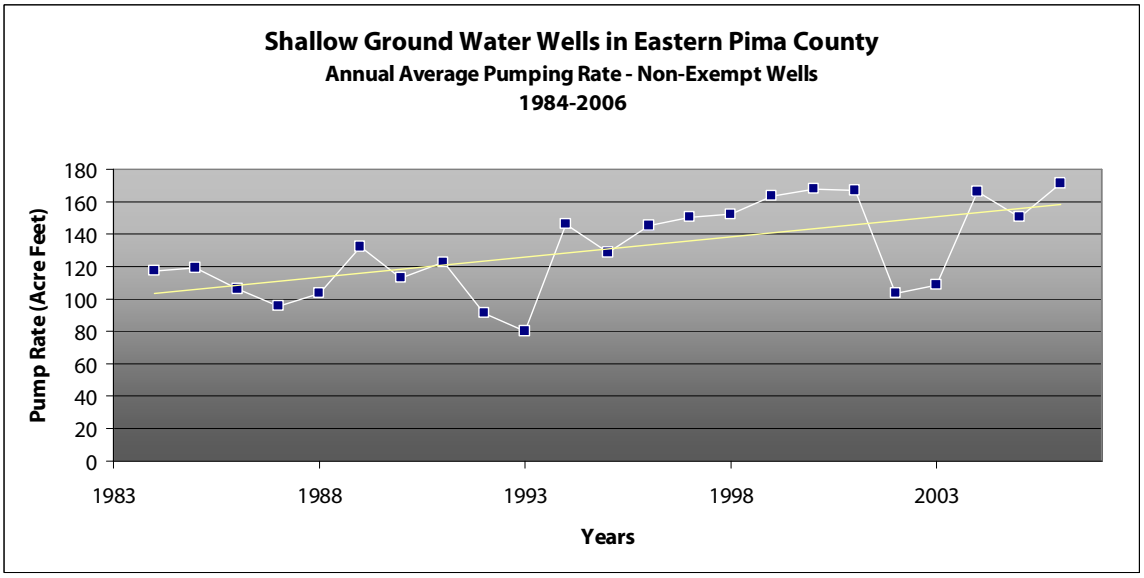
Shallow Groundwater Withdrawal Trends for the Eastern Pima County
(1984-2006)

Eastern Pima County

Graph 1

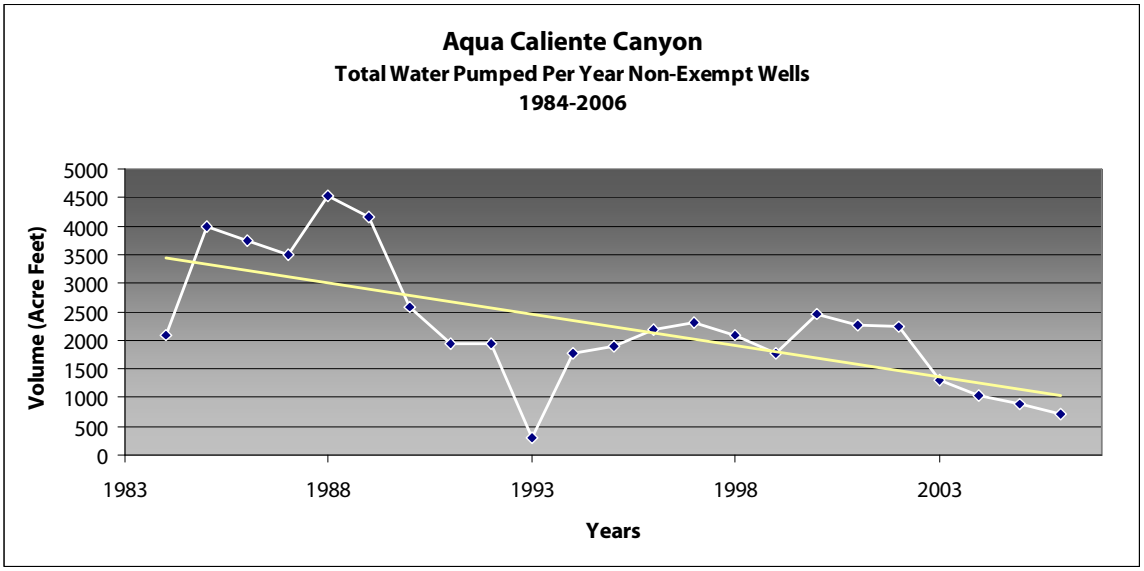


Graph 2

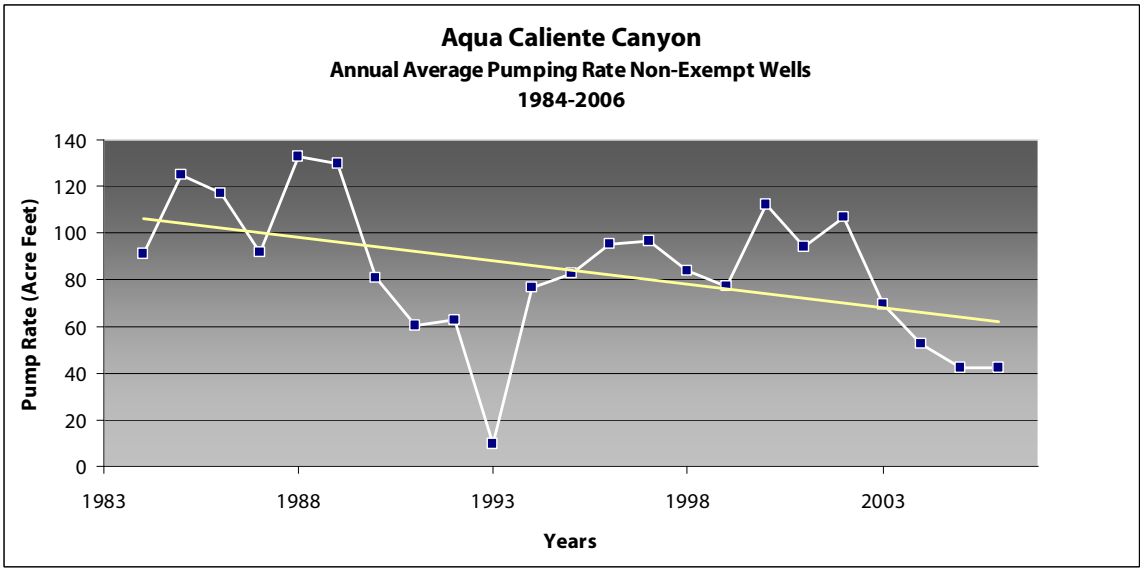


Agua Caliente Canyon

Graph 3

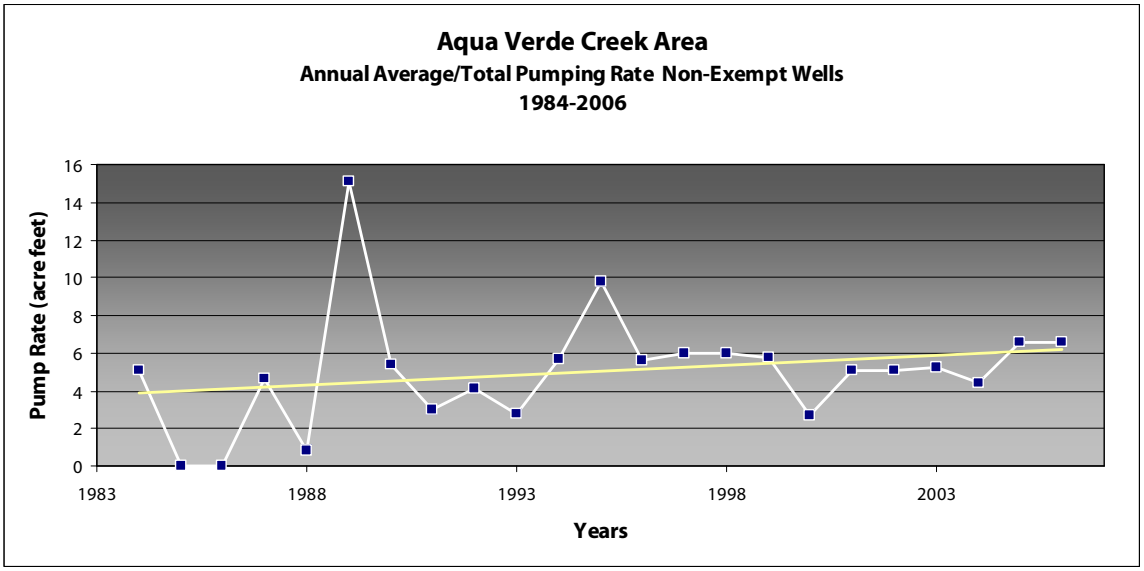


Graph 4



Agua Verde Creek Area

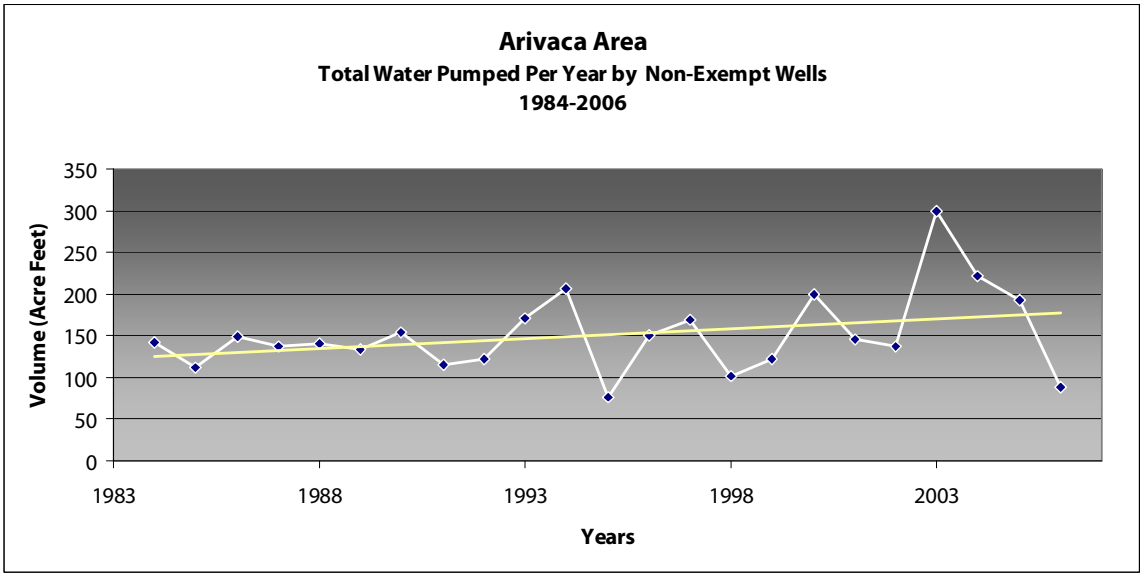
Graph 5



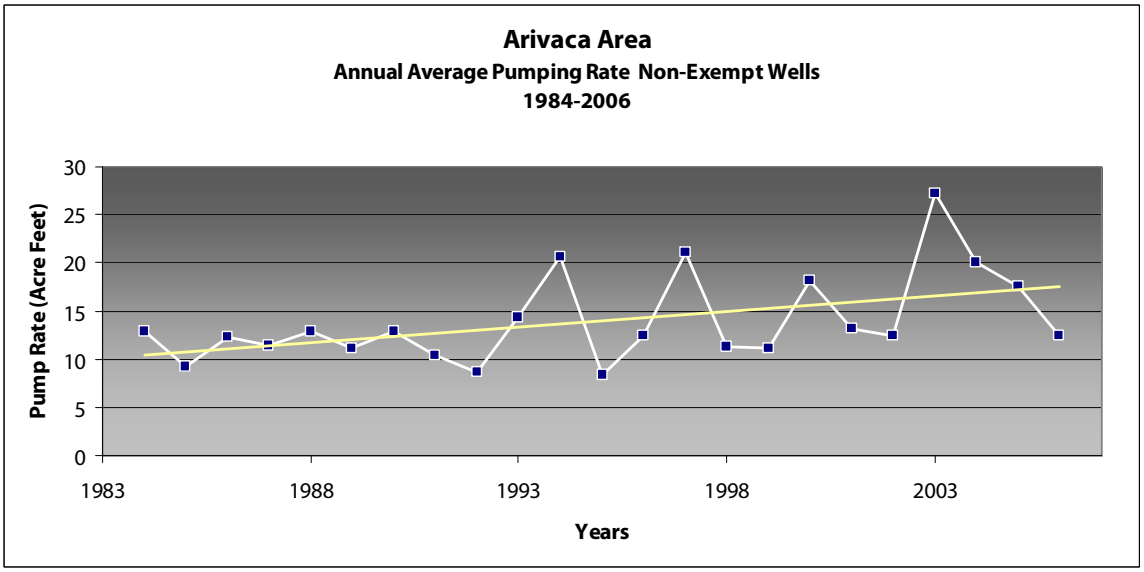
Agua Verde Creek shallow groundwater area had only one non-exempt well that reported pumping rates to ADWR. Therefore separate graphs were not prepared for annual total withdrawal rate of water pumping and annual average rate of water pumping.

Arivaca Area

Graph 6

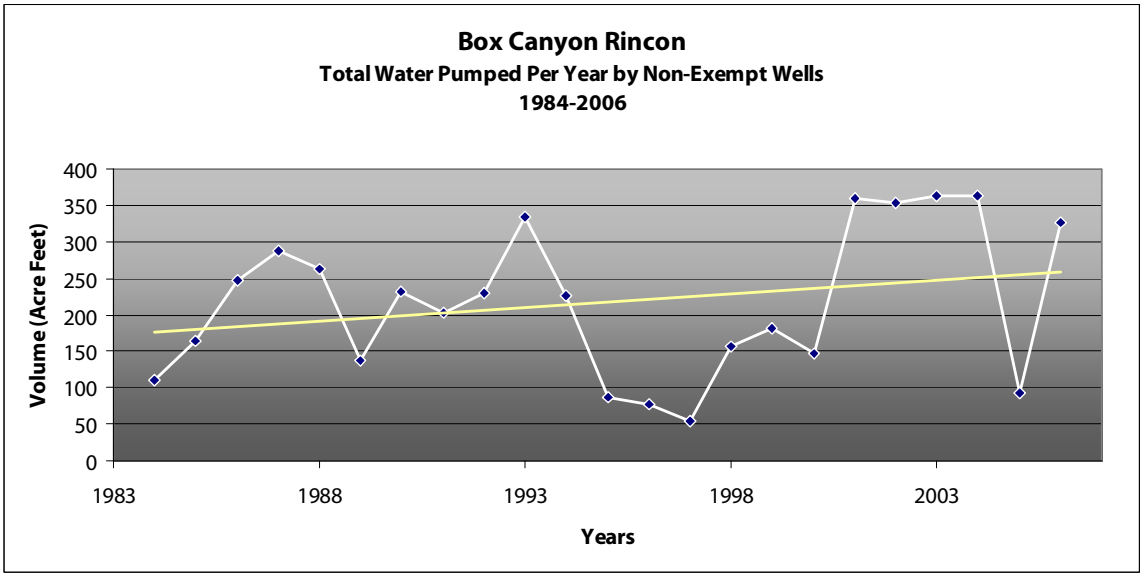


Graph 7

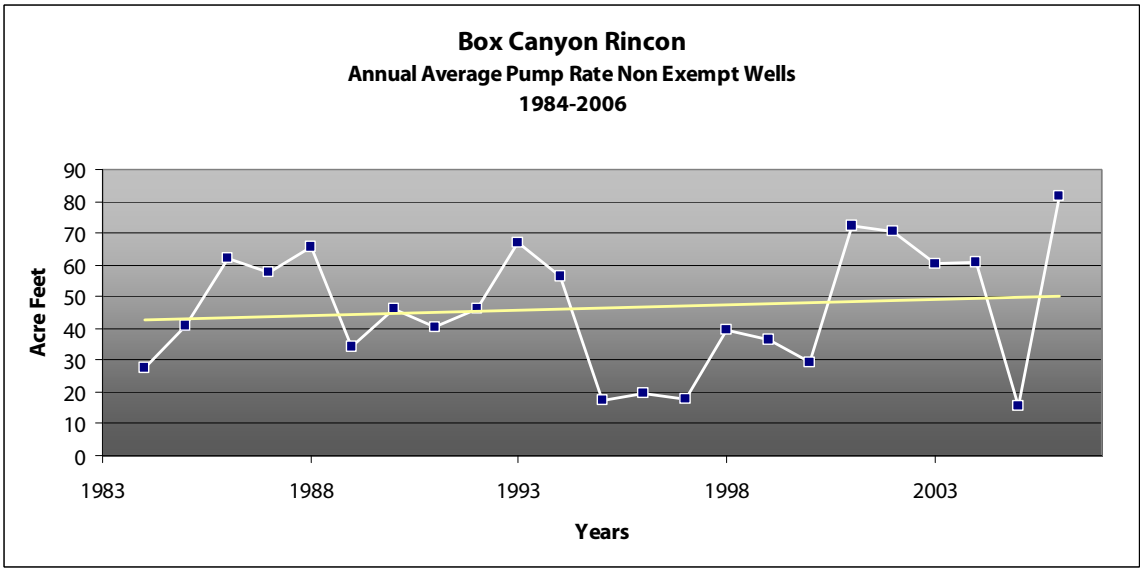


Box Canyon Rincon

Graph 8

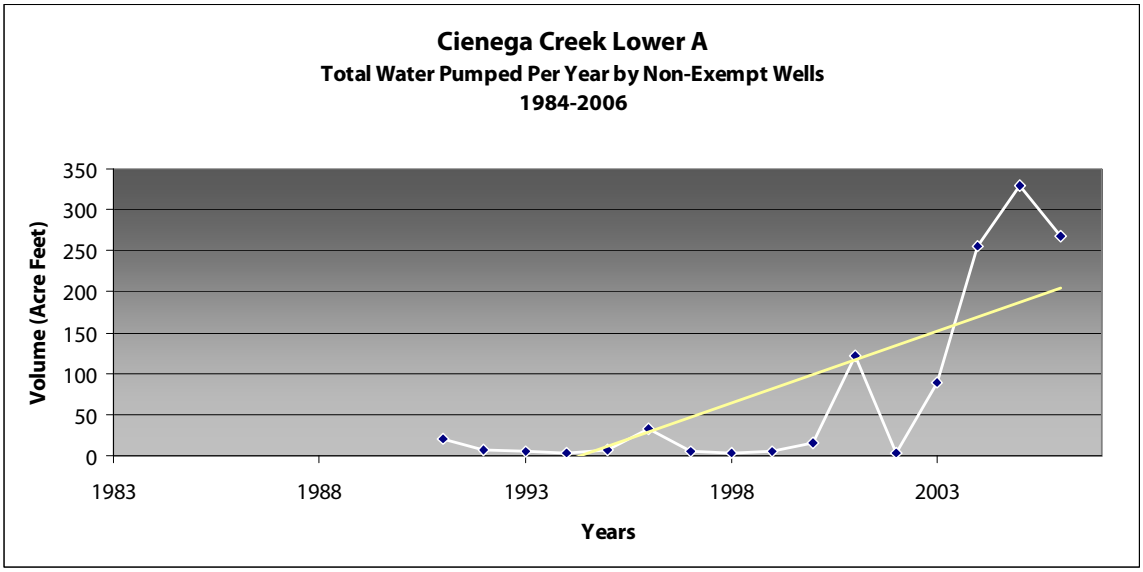


Graph 9

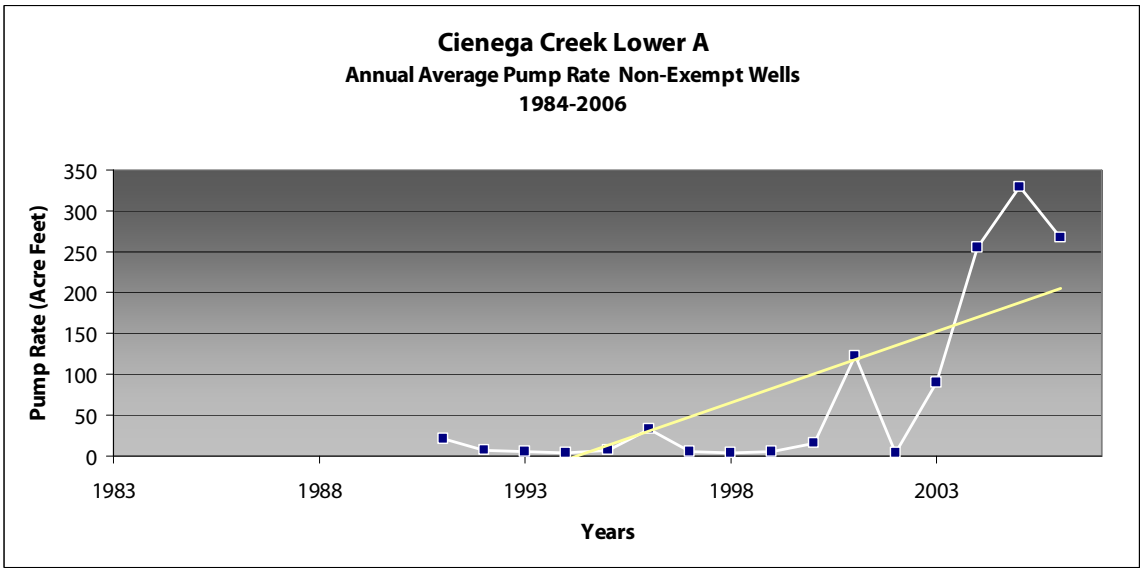


Cienega Creek (Lower)

Graph 10

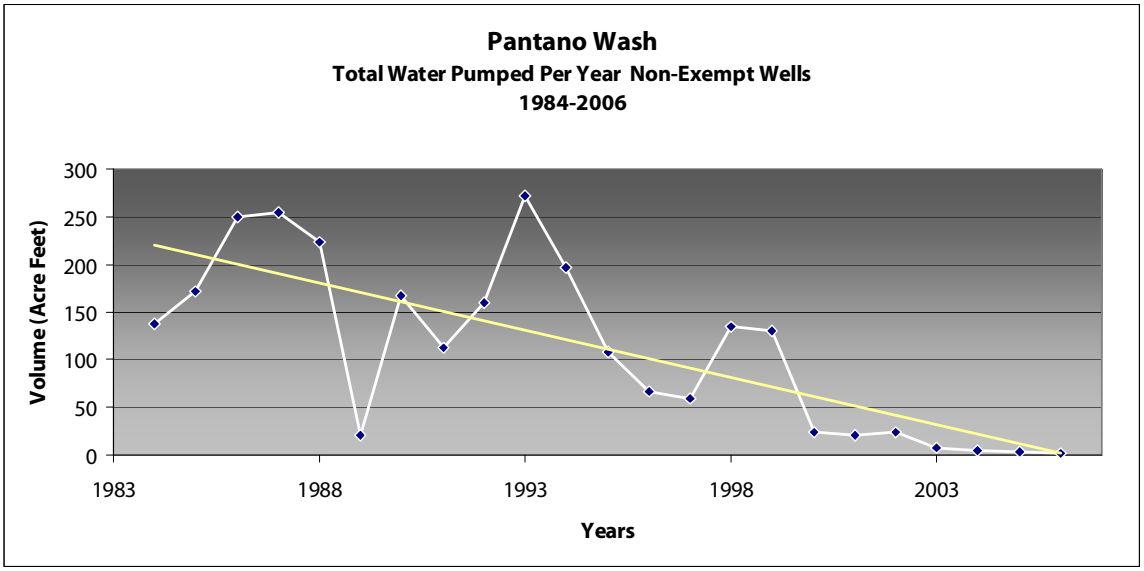


Graph 11

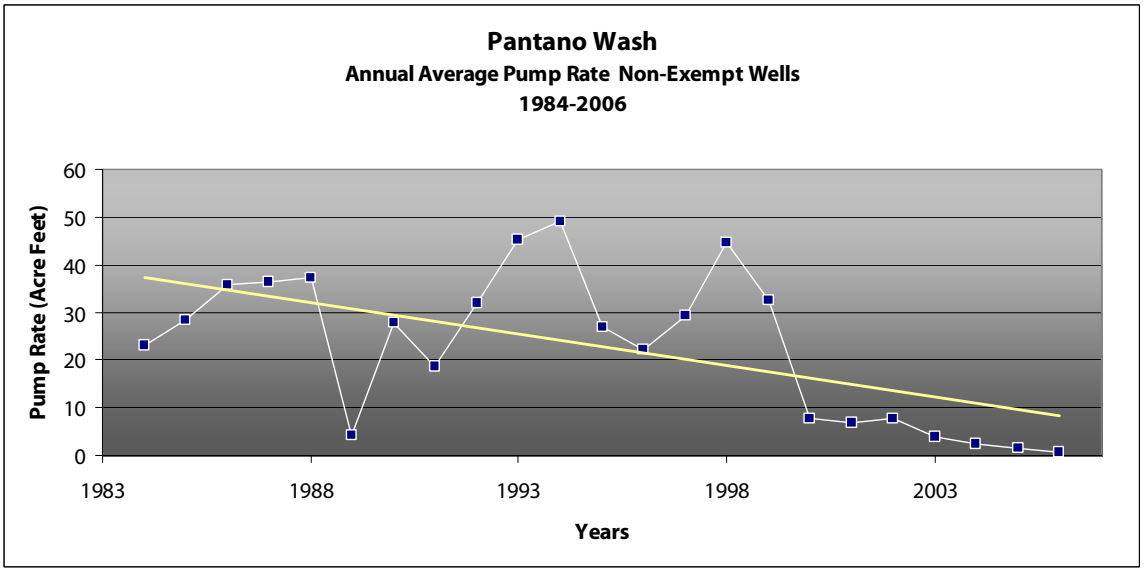


Pantano Wash

Graph 12

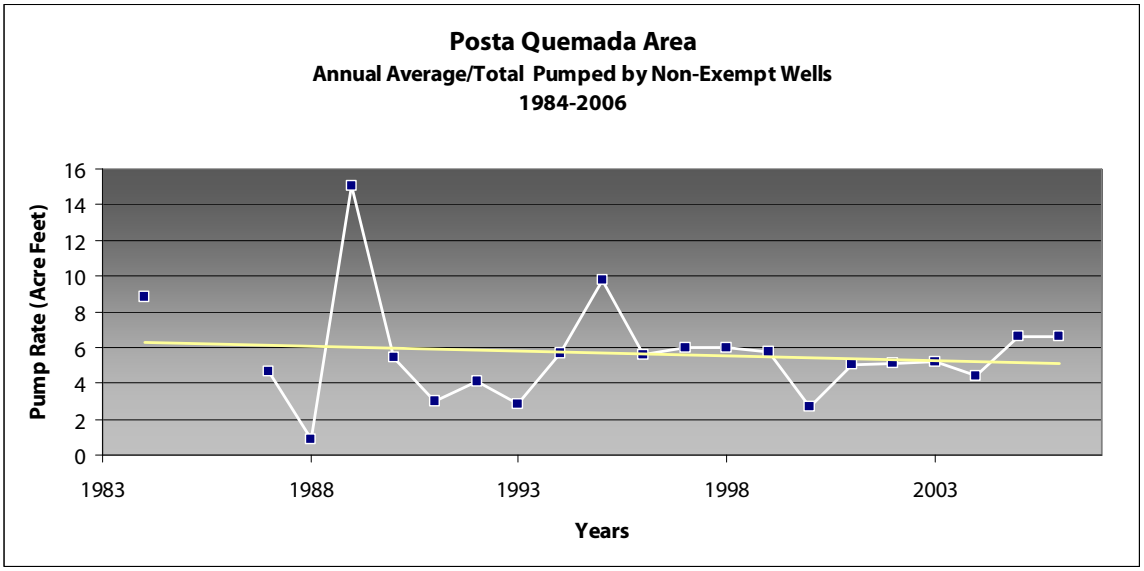


Graph 13



Posta Quemada Area

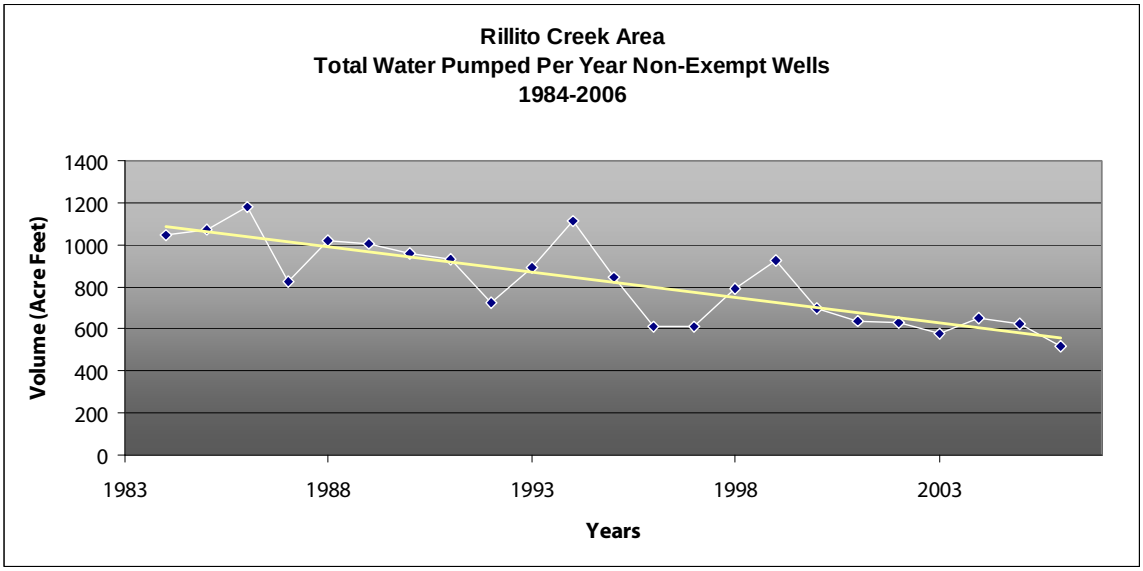
Graph 14



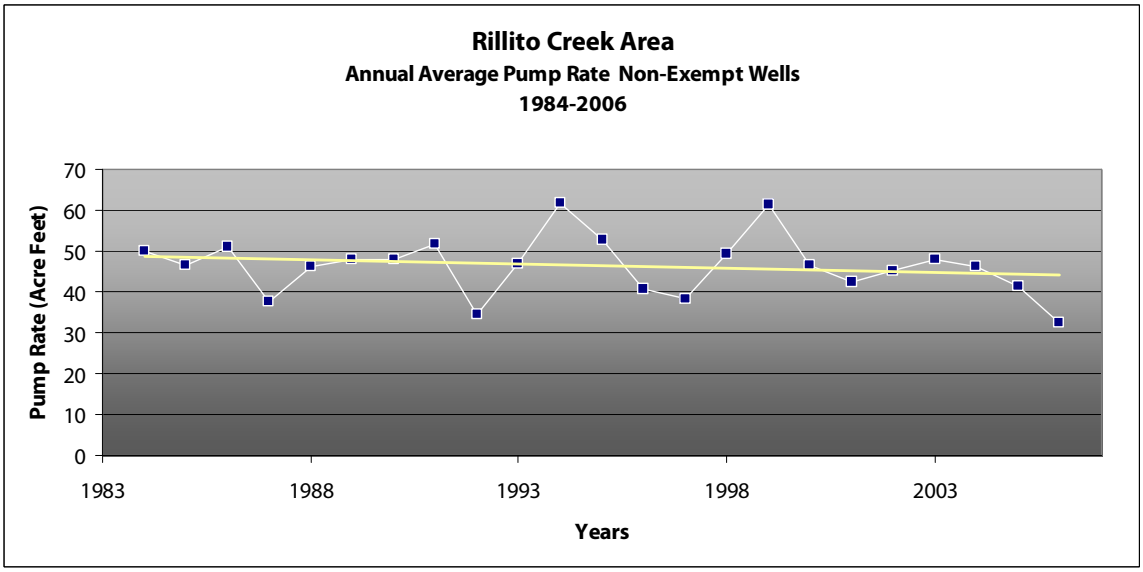
Posta Quemada shallow groundwater area had only one non-exempt well that reported pumping rates to ADWR. Therefore separate graphs were not prepared for annual total withdrawal rate of water pumping and annual average rate of water pumping.

Rillito Creek Area

Graph 15

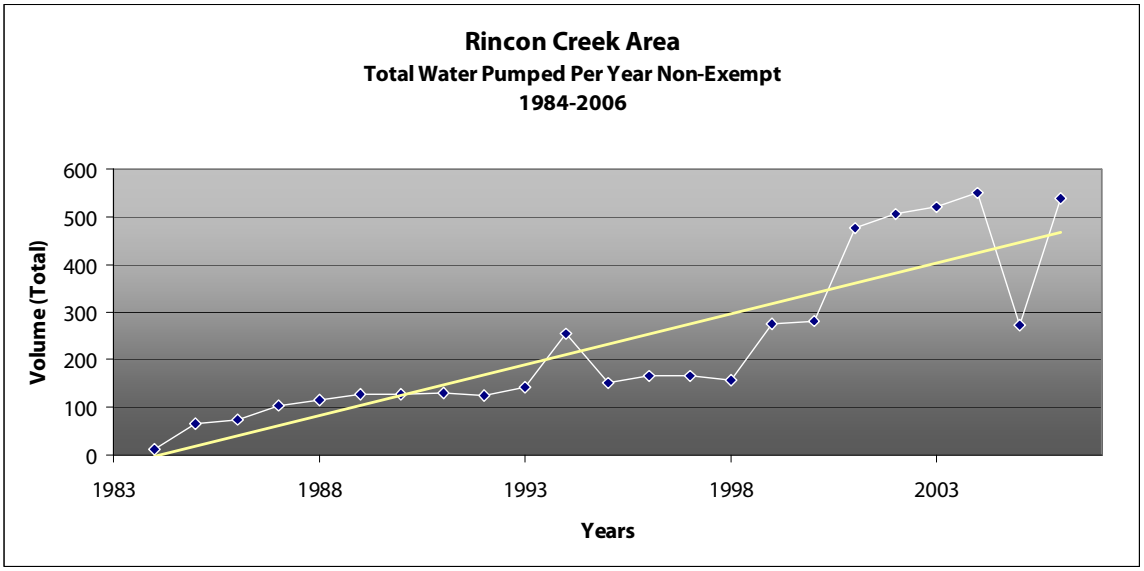


Graph 16

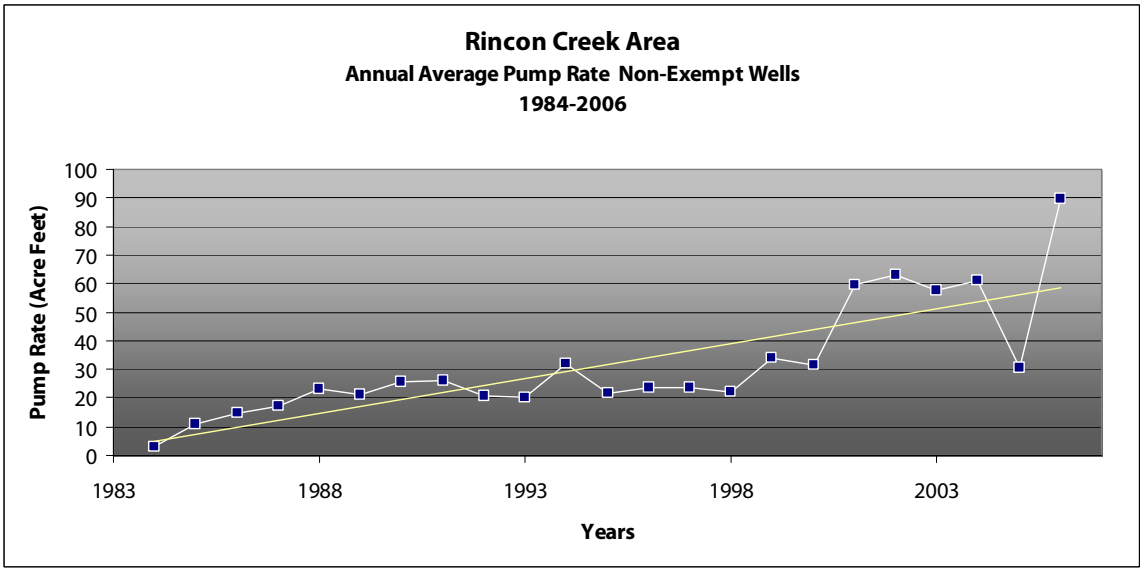


Rincon Creek Area

Graph 17

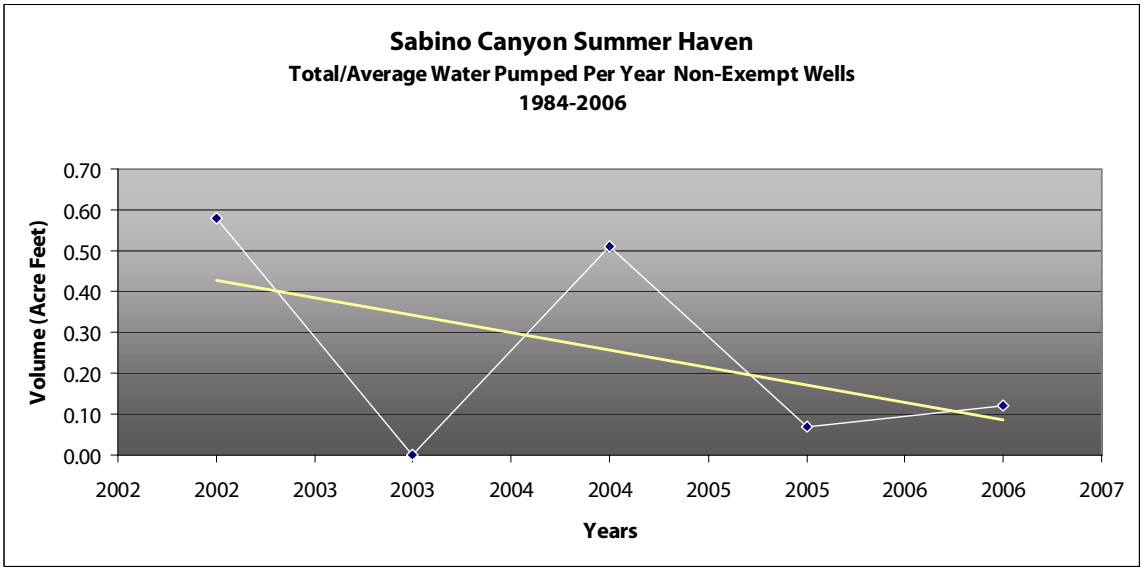


Graph 18



Sabino Canyon (Summerhaven)

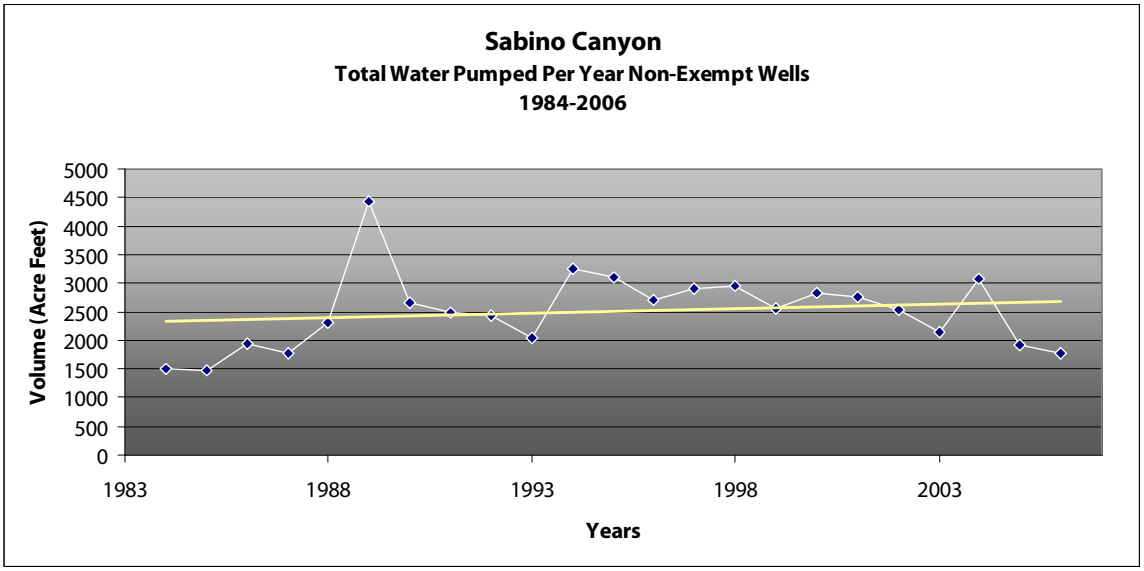
Graph 19



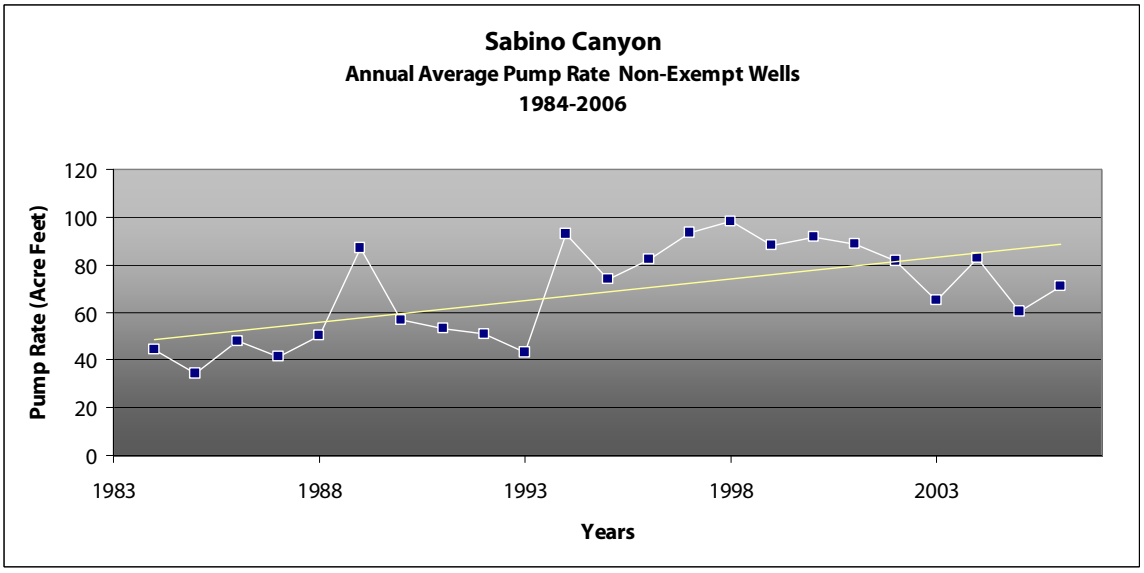
Sabino Canyon (Summer Haven) shallow groundwater area had only one non-exempt well that reported pumping rates to ADWR. Therefore separate graphs were not prepared for annual total withdrawal rate of water pumping and annual average rate of water pumping.

Sabino Canyon

Graph 20

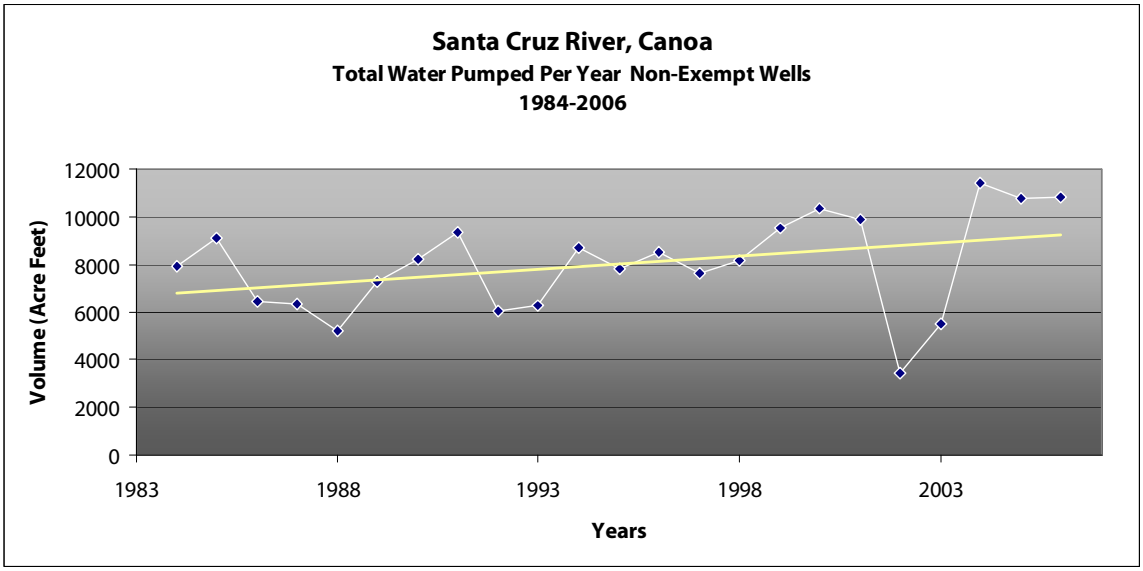


Graph 21

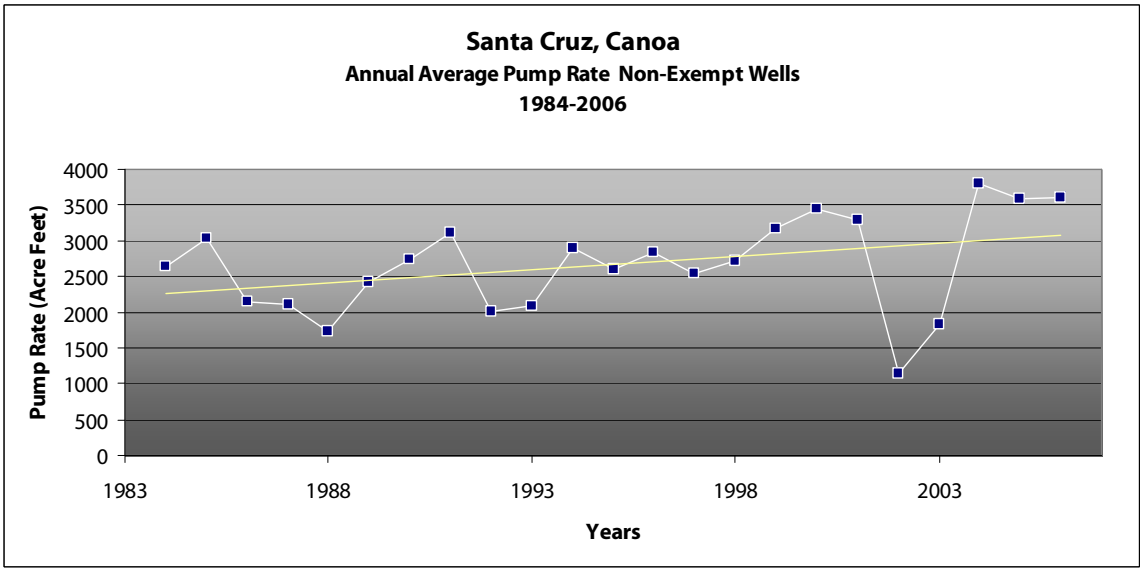


Santa Cruz, Canoa

Graph 22

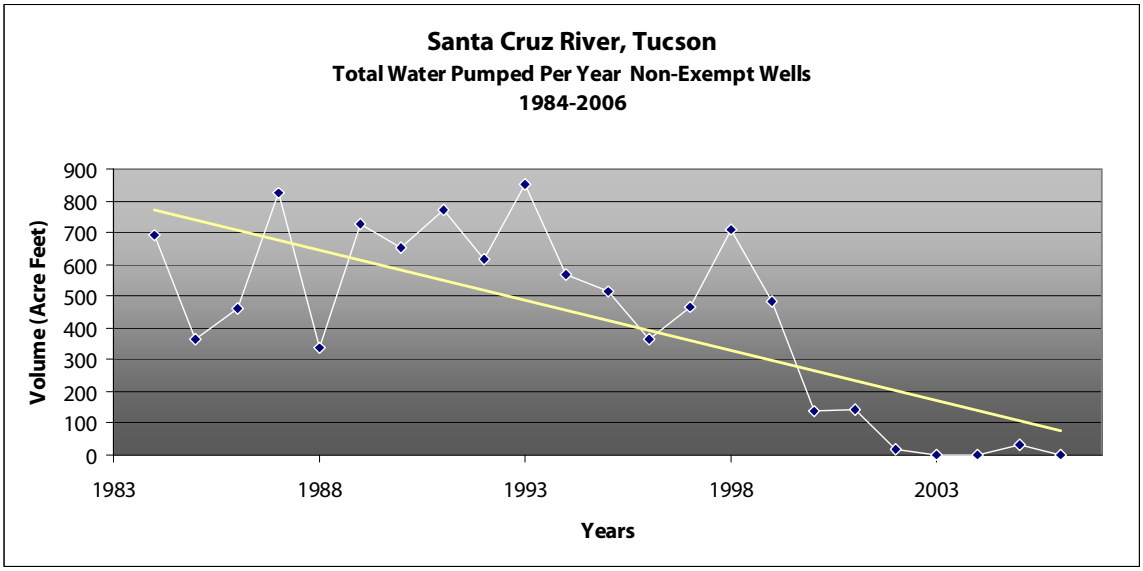


Graph 23

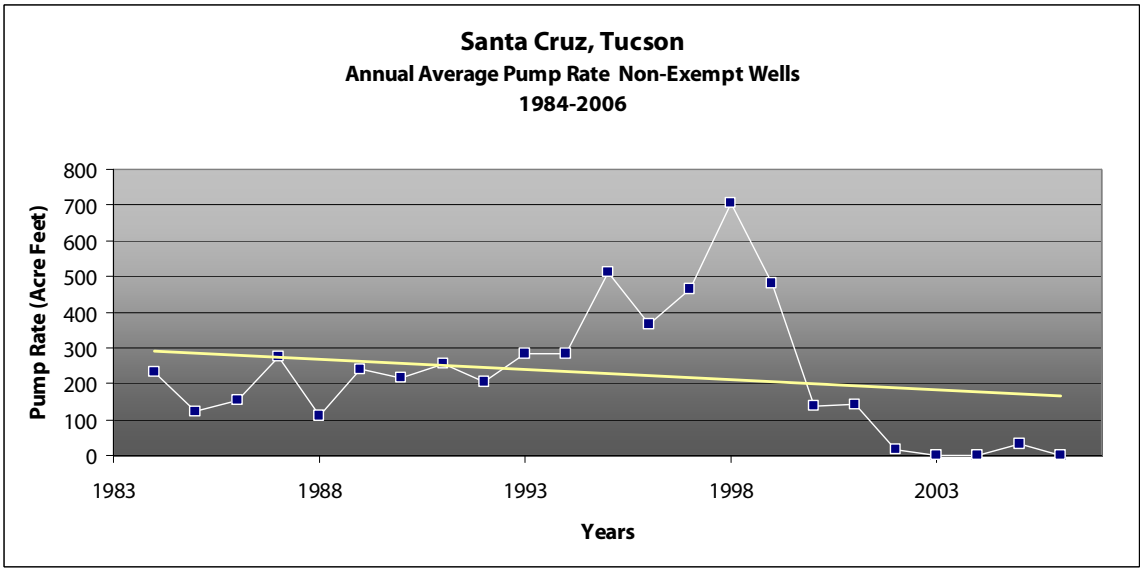


Santa Cruz, Tucson

Graph 24

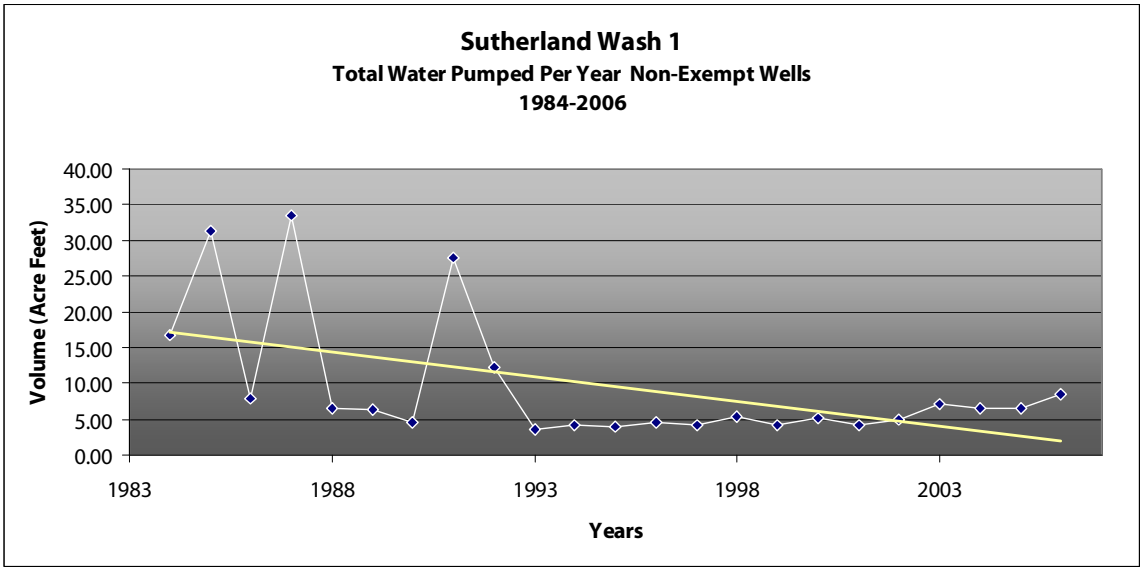


Graph 25

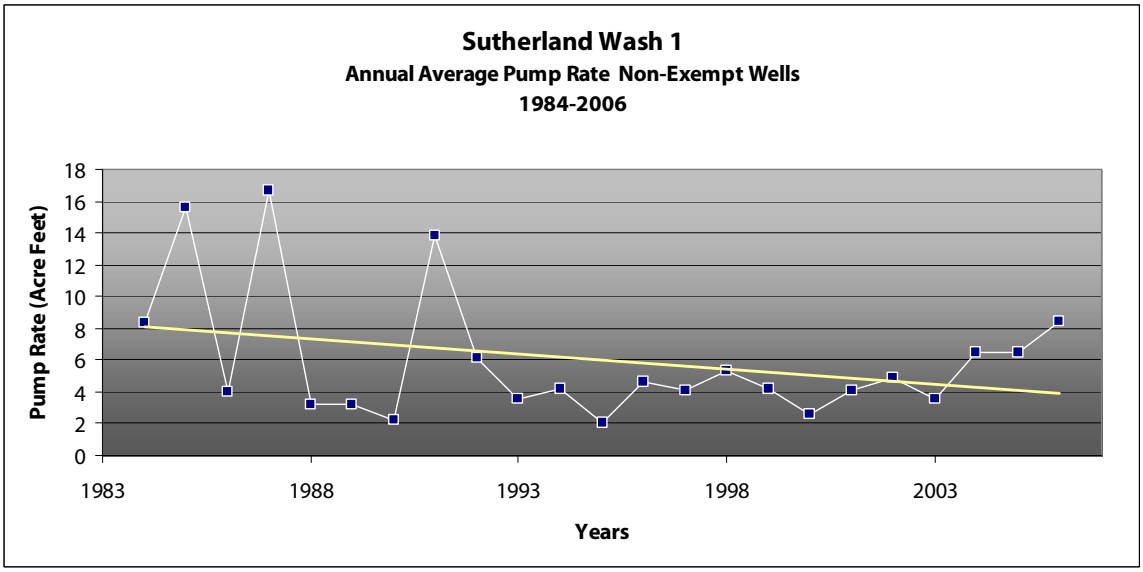


Sutherland Wash 1

Graph 26

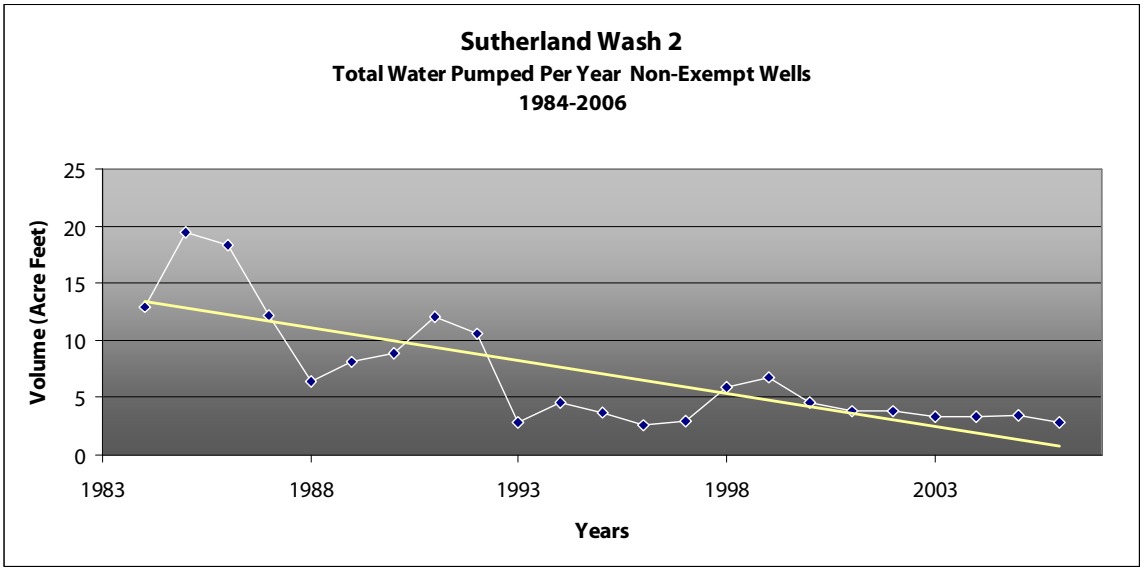


Graph 27

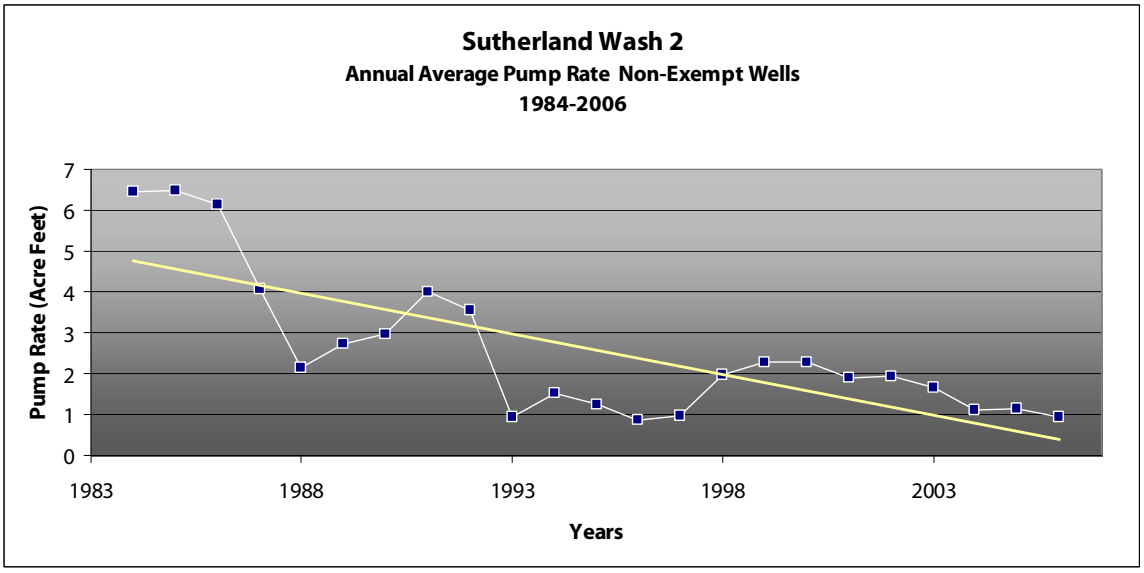


Sutherland Wash 2

Graph 28

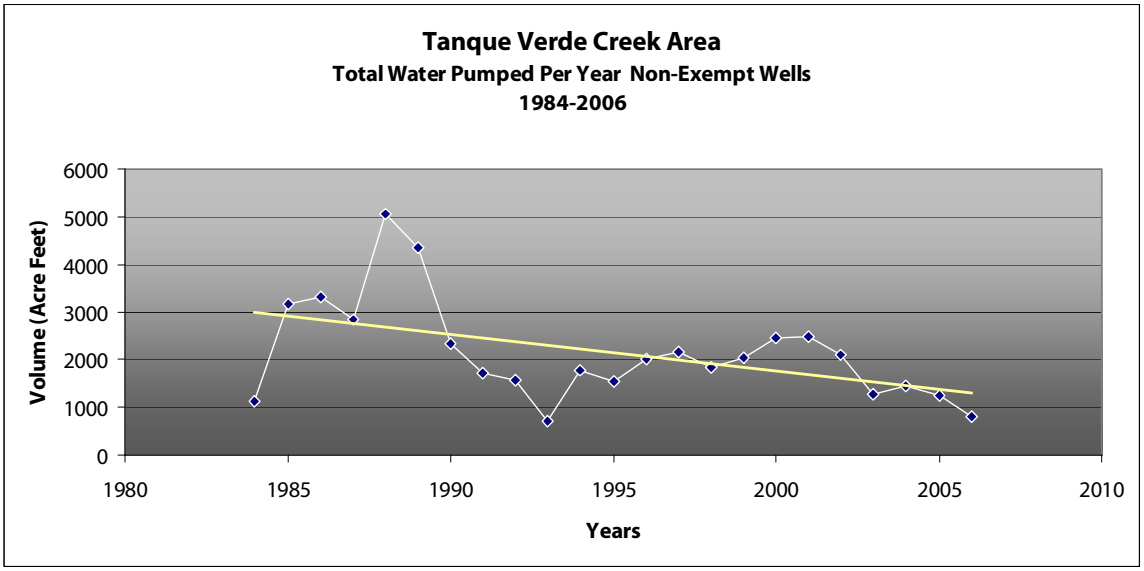


Graph 29

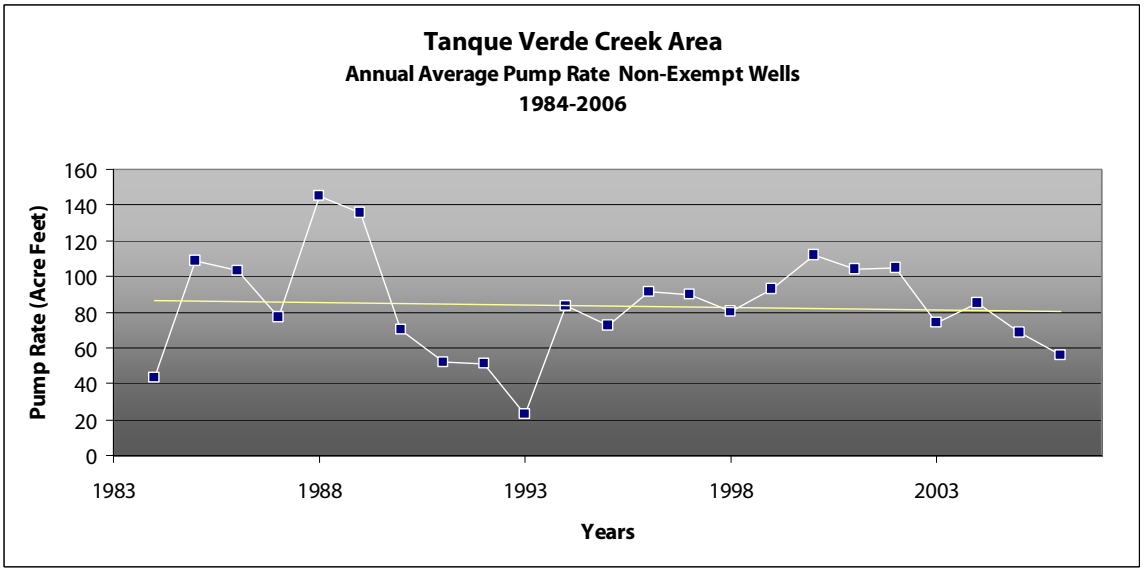


Tanque Verde Creek Area

Graph 30

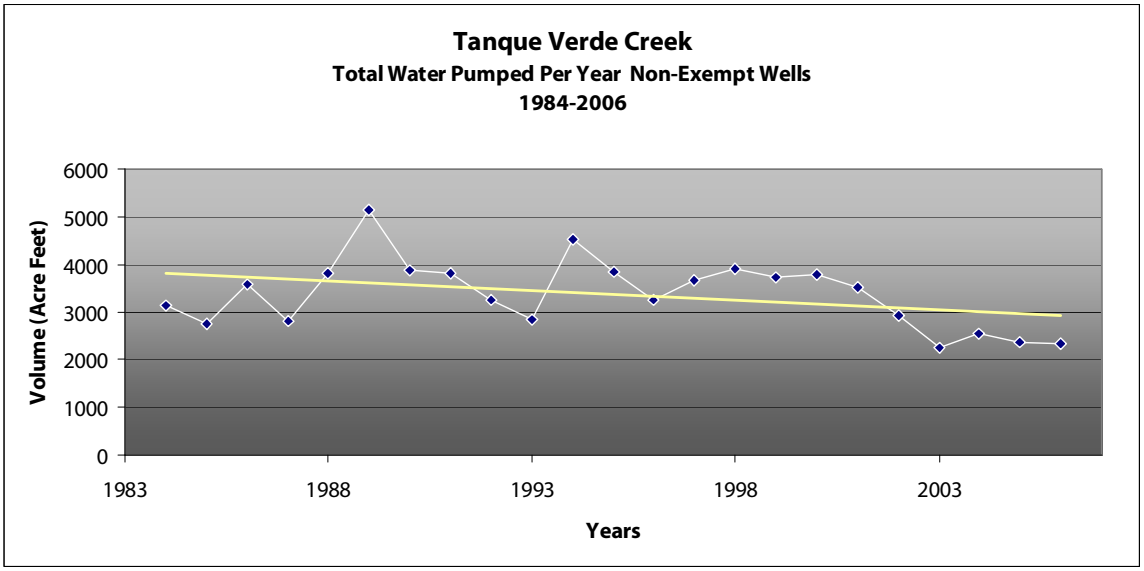


Graph 31

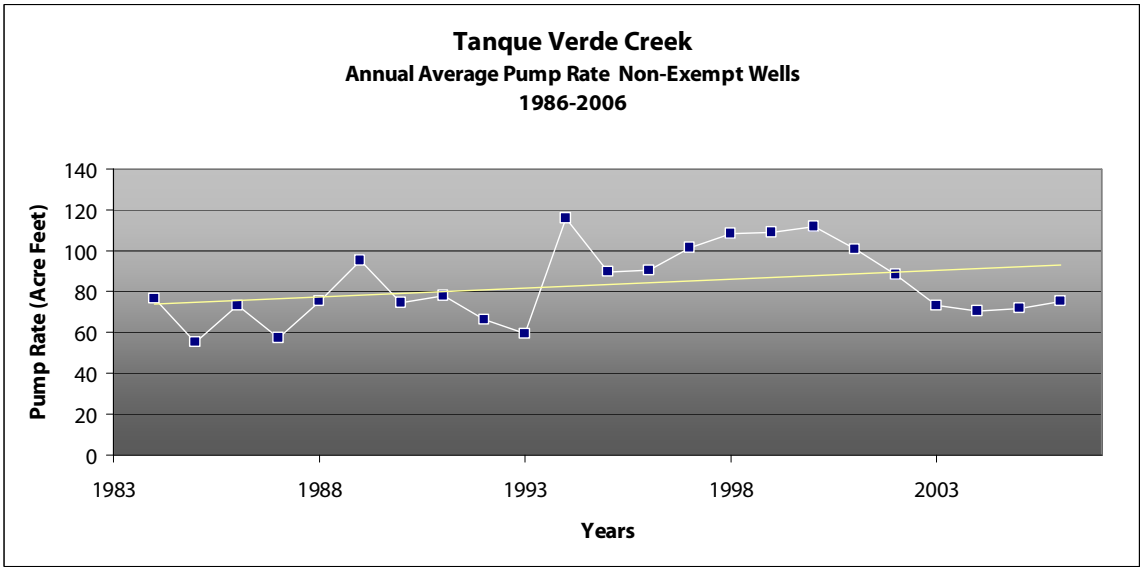


Tanque Verde Creek

Graph 32

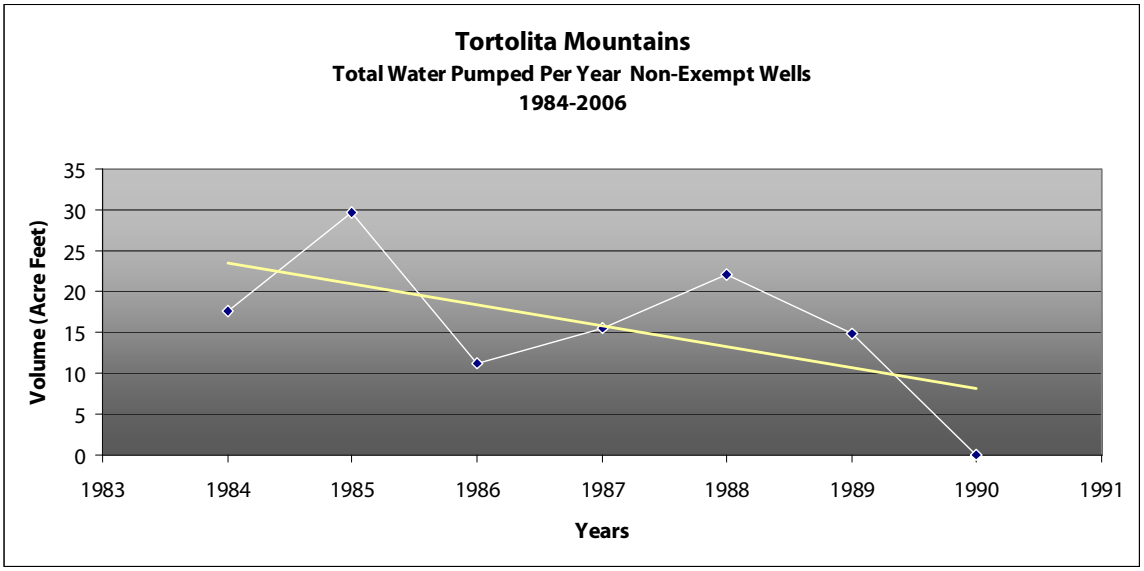


Graph 33



Tortolita Mountains

Graph 34



Graph 35