DRAFT Demand and Supply Assessment

July

2012

This Assessment is a compilation and study of historical water demand and supply characteristics for the SCAMA from the year 1985 through 2009. In addition, the Assessment calculates three projected demand scenarios and compares them to statistically generated "normal" and "dry" water supply scenarios to the year 2025.

Santa Cruz Active Management Area

DRAFT
Demand and Supply Assessment
1985-2025
Santa Cruz Active Management Area

July 2012

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EXECUTIVE SUMMARY

The *Water Demand and Supply Assessment 1985-2025, Santa Cruz Active Management Area* (Assessment) is a compilation and study of historical water demand and supply characteristics for the Santa Cruz Active Management Area (SCAMA) for the years 1985-2009. In addition, the Assessment calculates six water supply and demand projection scenarios - three baseline scenarios and three dry conditions scenarios - to the year 2025. The Arizona Department of Water Resources (ADWR) conducted the Assessment as preparation for the *Fourth Management Plan for Santa Cruz Active Management Area* (4MP) as required by the *1980 Groundwater Management Code* (Code).

The statutory management goals are established for each Active Management Area (AMA), and are the foundation for the implementation of the groundwater management programs established by the Code. Originally, the Code created four AMAs. In 1994 due to the locally unique nature of water supply and demand, a portion of the Tucson AMA (TAMA) was designated as a fifth AMA, the SCAMA. SCAMA experiences fluctuations in the annual balance of withdrawals and replenishment of its aquifer. The hydrologic system of the SCAMA is periodically replenished by large surface water flows events resulting in streambed recharge that can “reset” the system. Recognizing these unique characteristics, the legislature set the goal of the SCAMA to maintain safe-yield and prevent local water tables from experiencing long-term declines.

Safe-yield is a balance between the amount of groundwater pumped from the AMA annually and the amount of water naturally or artificially recharged. Groundwater withdrawals in excess of natural and artificial recharge lead to an overdraft of the groundwater supply in the AMA basin. While safe-yield is also an AMA-wide goal for the Phoenix, Tucson and Prescott AMAs, in these other AMAs some local areas may experience water level declines while other areas may experience rises in water levels. In the SCAMA, preventing long-term declines in local water tables means that while temporary declines may occur in water levels, a long-term balance must be maintained even at the local level throughout the AMA.

To help achieve the AMA goals, the Code prescribed management strategies which relied, in part, on (1) continuing mandatory conservation by all major water using sectors to reduce total groundwater withdrawals in the AMAs, identified in the Management Plan for the AMA, and (2) increasing the use of renewable water supplies in place of groundwater supplies. Five management periods were identified and required the development of Management Plans to assist in moving the AMA closer to its individual management goal by 2025.

The three baseline scenarios for future water use in this Assessment indicate that with additional growth, the fluctuating supply conditions endemic to the SCAMA will result in a widening gap between demand and available supply unless additional water supplies are obtained and can be stored to offset fluctuations in the natural system. Three of the six scenarios are dry conditions scenarios which examine the compounded effect of a possible extended drought, where fewer large flood flows occur to replenish the SCAMA aquifers and a greater difference between demand and available supply is projected to occur.

The purpose of this Assessment is to characterize the nature of water resource availability and demand through 2009 and, by developing future projections, analyze different supply and demand mechanisms that may affect the AMA’s ability to achieve its goal. This analysis embraces the variable nature of the supply in the SCAMA and incorporates stochastic analysis of streamflow that was conducted for ADWR. While ADWR recognizes these future projections are not exact representations of what will occur in the future, they do identify a range of possibilities that provide valuable information that benefits decisions regarding water management in the SCAMA. Most importantly, the information in this Assessment will be used to assist ADWR in working with the local communities to develop management strategies to assist the AMA in working to maintain safe-yield and prevent long-term declines in local water table levels by the end of the 4MP.

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ADWR	Arizona Department of Water Resources
ADES	Arizona Department of Economic Security
AMA	Active Management Area
ASFCs	Areas of Similar Farming Conditions
AWBA	Arizona Water Banking Authority
AWS	Assured Water Supply
BMP	best management practices
BOR	United State Bureau of Reclamation
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAWCD	Central Arizona Water Conservation District
CAWS	Certificate of Assured Water Supply
CC&N	Certificate of Convenience and Necessity
Code	Groundwater Code
CRM	Colorado River Management
DAWS	Designation of Assured Water Supply
DCDC	Decision Center for Desert Cities
DWID	Domestic Water Improvement District
ET	Evapotranspiration
FICO	Farmers Investment Company
GIS	Geographic Information System
GIU	General Industrial Use Permit
GPCD	gallons per capita per day
GSF	Groundwater Savings Facility
IGFR	Irrigation Grandfathered Right
IPCC	International Panel on Climate Change
mgd	million gallons per day
M&I	Municipal and Industrial
NIWWTP	Nogales International Wastewater Treatment Plant
NOI	Notice of Intention to Drill
Type 1 Right	Type 1 non-irrigation grandfathered right
Type 2 Right	Type 2 non-irrigation grandfathered right
USF	Underground Storage Facility
USGS	United States Geological Survey
WWTF	Wastewater Treatment Facility
1MP	First Management Plan
2MP	Second Management Plan
3MP	Third Management Plan
4MP	Fourth Management Plan
5MP	Fifth Management Plan
SCAMA	Santa Cruz Active Management Area
TAMA	Tucson Active Management Area

PART I INTRODUCTION TO THE ASSESSMENT

1. INTRODUCTION

1.1 History of ADWR Authorities and Programs

Early in its history, the Arizona Territory adopted the doctrine of prior appropriation to govern the use of surface water. This doctrine is based on the tenet of “first in time, first in right” which means that the person who first puts the water to a beneficial use acquires a right that is senior to later appropriators of the water. Under strict adherence to this prior appropriation system, the water needs of senior right holders must be fully satisfied before junior right holders can take delivery of their water. Prior to June 12, 1919, a person could acquire a surface water right simply by applying the water to a beneficial use and posting a notice of the appropriation at the point of diversion. On June 12, 1919, the Arizona surface water code was enacted. Now known as the Public Water Code, this law provides that a person must apply for and obtain a permit in order to appropriate surface water.

ADWR was created in 1980 with the passage of the Groundwater Management Act (Code) to address groundwater depletion in the state's most populous areas. The goal of the Code within the AMAs is twofold: 1) to control severe groundwater depletion; and 2) to provide the means for allocating Arizona's limited groundwater resources to most effectively meet the state's changing water needs. Areas where groundwater depletion is most severe are designated as Active Management Areas (AMAs). These areas are subject to regulation pursuant to the Code. Upon adoption of the Code, ADWR was also assigned statutory authority for the general control and supervision of the state’s surface water, its appropriation and distribution, and also of groundwater to the extent provided in the Code.

1.2 Groundwater Management in the AMAs

Originally, the Code created four AMAs. Each AMA has a statutory management goal. In the Phoenix, Prescott, and Tucson AMAs, the primary management goal is to achieve safe-yield by the year 2025. In the Pinal AMA, where the economy was primarily agricultural, the management goal is to preserve that economy for as long as feasible, while considering the need to preserve groundwater for future non-irrigation uses. Each AMA carries out its programs in a manner consistent with these goals, while considering and incorporating the unique character of each AMA and its water users.

In 1994, a portion of the Tucson AMA (TAMA) was designated as a fifth AMA, the Santa Cruz AMA (SCAMA). SCAMA experiences fluctuations in the annual balance of withdrawals and replenishment of its aquifer. The hydrologic system of the SCAMA is periodically replenished by large surface water inflows resulting in streambed recharge that essentially “reset” the system. Recognizing these unique characteristics, the legislature set the goal of the SCAMA to maintain safe-yield and prevent local water tables from experiencing long-term declines.

1.2.1 Management Plans

ADWR is required by statute to adopt Management Plans for each AMA. These Management Plans reflect the evolution of the Code, assisting in moving Arizona toward its long-term water management goals. Management Plans are required from each AMA for five sequential management periods extending from 1980 through 2025. The First Management Plan (1MP) applied from 1985-1990. The Second Management Plan (2MP) was in effect until 2000, and the Third Management Plan (3MP) from 2001 until 2010. The SCAMA was part of the TAMA for the 1MP and the 2MP. A SCAMA specific 3MP was prepared.

ADWR is in the initial stages of formulating the 4MP, through the development of this Assessment, scheduled for release in 2012. The provisions of the 4MP will be in effect from the first effective date after adoption of the 4MP through 2020. A Fifth Management Plan (5MP) will be developed for the years 2020 through 2025.

MUNICIPAL, INDUSTRIAL, AGRICULTURAL, CONSERVATION ASSISTANCE/AUGMENTATION

Most entities in the SCAMA who withdraw water from a non-exempt well are required, pursuant to the Management Plans, to participate in one of the following: the Agricultural Conservation Program, the Municipal Conservation Program or the Industrial Conservation Program.

Holders of an Irrigation Grandfathered Groundwater Right (IGFR) who withdraw water from a non-exempt well are subject to the Agricultural Conservation Program, which determines conservation requirements based on water duties and maximum annual groundwater allotments or through Best Management Practices (BMP). A key component of the Code prohibits the establishment of new IGFRs – precluding new acres from being put into agricultural production.

Under the Municipal Conservation Program, municipal water providers are required to meet conservation requirements based on reductions in total per capita use or through implementation of BMPs. Additionally municipal providers are required to limit the amount of lost and unaccounted for water in their delivery system.

All Type 1 and Type 2 Non-Irrigation Grandfathered Groundwater Right (T1 or T2 GFRs) holders and some General Industrial Use (GIU) permit holders are subject to the Industrial Conservation Program. Conservation requirements are based on the best available technology for the end use. The requirements range from BMPs to specific water allotments for water users such as turf facilities based on the permit or right type.

In 1991, the 2MP was modified to include a financial assistance program for the implementation of conservation programs/measures within an AMA. The goal of the Conservation Assistance Program was to assist water users in achieving the Management Plan requirements, ultimately leading to a realization of the management goal of the AMA.

The 2MP and the 3MP also include an Augmentation Assistance Program designed to provide augmentation grants for construction and pilot recharge projects. This program was designed to directly increase the utilization of renewable water supplies or water storage, conservation assistance, and planning, research and feasibility studies. The Conservation Assistance and Augmentation Assistance Program grants are funded by water withdrawal fees collected from those who pump groundwater in each AMA (or "water withdrawn from wells" in the SCAMA). This concept is explored in more detail in Section 1.2.3, below.

ADDITIONAL MANAGEMENT PLAN PROVISIONS FOR SCAMA

The management plans for the SCAMA must include criteria for the location of new wells and replacement wells in new locations consistent with the management goal of the AMA. In addition, the management plan for the SCAMA must also consider the potential impact of the SCAMA management plan on the TAMA.

1.2.2 The Assured Water Supply

The Assured Water Supply (AWS) program, created as part of the Code, is designed to provide consumer protection for the purchasers of subdivided real property within AMAs. The AWS program serves to preserve groundwater resources and promote long-term water supply planning in the AMAs. This is accomplished by adherence to ADWR enacted regulations that limit the use of groundwater by new subdivisions. Every person proposing to subdivide land within an AMA must demonstrate the availability of a 100-year AWS.

In 1995, ADWR adopted AWS Rules to implement the AWS program. Under the AWS Rules, developers can demonstrate a 100-year supply by either satisfying the criteria described below and obtaining a

Certificate of Assured Water Supply (CAWS) from ADWR or by obtaining a written commitment of service from a water provider with that has secured a Designation of Assured Water Supply (DAWS) from ADWR.

An AWS demonstration must include proof that the proposed subdivision will meet the following criteria, that the water supply or supplies: 1) will be of adequate quality; 2) will be physically, legally, and continuously available for the next 100 years; 3) will be consistent with the management goal for the AMA; 4) will be consistent with the Management Plan for the AMA; and 5) financial capability will be demonstrated to construct the necessary water storage, treatment, and delivery systems. The Arizona Department of Real Estate will not issue a public report that allows the developer to sell lots within an AMA without a demonstration of an AWS. For more information on the AWS Program, please visit the ADWR website at www.azwater.gov/AzDWR/WaterManagement/AAWS.

Because the AWS Rules were being adopted at the same time that the SCAMA was being created, consistency with AMA goal criteria for the SCAMA were not included in the AWS Rules. ADWR has initiated the process to develop a rule modification to include consistency with goal criteria for SCAMA. However, this rule making is currently suspended due to the moratorium on rulemaking.

The AWS requirement has proven to be an important tool to help attain the management goal of all of the AMAs. It forces newly subdivided property to rely, almost exclusively, on renewable water supplies within the safe-yield AMAs. Because the AWS requirements only apply to new subdivisions (existing uses and other non-subdivision new uses are exempt from the assured water supply requirement under the Code), additional tools are required to achieve the water management goal of the AMA.

1.2.3 The Underground Storage & Recovery Program

For decades, more groundwater has been pumped from Arizona's aquifers than has naturally recharged back into those aquifers. This imbalance has left some aquifers significantly depleted. Using renewable supplies and recharging renewable water supplies underground reduces this imbalance. Artificial recharge is a means of storing excess water supplies underground for future use. Artificial recharge is an increasingly important tool in the management of Arizona's water supplies, particularly in meeting the goals of the Code. Storing water underground to ensure an adequate supply for the purpose of satisfying current and future needs has proven to be both a practical and cost-effective alternative to direct use of renewable supplies. Currently, the SCAMA is the only AMA lacking any artificial recharge projects or infrastructure to move surplus supplies to areas where the water could be stored for future use during periods where demand exceeds the rate of natural replenishment.

In 1986, the Arizona Legislature established the Underground Water Storage and Recovery program to allow persons with surplus renewable supplies of water to store that water underground and recover it at a later time. In 1994, the Legislature enacted the Underground Water Storage, Savings, and Replenishment Act, which further refined the recharge program. For more information on the Underground Storage and Program, please visit the ADWR website at www.azwater.gov/AzDWR/WaterManagement/Recharge.

1.3 INTRODUCTION TO SCAMA

1.3.1 Creation of SCAMA

During the development of the 2MP, local water users in the Santa Cruz County portion of the TAMA became concerned about various local water issues including water transfers, CAP contracts, and assured water supply (ADWR, 1990). Lead by Santa Cruz County, SB 1436 was introduced during the 1989 legislative session to address concerns in Santa Cruz County about the impact of the Code upon future development potential. Although the local water users voiced many valid water management concerns, SB 1436 failed. One major drawback to the bill was that it proposed creating the SCAMA, as separate and distinct from the TAMA, by drawing the dividing line along political (between Santa Cruz and Pima Counties) rather than hydrologic boundaries.

In 1994, SB 1380 successfully established the SCAMA. The bill, now found under A.R.S. §§ 45-411.02 - 411.04, recognizes that the international nature of water management issues facing the Upper Santa Cruz River Basin differed significantly from the other sub-basins of the TAMA. The legislature notes that the hydrology of the basin requires coordinated management of surface water and groundwater as well as binational coordinated water management. The law also recognizes that local water interests seek to facilitate their participation in management of the local water resources.

1.3.2 Physiography

The SCAMA is located in the Sonoran Desert in south-central Arizona *(See Figure 1-1)*. It includes 716 square miles in the Upper Santa Cruz River Valley and is principally concentrated around a 45-mile reach of the Santa Cruz River from the International Boundary with Mexico to the location of the Continental USGS stream gauge on the Santa Cruz River, just north of the Santa Cruz/Pima County line (Erwin, 2007). For more detailed information about the SCAMA see the ADWR, *DRAFT Arizona Water Atlas: Active Management Area Planning Area (Vol. 8), Section 8.4, Santa Cruz Active Management Area* (2010).

Physical Landscape

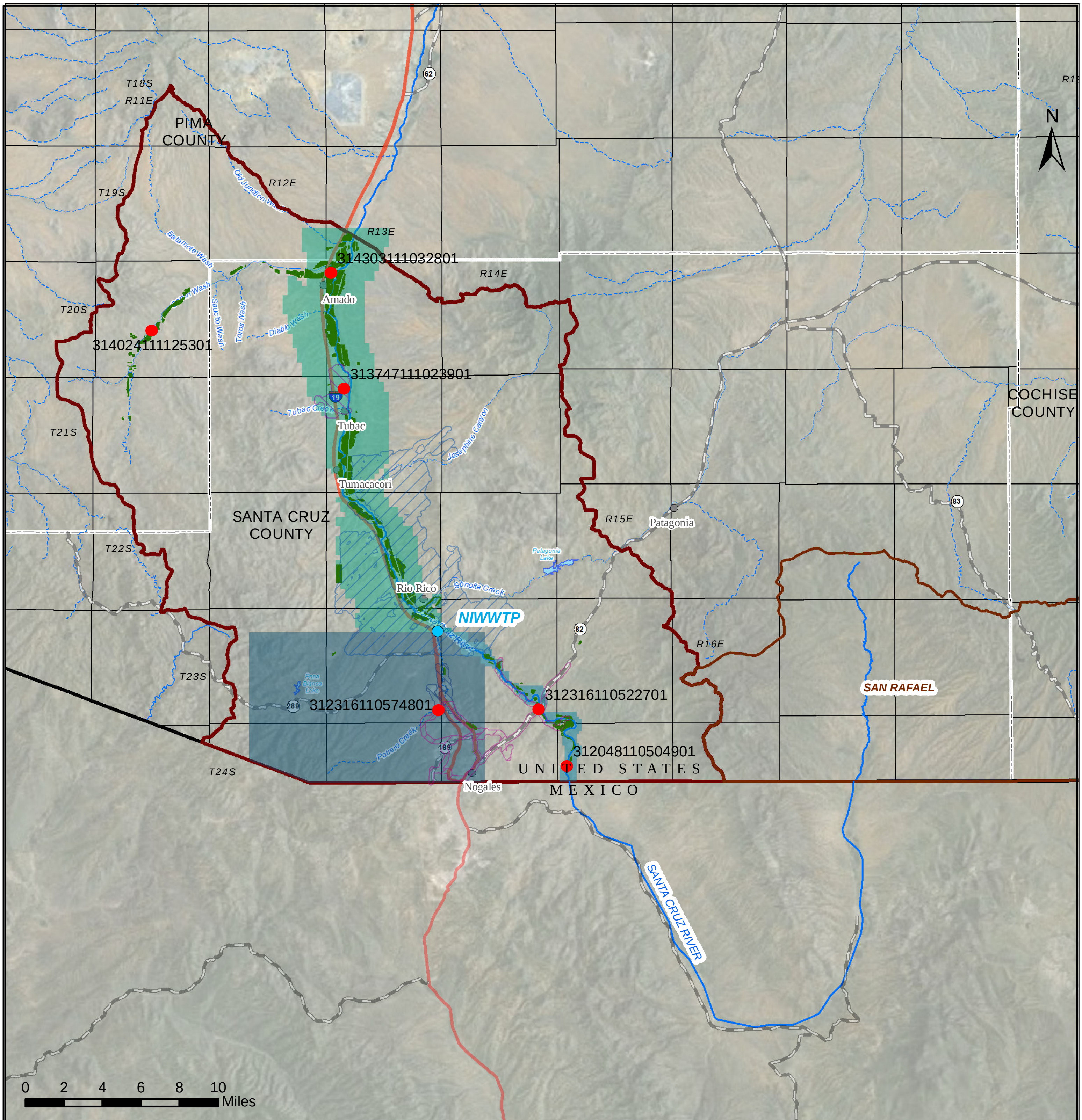
The SCAMA is delimited by mid to high elevation mountains surrounding the Santa Cruz River Valley. It is bounded on the west by the Cerro Colorado and the Atascosa Mountains and on the east by the Santa Rita and the San Cayetano Mountains. Vegetation types in the SCAMA include southwestern grassland, madrean evergreen woodland and riparian species, principally found along the Santa Cruz River and Sonoita Creek. The lowest elevation in the AMA is approximately 3,000 feet above mean sea level where the Santa Cruz River exits the AMA at its northern boundary. The highest point in the AMA is 9,453 feet at Mount Wrightson in the Santa Rita Mountains in the northeastern portion of the AMA.

Originating in the San Rafael Valley in southern Arizona, the Santa Cruz River flows south into Sonora Mexico, re-enters the U.S. east of Nogales, continues north past Tucson, and eventually joins the Gila River southwest of Phoenix. Historically, surface water flowed perennially along the Santa Cruz River from the U.S. - Mexico border to Tubac. By the 1940’s, intensive groundwater pumping and land-use changes had lowered groundwater levels in the Santa Cruz River Valley. Since the 1970’s reclaimed water from the Nogales International Waste Water Treatment Plant (NIWWTP) has been continuously discharged into the river channel augmenting baseflow, creating an additional source that recharges the near-stream aquifer, and helps sustain riparian habitat downstream of the point of discharge. Increases in stream recharge from major winter and fall-period flood events between 1960 and 2001 were also responsible for maintaining shallow water tables observed in the Santa Cruz River Valley over this period (Nelson, 2007).

Cultural landscape

The SCAMA includes most of Santa Cruz County and a small portion of southern Pima County. The major communities include the City of Nogales, Rio Rico, Tubac, and Amado. Population is concentrated along the Santa Cruz River corridor and at Nogales, Arizona. The SCAMA also experiences a large fluctuation in temporary residents attributable to the close business and family connections between the residents of the AMA and the Mexican state of Sonora.

Numerous families, both in the SCAMA and throughout the state, have relatives in Mexico. This accounts for much of the travel through Nogales, Arizona and Nogales, Sonora. Nogales is also a center for tourism and commerce as a port of entry for many products, including a significant volume of produce from Mexico and other Central and South American countries. These factors, along with others, combine to make Nogales, Arizona and Nogales, Sonora (collectively referred to locally as Ambos Nogales) the largest international transit corridor in Arizona. Small commercial properties, government facilities, schools and hotels continue to grow in order to serve the economic activity attributable to this traffic.



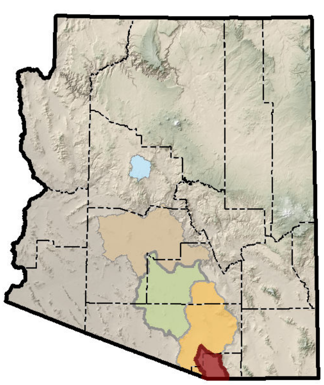


Figure 1-1
SCAMA and Sub-Geographic Areas

ARIZONA DEPARTMENT OF WATER RESOURCES ©

Legend

Santa Cruz AMA
Downstream
Microbasin Area
Potrero Area
NIWWTP
City or Town
Index Well
Major Road
Interstate Highway
Stream
State Boundary
Township/Range
County
SantaCruzGFRs

Large Municipal ProviderService Areas
Citizens Utilities Tubac Valley
City of Nogales
Rio Rico Utilities
Valle Verde Water Company

Each water demand sector in the SCAMA has unique water use characteristics that affect the trend in demand. Agricultural demand includes water used for crop irrigation by IGFR holders. Municipal demand includes water supplied by cities, towns, and private water companies for domestic, industrial, and commercial purposes. Water withdrawn from individually owned, small wells (exempt wells) are exempt from ADWR's reporting and water conservation requirements. Consequently, this use of water can only be estimated. Industrial demand includes water withdrawn pursuant to Type 1 and Type 2 Rights and Groundwater Withdrawal Permits from wells within the AMA. Typical Industrial uses in SCAMA include golf courses and sand and gravel operations, along with miscellaneous other uses.

The majority of this cultural water demand is concentrated along the Santa Cruz River.

1.3.3 Hydrology

Hydrologic and geologic characteristics in the SCAMA can be viewed as falling into four distinct geographic areas as follows: 1) the inner valley area of the Santa Cruz River downstream of the NIWWTP,(the "Downstream Area"; 2) the inner valley area of the Santa Cruz River upstream from the NIWWTP, the "Microbasin Area"; 3) the area surrounding and including Potrero Canyon in the southwestern area of the AMA, the "Potrero Area"; and 4) the remainder of the AMA other than these three areas, the "Other Area" (*See Figure 1-1 SCAMA and Sub-Geographic Areas*). The Microbasin and Downstream areas experience extreme fluctuations in water levels corresponding to natural variations in river flow. There are no man-made reservoirs in the SCAMA to retain flood flow for future times of water shortage.

The remainder of this Assessment includes sections showing the AMA as a whole followed by a more detailed review and comparison of each of these four sub-geographic areas. These areas coincide with areas defined by hydrologic model grid areas, a generalized area delineated for Potrero Canyon, and the balance of the AMA that does not fall within any of the other areas. Each sub-geographic area is characterized briefly below.

The Downstream Area

Since the 1970's, reclaimed water from the NIWWTP has been continuously discharged into the river channel, augmenting baseflow in the area downstream of the NIWWTP, and creating an additional recharge source which serves to sustain downstream riparian habitat. Increases in stream recharge from major winter and fall-period flood events during the period of record also contributed to shallow water tables observed in wells along the inner Santa Cruz River Valley *(See Figure 1-2)*. The hydrology associated with the inner Santa Cruz River Valley is characterized by complex stream-aquifer interactions. Groundwater pumpage, land-use changes, infiltration of discharged reclaimed water and increased evapotranspiration (ET) have modified the hydrologic system. The majority of the water demand in the AMA is located within this area, as are the majority of exempt wells. The potential for additional demand in this area is significant.

Rio Rico is the largest community in the Downstream Area within the AMA. Currently, Rio Rico Utilities serves about 6,820 housing units. A total of 24,000 approved platted lots are within the boundaries of the Rio Rico Utilities water franchise area, or Certificate of Convenience and Necessity (CC&N). Approximately 250 exempt wells also serve some parcels within the Rio Rico service area. Roughly 17,000 approved, but undeveloped lots remain that could potentially be served by the utility company without further application and approval by ADWR under the AWS program. Rio Rico's current water use rate per housing unit is approximately 240 gallons per lot per day. This equates to an estimated potential water demand for the 17,000 lot of an additional 4,500 acre-feet per year above Rio Rico's current water use, which, was about 2,600 acre-feet in 2010.

Other water providers in this area are Arizona-American – Tubac Water Company and other small water providers serving the communities of Tubac and Amado.

Figure 1-2 Hydrograph for Well Downstream from NIWWTP

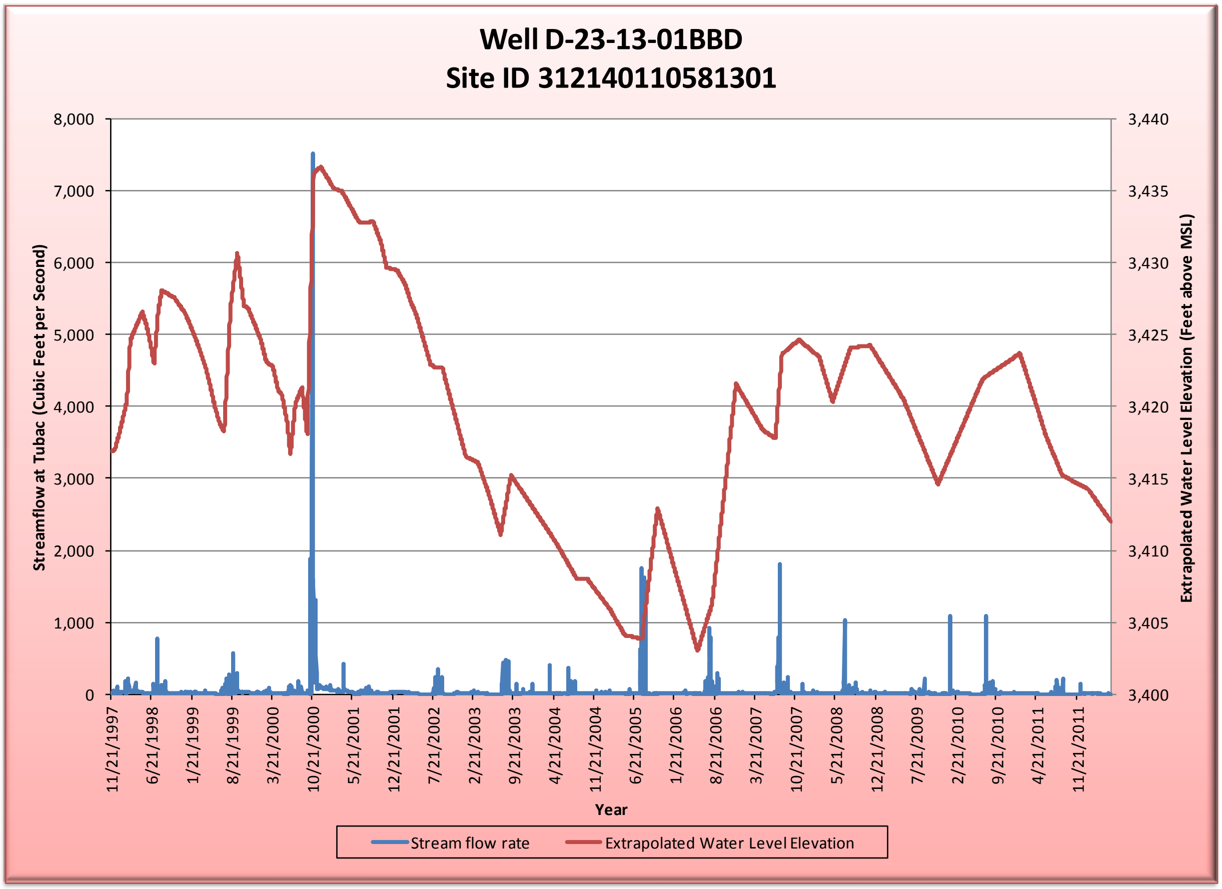
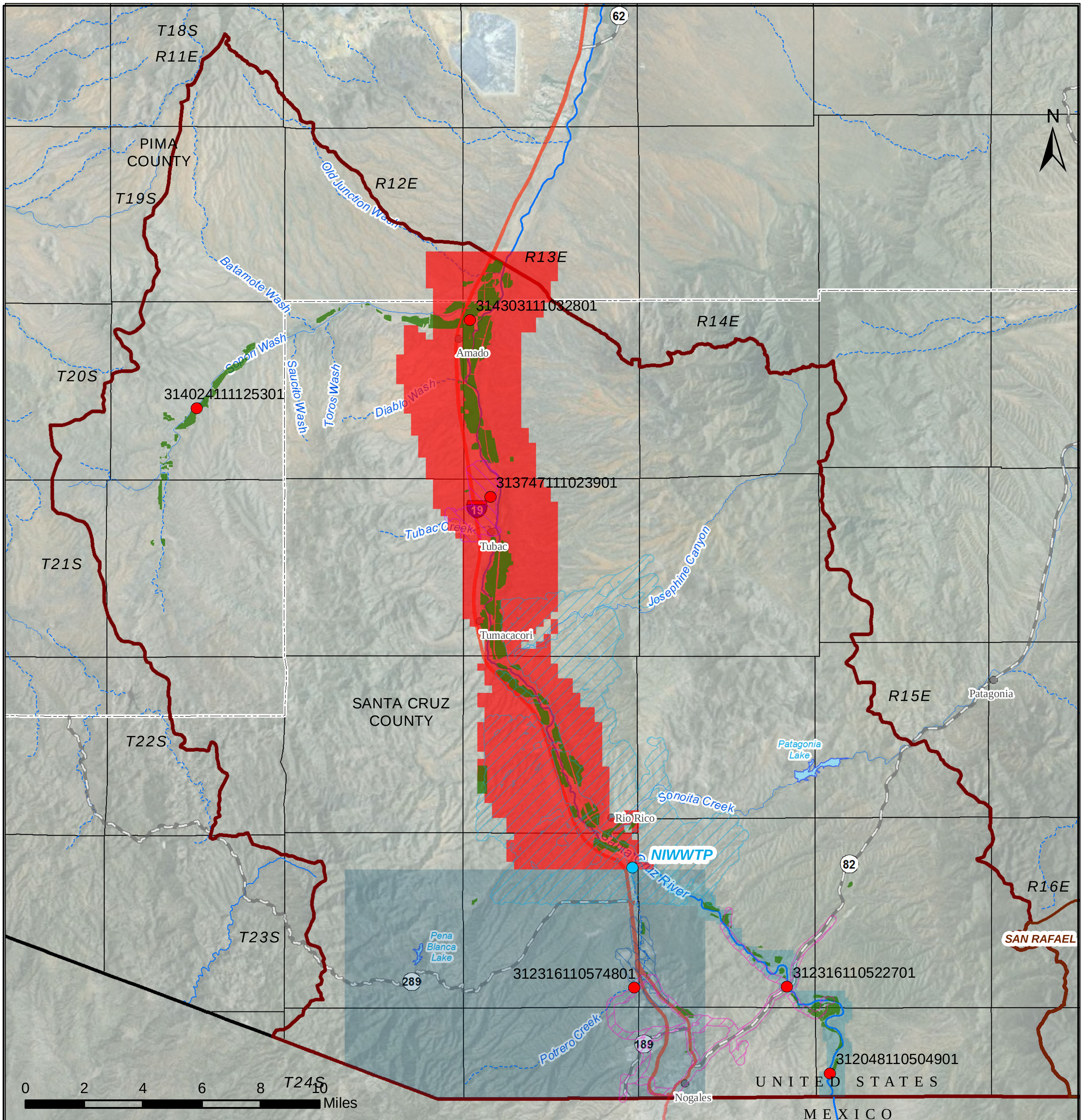


Figure 1-2 gives an indication in the magnitude and frequency of the variation in river flow and water level changes in a well along the River in the Downstream Area.

Figure 1-3 shows the area included in the "Downstream" area.



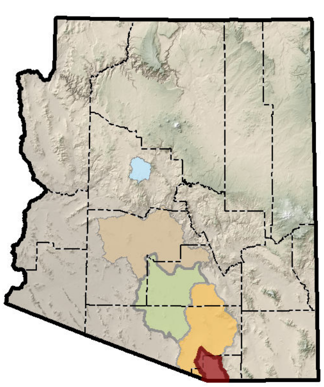


Figure 1-3
"Downstream" Area

Legend

- Santa Cruz AMA
- Downstream
- Microbasin Area
- Potrero Area
- NIWWTP
- City or Town
- Index Well
- Major Road
- Interstate Highway
- Stream
- State Boundary
- Township/Range
- County
- SantaCruzGFRs

Large Municipal Provider Service Areas

- Citizens Utilities Tubac Valley
- City of Nogales
- Rio Rico Utilities
- Valle Verde Water Company

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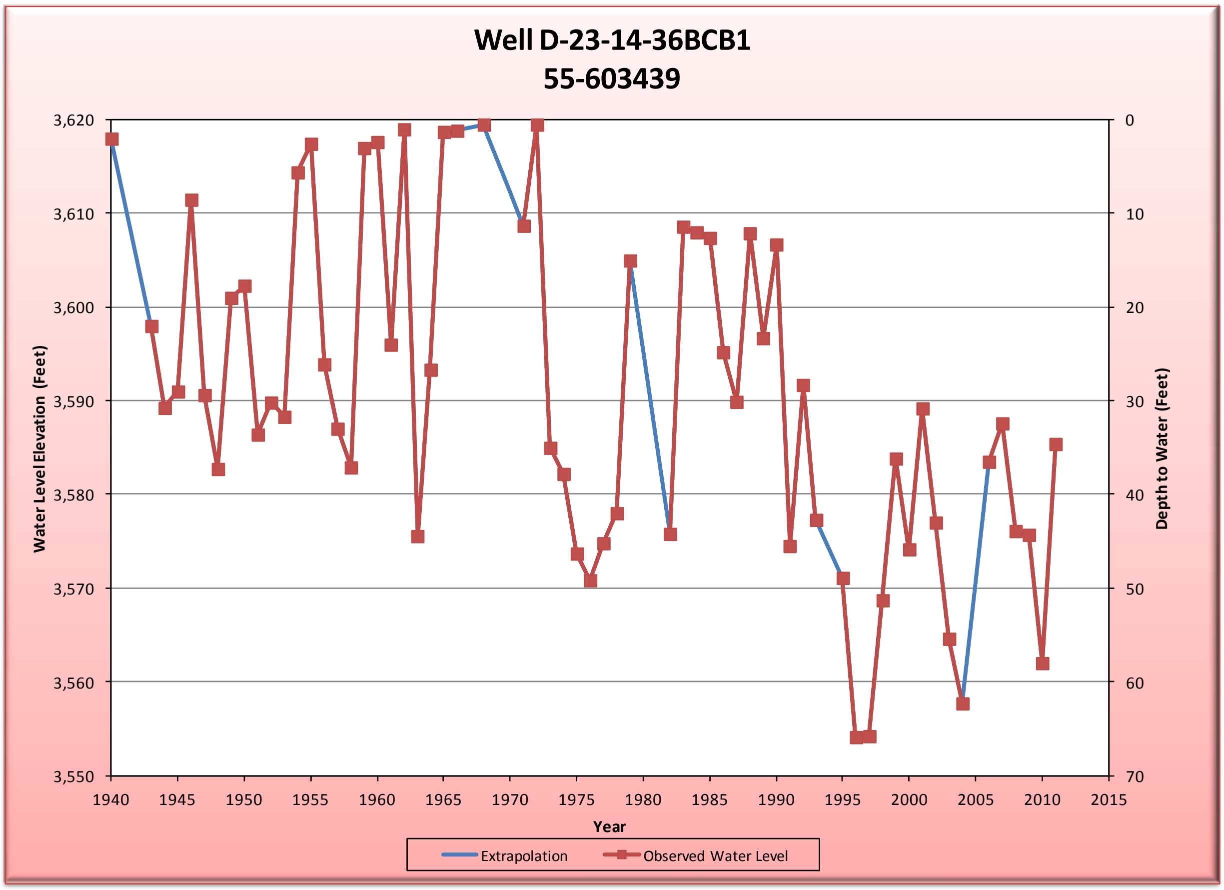
OF WATER
RESOURCES

The Microbasin Area

Along the Santa Cruz River upstream from the NIWWTP, the water supply is predominantly sourced from natural flow in the river. Surface water inflow to the area is measured at U.S. Geological Survey Gage (09480500), Santa Cruz River near Nogales (*See Figure 1-7*). The gage is located approximately 0.8 miles north of the International Boundary (Erwin, 2007). The drainage area contributing to this gage is 533 square miles, of which 348 are in Sonora, Mexico. The balance of the drainage area is in the San Raphael Valley in Arizona where the headwaters of the Santa Cruz are located. The River flows south from the San Raphael into Mexico before returning to the US. The drainage area at the Santa Cruz County line is approximately 1,466 square miles (Andersen, 1955).

Figure 1-4 illustrates the fluctuation in depth to water in well 55-603439 near Highway 82/Kino Springs in the Microbasin Area.

Figure 1-4 Hydrograph for Well in Microbasin Area



Very limited residential or commercial development is within this area. However, the City of Nogales owns wells within the Microbasin area that supply water for municipal purposes. *Figure 1-5,* below, superimposes City of Nogales annual pumpage from a well in the Microbasin on top of the chart showing fluctuating depth to water in this area. The chart shows that after several years of increasing depth to water, the City pumps less water from the Microbasin Area. For example, water depth increased from 1993 to 1999. In the following years, 2000 through 2008, the City pumped much smaller volumes from the Microbasin Area. During these years, the City shifted its pumping regime to rely more on its Potrero wellfield.

Water demand in the City of Nogales increased sharply from 1985 through 1989, but has been fairly flat since then, at about 4,500 acre-feet per year. Much of this water demand has historically been met through wells located in the Microbasin Area along the Santa Cruz River, especially at the City's wells where the Santa Cruz River is bridged by Highway 82. However, the City shifts its well pumpage between its wells in the Microbasin Area and its wells in the Potrero Area (and does a small amount of pumpage in the Outside Area) based on the productivity of the wells. During periods of reduced supply, water demand is met through wells in the Potrero Area and the Outside Area. When there is high or adequate flow in the river, much of the stream flow infiltrates into the aquifer and refills the Microbasins. Sometimes there is a lag in the period of time after the high flow occurs and the basins completely refill. The City withdraws more water from its Microbasin Area wells when the water level is shallow, in the months and year or two after large stream flow events, than it does after several years of limited or little stream flow has occurred. *Figure 1-6* below shows this pattern.

Figure 1-5 Gallery Well and City of Nogales Monthly Pumpage

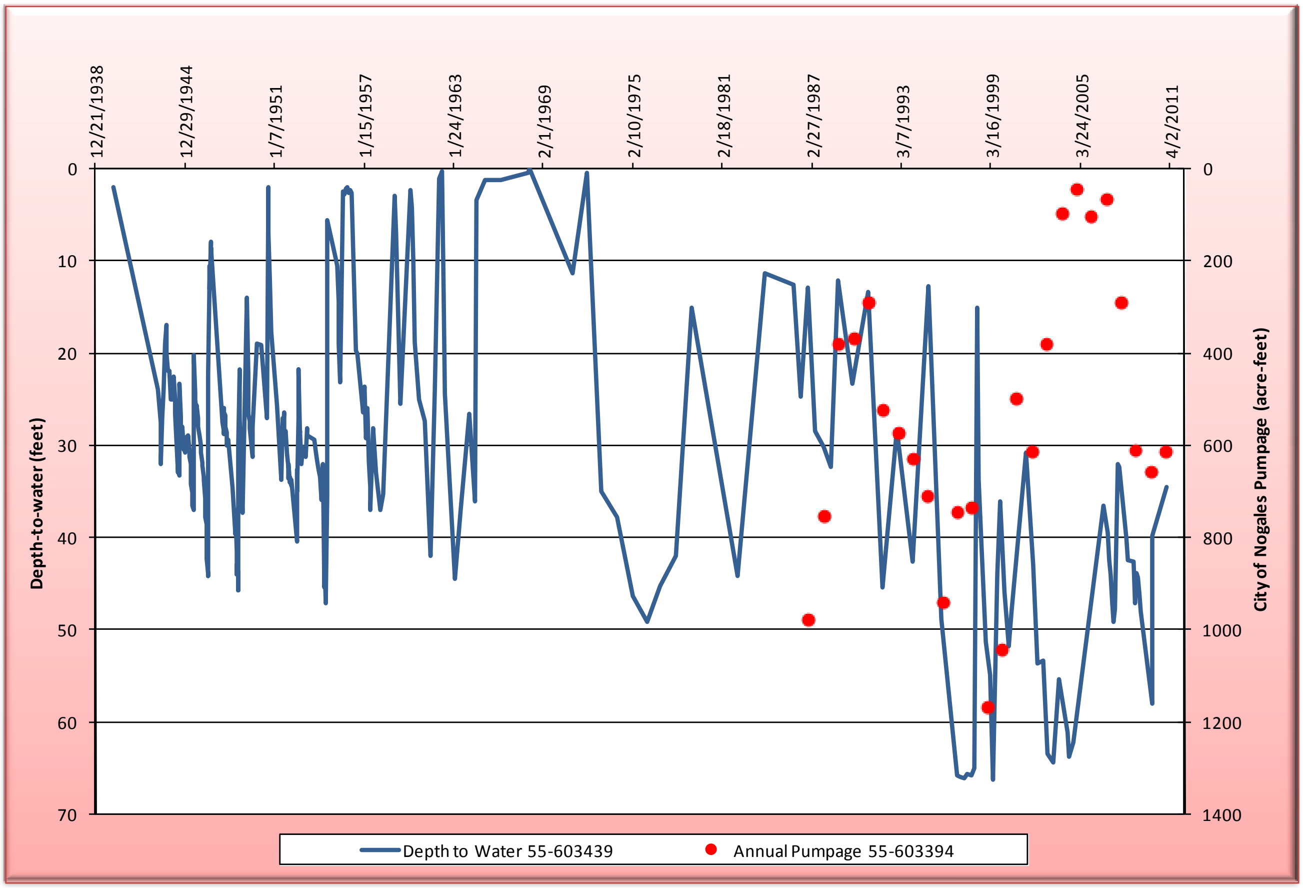
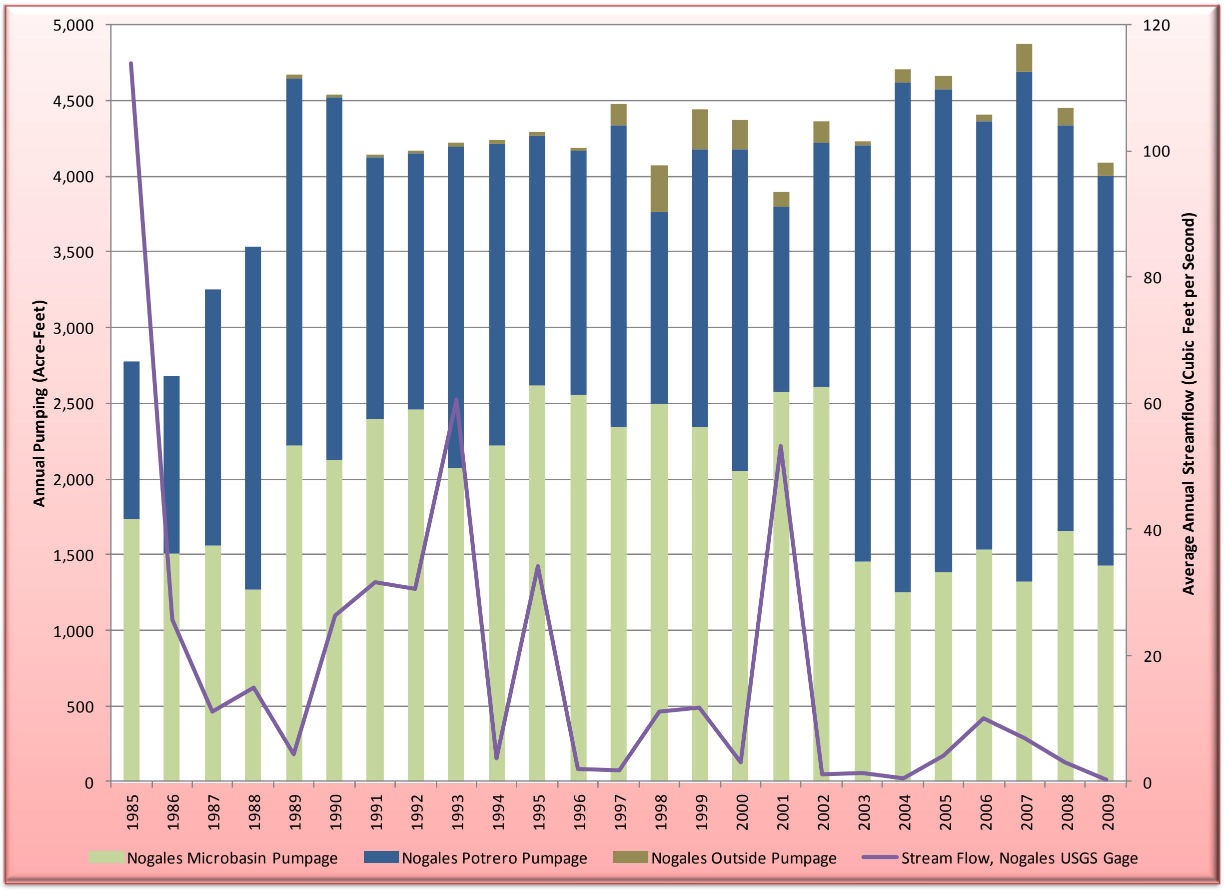


Figure 1-6 City of Nogales Well Pumpage by Geographic Area



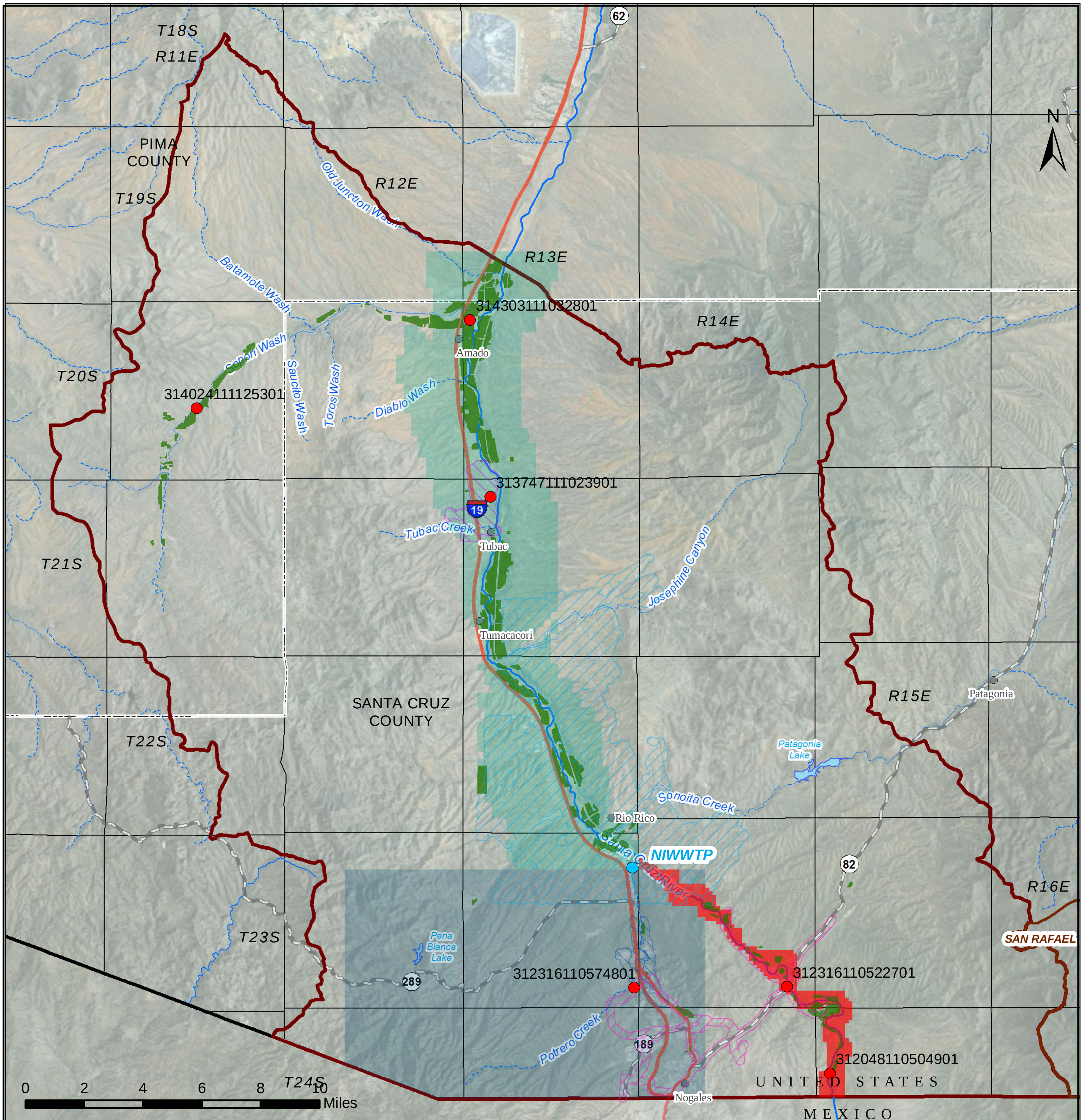


Figure 1-7
"Microbasin" Area

Legend

- Santa Cruz AMA
- Downstream
- Microbasin Area
- Potrero Area
- NIWWTP
- City or Town
- Index Well
- Major Road
- Interstate Highway
- Stream
- State Boundary
- Township/Range
- County
- SantaCruzGFRs

Large Municipal Provider Service Areas

- Citizens Utilities Tubac Valley
- City of Nogales
- Rio Rico Utilities
- Valle Verde Water Company

The Potrero Area

The Potrero Area and the Other Area rely primarily on mountain front recharge and natural flood flows along tributary ephemeral washes to replenish the aquifer systems. Both of these areas have relatively lower water demands as compared to the Downstream and Microbasin areas. Valle Verde Water Company is located partially within the Potrero Area. The backup well field for the City of Nogales is located in Potrero Canyon. *Figure 1-8* shows the Potrero Area.

The Remaining Area of the AMA

Most of the water demand in the surrounding hillsides, away from the Santa Cruz River, is from private, domestic, exempt wells, and some stock watering wells. The communities of Arivaca and Morning Star Ranch are located in this geographic area. *Figure 1-1* shows the Downstream, Microbasin and Potrero Areas within the SCAMA. The remaining AMA area is the "Other Area" of the SCAMA.

1.3.4 Water Management Activities in SCAMA

After the SCAMA was created, an AMA office was established in Nogales, Arizona and a Groundwater Users Advisory Council (GUAC) appointed. Because SCAMA was created during the second management period, the requirements of the TAMA 2MP were applicable to SCAMA until the 3MP was adopted and became effective. ADWR began work on the 3MP shortly after SCAMA was created. In addition, ADWR Hydrology field personnel began collecting water level data in SCAMA wells on a monthly basis to help characterize the dynamic nature of water supplies in the AMA and to prepare for the construction of a hydrologic model of the SCAMA. In 1995, an additional streamflow gage was installed in the Downstream Area at Tubac. Data collection began ~~d~~ late that year.

As development of the 3MP continued, the SCAMA GUAC provided a public forum for local water management concerns to be raised and discussed by water users, the public, and other local, regional, federal and international agencies and authorities.

Development of the 3MP

The 3MP was the first management plan specifically written for the SCAMA. However, the AMA was newly created and data gathering efforts had just begun. Although ADWR and local water users were aware of the unique characteristics of the SCAMA, there was insufficient time to collect and analyze additional data, and to prepare, promulgate, and adopt a 3MP with unique regulatory programs tailored to the SCAMA. Therefore, the 3MP for SCAMA is, in many ways, identical to the 3MP for the TAMA, with some small exceptions. Consumptive use and other crop needs for the agricultural program for SCAMA are identical to Area of Similar Farming Conditions (ASFC) 7 in the TAMA. The Industrial program in SCAMA is essentially identical to the TAMA 3MP, except that there are fewer types of Industrial users in the SCAMA than there are in TAMA. For example, there are no Metal Mining or Dairy/Feedlot Industrial sub-sectors in SCAMA. The model for interior per capita use for new residential housing units is identical for all five AMAs. However, the SCAMA 3MP has its own unique models for new residential exterior development.

Inventory of water rights

The majority of water uses in the SCAMA are served by water withdrawn from wells. Many of these withdrawals are from wells with shallow water levels in areas adjacent to perennial or intermittent stream reaches. The relationship between the pumping of wells and the supplies available to surface water right holders of nearby stream courses has been an on-going topic in the Arizona court system since the Pima Farms v. Proctor and MWD v. Southwest Cotton cases in 1926 and 1931, respectively. The issue remains largely unresolved and is still under review within the General Adjudication of the Gila River System and Source.

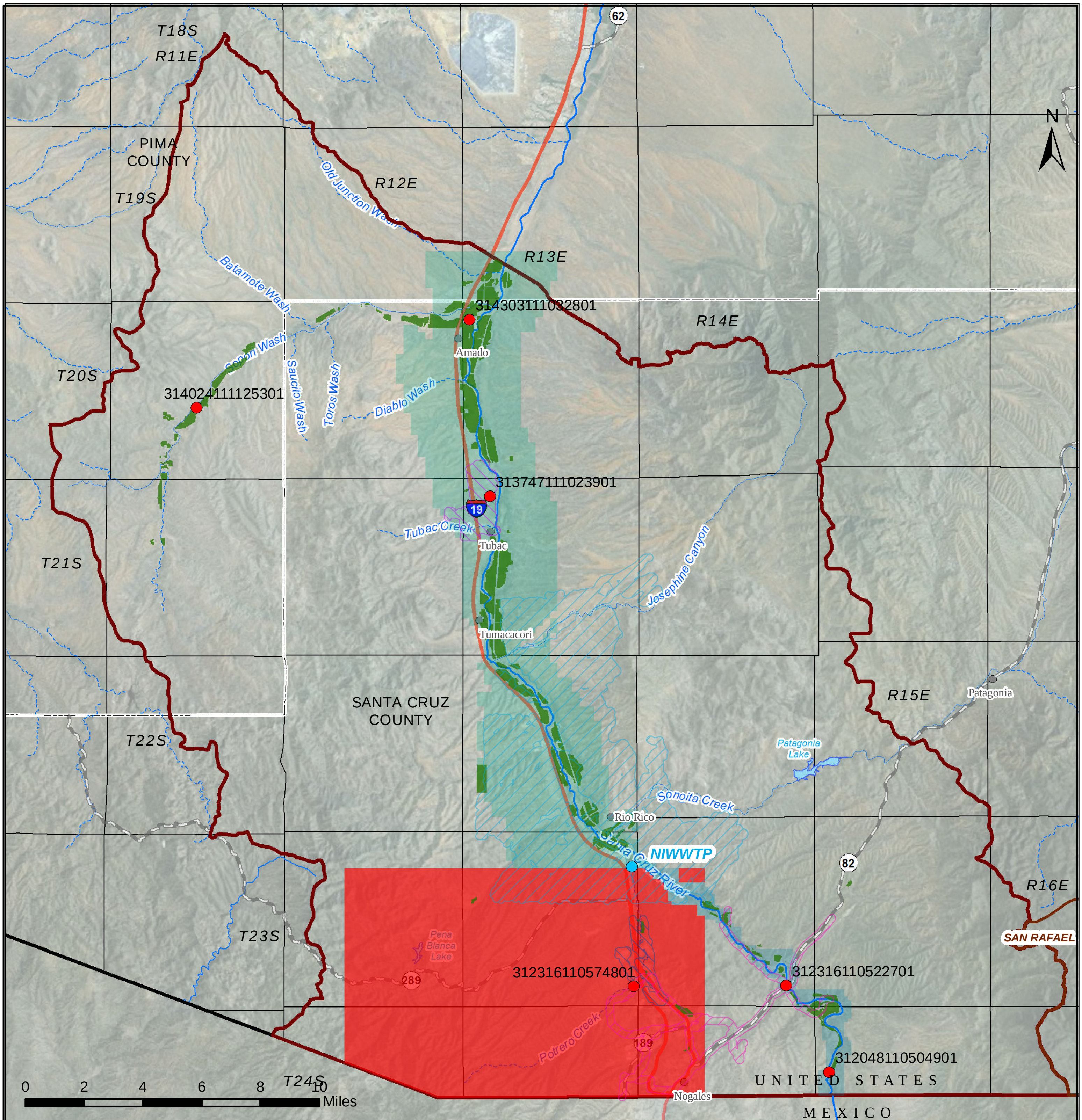
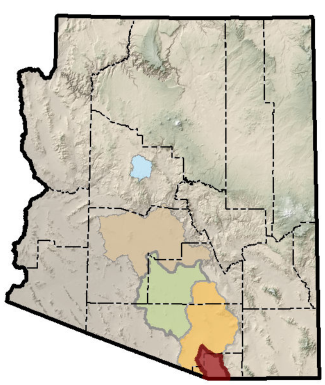


Figure 1-8
"Potrero" Area



Legend

- Santa Cruz AMA
- Downstream
- Microbasin Area
- Potrero Area
- NIWWTP
- City or Town
- Index Well
- Major Road
- Interstate Highway
- Stream
- State Boundary
- Township/Range
- County
- SantaCruzGFRs

Large Municipal Provider Service Areas

- Citizens Utilities Tubac Valley
- City of Nogales
- Rio Rico Utilities
- Valle Verde Water Company

This uncertainty as to the legal character of water produced by wells in close proximity to stream courses has resulted in many water users filing water right applications and claims under both the surface water and groundwater statutes. This legal uncertainty and the “dual-filed” rights that exist in response to that uncertainty complicate the development of a robust, workable, water management plan and administrative system for the SCAMA.

As ADWR, the GUAC, and local water rights holders and water interests continued to discuss the unique hydrology and water management issues of the SCAMA it became apparent that the lack of a surface water rights settlement complicated water management endeavors in the AMA. As a result, the SCAMA Water Rights Settlement Group was formed, which included several water rights interests in the Amado, Tubac, Rio Rico, and Nogales areas. The Settlement Group sought to forge its own local water rights settlement as an agreement amongst water users in the AMA as a stop-gap measure, until such time as the General Adjudication officially determined the nature and extent of surface water rights within the AMA. The Settlement Group held several meetings at regular intervals through the mid 2000’s but was unable to formalize a final settlement agreement.

ADWR staff conducted an inventory of all water rights, surface water or groundwater, in the SCAMA in response to a request by The Settlement Group. The inventory was drafted in March 2001, and it identifies for each water user in the AMA whether the land has a surface water claim, a groundwater right, or both, and includes all wells then in existence in the AMA. The inventory shows that dual-filed rights are prevalent in SCAMA.

Model Development

In 1997, ADWR initiated a monitoring program to guide development of a conceptual and numerical model of the SCAMA in the Downstream and Microbasin Areas (Nelson & Erwin, 2001). Many valuable hydrogeologic investigations have been conducted in the vicinity of the model area (Nelson, 2007). Along with others, ADWR staff conducted monthly water level and stream flow data collection efforts along the Santa Cruz River and its major tributaries from the Mexican border to the northern end of the AMA. In addition, transducers were installed in several wells in the SCAMA to obtain continuous water level measurements.

The primary goal of the SCAMA groundwater modeling studies was to develop an analytical tool capable of quantifying the effects of various water management programs on the water supplies within the study areas and to learn more about how the hydrologic system operates. The general objectives are to: (1) develop models that effectively simulate the groundwater/surface water interaction; (2) accumulate all hydrologic, geologic, pumpage, and ET data for each area into a single database format; and (3) provide analysis of specific predictive scenario model simulations that will assist in evaluating adequacy and reliability availability of supply.

SCAMA AWS Rule Development

AWS Rules with specific provisions for the Tucson, Phoenix, Pinal and Prescott AMAs were adopted in February, 1995. The ADWR water rights inventory of SCAMA was completed early in 2001 and in 2004. The Settlement Group’s objective to achieve a settlement agreement filed for court approval as part of the Gila River adjudication proceedings was discussed in ADWR’s draft AWS Rule Concepts for SCAMA (Concept Paper). ADWR noted that several of the settlement provisions under consideration would require modifications to existing law, through either the enactment of new statutes or amendment of existing statutes. ADWR also noted in a “Concepts Paper” that in order to support SCAMA’s statutorily mandated management goal, the AWS Rules must move forward as soon as possible. If in the future SCAMA water users reach a settlement agreement that is approved by the Gila River adjudication court, the Department will further modify the Rules at that time to the extent authorized by state law.

Work on the draft AWS Rules for SCAMA continued until a draft rule change was completed in April of 2007. The draft rules were presented to the SCAMA water users and comments were received and summarized in 2008. As a result of the comments, new concepts were developed in early 2008 and comments to those were compiled in December 2008.

In January 2009, the Governor's office ordered state agencies to suspend their rule-making activities. During the 2009 legislative session, the legislature passed a session law imposing a moratorium on rule-making by state agencies for FY 2009-2010, with certain exceptions. During the 2010 legislative session, the legislature again passed a session law with a similar rule-making moratorium for FY 2010-2011. The legislature did not extend the rule-making moratorium during the 2011 legislative session, so it expired on July 1, 2011. However, on June 30, 2011, the Governor issued an Executive Order extending the moratorium for most state agencies, including ADWR, until July 1, 2012. The objective of the Order is to eliminate any unnecessary increased monetary or regulatory costs on employers, persons, individuals, other state agencies, or political subdivisions of the State. ADWR has not as of the preparation date of this Assessment, acted on the draft SCAMA AWS Rules because the draft Rules are not yet complete and the moratorium on rule-making is still in effect.

1.3.5 Uncertainty and Water Management in SCAMA

In April 1990, ADWR published a document titled Santa Cruz County Water Issues Report which identified several issues affecting the ability to effectively manage water in SCAMA, some of which ADWR may or may not have the existing authorities to manage. These uncertainties persist to the present day and are described in the following sections.

State of the Mexican economy and water demand in Nogales, Sonora

Nogales, Sonora has a significantly higher population than Nogales, Arizona. Despite sharing a common hydrologic system, ADWR, the State of Arizona and other regulatory agencies have no control over increases in water demand in Mexico. In April 2007, the Arizona-Mexico Commission (AMC)/ Comisión Sonora-Arizona (CSA) Water Committee was created to address critical water resources issues in the Arizona-Sonora region in response to a joint request made by the Directors of the water resources agencies in the two states. ADWR and the Comisión Estatal de Agua del Estado de Sonora (CEA - State of Sonora's Water Commission) recognize the need for a state-level forum to facilitate discussion of shared water resources issues.

The Committee held its Inaugural meeting on June 20, 2007 in Tucson, Arizona as part of the AMC Summer Plenary Session. The committee is chaired by, and comprised of public and private sector representatives from both states.

The committee has been meeting regularly since its establishment, synchronized with the AMC Plenary Sessions.

Demographic trends within Arizona

The factors that drive demographic trends are often outside the management authority of most state agencies. However, ADWR does have the authority to deny applications for AWS that do not meet the criteria established in the AWS Rules. As described in Section 1.3.3 above, there are large areas of land within the SCAMA that are statutorily exempt from the AWS Rules, including much of the Rio Rico area. Statutory change would be required to make the proposed AWS rules for SCAMA applicable to the exempted areas within the AMA.

Outcome of the Surface Water Adjudication

A general stream adjudication is a judicial proceeding in which the nature, extent, and relative priority of water rights is determined. The Santa Cruz River is a tributary to the Gila and, as such, the lands within SCAMA are subject to the General Adjudication of the Gila River System and Source. As required by statute, ADWR provides technical and administrative support to the adjudication court and Special Master,

"...in all aspects of the general adjudication with respect to which the director possesses hydrological or other expertise." (A.R.S. § 45-256(A)). ADWR provides technical support for the adjudication through the investigations of claims for water rights and preparation of technical reports. ADWR Legal Services represent ADWR before the adjudication court and the Special Master, and assists with the preparation of technical reports and provide information as requested.

By statute, ADWR is required to prepare and publish comprehensive Hydrographic Survey Reports (HSRs) for each of the ten watersheds within the two adjudications. HSRs are typically multivolume publications that involve intensive data collection and field inspection efforts by ADWR, including detailed information regarding land ownership, hydrology, and the factual basis for each Statement of Claim (SOC), and ADWR's recommendations regarding the water rights attributes for each individual water right claim or use investigated.

ADWR has also prepared and published technical reports on specific issues or factual matters within the adjudications, such as Indian water rights settlements, the Globe Equity 59 Decree, de minimis water uses, inventory of uses within the Santa Cruz River watershed, the determination of subflow, comments on procedural issues, and status reports.

ADWR maintains and updates SOC information, including names and addresses of the parties to the adjudications, the location and nature of claims, property records and payment of filing fees that are forwarded to either the Maricopa County Court (Gila Adjudication) or the Apache County Court (Little Colorado River Adjudication). The information is updated as new SOCs are filed, and as existing SOCs are amended or assigned due to changes in property ownership or other changes.

Until such time as the Adjudication Court has rendered a final opinion on the water rights in the SCAMA, uncertainty as to the rights, quantities, and priority dates shall remain. This may affect both the distribution of rights between individual users within the SCAMA and the total volume of potentially available surface water as the jurisdictional area encompasses the Gila River Watershed as a whole, of which the Santa Cruz is small part.

ADWR does not determine the outcome of the general stream adjudication. This is outside ADWR's authority and control.

Reclaimed Water Generated in Mexico

Since 1972, wastewater generated in Nogales, Sonora has been piped into the United States to be treated at the NIWWTP. Mexico has the right to retain wastewater generated within Mexico pursuant to international treaty. In recent years, Mexico is pursuing construction of its own WWTP, in the Los Alisos groundwater basin in Mexico, for reasons including the following:

- Mexico pays a penalty for wastewater contributions in excess of 434 liters per second (LPS) (about 9.9 million gallons per day-an annual equivalent volume of just over 11,000 acre-feet per year);
- Wastewater retained in Mexico could be used to replenish the depleted Los Alisos aquifer; and
- Retaining and replenishing wastewater within Mexico could provide a source of water to foster economic development in the southern portion of Nogales, Sonora.

The stated intention of the decision makers in Nogales, Sonora is to continue to send 434 LPS to the NIWWTP in Arizona, but to retain the excess flows in Mexico to be treated at its new Los Alisos WWTP (LAWWTP), which is currently under construction. The initial phase of the LAWWTP, having a capacity of 160 LPS (4,091 acre-feet/year), is expected to be operational by May, 2012. The second phase, projected for completion in 2015, will add another 170 LPS (4,346 acre-feet/year) of capacity. In addition to diverting existing sewer flows to comply with the 434 LPS limit, the new LAWWTP is anticipated to treat wastewater from currently unsewered areas in the southern portion of Nogales, Sonora.

If these stated intentions change and instead Mexico reduces the volume of reclaimed water sent to the NIWWTP, SCAMA will experience a reduction in the volume of water replenishing the Downstream Area. In addition, less water will be available to meet the water demands of near stream well users and the riparian community along the Santa Cruz in the Downstream Area. This could also reduce the volume of water that spills from the SCAMA to the Tucson AMA.

Should Mexican officials decide to contribute less wastewater than the 434 LPS limit, it will be a decision based on factors other than the economics of wastewater treatment. Los Alisos WWTP is located up gradient from the City of Nogales. Significant costs will be incurred to operate the lift stations constructed to deliver this sewage to Los Alisos for treatment. It is anticipated that the cost of treatment at Los Alisos will exceed the cost of treatment of the base volume of effluent at the NIWWTP, which is fed by gravity sewers. This cost differential is believed to be sufficient incentive for Mexico to continue deliveries of sewage to the NIWWTP for treatment up to the 434 LPS limit.

ADWR is an active participant in the Water Committee of the Arizona Mexico Commission (AMC). The AMC serves as a forum for topic of Bi-National interest between Arizona and the Mexican State of Sonora. ADWR is attempting to use this forum to gain additional insight into Sonora's plans for continued sewage contributions to the NIWTTP. This information will then be leveraged to predict future conditions in the SCAMA. Unfortunately, this information was not available at the time of preparation of this Assessment.

VOLUME, FREQUENCY, AND LOCATION OF RAINFALL

The Santa Cruz River Valley receives the majority of its annual precipitation in two seasons, the summer monsoon season - July through August and the fall/winter season - October, December, and January. Summer storms are generally local in extent, have high intensity but are of short duration. Winter storms are generally more widespread and gentle, and are more intense in the mountains than in the valleys (Coates & Halpenny, 1954). Precipitation magnitudes and occurrences have fluctuated over time in the Santa Cruz River Valley. This variability is ultimately tied to long-term fluctuations in global weather patterns, including El Nino/ Southern Oscillation (ENSO) conditions (Webb & Bettancourt, 1990), Pacific Decadal Oscillation (PDO), and NINO3 (Shamir & al, 2005). Between 1953 and 2005 precipitation averaged 17.43 inches at the Nogales 6N weather station (WRRC, 2005). In recent years, however, less than average precipitation has occurred (*See Figure 1-9*). A detailed study conducted by the Hydrologic Research Center (Shamir & al, 2005) indicates the historical climate has experienced annual and seasonal variability. The SCAMA is more dependent on precipitation events than the other AMAs due the shallow aquifers and the concentration of pumping in the inner valley areas (Microbasin and Downstream Areas). The spatial and temporal distribution of precipitation is a critical variable in water availability on an annual and seasonal basis.

Figure 1-9 Annual Precipitation

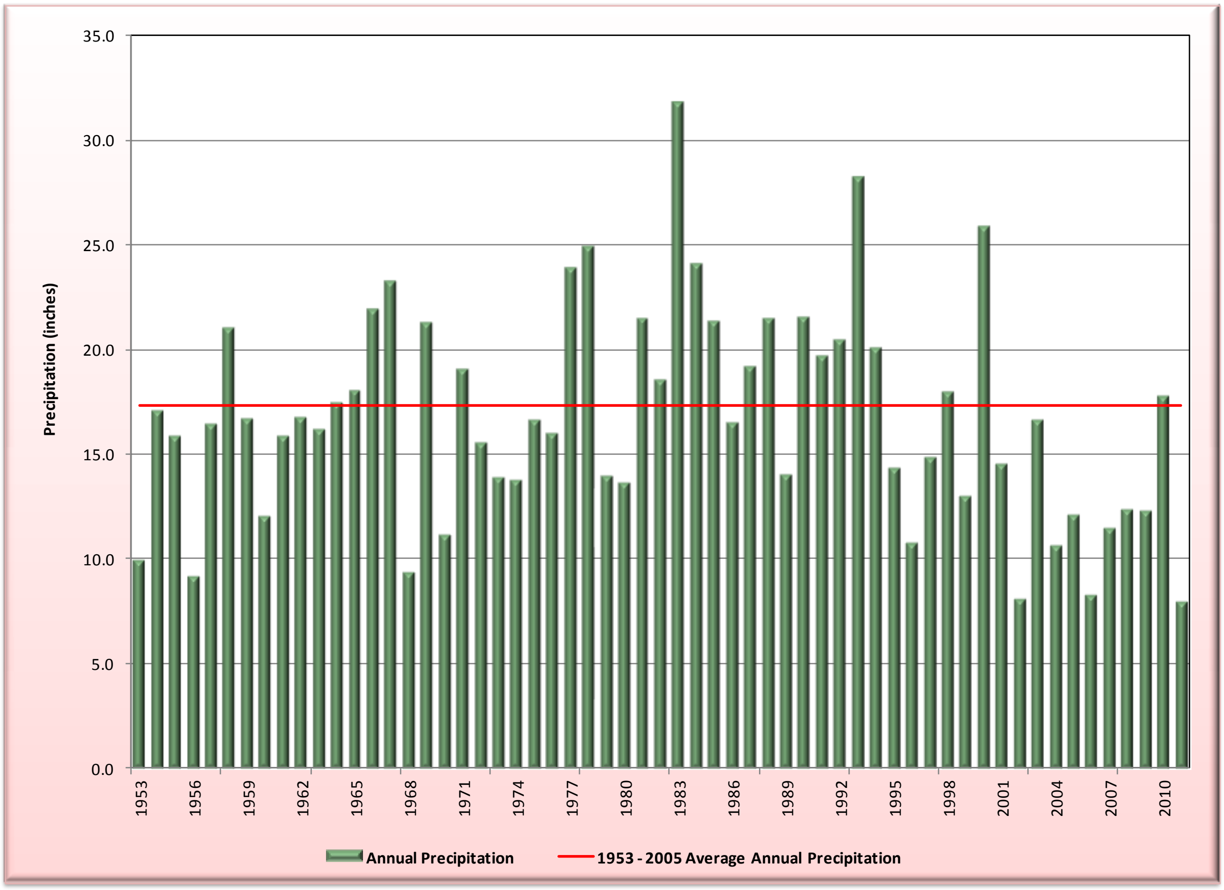


Table 1-1 Precipitation Rates in General Model Area

LOCATION	LONG-TERM ANNUAL AVERAGE			RECENT PERIOD (1997- 2002) AVERAGE ANNUAL PRECIPITATION HIGH AND LOW RATES		
	PERIOD OF RECORD	PRECIPITATION RATE	STANDARD DEVIATION σ	AVERAGE	HIGH	LOW
Tumacacori	*1948 – 2004:	15.7”	σ 5.1”	15.1”	19"	9.3"
Nogales 6 N	*1954 – 2004	17.4”	σ 5.0”	15.7	26"	8.0"
Old Nogales	*1901- 1946	15.7”	σ 4.1”			
Nogales	*1948- 1983	16.6”	σ 4.2”			
Santa Rita Experimental Range	*1950 – 2004	22.1”	σ 5.1”	21.1	25"	18.0"
Coronado Natl. Monument	*1960 – 2004	20.6”	σ 5.0”	20.1"	31"	13"
Canelo 1NW (near Patagonia)	*1910 – 2003	18.1”	σ 4.1	17.1"	26"	11"
Arivaca	**1971-2000	18.7”		17.7"	25"	12"
Patagonia	**1971-2000	18.3”		17.6"	23"	10"

[a] Missing more than 34 days of data; Source: *AZClimate, 2004; **NOAA, 2005. All units in inches.

LACK OF SUITABLE LOCATIONS FOR RESERVOIR AND UNDERGROUND STORAGE

Finding additional water resources to provide as back up supplies during drought periods is a primary water management concern in SCAMA. Once such supplies are secured, local storage facilities will need to be developed. If this storage is to be conducted within local aquifers, locations with sufficient infiltration or injection capacity will need to be identified and acquired. Additionally, the water will need to be stored in locations that will allow the water to be retained for use within the SCAMA and not be subject to the claims of downstream appropriators. ADWR has contributed to the evaluation of whether there are appropriate sites for construction of underground storage facilities for artificial recharge within SCAMA. In October, 2006 ADWR, the City of Nogales and the U.S. Bureau of Reclamation entered into a cooperative agreement to evaluate the potential of long-term water storage alternatives for SCAMA. Preliminarily, the study identified 17 potential alternatives for consideration. Further effort, including economic analysis, is needed to complete the study. Insufficient fiscal resources have been available to complete the evaluation effort. Should this effort be completed and potential storage sites identified, significant resources would then be required for acquisition or securing access to the facility and the development of delivery, storage, and recovery infrastructure. Depending on the source of supply, acquisition costs may also be required. The prolific aquifer underlying the southern portion of Santa Cruz County is shallow, narrow, and limited to the near-stream alluvium of the Santa Cruz River. Discharges of reclaimed water have raised the water table downstream from the NIWWTP, limiting available vadose zone. In general, sites selected for recharge/recovery projects must be located in an area with sufficient hydraulic conductivity to allow the water in to enter the aquifer and sufficient vadose zone to prevent mounding of the recharged water from impeding infiltration.

International agreement on ownership of reclaimed water, as well as the quantity and quality of wastewater flowing from Mexico to the United States at Nogales, are important considerations in any augmentation project that relies on reclaimed water. Regardless of whether or not Mexico elects to construct additional reclaimed water reclamation projects, the quantity and quality of water flowing across the border into the SCAMA remains an important consideration.

Limited availability of “wet water” is a problem for areas where growth has historically been concentrated in the SCAMA. Consequently, there may also be physical availability problems with recovering stored water outside the hydrologic area of impact of storage.

Interference with surface water rights is also a concern. Due to the interconnection of surface water and groundwater in SCAMA (and associated legal uncertainty), recharge/recovery of reclaimed water could result in increases in localized pumpage and decrease surface water availability in portions of the Santa Cruz River. Planning and permitting of these activities will need to account for such impacts.

PART II AMA ASSESSMENT WATER BUDGETS AND THE SCAMA WATER BALANCE FORMAT

This Assessment is a compilation and study of historical water demand and supply characteristics for the SCAMA for the years 1985 through 2009. In addition, the Assessment calculates six water supply and demand projection scenarios (three baseline scenarios with different demand assumptions and normal supply conditions; and three dry conditions scenarios using the same demand assumptions as the baseline scenarios but with reduced supply) to the year 2025. ADWR conducted this Assessment as preparation for the 4MP as required by the Code. The Assessment will provide the foundation upon which regulatory and incentive programs and water management planning strategies are developed and adopted for the 4MP and implemented during the fourth management period, extending to the year 2020.

The historical data contained in this Assessment were compiled from Annual Water Withdrawal and Use Reports (annual reports) filed by water users since 1984. Other components required to estimate both historical and projected overdraft were derived from ADWR’s Hydrology Modeling Section as part of development of a regional hydrologic model for the SCAMA. The detailed dataset compiled during this effort is stored in the *Santa Cruz Master Data Template* (Template) (ADWR, Assessments, 2012). The Template is an inventory of the demand and supply for the AMA. The data housed in the Template has been summarized in a budget format, referred to as the Summary Budget. Both the Template and Summary Budget are available online at www.azwater.gov/AzDWR/WaterManagement/Assessments.

In order to be consistent across the years and sectors, ADWR staff took extensive efforts to re-evaluate demand and supply data from the individual annual reports submitted by water providers, irrigation districts, industrial facilities, farms and individual users to populate the Template and Summary Budget, rather than relying on previously compiled totals. During the 24 years considered, the data required by annual reports has become more complicated as the statutes, rules and Management Plans have changed, and as water management itself has become more complex. Meanwhile, the methods used to store, retrieve and compile the data have become more sophisticated. This evolution of data development and retrieval may cause the more recently compiled totals for demand or supply to be slightly inconsistent with previously published numbers in previous Management Plans. While data reporting details and data retrieval have changed over the years, annual water use data have been reported in a relatively consistent manner for over 24 years. This long period of consecutive annual reporting provides the opportunity for ADWR to analyze past use and project future water demand using the longest period of record yet available. The data regarding future potential demand and supply were projected using various methods, as explained in detail beginning in Part III. *Appendices 1-5* contain additional information regarding how these numbers were developed.

2. BUDGET TEMPLATE FOR OTHER AMA ASSESSMENTS VERSUS FORMAT FOR SCAMA

The SCAMA budget template and data presentation for this Assessment differ from the other four AMAs. Rather than choosing the years 1985, 1995 and 2006 to present in charts and figures, as is done in the other Assessments, ADWR presents the entire history from 1985-2009 for SCAMA to illustrate the variable nature of and demand and supply.

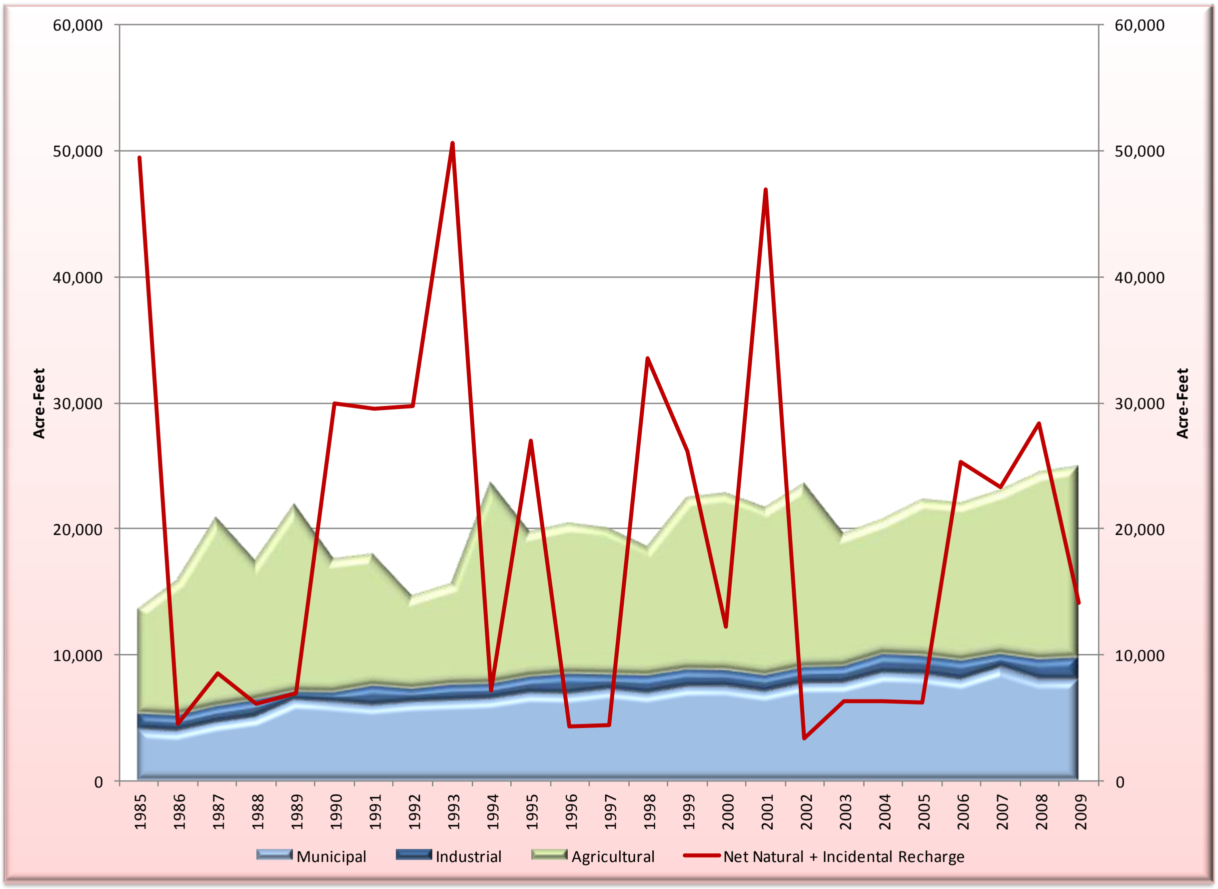
For other AMAs, ADWR included charts showing the multiple supplies used to meet historical demand. Because almost all water used in SCAMA is derived from wells, overall supply charts do not illustrate the relative importance of natural stream flow, intermittent flood flows, and discharge of treated reclaimed water in the river areas, all of which replenish the aquifers from which the wells pump. An AMA-wide supply chart also does not show the different nature of water resources within various sub-regions in the AMA and particularly in areas away from the inner valley. Therefore in the SCAMA Assessment, to begin to explore the concept and character of maintaining local water table levels, ADWR is using a different approach where the water balance within sub-geographic areas of the AMA are separately evaluated in addition to the AMA as a whole.

2.1 SCAMA Water Balance

Although there is hydrologic interaction between the SCAMA sub-geographic areas, ADWR believes it is helpful to present the demand data for SCAMA in this way to understand the different water supply and demand dynamics at a more localized level. The figures below show the historical pumping patterns by large, non-exempt (associated with an authority to withdraw groundwater, as opposed to a private, exempt well) users at the AMA wide level and in each of the four sub-geographic areas over the historical period of 1985 – 2009.

Figure 2-1 compares annual demand by sector and supply at the AMA level. In some years, the Net Natural and Incidental Recharge, shown by the red line, far exceeds the sum of the water demand in the three sectors. During these periods, the additional supply replenishes the aquifers as it moves through the inner valley areas and, if flows are in excess of the recharge capacity of the stream channel soils or the inner valley aquifers are fully saturated, the water moves north into the Tucson AMA. In other years, the demand is greater than the Net Natural and Incidental Recharge. In these years, there may be limited visible surface flow in the Santa Cruz River, or flow may occur only during certain periods of time. In years where the sum of the sector demands is greater than Net Natural and Incidental Recharge, water is drawn from aquifer storage (overdraft) and water levels decline.

Figure 2-1 SCAMA Demand and Supply

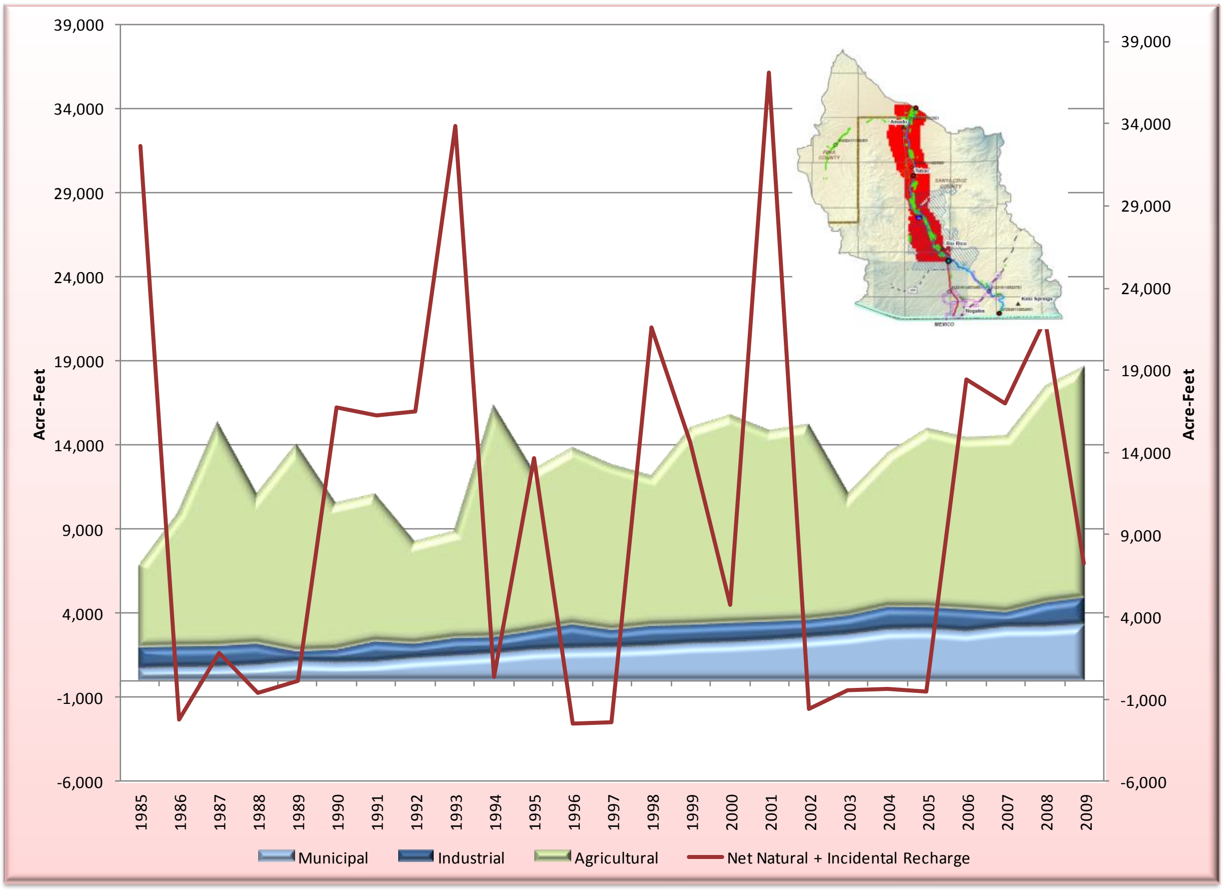


<u>Downstream Area</u>

As demonstrated by *Figure 2-2*, the Downstream Area is dominated by agricultural uses. The largest agricultural right in the AMA, owned by Rio Rico Properties, is located in this area. The annual reported water used by Rio Rico fluctuates beyond what would be expected for a stable agricultural water user because they periodically use larger volumes of water to in response to statutory language regarding the forfeiture and abandonment of surface water rights.

Municipal uses in the Downstream Area have gradually increased over time. Rio Rico Utilities is the largest municipal provider in this area. Other providers in the area include Arizona-American – Tubac and some smaller providers. Industrial uses of water in this area have fluctuated somewhat over time. However the volume of Industrial use in this area is significantly less than Municipal and Agricultural demand. Rio Rico Resort Golf Course and Tubac Golf Resort are both located in this area and use Type 2 GFRs as the legal authority to withdraw water to irrigate the courses.

Figure 2-2 Downstream Area Demands by Sector and Supply



The majority of the AMA water demand is concentrated in the Downstream area, increasing from about half of the total AMA demand in 1985 to roughly three-quarters of the total AMA demand in 2009.

<u>Microbasin and Potrero Areas</u>

Microbasin pumpage, shown in *Figure 2-3,* is dominated by municipal demand and is largely conducted by the City of Nogales. When there are sufficient supplies in the near-stream aquifer of the Santa Cruz River, Nogales utilizes this supply. When well yields in the Microbasins are insufficient to meet its demands, Nogales shifts its pumping to a secondary well field in the Potrero Area. This shifting in pumpage from the Microbasin Area to the Potrero Area is visible when *Figures 2-3 and 2-4* are compared. In years prior to about 2002 or 2003, Nogales relied more heavily on its Microbasin wellfield. However, in more recent years, drought conditions and water users upstream in Mexico have limited Microbasin well yields, increasing City reliance on its Potrero wells. Although there are other water providers in these two sub-geographic areas, the majority of the pumpage, and thus the pattern of pumpage, is influenced strongly by the City's water management decisions.

Figure 2-3 Microbasin Area Demands by Sector and Supply

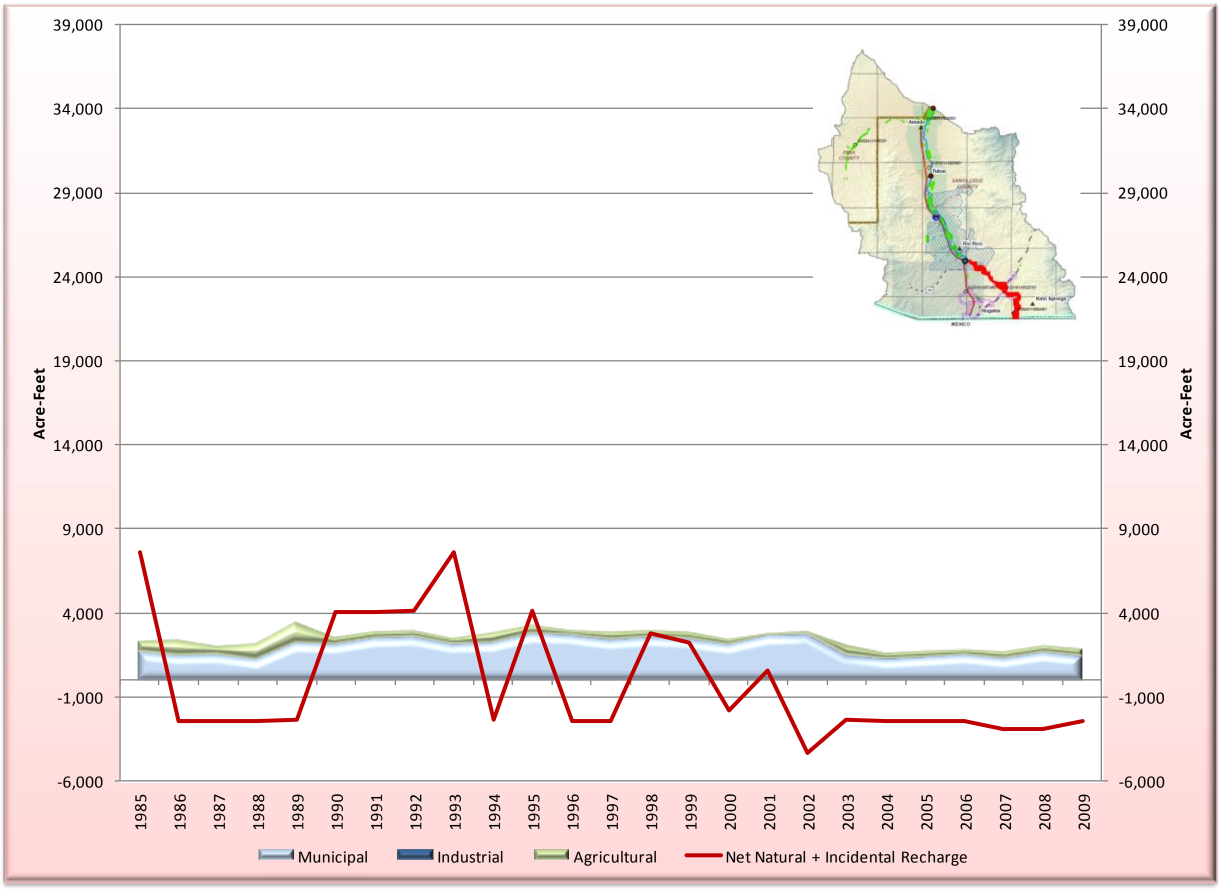
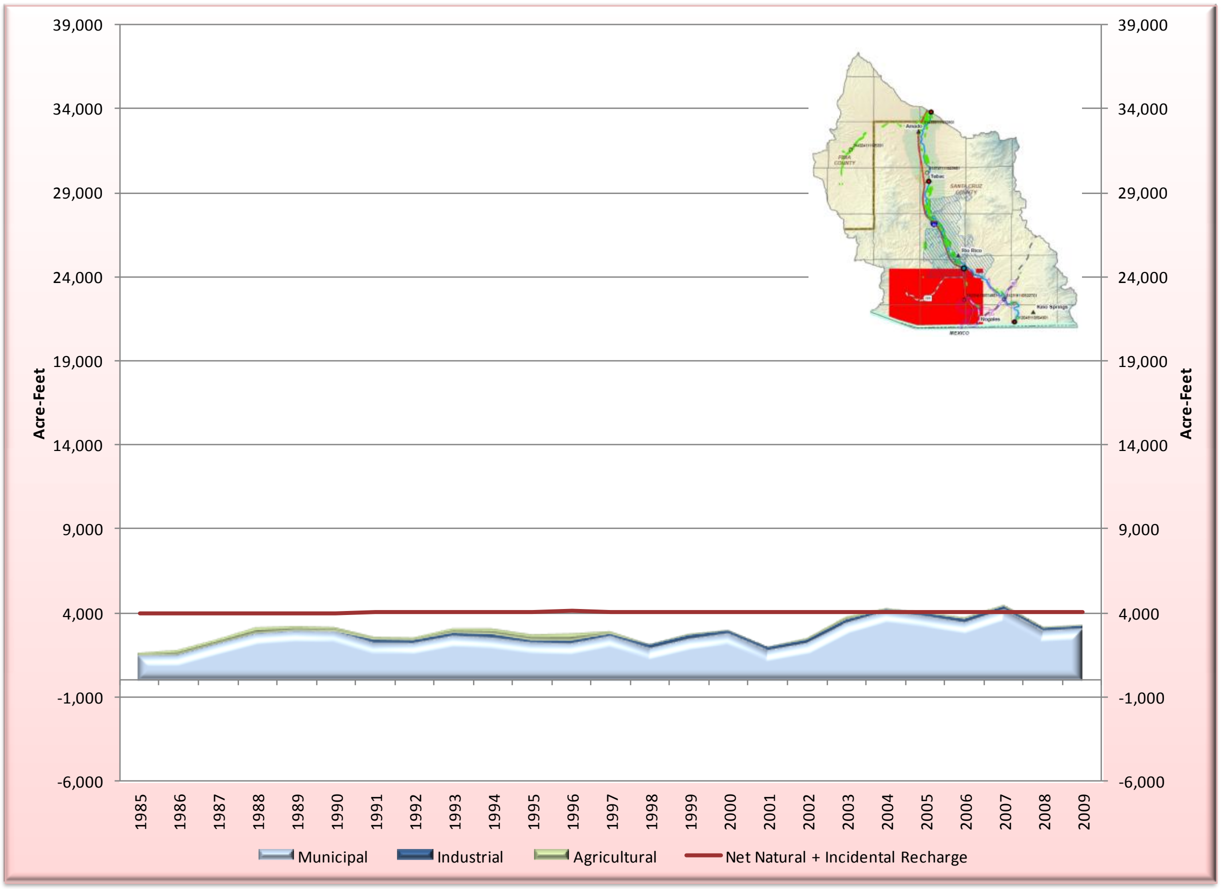


Figure 2-4 demonstrates the trend in historical pumpage in the Potrero Area. This pumpage is nearly all municipal and conducted by the City of Nogales. As stated above, the City's secondary well field is located in this area and has been increasingly relied upon due to limited yields from their Microbasin wells. Valle Verde Water Company also withdraws water from this area.

It should be noted that, while Figure 2-4 demonstrates the estimated net natural and incidental recharge above the Potrero demands, localized water levels have been dropping in the portions of Potrero proximate to Nogales' wells.

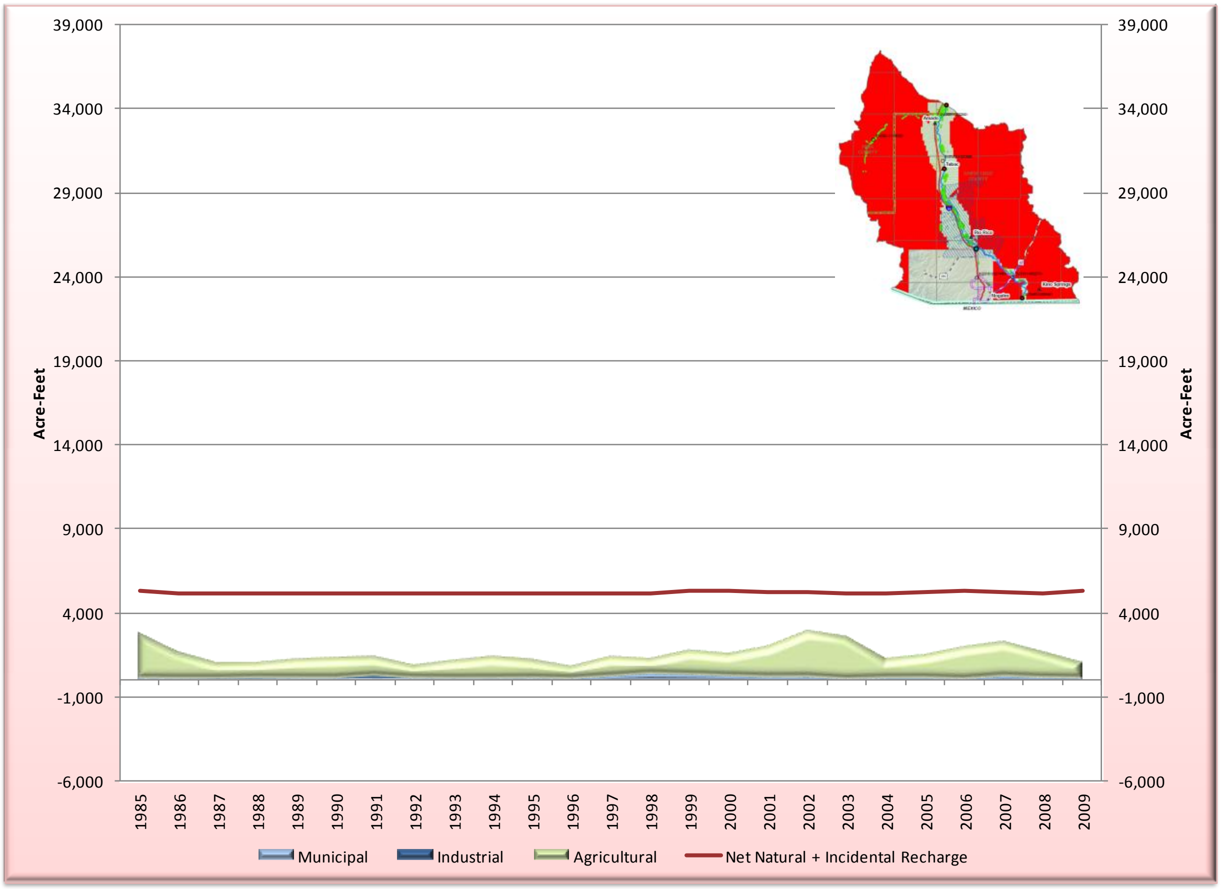
Figure 2-4 Potrero Area Demand by Sector and Supply



<u>Outside Area</u>

The "Outside Area" has been defined as those portions of the AMA that do not fall into the Downstream, Microbasin, or Potrero areas. *Figure 2-5* shows the historical pumpage in the Outside Area. Pumpage in the Outside Area is dominated by agricultural uses, concentrated mostly in the Sopori Wash area in the northern part of the AMA near Amado. While the dominant water use, pumping for agricultural in the Outside Area is much less than in the Downstream Area. Industrial and municipal uses have varied from near zero to a few hundred acre-feet per year.

Figure 2-5 Outside Area Demand by Sector and Supply



The charts demonstrate the variability of pumpage and supply between the four sub-geographic areas in SCAMA. The Downstream Area is a "dynamic system" that has experienced growth coupled with highly fluctuating supply, where in some years there is more supply than demand, and in other years demand exceeds the volume of replenishing supply. The Microbasin Area shows a pattern of first increasing and then decreasing demand, but like the Downstream Area, also experiences significant fluctuations in supply, albeit lacking the reliable contribution of effluent discharges from the NIWWTP that the Downstream Area enjoys. The Potrero and Outside areas have experienced some growth, but more limited than the Downstream Area and, by contrast, are assumed to have fairly stable supplies.

3. THE BASIC WATER BALANCE COMPONENTS

The basic components of the Water Balances by area are demand by sector: Municipal, Agricultural and Industrial, as well as natural system demand; and supply, which is primarily stream channel recharge, but also includes reclaimed water reuse and groundwater inflow. Each of these components, necessary for calculating the long-term balance between demand and supply is discussed in greater detail in the following sections. While SCAMA has a goal of safe-yield like the Phoenix, Prescott, and Tucson AMAs, another component of the SCAMA management goal, and a major water management issue, is the annual fluctuation in local water levels along the Santa Cruz River corridor and susceptibility to drought conditions due to a lack of storage capacity. To begin to examine the sub-AMA level geography, data in this Assessment is broken into the four sub-geographies described above, which better illustrate the annual variation in supply availability and demand at a more localized scale.

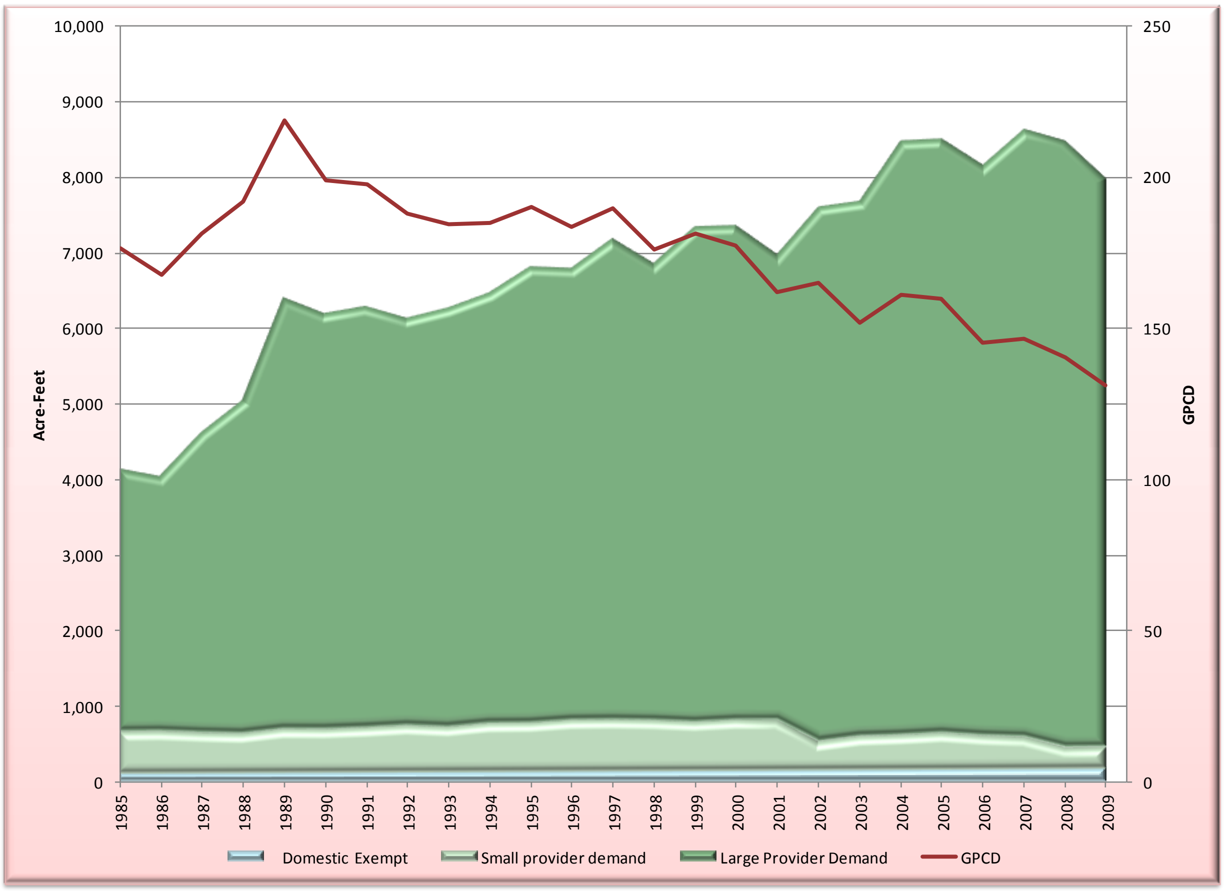
3.1 Demand

Demand consists of the beneficial use of water for by the Municipal, Industrial, and Agricultural sectors. Demand also includes natural system debits on the aquifer, such as riparian demand and groundwater outflow.

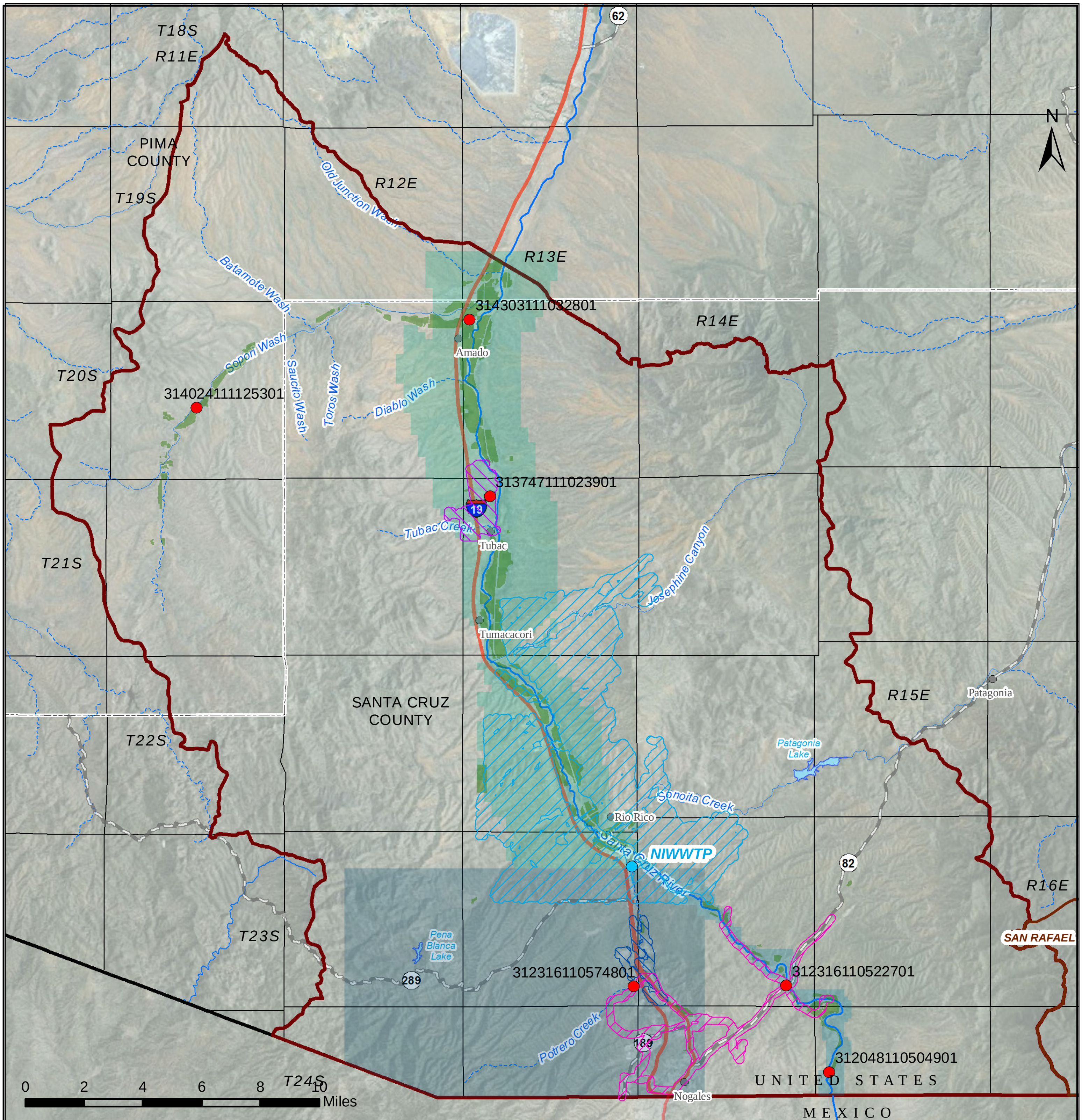
3.1.1 Municipal Demand

Municipal water use includes water delivered for non-irrigation uses by a city, town, private water company, or irrigation district. Municipal demand is composed of the Large Provider, Small Provider, and Domestic Exempt subsectors. *Figure 3-1* below shows the trend in water demand of municipal subsectors. The demand of Individual Users, such as turf-related facilities, is also included in the Municipal demand since municipal providers often serve them. These subsectors are listed and defined below in the order of magnitude of use.

Figure 3-1 AMA-Wide Municipal Demand by Sub-Sector



<u>Large</u> <u>Provider</u> <u>Demand</u>: Large provider demand is the sum of residential, non-residential, and lost and unaccounted for water delivered by a large provider. A large provider is a municipal provider serving more than 250 acre-feet of water for non-irrigation use per year. There are currently four large municipal providers in the SCAMA: the City of Nogales, Rio Rico Utilities, Valle Verde Water Company, and Arizona-American – Tubac (*See Figure 3-2*).



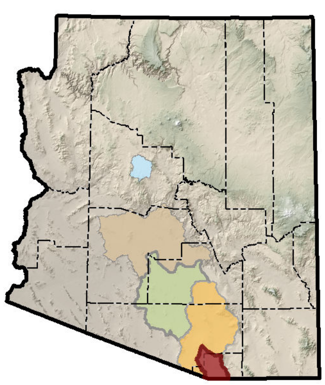


Figure 3-2
Municipal Water Providers in SCAMA and Sub-Geographic Areas

Legend

- Santa Cruz AMA
- Downstream
- Microbasin Area
- Potrero Area
- NIWWTP
- City or Town
- Index Well
- Major Road
- Interstate Highway
- Stream
- State Boundary
- Township/Range
- County
- SantaCruzGFRs

Large Municipal Provider Service Areas

- Citizens Utilities Tubac Valley
- City of Nogales
- Rio Rico Utilities
- Valle Verde Water Company

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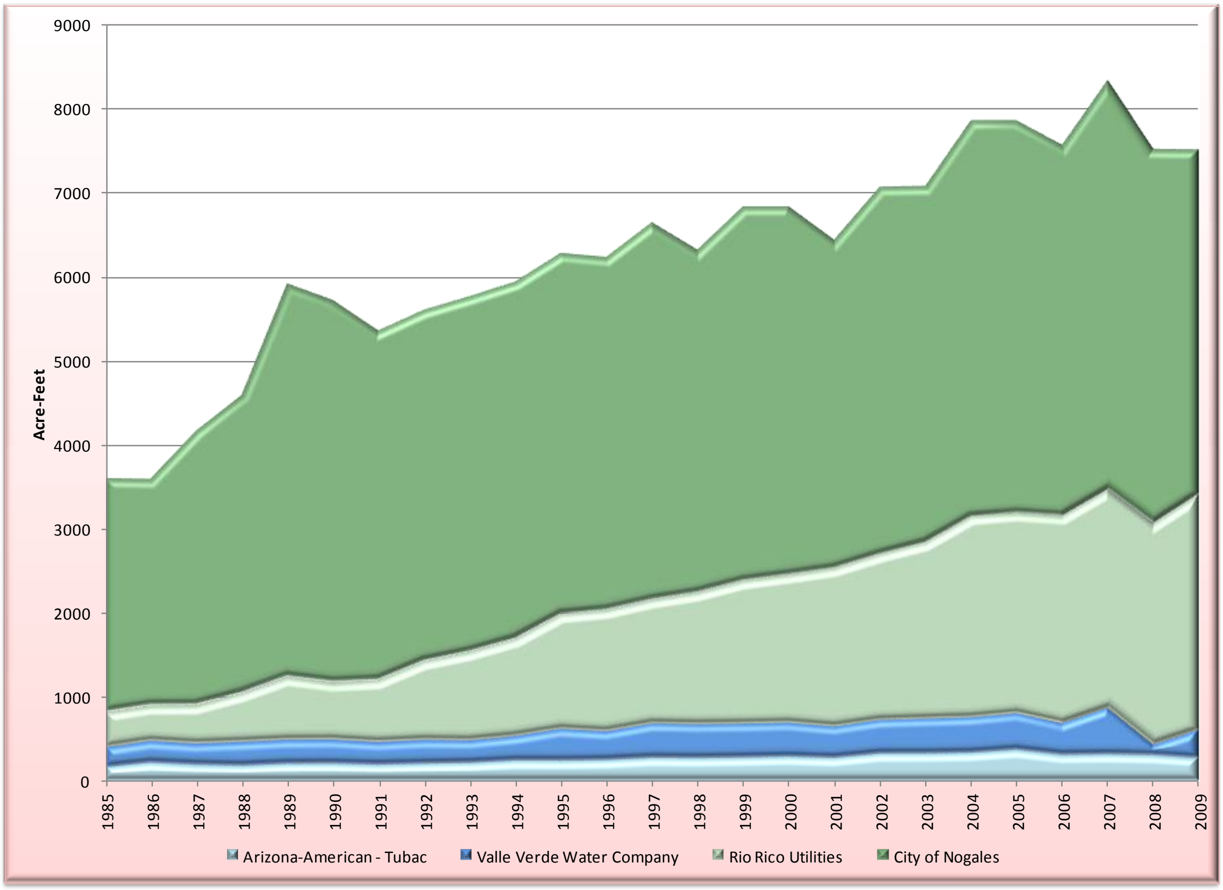
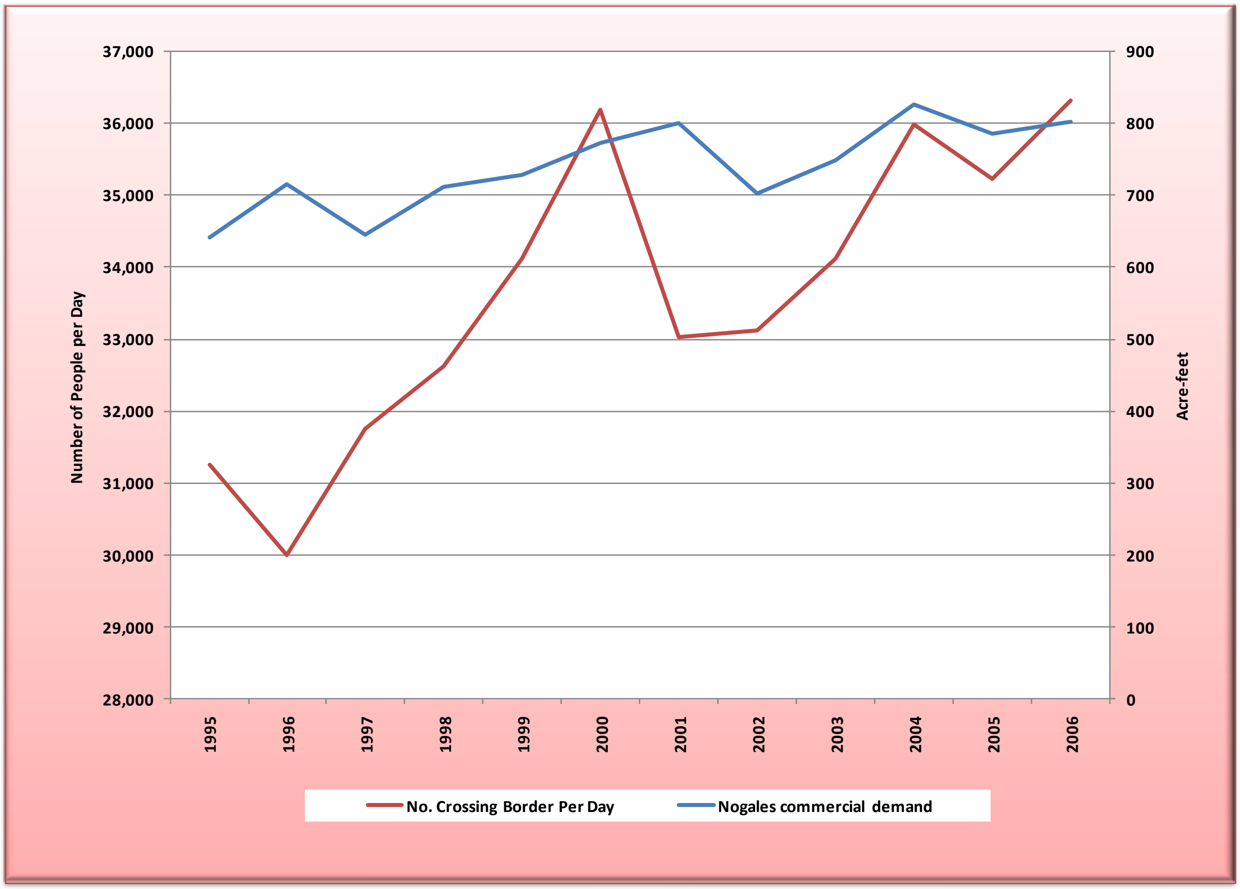
The *City of Nogales* is the largest water provider in the SCAMA, representing almost 54 percent of the large provider demand and 52 percent of the total Municipal sector demand. *Figure 3-3* shows the relative demand of the four large providers in SCAMA from 1985-2009.

Figure 3-3 Large Municipal Water Provider Demand, 1985-2009



Daily international border population influx has a marked effect on Nogales' water demand. The resident service area population does not reflect the large number of people who visit the area during the day. There is a relationship between daily border crossings and commercial water demand in the City's water service area (*See Figure 3-4*).

Figure 3-4 **Border Crossing and Commercial Water Use, City of Nogales, AZ Santa Cruz Active Management Area, 1985 - 2006**



Rio Rico is the second largest municipal provider in the SCAMA. In 2009, it accounted for 37 percent of total large provider demand. Since prior to the passage of the Code, the majority of the growth seen in the municipal sector in SCAMA has occurred with the Rio Rico service area.

The *Valle Verde* system is the third largest provider in the SCAMA. It has not exhibited the same growth as Rio Rico. In 2009, this system represented less than five percent of large municipal provider demand in the AMA.

The *Arizona-American – Tubac* system did not become a large provider until 2002. Its 2009 demand was 346 acre-feet, representing just over four percent of the large municipal provider demand.

The components of Large Provider Demand are:

> *Large Provider Residential Deliveries*: A non-irrigation use of water delivered by a large provider related to the activities of single family or multifamily housing units, including interior and exterior water use.
>
> *Large Provider Non-Residential Deliveries*: Water supplied by a large provider for a non-irrigation use other than a residential use. Deliveries to individual users are included in this category. Individual users are facilities that receive water from a municipal provider for non-irrigation uses to which specific Industrial conservation program requirements apply, including turf-related facilities, large-scale cooling facilities, and publicly owned rights-of-way.

Large Provider Lost and Unaccounted for water: The difference between the total water withdrawn, diverted, or received for use within the water provider's water service area and the sum of the residential and non-residential metered deliveries to customers.

In the SCAMA, the variability of the water supply has a significant effect on water use. Many of the wells in the AMA depend, at least to some degree, on seasonal replenishment of the aquifer. When supplies are low, water providers imposed strict conservation measures to reduce water demand. This variability in supply also presents challenges in proving an assured water supply. In the SCAMA, four municipal water providers have obtained a DAWS; City of Nogales, Baca Float Water Company, Sopori Domestic Water Improvement District and Tubac Water Company.

Small Provider Demand: A small provider is a municipal provider that supplies 250 acre-feet of water or less for non-irrigation use per year. Small provider demand consists of deliveries by a municipal provider for non-irrigation use related to the activities of single family or multifamily housing units. Small provider demand may also include deliveries to non-residential customers and individual users. The number of small providers has been fairly constant over time. Small provider population has increased steadily from 1,642 people in 1985 to 2,870 people in 2009; nonetheless, small provider demand has remained fairly constant. Most small providers in the SCAMA have service areas that are not likely to grow because they serve specific areas such as mobile home parks, ranches, and co-operatives. Still, a few small providers have been growing slowly. Most small providers are located in the more rural areas of the AMA and have shown little or no growth over the historical period.

Domestic Exempt: Domestic exempt water use is non-irrigation water supplied by exempt wells (pumping not more than 35 gallons per minute) for domestic purposes to persons not served by a large or small provider distribution system. The number of exempt wells in the SCAMA has increased steadily from 788 in 1985 to 1,308 in 2009. Exempt well demand is estimated to have been about 177 acre-feet in 2009.

Exempt well owners are not required to meter their wells or report annual water use or number of people relying on the exempt well. Because of this, exempt well demand and population are estimated for the historical period. The domestic exempt well population in 2000 was calculated by subtracting the known populations of the large providers and small providers based on data from the 2000 US Census population for the AMA. The Santa Cruz County historical growth rate was used to regress the exempt well population from the year 2000 to an estimate of the 1985 exempt well population. The same growth rate was used to estimate domestic exempt well population from 2001 through 2009. This method yielded exempt well population estimates of 1,123 people in 1985 and 1,757 people in 2009.

The domestic exempt well water demand can only be estimated because the statutes do not require metering or reporting by exempt wells. In previously published documents, ADWR has used an assumption of between 0.5 and 1.0 acre-feet per well per year. For this Assessment, ADWR used a different approach. The interior and exterior demand models for new single family development (ADWR, 2003) and the 2000 U.S. Census average persons per household for Santa Cruz County were used to estimate exempt well demand. As a result, a demand of 90 gallons per person per day was applied to the population estimate. ADWR recognizes that some domestic exempt wells withdraw significantly more than this amount per year, while others may withdraw less. Because domestic exempt wells are not regulated, there is no requirement or incentive to conserve water or to use renewable water supplies.

Population Numbers: Although not used directly to calculate water use during the historical period, population numbers are included in the Template and are broken out by persons served by large providers, small providers, and those seved by domestic exempt wells. Population is used directly in the projected scenarios to estimate Municipal use.

Municipal providers withdraw water in all four of the sub-geographic areas. However, with the growth in Rio Rico, the majority of the municipal pumpage now occurs in the area downstream of the NIWWTP. *Figure 3-3* shows the location of municipal providers within the four sub-geographic areas.

Municipal Pumpage by Sub-Geographic Area

It is important to note that there is a difference between *demand* by sector and *pumpage* by sector. This is because water may be withdrawn by one type of right and delivered to a different type; from Municipal to Agricultural or Industrial, for example. Also, several entities withdraw and use water from more than one sub-geographic area. (*See Figure 3-3)* For these reasons, data in this *Assessment* related to pumpage by sector may not match data in other tables in this document showing the demand by sector.

Municipal water providers who withdraw water from within the Microbasin Area include one large provider, the City of Nogales, and two small providers; Buena Vista Ranch and Cabot Sedgwick (Santa Fe Ranch). Domestic exempt well pumping within the Microbasin Area is estimated to have increased from about eight acre-feet in 1985 to about 12 acre-feet by 2009.

Municipal providers who withdraw water in the Potrero Area include the City of Nogales, Delta Properties, Mi Casa Mobile Home Park and Valle Verde Water Company. Domestic exempt well pumpage in this area is estimated to have remained fairly stable from 1985 through 2009, estimated at about 16 acre-feet per year.

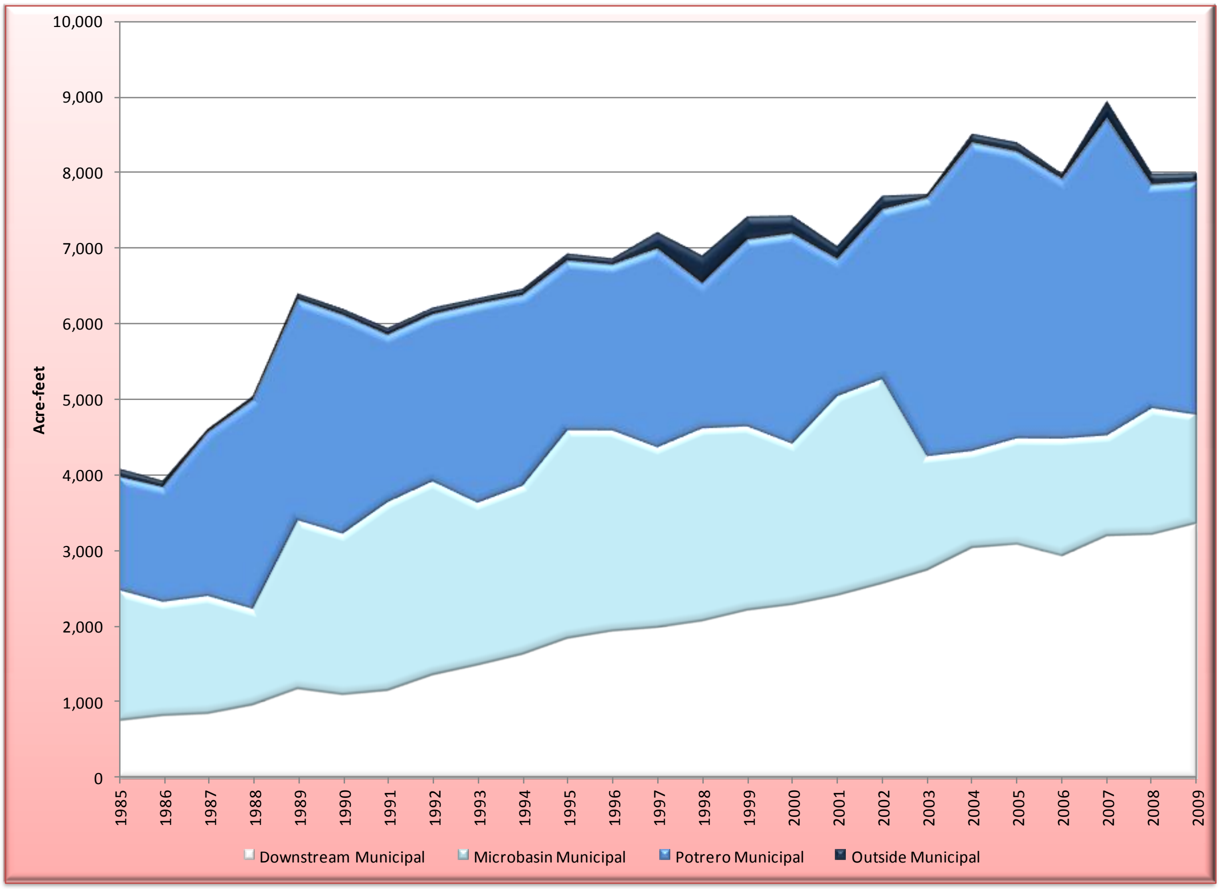
There are eight municipal water providers in the Downstream Area, two of which are large providers; Rio Rico Utilities and Arizona-American – Tubac system. Small providers in the area include Baca Float Water Company, Lakewood Water Company, Olivas Family, Spencer Water Company and Mike Ewing. Domestic exempt well users in the Downstream Area are estimated to have increased their annual pumpage from about 42 acre-feet in 1985 to about 65 acre-feet by 2009.

Two municipal providers pump in the Outside Area; City of Nogales and Morning Star Ranch. Persons using domestic exempt wells in this remaining area of the AMA are estimated to have increased from 48 acre-feet in 1985 to 84 acre-feet in 2009.

Domestic exempt well pumping occurs throughout the AMA. Increases in domestic exempt well pumping is due solely to the addition of new exempt wells in each area because ADWR’s method of estimating exempt well demand is to multiply a water use factor by the number of exempt well registrations in each sub-geographic area. The Outside and Downstream areas have the highest concentration of domestic exempt wells.

Figure 3-5 compares the pumpage from each sub-geographic area for the historical period.

Figure 3-5 Municipal Pumpage by Sub-Area



Municipal Reclaimed Demand

Direct use of reclaimed water does not occur in the municipal sector in the SCAMA. There are no reclaimed water distribution systems for landscape irrigation operated by municipal water providers, nor is reclaimed water stored in ADWR permitted underground storage facilities and recovered, as is done in other AMAs. Wastewater generated within the City of Nogales is treated at the NIWWTP. The reclaimed water is discharged into the Santa Cruz River channel. A small portion of the Rio Rico service area is on a sewer system, which also sends the wastewater to the NIWWTP. However the majority of water customers within the Rio Rico service area rely on septic systems, as do the remaining municipal water users, whether served by large or small providers, or from domestic exempt wells, within the SCAMA. A few water users utilize evaporation ponds to dispose of wastewater.

3.1.2 Industrial Demand

Industrial use is a non-irrigation use of water, not supplied by a city, town, or private water company. These users include animal industry and expanded animal industry uses. In general, Industrial users withdraw water from their own wells that are associated with Type 1 and Type 2 GFRs, GIUs or other withdrawal permits. In the SCAMA, Industrial demand is composed of the following subsectors: Sand and Gravel, Turf, Other, and Drainage and Dewatering. All of these categories except Drainage and Dewatering have specific conservation requirements. These subsectors are defined below:

> *Sand and gravel:* Sand and Gravel demand is the water use at a facility that produces sand and gravel and that uses more than 100 acre-feet of water from any source per year.

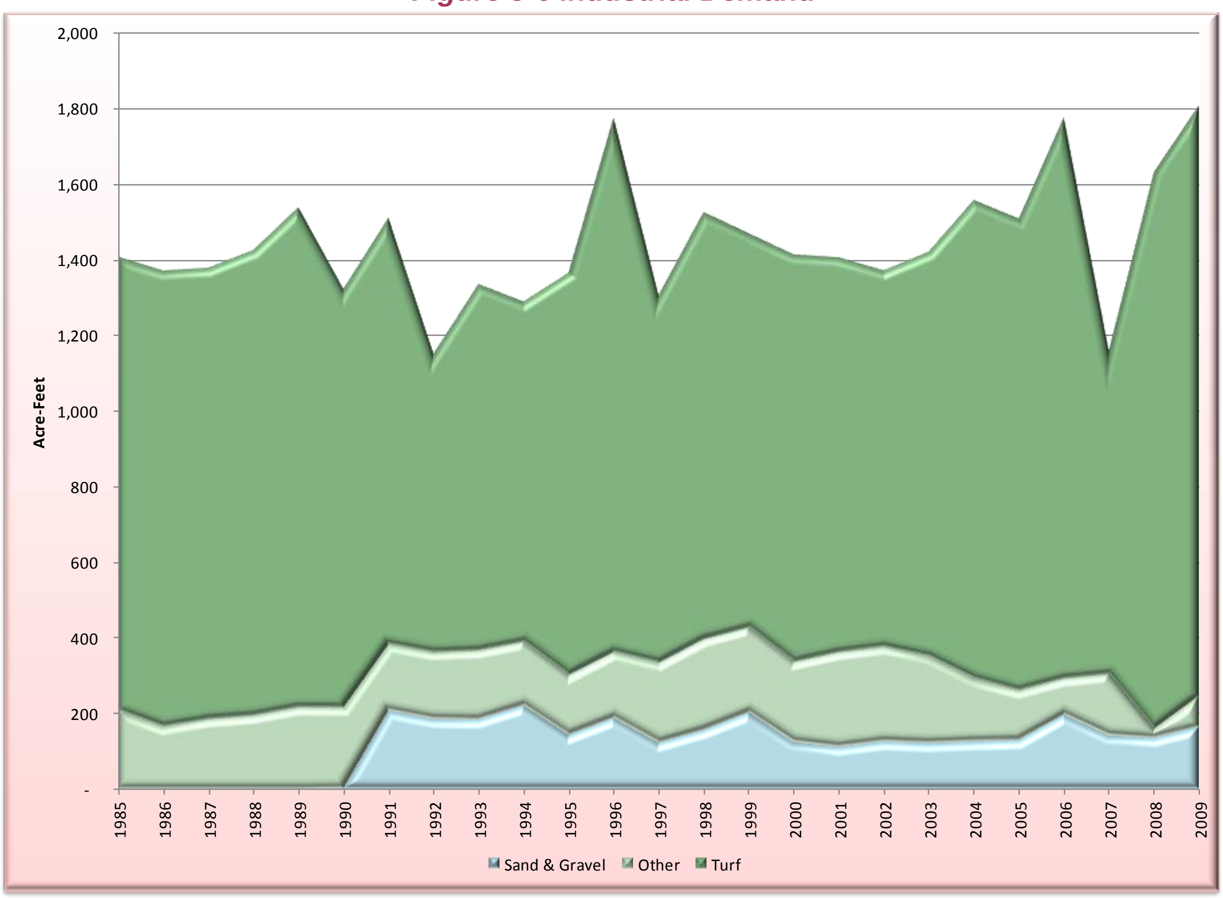
Turf: Turf demand is the water use by cemeteries, golf courses, parks, schools, or common areas within housing developments with water-intensive landscaped areas of 10 or more acres. Turf-related facilities that use any groundwater have a maximum annual water allotment based on the size and age of the facility, regardless of whether they are Industrial users or are served by a municipal provider (individual users). Water demand for golf courses is further broken out in the Template, as it is the largest turf user. Golf course demand is water use at turf-related facilities that are used for playing golf that have a minimum of nine holes including any practice areas.

Other Industrial: Other Industrial demand is the non-irrigation use of water not supplied by a city, town, or private water company, including animal industry use and expanded animal industry use, which are not included in any of the specific Industrial subsectors described above. In SCAMA, these users include agricultural processing, commercial, landscape, recreational, residential, and small turf and sand and gravel uses.

Drainage & Dewatering: Drainage and dewatering demand pertains to entities that must pump groundwater in order to drain or dewater a site for construction or continued use of a site. Sand and gravel operators commonly locate along stream channels and have to dewater to extract materials. The water withdrawn in these dewatering operations is not deemed to have been put to a beneficial use and, as such, is not included in overdraft calculations. Additionally, this small volume of water is not included in Industrial Demand in this Assessment. Commonly employed practices are believed to result in this water returning to the aquifer immediately downstream of the dewatering activities.

Figure 3 -6 shows the trend in the water demand of the Industrial subsectors and total Industrial demand in the SCAMA from 1985 through 2009.

Figure 3-6 Industrial Demand



Type 1 and Type 2 rights are the predominant withdrawal authority used by Industrial users. Industrial users can also withdraw water pursuant to groundwater withdrawal permits, such as GIU or Mineral Extraction permits (limited permits used for mining or sand and gravel operations). All of these rights and permits have an allotment associated with them limiting the amount of water that can be withdrawn on an annual basis. In addition to these associated right and permit allotments, certain types of Industrial facilities are subject to conservation requirements adopted in the Management Plans that may impose additional restrictions on the amount of water that can be used at a facility.

Industrial use is dependent on population growth and the economy. In some cases, the difference between the actual water use and the total allotment is substantial (*See Table 3-1*). This is largely a consequence of the allocation process used to establish Type 2 rights. This process assigned users allotments based on the highest annual groundwater withdrawal between the years 1975 and 1980 before the imposition of conservation requirements. On average, approximately 20 percent of the SCAMA's Industrial rights and permit volumes are used.

Table 3-1 **Industrial Groundwater Rights and Withdrawal Summary 2009**
Santa Cruz Active Management Area

User Category	Right or Permits	Number of Facilities	Right or Permit Volume (ACRE-FEET/YEAR)	Water Withdrawn From a Well (AF)
Sand and Gravel Facilities	Type 2, Non-Irrigation Rights, Mineral Extraction Permit	2	753	163
Turf-Related Facilities[1]	Type 2 Non-Irrigation Rights	2	1,566	1,559
Other Industrial Facilities	Type 1 and 2 Non-Irrigation Rights, Mineral Extraction Permits, General Industrial Use Permits	46	6,522	84
Total		**50**	**8,841**	**1,806**

Note: All water values are in acre-feet. [1]Includes Industrial turf-related facilities only. Two additional golf courses in SCAMA are served municipal water and are considered individual users.

Historically, the Industrial sector in the SCAMA has been relatively stable, and compared to most other AMAs, is quite small. Total Industrial water use in the SCAMA was 1,407 acre-feet in 1985, 1,365 acre-feet in 1995, and 1,806 acre-feet in 2009 (*See Table 3-1*). In 1995, the turf sector accounted for almost 80 percent of Industrial use. The remaining water use was split between sand and gravel operations (10 percent) and other uses such as manufacturing and cooling (12 percent). In 2009, the percentages of these uses remained resonably consistent with historic figures.

TURF-RELATED FACILITIES

A turf-related facility is defined in the 3MP as a facility with ten or more acres of water intensive landscaped area. Turf-related facilities include parks, schools, cemeteries, and golf courses. In 2009, there were two turf-related facilities in the SCAMA, the Rio Rico and Tubac golf courses, whose total water use was 1,559 acre-feet in 2009. Type 2 GFRs serve as the withdrawal authority for these turf facilities. This Industrial subsector has fluctuated from a low of less than 800 acre-feet in 1992 to a high of 1,559 acre-feet in 2009. Variation could be due to weather conditions, inaccurate reporting, or changes in turf management and practices, such as overseeding. Turf use accounted for 86 percent of total Industrial demand in the SCAMA in 2009.

Two additional golf courses, the Kino Springs and Palo Duro golf courses, received water from the City of Nogales and were classified as *individual users*. Their water use is included in the water demand for the Municipal sector. The Palo Duro Golf Course suspended operations in, 2010. ADWR is unaware of any plans to resume irrigation and reopen to course.

Conservation requirements are established in the Management Plans for all four turf facilities in the SCAMA. Absent any ADWR variances, the maximum annual water allotments are based on the size and age of the individual facilities.

Sand and Gravel

In 2009, there were two active sand and gravel operations in the SCAMA. Sand and gravel facilities in the SCAMA used 142 acre-feet of water (*See Table 3-1)* in 1995 and 163 acre-feet of water in 2009. One of these facilities is municipally served, however, they have their own mineral extraction permit that could be used if necessary. Water in this subsector is primarily used to wash aggregate before sale; a small amount is used to clean trucks and equipment. Increases in sand and gravel production and associated water use are closely tied to population growth and urbanization. Whether municipally- or self-served, all sand and gravel operations in the SCAMA rely on water withdrawn from wells. A significant portion of this water use is believed to return to the near-stream aquifer.

Other Industrial

Other Industrial is a water use category that typically includes a variety of commercial and manufacturing uses that do not fit into the subsectors listed above. Other Industrial water use has remained relatively constant in the SCAMA over the last decade. Water use in this subsector totaled 160 acre-feet in 1995 and 84 acre-feet in 2009. Water withdrawn from wells has historically been used to meet the demands of this subsector.

Figure 3-7 **Distribution of Industrial Demand by Subsectors 1995**
Santa Cruz Active Management Area

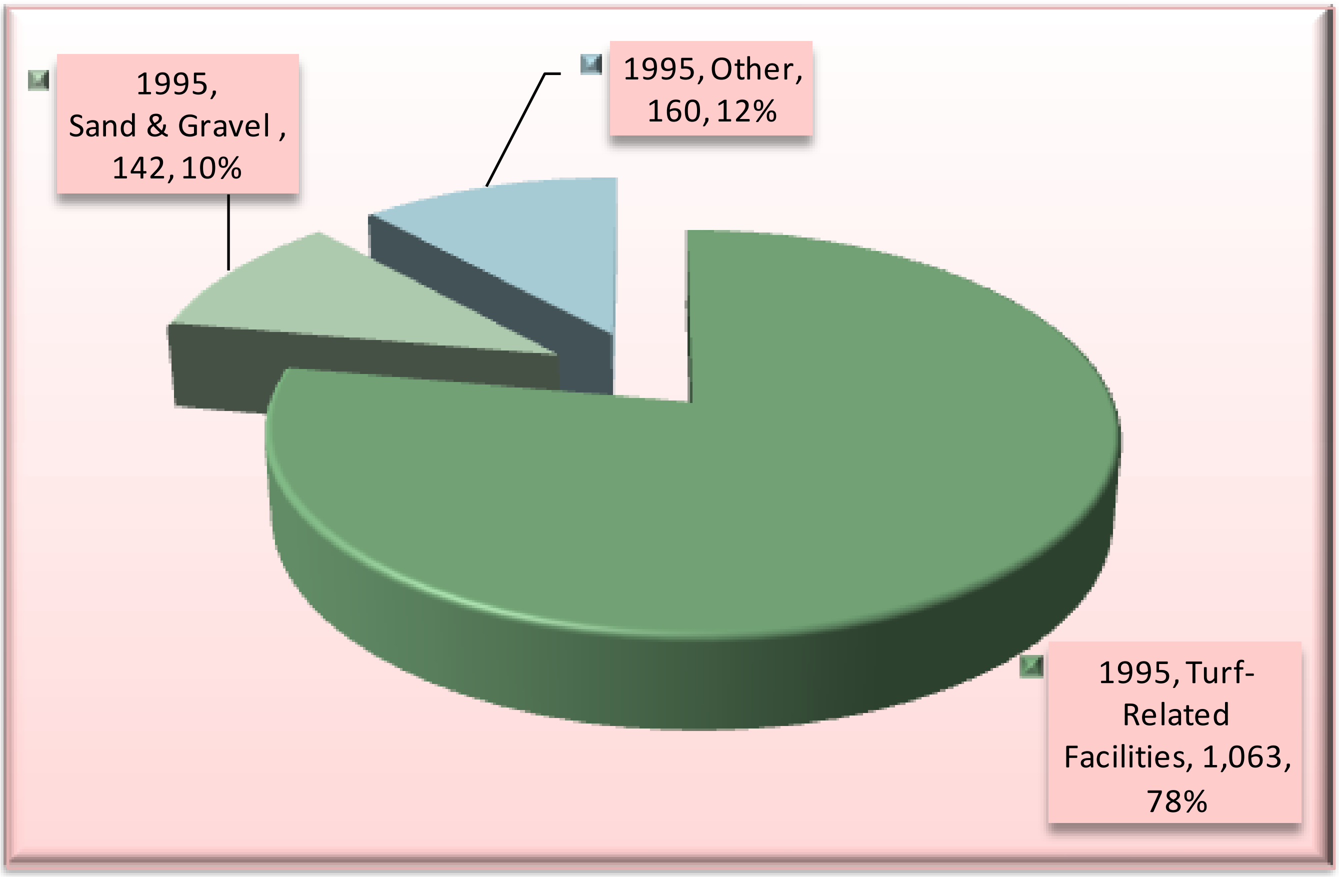
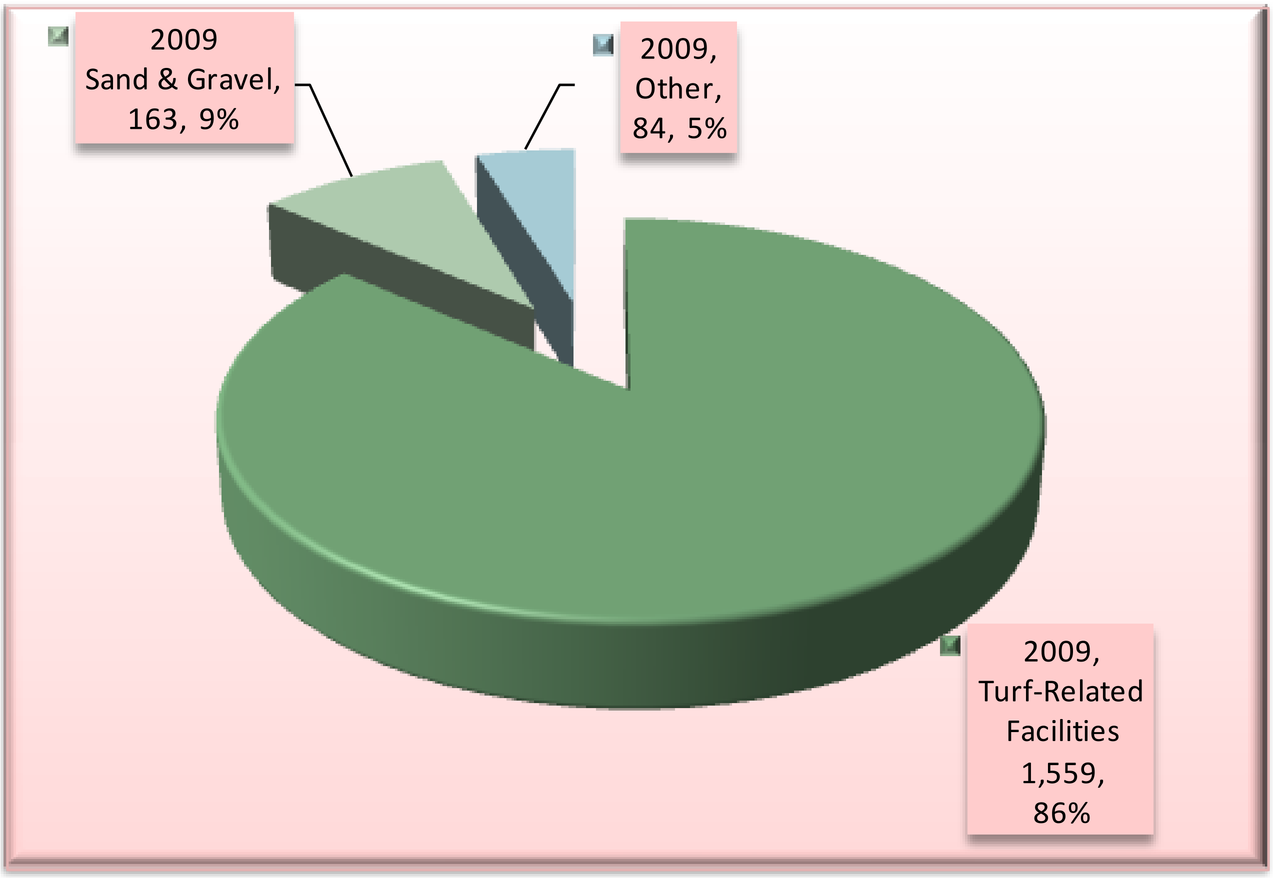


Figure 3-8 **Distribution of Industrial Demand by Subsectors 2009**
Santa Cruz Active Management Area



Industrial Pumpage by Sub-Geographic Area

Several small Industrial rights and two golf courses withdraw water in the Downstream Area. Rio Rico Golf Course and the Tubac Country Club are regulated turf facilities located in this sub-geographic area of the AMA.

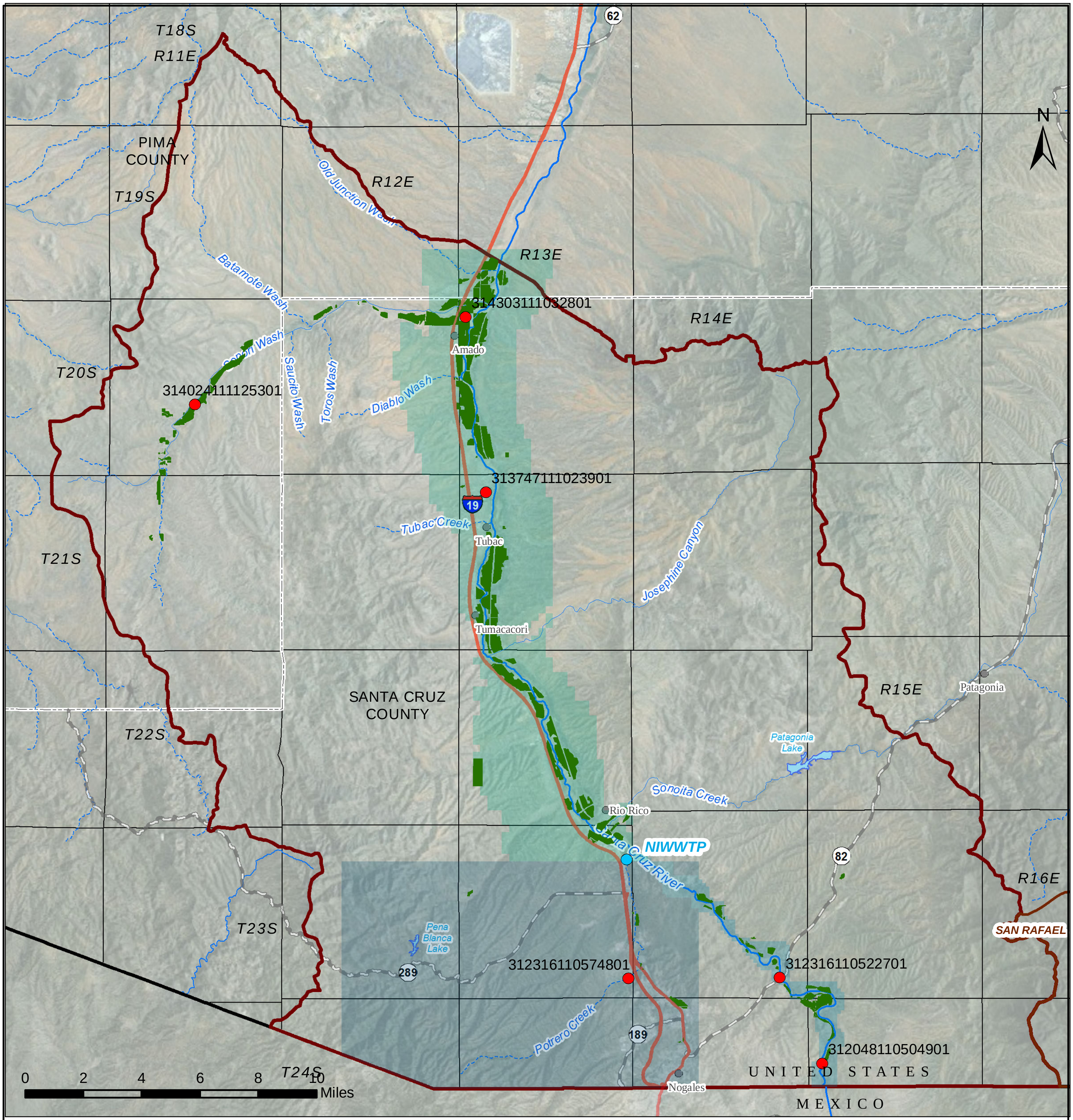
Three small Industrial users withdraw water within the Microbasin Area. Demand has been consistent and less than 50 acre-feet per year for the three users in total.

There are more than fifteen groundwater rights and permits that have been used in the Potrero Area. Uses include sand and gravel, stock watering, school landscaping and other small Industrial uses, plus some permitted uses including a single Poor Quality Withdrawal Permit (United Musical Instruments). Industrial demand in the Potrero Area has fluctuated over time but has been within the range of 50 to 250 acre-feet per year.

Industrial users in the Outside Area are concentrated in the northern portion of the AMA. Total average demand for the period 1985 - 2009 was about 35 acre-feet per year.

3.1.3 Agricultural Demand

Only land associated with a Certificate of IGFR can legally be irrigated with groundwater within an AMA (*See Figure 3-9*). IGFRs are categorized as either non-exempt or exempt. Non-exempt IGFRs have specific conservation requirements established in the Management Plan for each management period. Exempt IGFRs, which are ten acres or less and not part of an integrated farming operation, are no longer required to report water use or comply with specific conservation requirements.



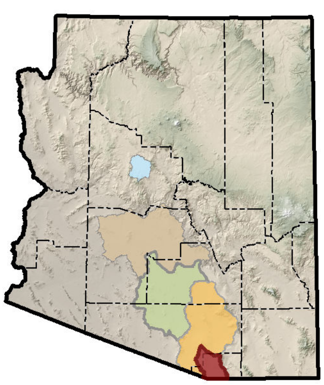


Figure 3-9
IGFRs within SCAMA and Sub-Geographic Areas

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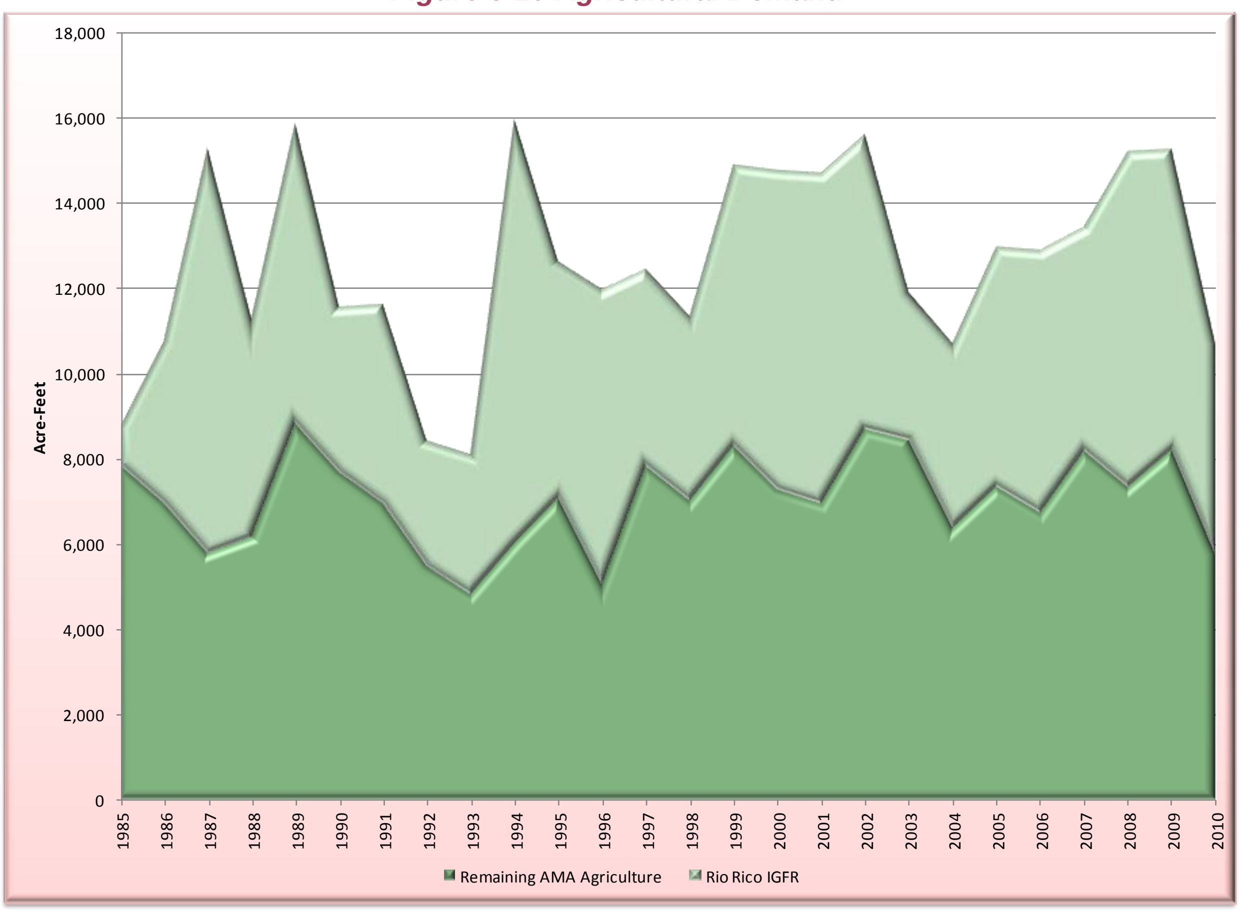
Since the Code prohibits newly irrigated acres, the total number of IGFR certified acres has decreased over time as lands in the SCAMA have urbanized (*See Table 3-2*). The decrease in allotments was due in part to the reduction in acreage, but is also due to reductions in assigned water duties, as a result of Management Plan requirements increasing irrigation efficiencies. Historically, use has been substantially lower than allotments. In the future, use may exceed allotments because of flexibility accounting provisions in the Base Conservation Program. For more information on flexibility accounting, refer to the 3MP.

Although highly variable, agriculture is the largest demand sector in the SCAMA. Annual use has fluctuated between from between 52 and 72 percent of AMA demand, and averages 61 percent of total AMA demand.

Cropping patterns in the AMA have remained fairly stable since 1980. Primary crops include Bermuda grass, fescue, and rye pasture. Alfalfa was historically grown for hay in the area, but production is currently infeasible due to toxic pests (Larkin, 2008); (Noon & Cuneo, 2009).

Demand in the Agricultural sector has averaged 11,900 acre-feet between 1985 and 1995 and 13,500 acre-feet between 1996 and 2009. The variability of the water supply, combined with some users using large volumes of water in response to statutory language regarding the perfection of surface water rights, causes use to vary widely from year to year. Market conditions also contribute to variability in this sector. Rio Rico Properties has accounted for 43 percent of total agricultural demand in the SCAMA since 1985. The annual farming techniques employed by this right holder, which relate to some degree to the landowner's surface water claim, strongly influence total demand. *Figure 3-10* below shows the total historical agricultural demand and the demand by Rio Rico Properties.

Figure 3-10 Agricultural Demand



In 1994, IGFRs less than ten acres in size and not part of an integrated farming operation were exempted from conservation requirements and reporting obligations; therefore, their demand since 1993 is not known. Historical use of such rights in the SCAMA was not considered in this Assessment because they were negligible.

AGRICULTURAL PUMPAGE BY SUB-GEOGRAPHIC AREA

Table 3-2 shows the Agricultural demand, irrigation acres and allotment for 2009 by Sub-Geographic Area in the SCAMA.

Table 3-2 Agricultural Demand, Irrigation Acres and Allotment by Sub-Geographic Area 2009
Santa Cruz Active Management Area

Sub-Geographic Area	Number of IGFRs Permits	Number of Irrigation Acres	Allotment (ACRE-FEET/YEAR)	Annual Pumpage (AF)
Downstream	20	3,022	13,948	13,719
Microbasin	3	105	494	256
Potrero	1	72	287	40
Outside	13	1,066	3,571	958
Total	**37**	**4,265**	**18,300**	**14,973**

The majority of the agricultural demand in the SCAMA is in the Downstream Area. This is where the largest agricultural user, Rio Rico Properties, is located, along with several other large agricultural users. The demand for these uses has ranged from between 4,800 and 14,000 acre-feet per year between 1985 and 2009 and averaged about 10,000 acre-feet per year. Agricultural demand in the Microbasin Area ranged from between 100 and 1,200 acre-feet over the period 1985 - 2009, with the average being about 440 acre-feet per year. Potrero Area agricultural demand ranged from just under 20 acre-feet to slightly over 400 acre-feet per year. Potrero Area agricultural use averages about 150 acre-feet per year. Agricultural demand in the Outside Area is fairly significant – the second largest agricultural area in the AMA. Agricultural users along the Sopori Wash and in the relatively larger alluvial area in the northern end of the AMA account for these demands. Demand in the Outside Area for agriculture has ranged from between about 800 and about 2,700 acre-feet per year, averaging about 1,400 acre-feet per year.

AGRICULTURAL SURFACE WATER DEMAND

One IGFR holder has historically reported receiving surface water on their annual report. This right is located in the Sopori Wash area of the AMA. Over the period 1985 - 2009, an average of just over 700 acre-feet per year has been diverted, with the minimum being about 110 acre-feet and the maximum about 1,300 acre-feet per year. For the purpose of this *Assessment* this water is treated as “water withdrawn from wells” and is not broken out as a separate supply source.

3.1.4 Riparian Demand

Riparian Demand in the Downstream Area

Evapotranspiration (ET) in the Santa Cruz River Valley is an important outflow component of the groundwater flow budget during summer periods. ET is concentrated in the Downstream Area of the Santa Cruz River. ADWR conducted an investigation (Masek, 1996) to delineate riparian coverage and estimate ET rates for the portion of the hydrologic model downstream of the NIWWTP. Aerial photographs taken in 1954 and 1995 were interpreted to estimate vegetation type and density. Vegetation types were separated into seven categories based on the historical photograph interpretations. Annual ET water use rates were calculated from the extent, density and composition of the riparian community. Recent investigations suggest that some ET (not originally accounted for in this investigation) may also originate from grasses and shrubs (Scott & al, 2000). Thus there remains some uncertainty regarding the total quantity of ET. In addition the distribution of ET between the saturated and unsaturated zone within the inner valley areas is not well understood.

Geographical Information Systems (GIS) software was used to analyze historic ET (Masek, 1996). This analysis suggests that there was considerably more ET surface cover and demand in 1995 than in 1954 (Scott & al, 2000). Increases in ET between 1954 and 1995 may be attributed to different factors including increased reclaimed water discharge, additional trees, geomorphic channel changes, and weather cycles (Masek, 1996). The total ET rate includes both the saturated and unsaturated zone. Therefore, the ET associated with the saturated water-table aquifer is assumed to be less than the collective rate of 15,000 acre-feet/year. ET is seasonal and occurs primarily between May and October (Gatewood & al, 1950). [Note that infrared aerial photographs show increases in plant growth within the inner Santa Cruz Valley between 1995 and 2004, suggesting the ET has increased since 1995.]

Riparian Demand in the Microbasin Area

The low floodplains associated with the Santa Cruz River are vegetated by Fremont cottonwood and Gooding willow. Mesquite bosques, netleaf hackberry and Mexican elder occur further away from the river. Cienegas, sacaton, giant sacaton, and alkali sacaton grasslands are present, as well as riparian scrublands of seepwillow, rabbit brush, and burro brush (ADWR, 1994). Grasses and small brush cover the bajada slopes of the alluvial valley. Riparian vegetation along the Santa Cruz River has experienced significant historical change. Riparian vegetation composition and density continues to respond to changes in land use, groundwater levels, fire suppression, livestock grazing, geomorphic changes along the River corridor, climate changes and possibly changes in water quality as exhibited in the Downstream Area.

3.2 Supply

Nearly all the water supply for anthropogenic water uses in the SCAMA comes from wells. Historically, water users have shifted from one well field to another when water levels decline in wells located closer to the influence of surface flow in the Santa Cruz River. Pumping near the River resumes when the near-stream aquifers have been replenished by precipitation derived streamflow. There is neither constructed regulatory storage of surface supplies, nor underground storage and recovery occurring in the SCAMA as of the date of this Assessment. Further, direct use of reclaimed water also does not occur, with only one small exception (a very small volume of reclaimed water is commingled with groundwater and surface water to deliver for irrigation of turf areas by one entity). Currently, the statutory language in the Code pertaining to SCAMA does not refer to groundwater or surface water but “water withdrawn from wells.” However, depending on the result of the General Stream Adjudication, individual water uses in the SCAMA will be regulated in the future either as groundwater or as surface water.

3.2.1 Characterizing the AMA water supply

Water supply varies by geographic sub-area within the SCAMA due to: the location of the NIWWTP; the productivity of the aquifer in areas outside the Downstream and Microbasin Areas, the amount of riparian area and ET; and due to the variable nature of natural surface water flow.

The SCAMA covers 716 square miles in the Upper Santa Cruz Valley River Basin. Its principal hydrologic features is a 45 mile reach of the Santa Cruz River from the international border to the Continental gauging station, a few miles north of the Santa Cruz/Pima County line (*See Figure 1-1*.) Along this reach, the Santa Cruz River is characterized largely as an intermittent desert stream that contains uninterrupted perennial and reclaimed water dominated reaches. The drainage area of the Santa Cruz River upstream from the Continental gauging station is about 1,680 square miles in the US and Mexico. From its headwaters in the San Rafael Valley in Arizona, the river flows southward approximately nine miles and enters Mexico. During its 35 mile course through Mexico, the river continues its southward path for a short distance and then turns northward and enters Arizona five miles east of Nogales. Within the U.S., the Santa Cruz River continues northward for 65 miles from Nogales to Tucson, and then continues to the confluence of the Gila River in the southwest portion of the Phoenix metropolitan area.

In the Basin and Range Physiographic Province in Southern and Central Arizona, natural groundwater recharge occurs along the periphery of the basin (a phenomenon commonly referred to as Mountain Front Recharge) and along the stream courses. In the SCAMA, only a limited amount of groundwater recharge is believed to occur along the basin periphery. The areas along the Santa Cruz River are dynamic, with water recharging the near-stream alluvium during times of high flow. Pumping of wells located in the near-stream alluvium can induce flows from the River into the alluvium and can also create unsaturated alluvial conditions that will re-fill in subsequent flow events. Well yields along these reaches are highly variable, changing in response to streamflow, competing near-stream water uses in the US and Mexico, and the resultant alluvial aquifer conditions. At times, well yields can be reduced to the point where water supplies must be replaced, or water uses curtailed until supply conditions improve.

Discharges to the Santa Cruz River from the NIWWTP north of the City of Nogales serve as a consistent and reliable source of supply for the downstream river and associated alluvial aquifer.

Well yields are generally lower, but more stable, in wells completed in the older alluvial aquifer system.

3.2.2 Hydrologic Model Development

In order to help characterize and understand the water management issues and nature of water supply and demand within areas of the AMA, ADWR staff have collected additional data and developed two hydrologic models of the SCAMA since its creation. One model covers the area downstream of the NIWWTP, the other, the covers the “Microbasins”.

Model Geography

Figure 3-11 below identifies the extent of the model areas. It also shows the differentiation in hydraulic characteristics between model cells, which serves to define the inner valley from other portions of the SCAMA as represented in the model grid.

Inner Valley Downstream Area

ADWR has developed a regional groundwater flow model of the SCAMA that covers the reclaimed water-dominated stretch of the Santa Cruz River. The model was developed as a tool to better understand the complex and interdependent stream-aquifer system, and to provide guidance for the management of regional water resources (Nelson, 2007).

The hydrology of the inner Santa Cruz River Valley is characterized by complex stream-aquifer interactions. Groundwater pumpage, land-use changes, reclaimed water recharge and increased ET have modified the hydrologic system and created the need for a management tool to help understand and predict hydrologic impacts of water management changes. In recognition of this need, ADWR initiated a monitoring program in 1997 to guide development of a conceptual and numerical model (Nelson & Erwin, 2001).

To better understand and quantify the hydrologic system, a three-dimensional finite-difference groundwater flow model (MODFLOW) was developed for the area downstream of the NIWWTP The model domain covers the area between the NIWWTP and Elephant Head Bridge and is bounded between the Atascosa and Tumacacori Mountains to the west, and the San Cayetano and Santa Rita Mountains to the east *(See Figure 1-3).* The model simulates groundwater flow in three basin-fill units including the Younger Alluvium, Older Alluvium and the Nogales Formation. Model results include simulated hydraulic heads, flows and water budgets for steady state and transient conditions between October 1, 1997 and September 30, 2002. Examination of seasonal head and flow data collected between 1997 and 2002 show spatial and temporal groundwater level variations. However, the cumulative net change-in-storage over the model area during this period was small. Also during this period, the system tended towards steady state conditions over most winter baseflow periods.

Details of these modeling efforts are documented in Nelson & Erwin (2001) and Nelson (2007). In general, the model replicates observed heads and flows over space and time with good accuracy. Most hydraulic conductivity zones were estimated with good reliability in the Santa Cruz Valley. Although only one model is formally presented in this report, several other high-ranking alternative conceptual models were discussed in Chapter 6 of the Nelson (2007) report.

Model results show that between 1997 and 2002 the net annual recharge along the Santa Cruz River aquifer varied from less than 20,000 acre-feet/year to greater than 50,000 acre-feet/year for drought (2002) and flood-dominated (2000) years, respectively. Stream recharge variability between 1997 and 2002 reflected precipitation fluctuations, which ranged from about eight to 26 inches per year at the NIWWTP. The average precipitation rate over this period was similar to the long-term average precipitation rate, roughly 16 inches per year. Although rates of long-term mountain front recharge and tributary recharge (totaling about 10,250 acre-feet/year) were estimated with less certainty, they were nonetheless, consistent with conceptual long-term estimates. Other system inflows including underflow and incidental agricultural recharge varied over time averaging about 8,500 and 2,600 acre-feet/year, respectively. System outflows including: pumpage; ET (saturated zone);and underflow also varied over time, averaging about 15,000, 13,000 and 24,000 acre-feet/year, respectively. Net groundwater discharge along the River between the Peck Canyon confluence and Tumacacori over winter baseflow conditions between 1997 and 2002 wasalso simulated.

Inner Valley of the Microbasins

The Microbasin model addresses the area in the valley along the Santa Cruz River from the International Boundary to the NIWWTP. The microbasins are described as a series of four small alluvial basins surrounded by impermeable or very low permeability formations, either bedrock or Nogales Formation. Hardrock outcrops serve to separate the basins from each other.

ADWR has developed a groundwater flow model to assist in the understanding of this complex hydrologic system. Additionally, the model will aid the SCAMA in determining if they are achieving their Management Goals and with analysis of future management strategies.

ADWR conducted an analysis of the hydrogeology and water resources for the general area around and including the microbasins. Three lithologic units were identified as the younger alluvium, older alluvium and Nogales Formation. Hydraulic characteristics of each of these units were quantified. Surface water data were collected including streamflow measurements for five locations on the main stem of the Santa Cruz River. Groundwater pumpage data from Annual Reports was collated, analyzed, and summarized.

A regional MODFLOW model was constructed and used to simulate hydrologic conditions from October, 1997 through September, 2002. The active model domain encompasses approximately 40 square miles and has approximately 2,500 active model cells distributed among three layers, each layer simulating a distinct hydrogeologic unit. Model cells are 660 feet by 660 feet or ten acres each. The model simulates the hydraulic interconnection between the Santa Cruz River and the groundwater system. Details on the model construction and hydrology of the microbasins are presented in (Erwin, 2007).

In general, the groundwater flow model developed for the Santa Cruz River microbasins appears to reasonably simulate groundwater conditions in the younger alluvial aquifer. Results indicate that the younger alluvium, particularly the Kino Springs and Highway 82 microbasins, are recharged almost solely from discharge in the Santa Cruz River. The older alluvium and Nogales Formation contribute very little recharge to the younger alluvium. Consequently, recognizing the significance of climatic patterns and streamflow in the area will be central to the success of future management strategies.

Data are inadequate in the older alluvium and Nogales Formation to draw any specific conclusions or use the model reliably as a predictive tool in those hydrogeologic units.

Potrero Area

The Potrero Area is not modeled, but is separated out for purposes of this Assessment because it differs from the other portions of the AMA outside the modeled areas. Potrero serves as the backup wellfield for the City of Nogales and as the primary wellfield for Valle Verde Water Company. An inner valley area has yet to be delineated for the Potrero Area, so for this Assessment, the entire area around Potrero (delineated simply with a large rectangle on the map in *Figure 1-8)* was used to query historical pumpage and prepare projections of demand and supply.

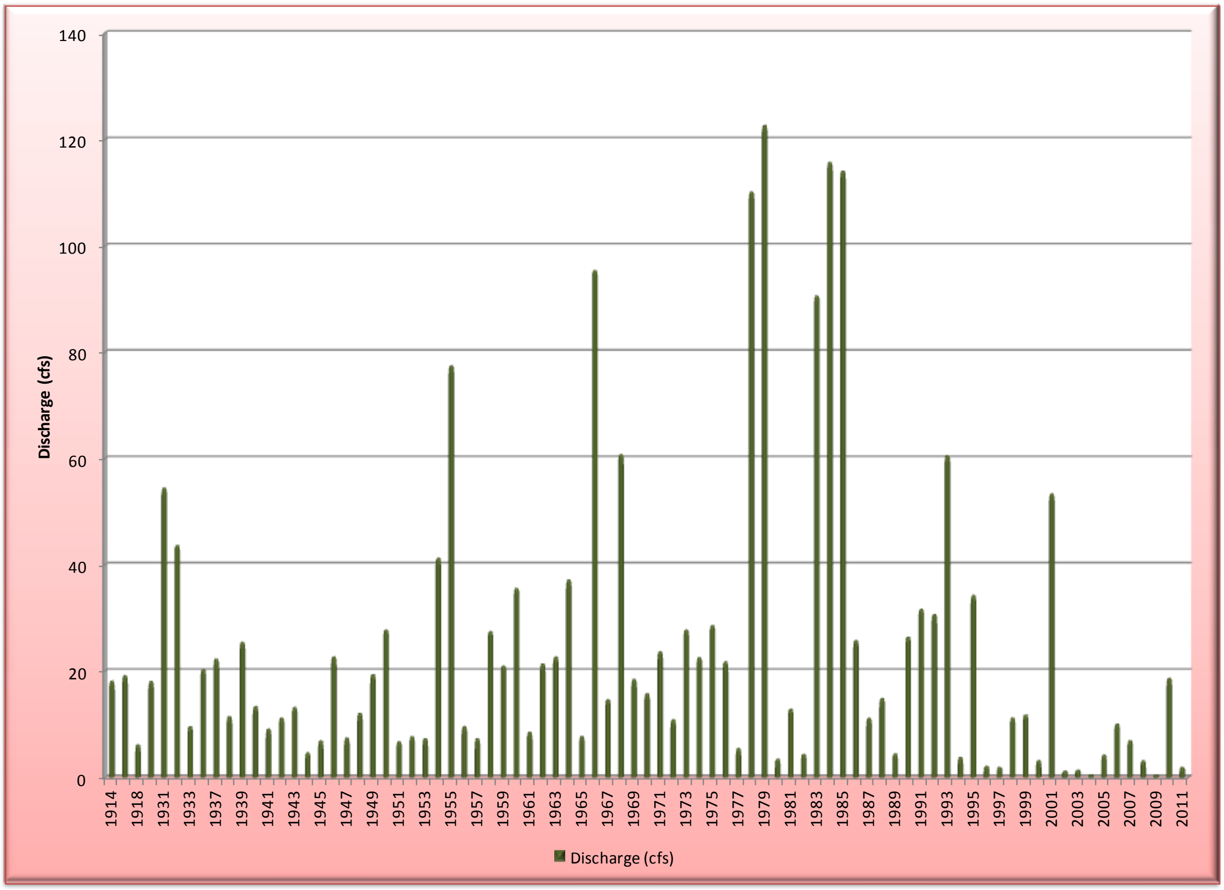
Area Outside the Inner Valley and Potrero

Any portion of the AMA that is not within any of the three sub-geographies described above is considered to be outside the inner valley model area or the Potrero Area for the purpose of this Assessment. This includes portions of the Downstream and Microbasin models outside the inner valley areas. Generally the outside area is characterized by underground water supplies that are less affected by the dramatic variation in surface flow in the Santa Cruz River, and that respond more slowly, or not at all to variations in stream channel recharge.

Uncertainty of Supply Availability

Upstream of the NIWWTP discharges, flow in the Santa Cruz River is ephemeral to intermittent. This river reach experiences significant variability in seasonal and annual flow. Streamflow downstream of the U.S. Geological Survey gage is the result of a combination of runoff past the gage, tributary inflows, and subflow or groundwater forced to the surface at bedrock constrictions. The stream is highly variable and flow is mostly from direct runoff and has a minimal amount of bank storage (Putman & etal, 1983). Seasonal discharge on the Santa Cruz River is related to climatic variability. Precipitation in southern Arizona has distinct peaks in summer and winter. Averages of monthly discharge for the Santa Cruz River at Nogales indicate that runoff occurs mainly from December through February and July through October. Variability in monthly streamflow is high, and coefficients of variation range from 1 to 4.3 (*See Figure 3-11 below).*

Figure 3-11 Average Annual Discharge of the Santa Cruz River at Nogales



Artificial Recharge Potential

Due to the poor permeability of the soils on the steep slopes outside the inner valley areas, and the shallow nature of the aquifer (at least in the southern portion of the AMA), there is a general dearth of suitable locations for artificial recharge in the SCAMA. Should an underground storage project be proposed, careful analysis would be required to ensure that water stored underground would remain in the AMA until needed, and not exit the AMA as underflow.

Pumpage

Historically, pumpage from wells within the inner valleys has created water level declines which have been replenished by subsequent surface flows occurring throughout the year. This dynamic system is essentially the water supply equivalent of living within one's means. When water is available in the system, it is available for use. When water levels and well yields in the inner valley wells drop, alternative wells further away from the river are used until such time as natural flood events refill the inner valley aquifers. As long as the overall water demand remains fairly constant, and as long as timely replenishing surface flows occur of sufficient duration, frequency and magnitude, sufficient supply is available to meet demand without curtailment.

Similarly, downstream of the NIWWTP, where water availability is to a degree dependent upon the more constant release of treated reclaimed water into the river channel, historic demand has been close to the volume of water discharged from the plant. As long as demand remains fairly constant and the volume of reclaimed water discharged remains fairly constant, shortages in this area are likely to continue to be infrequent and manageable. Construction and operation of the Los Alisos WWTP in Sonora will divert flows from the NIWWTP and has the potential to impact this balance.

3.3 Renewable Supplies

Renewable water supplies in the SCAMA, which offset pumping and natural system demands such as riparian ET and groundwater outflow, include natural system as well as cultural components. Natural inflow minus natural outflow is termed net natural recharge. Recharge from cultural activities is referred to as incidental recharge.

3.3.1 Net Natural Recharge

Net natural recharge in the SCAMA includes the components described in detail below.

> *Mountain Front Recharge*: Mountain front recharge is natural recharge that occurs primarily from infiltration along small stream channels and from subsurface seepage of water from consolidated rocks. In the mountains, ephemeral streams lose small amounts through joints and cracks in the consolidated rocks. The water moves toward the valley and seeps into the basin fill deposits that fill the valley (Erwin, 2007).
>
> *Streambed Recharge:* Streambed recharge along the main stem of the Santa Cruz River has a significant impact on the groundwater flow regime in the Santa Cruz River Valley. Streambed recharge is a function of many interdependent factors including the hydraulic properties of the aquifer, the geometrical boundaries of the system, bank storage, storage availability of the aquifer, demands such as ET and pumpage, the characteristics of flow events, i.e., flood frequency, duration, magnitude and timing and season, and streambed properties including the saturated and unsaturated hydraulic streambed conductivity (Nelson, 2007).
>
> *Groundwater Inflow:* Groundwater Inflow is water that flows into the SCAMA from the Potrero Sub-area, between the Santa Cruz River and Sonoita Creek (Nelson, 2007), and from Mexico via the older alluvium and Nogales Formation (Erwin, 2007).
>
> *Groundwater Outflow:* Groundwater outflow occurs when groundwater exits the SCAMA and flows into the TAMA at the northern boundary of the SCAMA (Nelson, 2007).

The sum of mountain front recharge, streambed infiltration, and groundwater inflow minus groundwater outflow yields *Net Natural Recharge*. The amount of Net Natural Recharge can vary significantly from year to year with the amount of precipitation and the timing and magnitude of storm events. For the purposes of this Assessment, mountain front recharge is held constant at the assumed long-term average. Historical streambed recharge was categorized into low, moderate or high based on the range of stream flow values. Due to its high degree of variability, projected streambed recharge was generated using a statistical approach based on historical data (*See Table 8-1).* Average rates for groundwater outflow varied slightly for the historical period and were based on Nelson (2007). For the projected years, historical groundwater outflow was averaged.

These components have been further disaggregated into the four sub-geographies of the AMA to illustrate the relative importance of each of these components at a more local level. For the method of disaggregation see *Appendix 1*.

3.3.2 Incidental Recharge

Incidental recharge is another offset to groundwater overdraft, a by-product of water used for human activities. ; Percolation of irrigation water below the root zone of irrigated crops is one example. ADWR assigns incidental recharge rates for Municipal, Industrial and Agricultural demands and for canal seepage (*See Table 3-3)*. For purposes of this Assessment, incidental recharge for each of the demand sectors is assumed to occur in the year the water is applied.

Table 3-3 Incidental Recharge Rates Used in the Summary Budget
Santa Cruz Active Management Area

Source of Incidental Recharge	Percent of Total Demands or Volume Applied to Source of Recharge
Municipal Demand	
Municipal Demand	0%
Agricultural Demand	
Agriculture	25%
Industrial Demand	
Turf-related Facilities, Sand and Gravel Operations	12%
Other Industrial Facilities	4%

Incidental Recharge from Nogales, Sonora Infrastructure

It is believed that a certain volume of incidental recharge enters the SCAMA from Mexico due to leaks in water and sewer infrastructure within Nogales, Sonora. This has not been quantified, but is likely to occur due to the downstream gradient of Nogales, Arizona from Nogales, Sonora.

Septic Systems Leachate Outside the Inner Valley

Another potential, though as yet un-quantified, source of incidental recharge is septic leach field seepage from the hillsides outside the inner valley area. However, this volume may be masked and included in the estimate of mountain front recharge.

Farming IR

The primary source of incidental recharge in the SCAMA is recharge resulting from the method of application of irrigation water to crop fields. This can result in a considerable amount of water depending on the volume applied to the field in excess of the crop needs. In the SCAMA, it can be as much as 40% of the water applied to irrigated pastures (*See Appendix 2).*

3.3.3 Reclaimed Water Discharge - NIWWTP

Historically, reclaimed water has been discharged into the Santa Cruz River from the NIWWTP. The percentage of the total volume of discharged reclaimed water that incidentally recharged the aquifer is calculated based on infiltration studies. These discharges have been a source of recharge for the aquifers downstream, but their future availability is uncertain. About 10,000 acre-feet of the total volume of reclaimed water generated annually are from Mexico. By International Treaty this reclaimed water could be retained by Mexico. It is estimated that an average of approximately 7,000 acre-feet per year of the reclaimed water discharged into the Santa Cruz River infiltrates into the aquifer (Nelson, personal communication, 2009). This 7,000 acre-feet is included in the overall streambed recharge figure.

Reclaimed water discharges to the Santa Cruz River increased from 10,000 acre-feet in 1985 to more than 17,000 acre-feet in 2009 and are a significant water supply in the SCAMA (*See Table 3-4 below)* and also potentially contribute to the TAMA.

Table 3-4 Historical Reclaimed Water – NIWWTP (acre-feet/year)

Year	Reclaimed Discharge NIWWTP	Source	
		United States	Mexico
1985	9,986		
1986	9,627		
1987	9,167		
1988	10,398		
1989	10,738		
1990	10,203		
1991	13,447	5,355	8,092
1992	14,740	5,194	9,545
1993	15,465	3,102	12,363
1994	18,576	6,377	12,199
1995	16,721	5,514	11,207
1996	14,301	4,494	9,807
1997	14,207	4,679	9,529
1998	16,295	5,584	10,711
1999	16,292	6,249	10,043
2000	17,538	5,666	11,872
2001	17,451	5,025	12,426
2002	16,531	6,209	10,322
2003	16,064	4,954	11,110
2004	16,222	4,761	11,461
2005	16,627	5,191	11,436
2006	15,500	4,497	11,002
2007	17,311	4,331	12,979
2008	16,810	5,205	11,605
2009	17,184	4,419	12,765

Mexico has begun, and will soon complete, construction of the first phase of a wastewater treatment plant in the Los Alisos basin within Nogales, Sonora. The first phase of the Los Alisos Wastewater Treatment plant (LAWWTP) will have a capacity of about five million gallons per day (mgd). Pumps are being installed at El Tecnologico Wash for delivery of wastewater through a force main to the LAWWTP. Construction is scheduled for completion in May, 2012. The pumps will have a capacity of about nine mgd. Nogales, Sonora plans to install additional pumps in the future to realize a total capture of about 17 mgd. A steady five mgd reduction in flow to the NIWWTP is equivalent to a reduction of about 5,600 acre-feet per year. This reduction in the Mexican contribution to the NIWWTP may result in significant changes to the aquifer system and the riparian community downstream of the point of discharge. Additionally, while it is not a simple 1:1 reduction, the reduction in reclaimed water contribution will also impact the water balance and determination of safe-yield status for the SCAMA and the TAMA.

3.3.4 Contribution of Conservation and Renewable Supplies

Although there has clearly been a reduction in GPCD, conservation of water supplies is not explicitly accounted for in the Summary Budget. Each water use sector (Municipal, Agricultural and Industrial) has associated conservation requirements that are described in the 3MP. Conservation helps stretch existing supplies, but more importantly perhaps for the SCAMA, short-term conservation and curtailment are effective tools to reduce demand during periods of reduced supply.

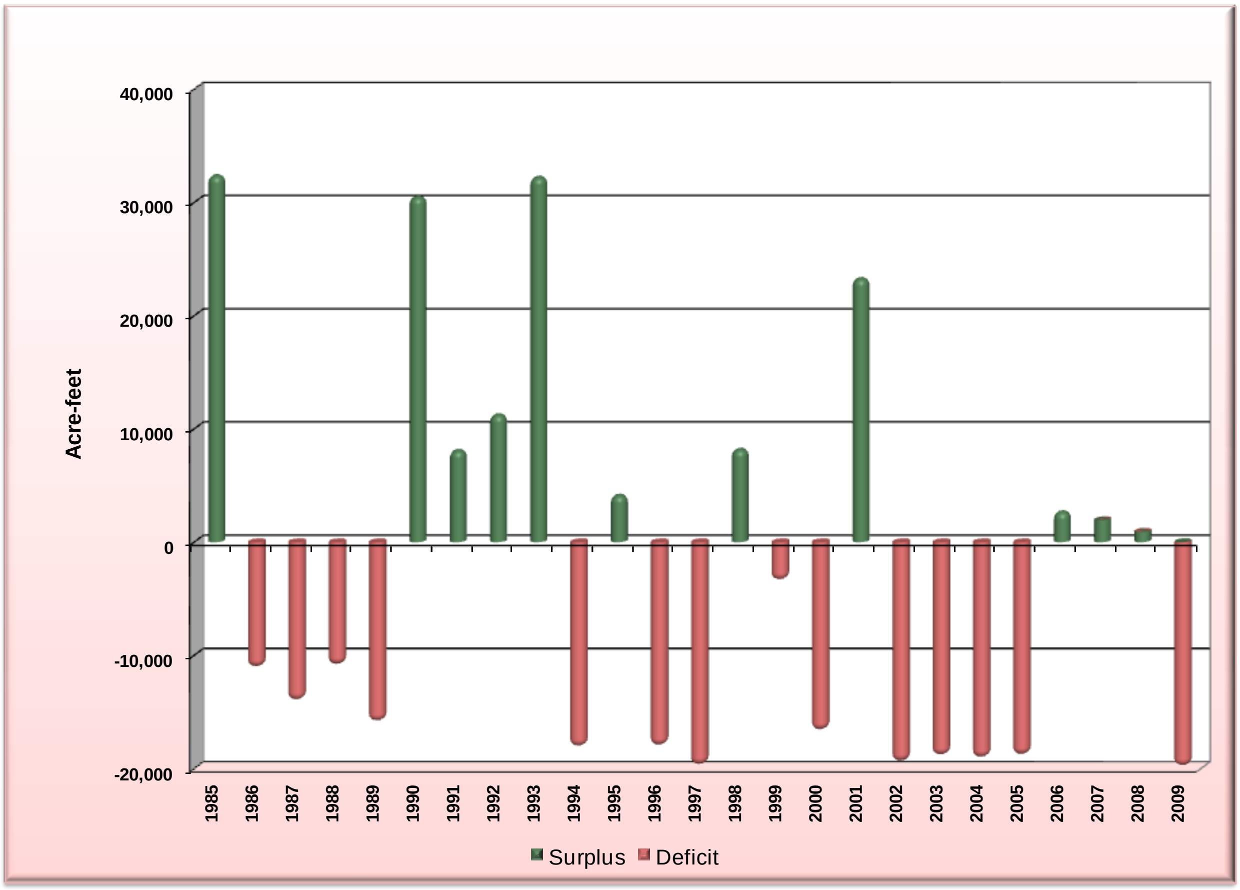
Constructing additional infrastructure to capture and treat additional wastewater generated from new development will provide additional renewable supplies for either direct use for turf irrigation or to be artificially recharged at either a managed or constructed recharge project.

4. EVALUATING THE AMA WATER BALANCE; A DYNAMIC ANALYSIS OF SUPPLIES AND DEMANDS

In AMAs with the sole goal of safe-yield, an overall water budget is often used to evaluate the progress the AMA is making towards achieving its goal. Because SCAMA has the additional goal of preventing local water tables from experiencing long-term declines, the traditional water budget approach is not sufficiently site-specific to evaluate the dynamic nature of the local water balance. For this reason, in addition to an overall annual budget for the AMA related to its safe-yield goal, charts are presented below for each of the four sub-geographies within the AMA.

The overall AMA water balance chart is shown in *Figure 4-1* below. This chart illustrates how the AMA as a whole experiences years when it is at safe-yield and years when it is in overdraft and evidences the dynamic nature of the system.

Figure 4-1 Historical Dynamic Water Balance AMA-Wide 1985-2009



As previously stated, surface flow in the Santa Cruz River fluctuates dramatically from year to year. The highest flow during the evaluation period occurred in 1993. In extremely high flow years, there is a sufficient volume of water in the river that surface flow exits the SCAMA and contributes to the TAMA's supplies.

Depending on the volume of water in storage in the aquifers when the surface flow occurs, a good portion of the streamflow can infiltrate and recharge the alluvium. Because most of the wells in the AMA are located in or near the Santa Cruz River, water availability for Municipal, Industrial and Agricultural demand is influenced by flows in the River.

The historical flow of water in the River and the dynamic nature of the shallow aquifer system have allowed the establishment of a significant riparian habitat, especially downstream of the NIWWTP. The riparian habitat is an additional significant demand on the hydrologic system of the SCAMA.

Groundwater also flows into and out of the AMA some distance beneath the land surface. Because there is a physical connection between surface water and groundwater, when there is more surface water flow, there is often more groundwater flow. However, there is also groundwater flow that is some distance away from the Santa Cruz River and is not likely to be significantly influenced by the variability of streamflow in the river. Like surface water, groundwater also flows out of the SCAMA into the TAMA, and the portion of the groundwater outflow that is influenced by variable surface water flow also fluctuates from year to year.

Both surface water outflow and groundwater outflow are debits on the water budget of the SCAMA in addition to riparian demand, and the cultural demands of municipal, Industrial and agricultural uses and, for the purposes of this Assessment, considered demands on its hydrologic system.

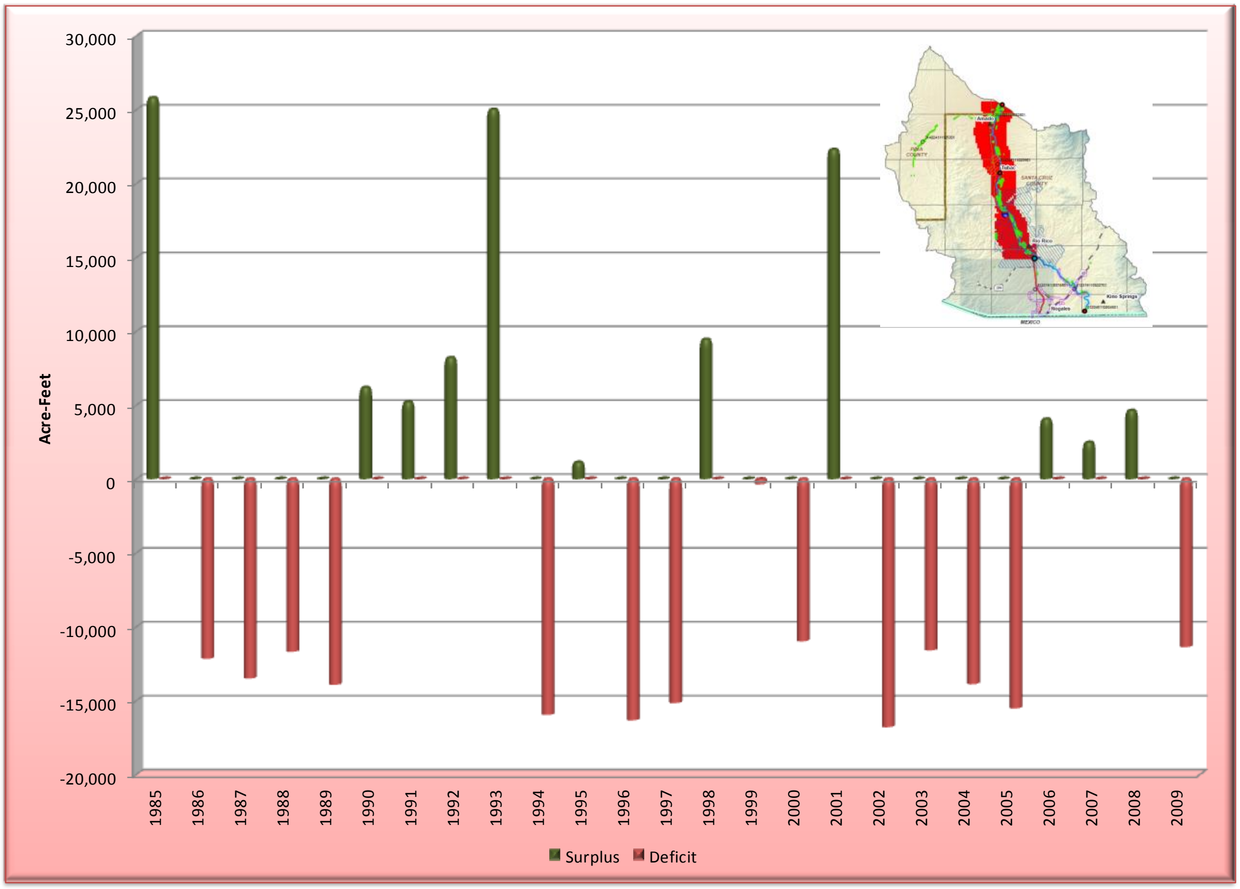
Variability of the water supply is an important factor that must be addressed in order to assess and achieve the water management goal of the SCAMA. Natural system demands, such as groundwater outflow and riparian demand, will vary in response to supply variations. However, the cultural demands of municipal, agricultural and Industrial use do not adjust as readily to variations in the supply volume.

Pursuant to the Code, grandfathered groundwater rights were issued based on historical use between 1975 and 1980. For entities who did not withdraw water during that period, and who did not have grandfathered groundwater rights, the Code contained provisions for issuance of groundwater withdrawal permits. These permits may be issued for a specific length of time and volumes based on projected need. Historically, municipal providers in the SCAMA used water from wells. The amount of water a municipal provider could serve was based on conservation requirements set forth in the Management Plans, but that volume could generally increase with population growth. Further, new municipal provider service areas can be established, which can then continue to grow and increase water demands. Although the Code contained provisions for the AWS program, the AWS Rules were not adopted until 1995, and rules for consistency with the AMA Management Goal for the SCAMA are still under development.

With historic demands fairly flat, although varying between sectors and between cultural demands and natural system demands, the AMA has been able to meet demand without the frequent need to curtail use or constructing water storage facilities or underground storage and recovery projects. However, as the cultural demand in the AMA continues to grow, it may become increasingly more difficult to meet demand during periods of little or no streamflow without some mechanism to store water or augment the natural component of the AMA's water supply. Similarly, should demands increase in Mexico or reclaimed water from Mexico be retained in Mexico, water users in the AMA would eventually need to find alternative supplies to make up for the loss of those supplies.

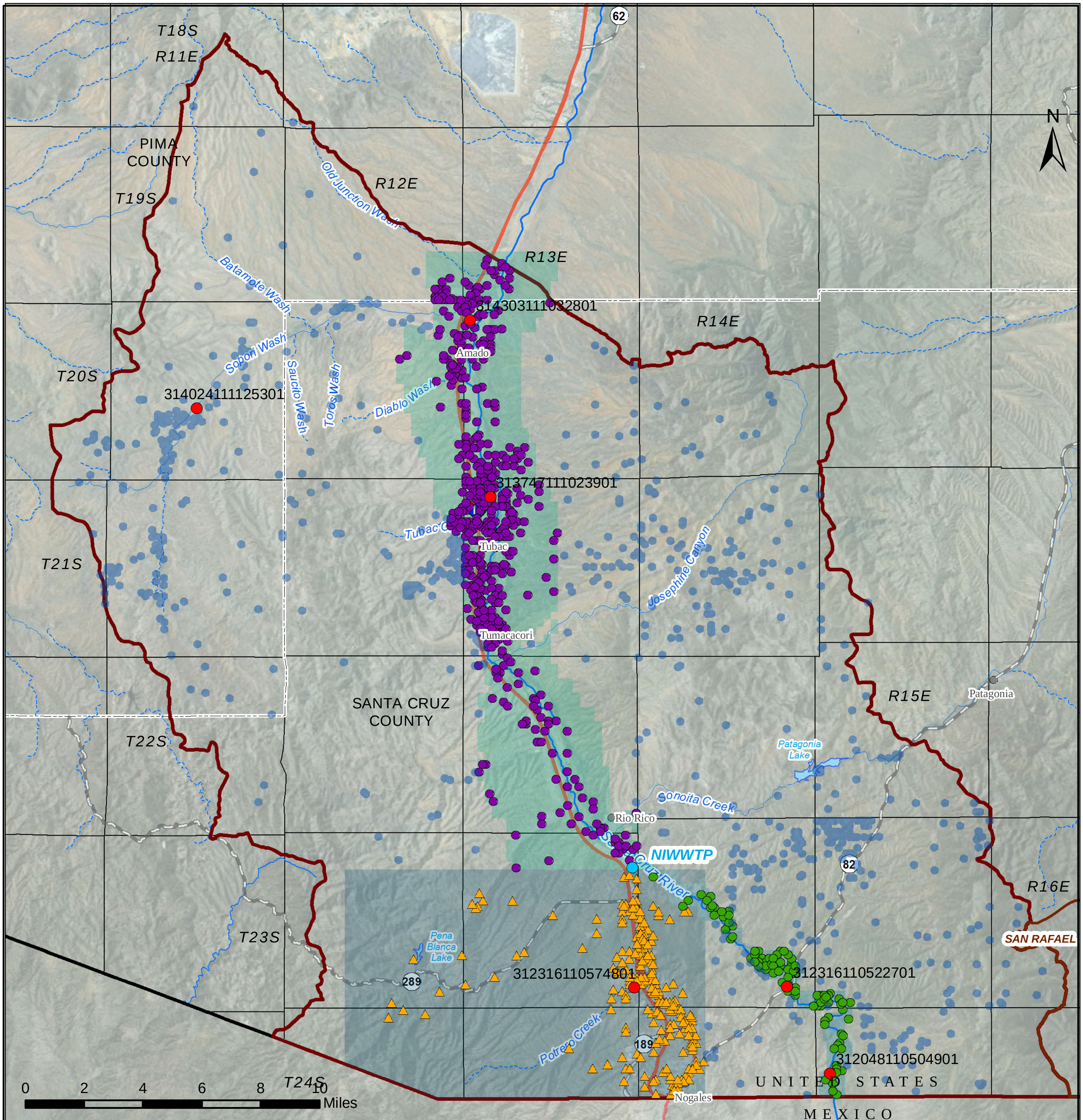
Water balance charts for each of the sub-geographic areas follow demonstrating that different sub areas experience more dramatic fluctuations in the water balance than other areas do. In the Downstream Area, there have been many years of significant surplus and also years of similar magnitude deficit (see Figure 4-2, below).

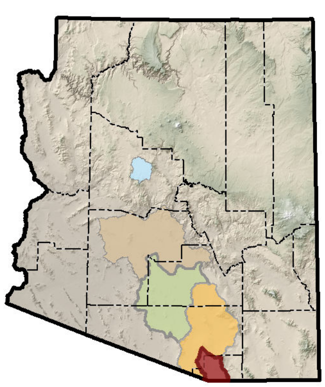
Figure 4-2 Dynamic Water Balance – Downstream 1985-2009



It is important to note that water levels in wells may or may not be indicative that a deficit is occurring, due to the location of the well within the Sub-Geographic Area and the volume of pumpage occurring. There is also a lagging natural replenishment of the wells and a seasonality that is not evident when charting annual balances, which can manifest as both deficits and surpluses in the same area within the same year due to the timing of replenishing precipitation and subsequent stream channel recharge events.

Recent water level change hydrographs have been prepared by ADWR's Hydrology Division and show fluctuations in water levels in all the Sub-Geographic areas of the SCAMA. It is important to note that a trend of water level decline in one well within the area may not be indicative of general declines in all well within the Sub-Geographic Area. *Figure 4-3* shows the location of each of the index wells from which the hydrographs were generated. *Figures 4-4 through 4-10* are the hydrographs for each of these wells.





ARIZONA DEPARTMENT OF WATER RESOURCES ©

Figure 4-3
Location of Hydrograph Index Wells in SCAMA

Legend

- Santa Cruz AMA
- Index Well
- Microbasin Area Wells
- Downstream Area Wells
- Potrero Area Wells
- Wells Outside the Inner Valleys and Potrero
- Microbasin Area
- Downstream
- Potrero Area
- NIWWTP
- City or Town
- Major Road
- Interstate Highway
- Stream
- State Boundary
- Township/Range
- County

Figure 4-4 Downstream Well Hydrograph Along the SCR between Arivaca Junc. and Amado

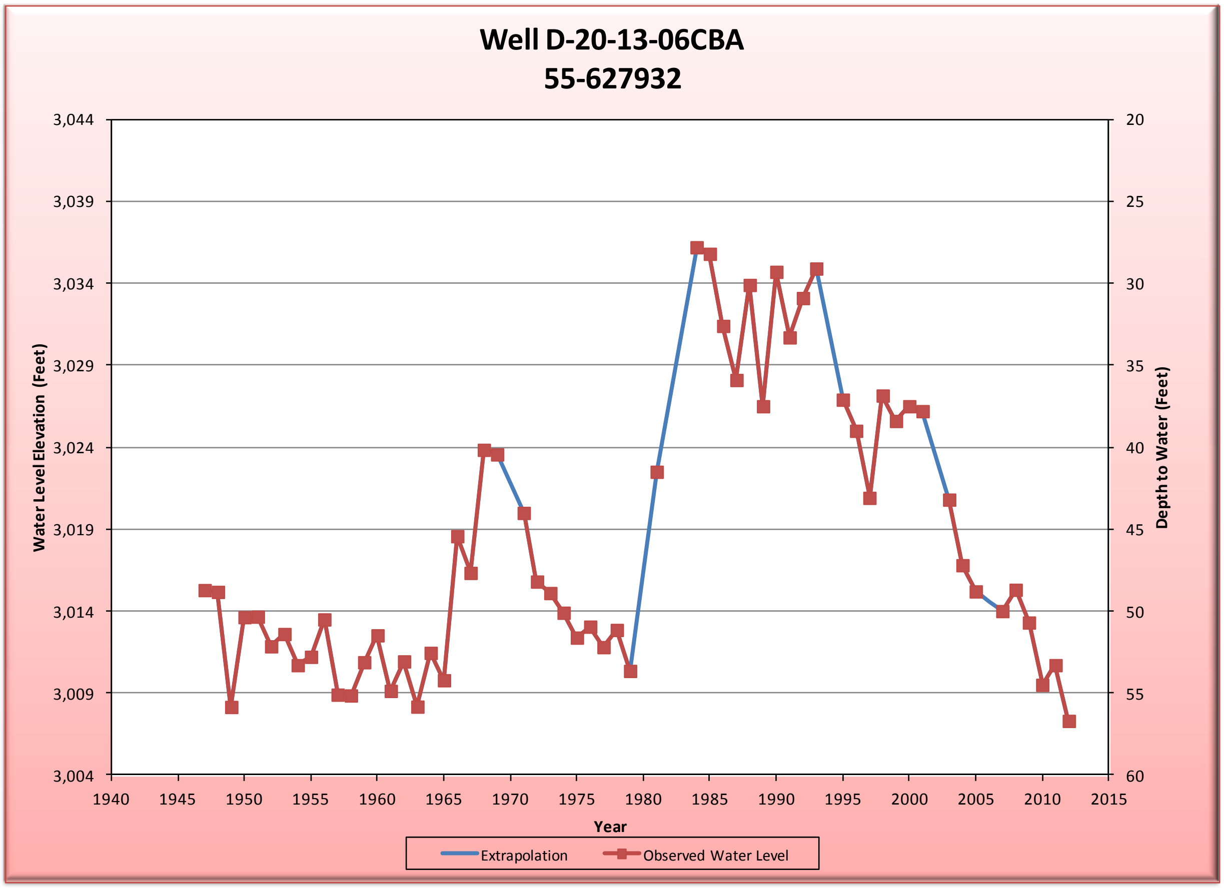


Figure 4-5 Hydrograph of Downstream Well Near Tubac

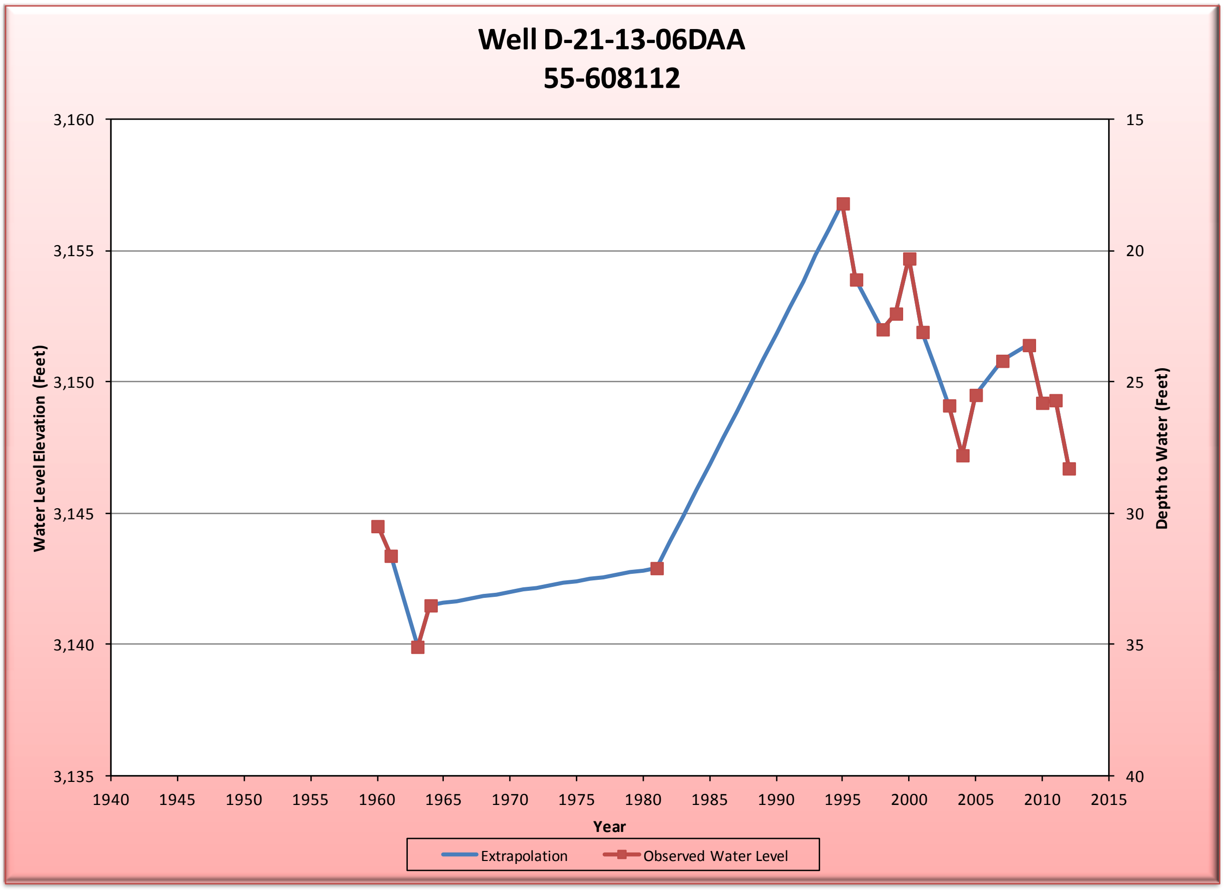
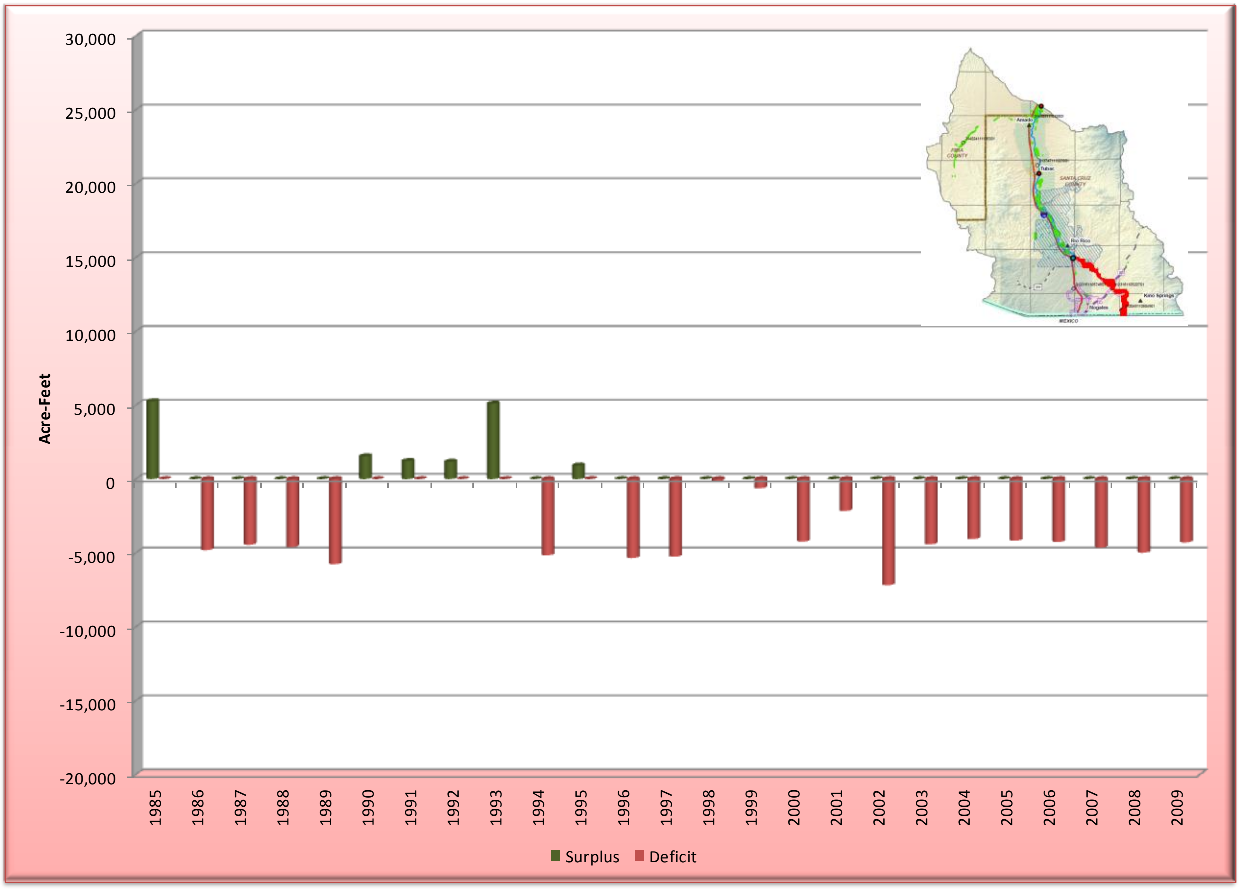


Figure 4-6 Dynamic Water Balance – Microbasins 1985-2009



The Microbasin Area is more susceptible to deficit conditions, as demonstrated in Figure 4-6, above. Hydrographs from wells within the Microbasin Area show the fluctuation based on seasonal precipitation and streamflow events.

Figure 4-7 Hydrograph of Microbasin Well Along Santa Cruz River Near US/Mexico Border

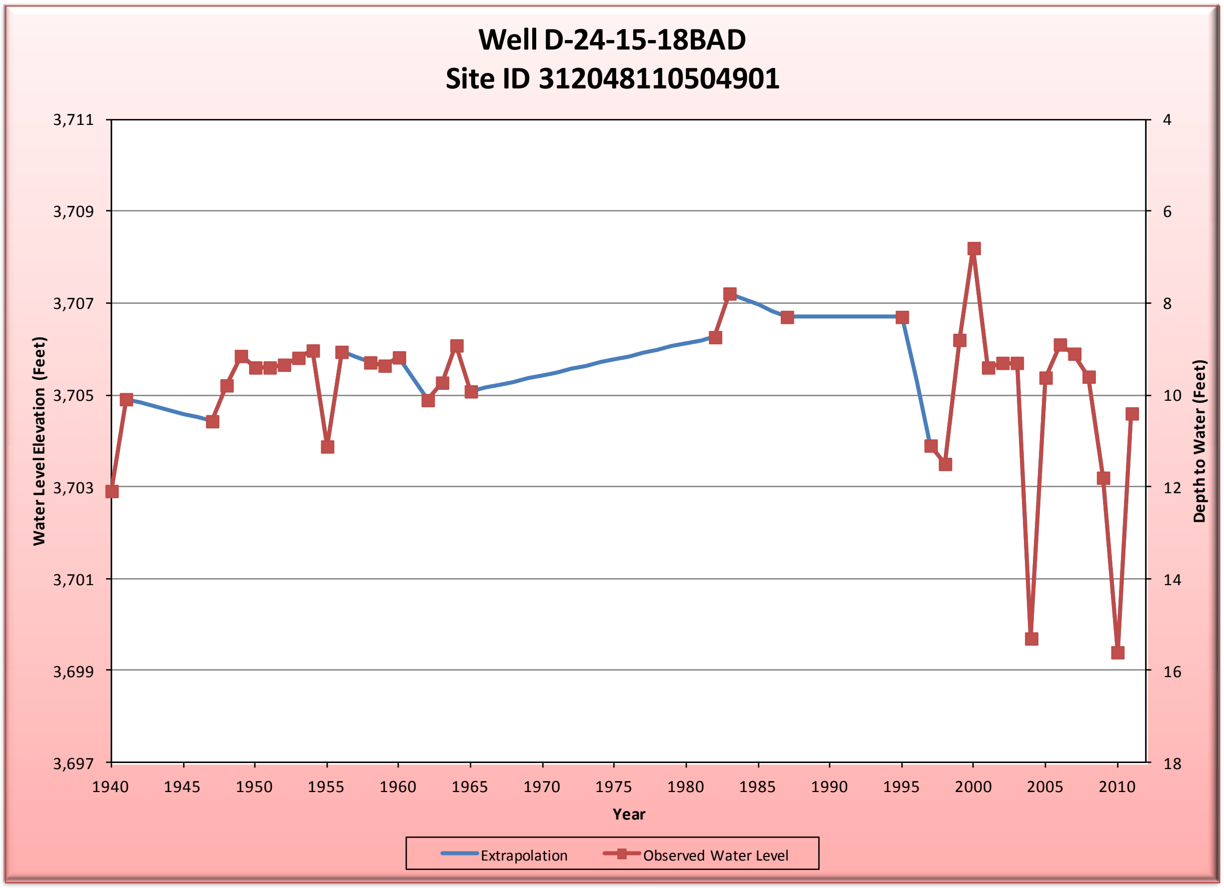


Figure 4-8 Hydrograph of Microbasin Well at Santa Cruz River Near Highway 82

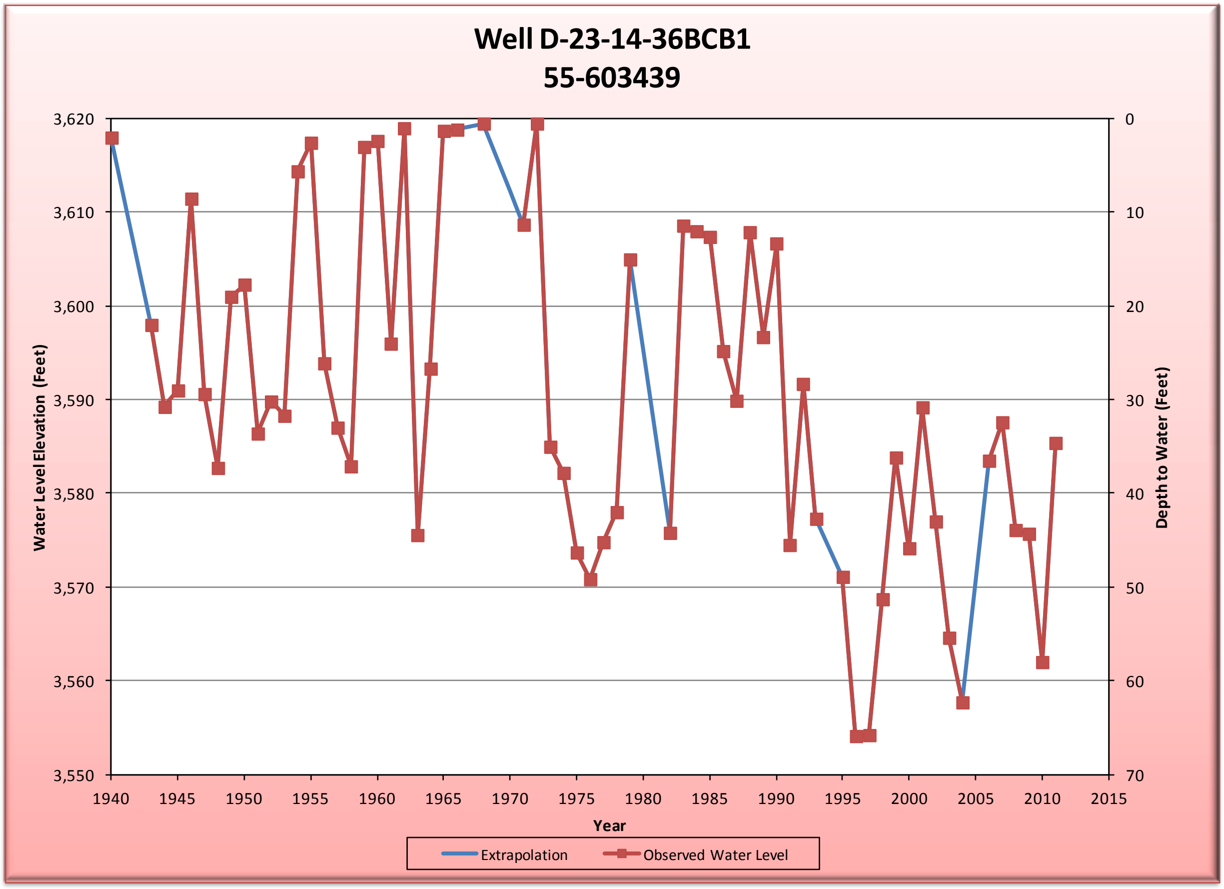
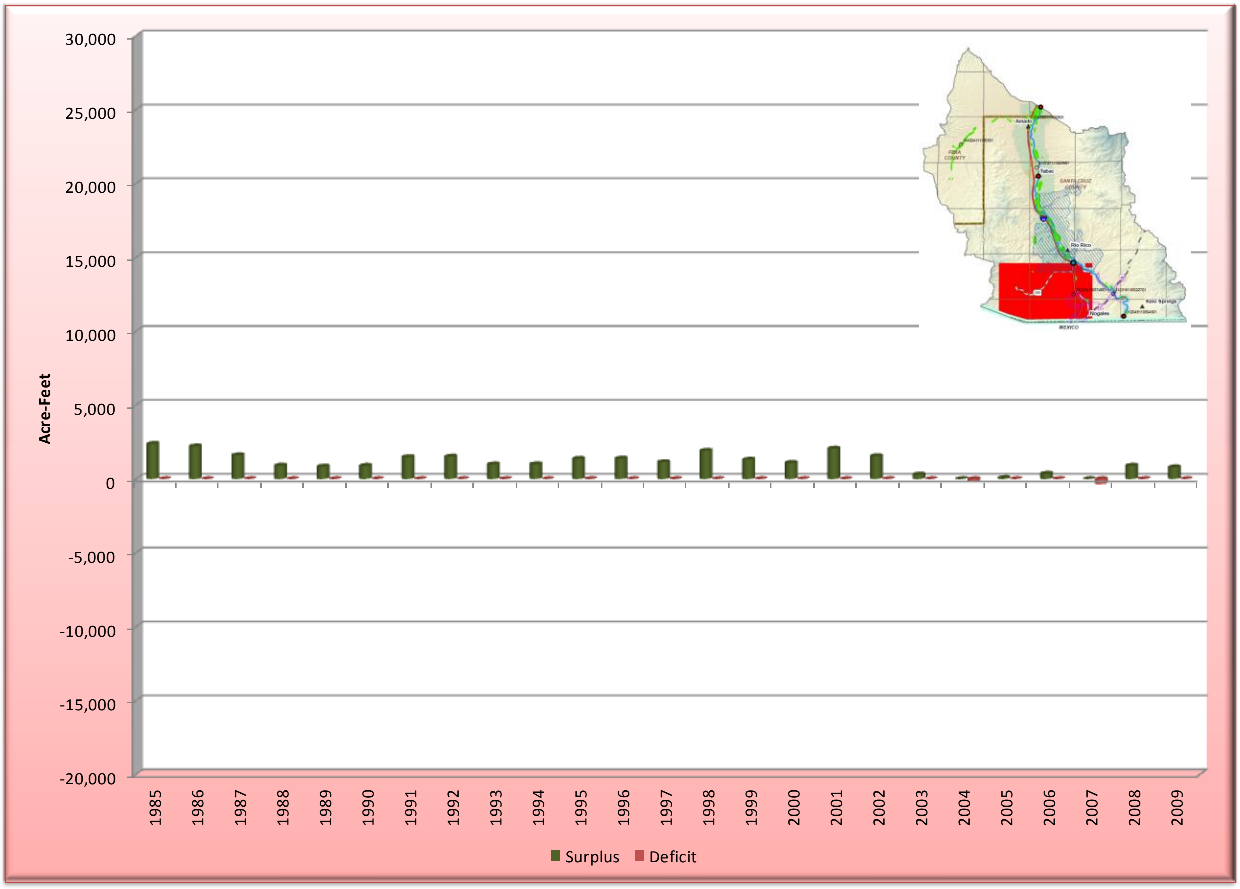


Figure 4-9 Historical Dynamic Water Balance – Potrero 1985-2009



Although the Potrero Area is generally in a surplus condition (except in recent years), its supply compared to the other areas is smaller. Note that although the Sub-Geographic Area water balance shows the Potrero Area primarily in a slight surplus, water levels in hydrographs show persistent declines. This may be due to the location of the well within the Sub-Geographic Area, or the condition is isolated to the well site only, or the general characterization of the Potrero Area is inaccurate and its net natural recharge is not a constant as indicated in the Hydrologic model. The model area is not as fine in definition as actual conditions, but does include generalized assumptions for some hydrologic components such as mountain front recharge.

Figure 4-10 Potrero Well Hydrograph

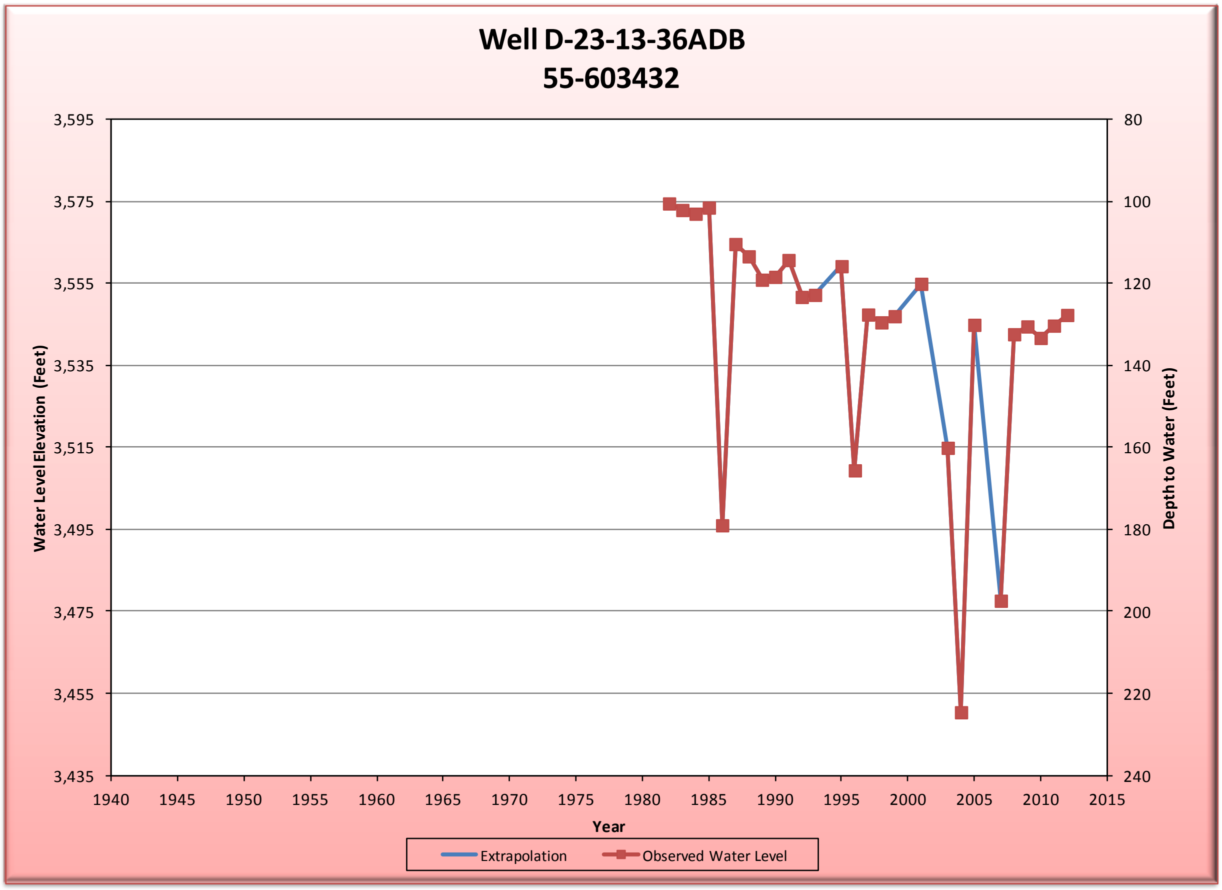
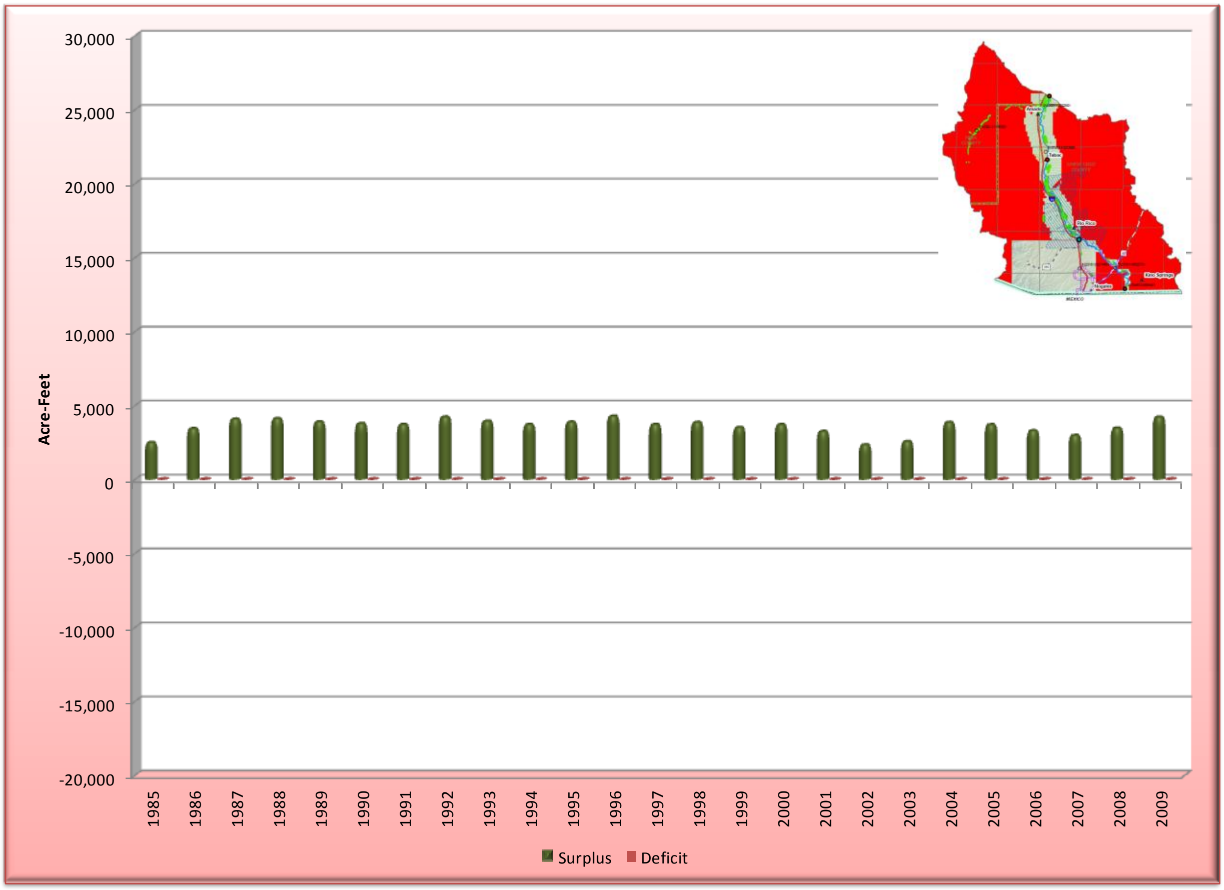


Figure 4-11 Dynamic Water Balance – Outside 1985-2009

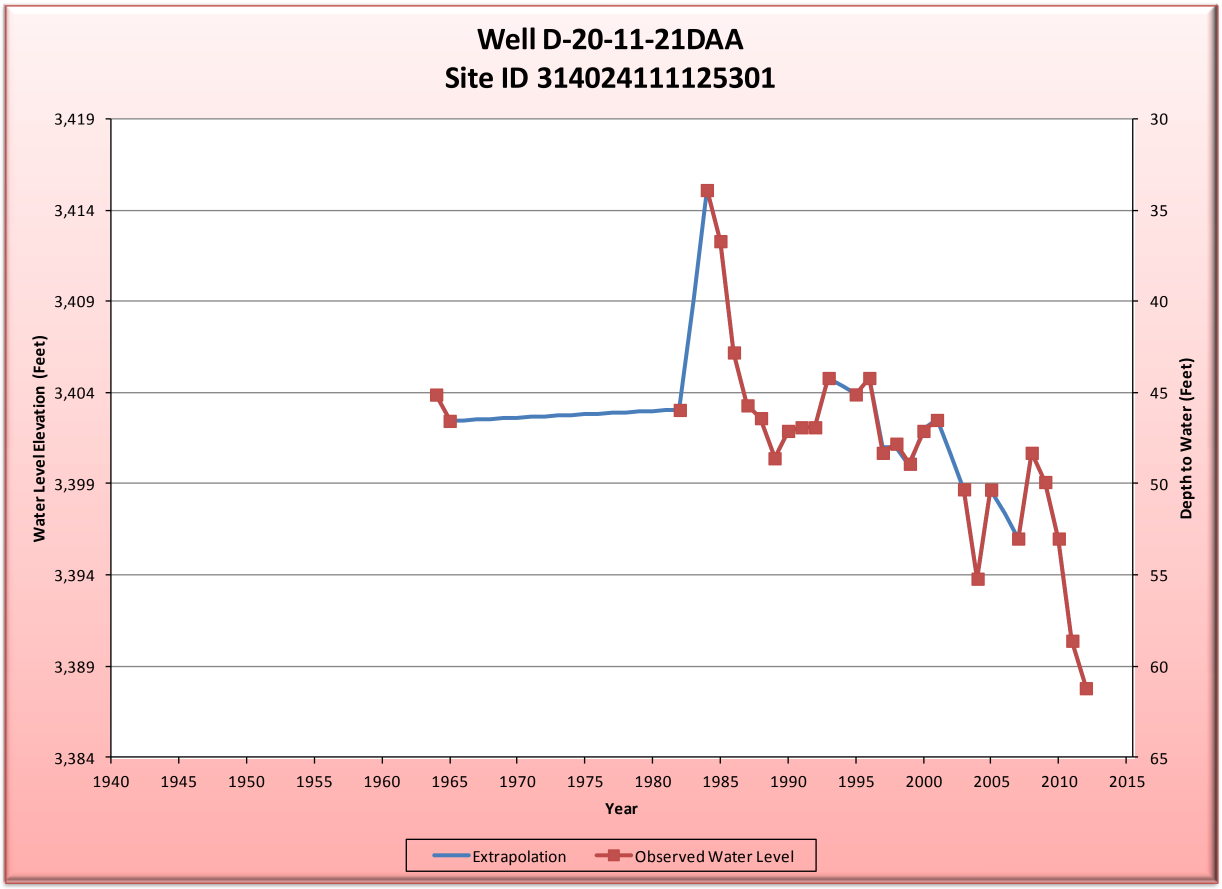


The Outside Area also shows surplus condition. There is no year in the historical period where there is a deficit. However, demand in this area is currently limited. The supply data in this Assessment assumes that the primary source of supply for this area is mountain front recharge. As such, excess supply in this area would move to the other areas in the AMA more slowly than tributary recharge, and would not be as immediate as flood recharge.

Review of historic water balances, subtracting water demands from supplies in the sub-geographies of the SCAMA for this Assessment identifies some areas with almost continuous or continuous surplus, and other areas with varying degrees of magnitude of vacillation between surplus and deficit conditions. When compared to the AMA as a whole, this demonstrates that localized supply and demand conditions may not track those of the entire AMA. It also reflects how the Downstream Area, where the majority of the demand and supply are located, strongly influences the total AMA balance.

Conditions in the remainder of the AMA Outside the Downstream, Microbasin and Potrero Areas can vary significantly depending on local hydrologic conditions. The hydrograph shown below is for a well near Sopori Wash, in the northern portion of the SCAMA.

Figure 4-12 Outside Area Well Hydrograph – Sopori Wash



PART III PROJECTED DEMANDS AND POTENTIAL FUTURE WATER BALANCE

5. INTRODUCTION TO THE PROJECTIONS

5.1 Purpose and Approach for Projecting Demands

ADWR is working towards finalizing the hydrologic models for the Downstream and Microbasin areas of the AMA so that they can be used for predictive modeling. Scenarios under consideration include: buildout of platted lots in municipal service areas within each area; continuation versus reduction in agricultural pumping; and evaluating whether a reduction in agricultural pumping could result in an increase in riparian demand. For this Assessment, the models are not yet ready to be used in this fashion. Demands have been projected based on historical trends from 1985 through 2006. Although more recent pumpage data is available, ADWR has not yet updated the historical trend analysis to include 2007 through 2009. Information on proposed future development was also used to develop projections. Projected demands have been broken out for each sub-geographic area based on the location of historical pumpage, entity by entity, as further described below.

5.1.1 Water Demand Projection Techniques

In order to determine if the SCAMA will be able to reach and maintain safe-yield, future demand, supply utilization and overdraft must be projected. ADWR recognizes for this Assessment that as planners and decision makers, it needs to move away from expectations of a single perfect or near-perfect forecast (Arizona State University, 2009). Instead, ADWR, in consultation with outside entities, has developed six different scenarios, each with slightly different assumptions. This Assessment contains three baseline scenarios, and three additional shortage scenarios incorporating possible climate change impacts.

Staff developed a plausible range of demand and overdraft scenarios up to and including the year 2025, recognizing that it is impossible to accurately predict what future demand will be. Each of the baseline scenarios uses a statistically generated series of annual streamflows ADWR projected using historical data to mimic the conditions typically observed in the Santa Cruz River.

For demand, Baseline Scenario One incorporates the lowest reasonable water demand for each of the three cultural demand sectors; Municipal, Industrial and Agricultural. Baseline Scenario Three incorporates the highest reasonable water demand projection, while Baseline Scenario Two is a mid-level projection.

For the purposes of this Assessment, none of the baseline scenarios incorporate changes in streamflow as a response to climate change.

Debate continues over climate change. Several climate change models exist for the southwestern region of the United States, but at this time, these models are not localized enough to be useful for the purposes of this Assessment. However, ADWR could not ignore the potential water supply impacts from climate change, so an effort was made to incorporate a period of reduced streamflow based on a similar historical occurrence in the three climate change scenarios. Assumptions behind these additional scenarios, and the potential impact on groundwater overdraft, are described in *Section 8*.

For the purposes of this Assessment, staff used three methods to project demands: the per capita or per unit water use approach, the time-series approach, and the regression analysis approach. For Municipal demand estimates, a Gallons Per Capita Per Day (GPCD) rate was multiplied by the population projection. The time-series approach was employed to statistically analyze the historical water use trend line to inform future demand trend extrapolations. The Industrial and Agricultural projected demands were derived from application of this technique. Finally, the regression analysis approach utilized the Coefficient of Determination to analyze water use related to influencing factors such as demographic changes, climate changes, and socio-economic changes. This allowed staff to estimate parameters that measure the historical relationship between water use and different factors, assuming that those parameters will continue to influence water use into the future.

5.1.2 Demand Range

Total projected 2025 demand for the AMA as a whole ranges from 21,847 acre-feet in Scenario One to 30,959 acre-feet for Scenario Three (See *Table 5-1* and *Figure 5-1*). Generally, the difference in Municipal demand between the three baseline scenarios is due to a combination of assumptions regarding future population growth and the corresponding water use. The difference in Agricultural demand in the three baseline scenarios involves varying assumptions regarding whether agricultural land will be taken out of production for new residential development. The assumptions and methodology used for water demand projections are detailed in the sections below.

MUNICIPAL

Large providers, small providers, and private, domestic well owners make up the Municipal sector in the SCAMA. The methodology used to project each Municipal sub-sector differed as described in the section below.

Municipal Population Projection Methodology and Assumptions

Projecting Municipal demand typically begins with population. Some Industrial subsector demand is also directly related to population. This is discussed further in the Industrial projection section. Various methods of projecting population incorporating multiple steps were used for this Assessment. Some of the scenarios used all the steps, and others did not. Methods and information utilized includes:

- *Population projections prepared by other agencies* were used to develop a total SCAMA population projection. In Pima County, the regional Association of Government's projections were used. For the Santa Cruz County portion of the AMA, ADWR used the Arizona Department of Economic Security (ADES - now under the Arizona Department of Commerce) projections.
- A *calculated total AMA population* was developed using different methods for large providers, small providers, and exempt wells:

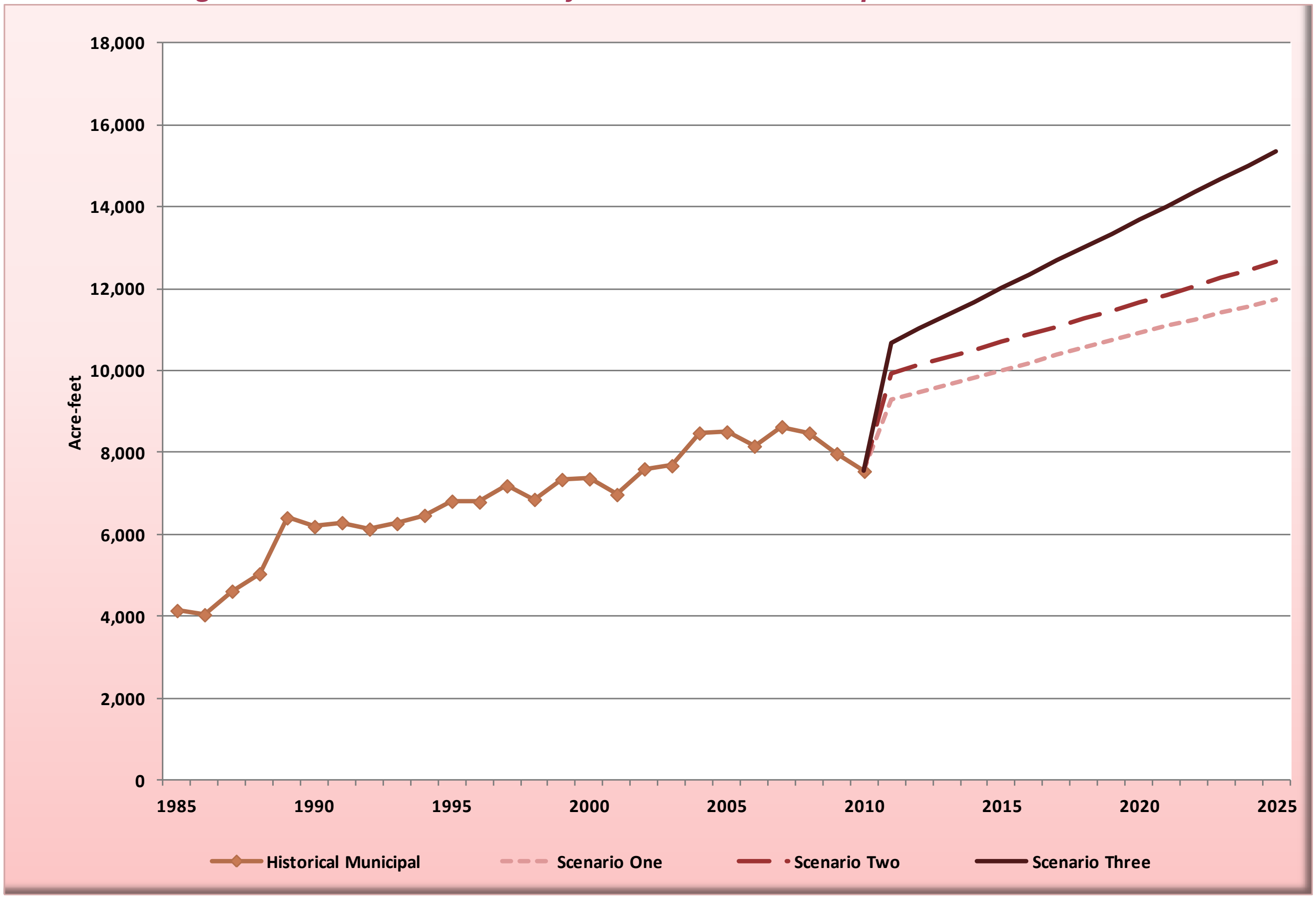
  - *Simple statistics* were used to project population for each individual large municipal provider that does not hold a DAWS ("Undesignated" providers). These include Rio Rico, Arizona-American – Tubac System and Valle Verde Water Company. For the designated large provider, the City of Nogales, the projected population and demand that serves as the basis for the Nogales' DAWS was used. Trend lines with the highest statistical correlation were selected for each undesignated provider. The trend lines used data from 1985 through 2006. In some cases, water providers submitted population projections to ADWR that extended for some years beyond 2006 but did not extend out to 2025. ADWR used the providers' projections for as many years as were given, and extended the projections to 2025 with statistical trend lines.

  - The small provider and exempt well sub-sector populations were projected using an *average percent growth rate, or average number of people added per year growth rate*. The period used to generate the growth rate varied by scenario, but was either from 1985 to 2006 or from 2000 to 2006.

  - Using these methods, the projections for large providers, small providers, and exempt wells were summed to develop a *calculated total AMA population*.

The methods were compared and categorized from lowest to highest. *Appendices 3 through 5* describe the individual Municipal assumptions for the SCAMA in more detail. Although for this *Assessment* data from 1985 through 2006 served as the basis for the projections, the figures depicting projected demand include actual data for 2007 through 2010 in the historical period.

Figure 5-1 Historical and Projected Annual Municipal Demand SCAMA



Municipal Projected Demand Range

Projected municipal demand ranges from about 12,000 acre-feet to approximately 15,500 acre-feet in the year 2025.

The recent reduction in residential construction due to economic conditions not reflected in any of the three baseline scenarios. As such, these Municipal sector demand projections may be upwardly biased. Nonetheless, the Municipal sector still represents significant potential demand in the SCAMA. The three baseline scenarios are close together in terms of overall demand; Baseline Scenario Three, the highest demand scenario, is only 30 percent greater than Baseline Scenario One, the lowest demand scenario. Therefore, the anticipated range in potential future Municipal demand is relatively small, but this sector is projected to grow over time. Municipal demand in the SCAMA is the largest use sector in all three scenarios. *Table 6-1,* below, shows the total AMA municipal projections in 2025 by sub-sector and sub-geography for all three projection scenarios.

Table 5-1 Projected Municipal Demand in 2025 by Sub-Geography by Scenario (acre-feet/year)

Scenario		AMA	Downstream	Microbasin	Potrero	Outside
One	Municipal					
	Large	10,765	6,047	2,279	2,440	0
	Small	726	483	55	166	22
	Exempt	220	81	15	20	105
Two	Municipal					
	Large	11,611	6,142	2,279	3,190	0
	Small	813	541	61	186	25
	Exempt	238	87	16	22	113
Three	Municipal					
	Large	13,572	7,180	2,279	4,114	0
	Small	1,317	876	99	301	40
	Exempt	278	102	18	26	132

INDUSTRIAL

As discussed in *Section 3.1.2*, the Industrial sector is made up of a number of different subsectors. When completing the Industrial projections, ADWR developed three baseline scenario projections for each Industrial subsector in the AMA. This method allowed for individual subsector analysis resulting in a broad range of potential Industrial demands in the AMA. The SCAMA Industrial subsectors are turf, sand and gravel, and a generic catch-all category "Other Industrial". Subsector demand scenarios were added together to derive the AMA's range of the total Industrial demand projections.

Industrial Projection Methodology and Assumptions

The SCAMA Industrial demand projection scenarios were developed using a combination of methods:

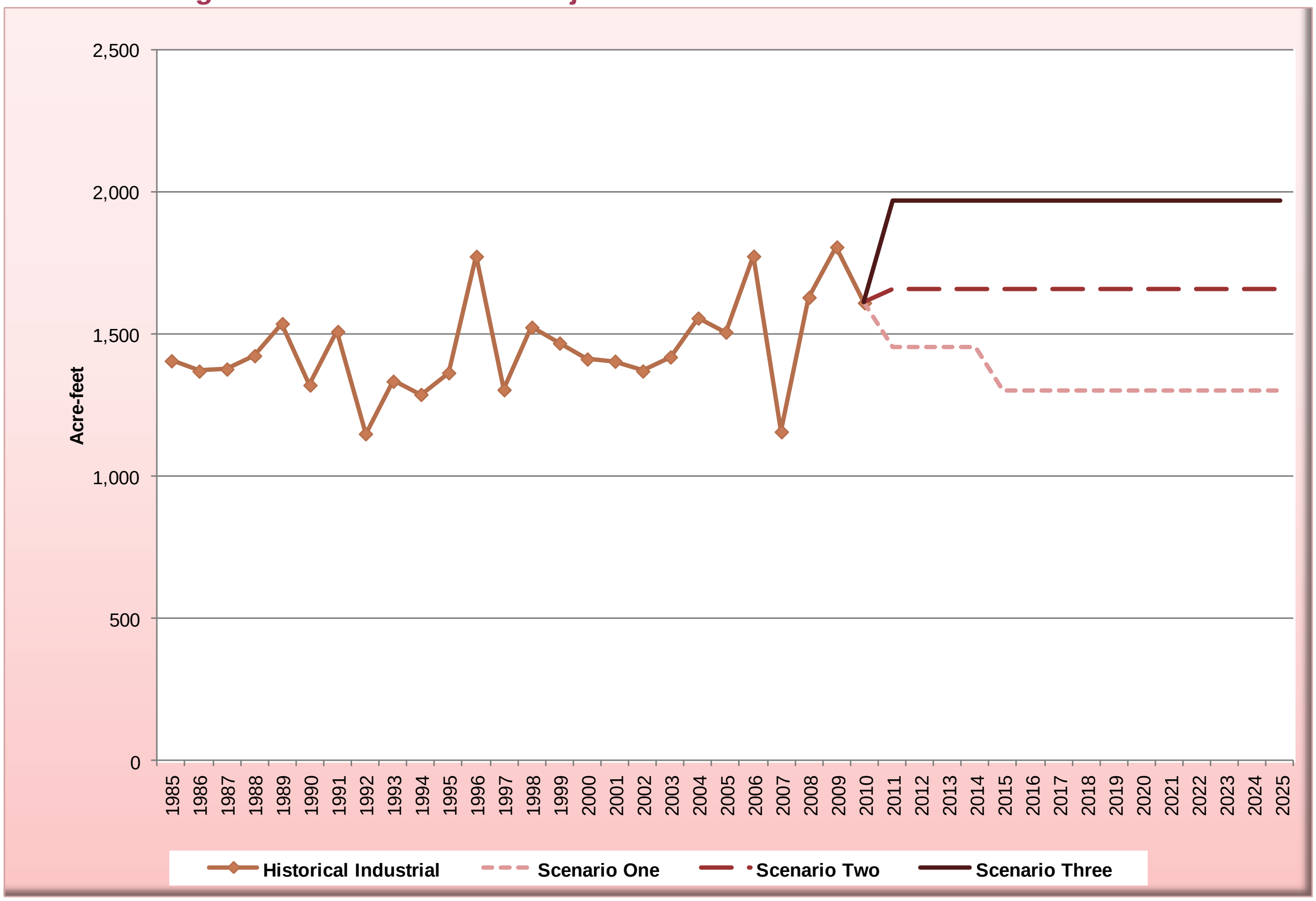
- *Trend line* analysis was generally used to predict future water use if an Industrial subsector's historic water use had a strong relationship ($R^2 > 0.6$) to time. Future water use was projected by assuming the past trend would continue into the future. Trend line analysis was also used to study the rate of growth or decline in the number of facilities within a subsector over time. This analysis was especially helpful in detecting when established water use trends start to change.
- Generally, if a subsector's demands did not exhibit a strong relationship to time, then one of the following methods were used: the scenario was developed by AMA staff or sector professional based on professional judgment; or the *average historical use* or *current use* was *held constant through time*. Subsectors, such as metal mines, whose drivers are based on commodity prices and global economic factors generally fit into this category. See *Appendix 6* for more details on the specific methodology used in projecting each Industrial subsector.

As mentioned previously, it is important to remember that ADWR defines an Industrial user as an entity that uses water for a non-agricultural purpose and does not receive water from a municipal source. Generally, Industrial users have their own wells and associated water rights or withdrawal permits. The Industrial sector predominately uses water withdrawn from wells to meet its demand. See *Appendix 6* for a more detailed description of individual subsector assumptions.

Industrial Projected Demand Range

In the Industrial sector, projected demand ranges from about 1,300 acre-feet to nearly 2,000 acre-feet in 2025 *(See Figure 5-2).* Although analysis of historical data included the years from 1985 through 2006, the chart of projected Industrial demand includes the years 2007 through 2010 in the Historical category.

Figure 5-2 **Historical and Projected SCAMA Annual Industrial Demand**



Although population growth typically tends to drive Industrial use, and population has steadily increased in the SCAMA over the last two decades, Industrial use, as defined by the Department, has not shown a corresponding increase like it has in other AMAs.

Despite the presence of only two Industrial golf courses, Industrial turf is the largest Industrial subsector in the SCAMA and has remained fairly constant over the last twenty years. Yearly fluctuations in use appear in part due to annual fluctuations in climate conditions, application rates of the existing facilities, and reporting anomalies. In 1985, there were two Industrial turf facilities in the SCAMA: Rio Rico and Tubac Ranch Properties, both golf courses. In 2006, these two golf courses are still the only Industrial turf facilities in the AMA. There are several schools that receive water from their own wells and associated groundwater rights. However, these facilities have less than ten acres of turf and are not regulated as turf-related facilities. Assessment projections assume that any new turf-related facilities will be served by a municipal provider and will not fall under the Industrial category. Consequently, future AMA projections show relatively constant future demand with the possibility of only a slight increase or decrease in historical water use. Current economic conditions in the golf industry make it unlikely that any new courses will be built in the SCAMA in the foreseeable future as evidenced by the closure of the municipally-served Palo Duro Golf Course.

Table 5-2 shows the projected Industrial demand by sub-sector and sub-geography in 2025.

Table 5-2 Projected Industrial Demand in 2025 by Sub-Geography and Scenario (acre-feet/year)

Scenario		Entire AMA	Downstream	Microbasin	Potrero	Outside
One	Industrial	1,300	1,193	17	53	37
	Turf	1,100	1,100	0	0	0
	Sand & Gravel	0	0	0	0	0
	Other	200	93	17	53	37
Two	Industrial	1,657	1,393	17	210	37
	Turf	1,300	1,300	0	0	0
	Sand & Gravel	157	0	0	157	0
	Other	200	93	17	53	37
Three	Industrial	1,972	1,523	17	395	37
	Turf	1,430	1,430	0	0	0
	Sand & Gravel	342	0	0	342	0
	Other	200	93	17	53	37

AGRICULTURAL

Total agricultural demand is the sum of the reported water use of the Irrigation Grandfathered Groundwater Rights (IGFRs) in the AMA. These demands were categorized as non-exempt IGFR and exempt IGFR demands. In the SCAMA, exempt users are a negligible portion of total AMA demand, and have not been considered in this Assessment (*See Section 3.1.3*).

Three baseline demand scenarios were developed for the non-exempt IGFRs in the SCAMA.

Table 5-3 shows the current (2009) and projected agricultural demand by sub-geography in 2025.

Table 5-3 Current and Projected Agricultural Demand in 2025 by Sub-Geography (acre-feet/year)

Scenario	Entire AMA	Downstream	Microbasin	Potrero	Outside
Current Demand	15,130	13,719	413	40	958
One	8,826	7,755	367	129	575
Two	11,233	9,758	455	160	861
Three	13,640	11,760	542	191	1,147

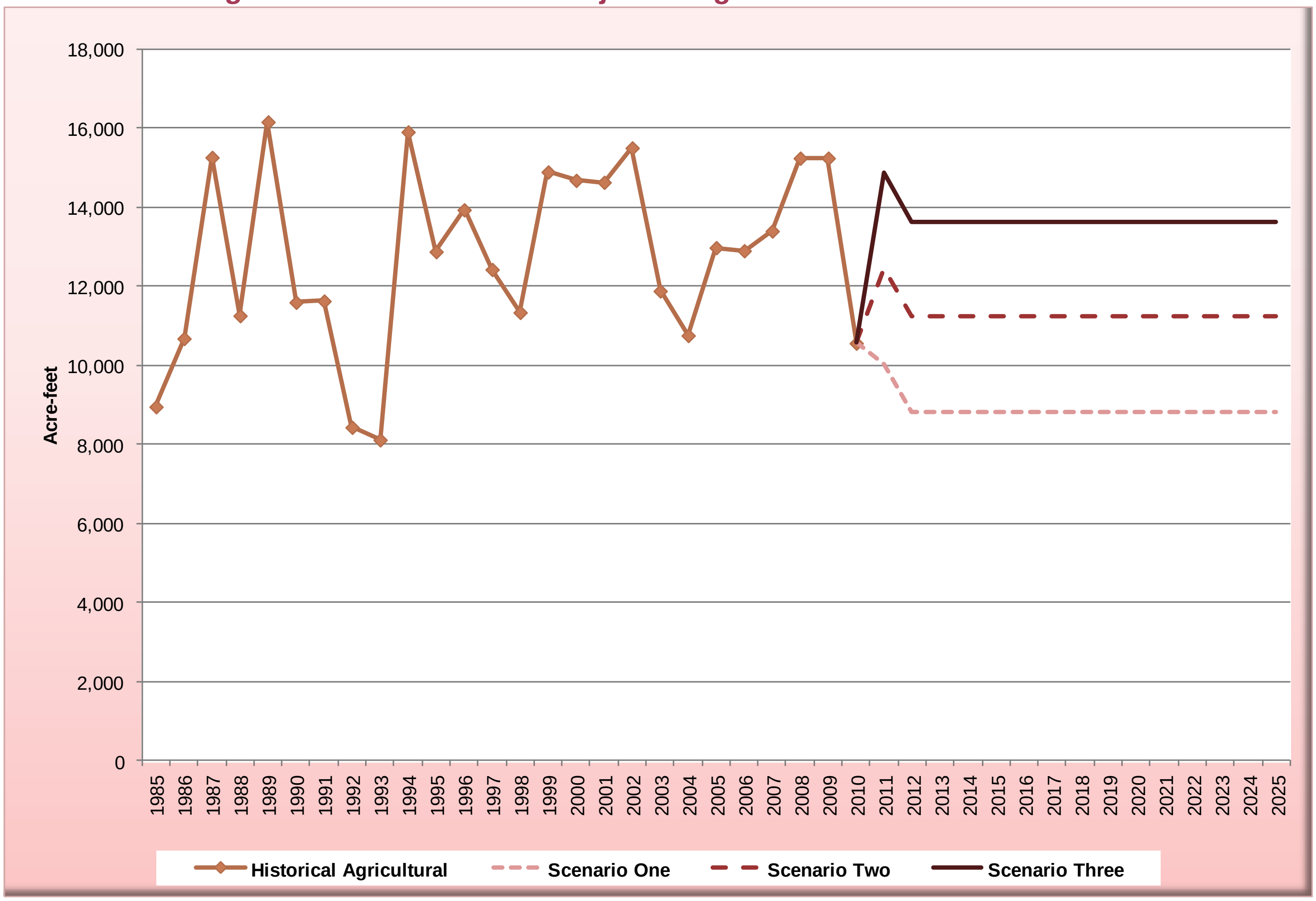
Agricultural Projection Methodology and Assumptions

Generally, future agricultural demand in the AMA was difficult to project due to the highly variable historical use and the unique nature of surface and groundwater supplies in SCAMA. For that reason, projections were based on average historical water use (+/- one standard deviation for alternative scenarios), with additional reductions based on AMA staff knowledge regarding planned residential and commercial development on land with appurtenant individual IGFRs.

Agricultural Projected Demand Range

The projected Agricultural demand ranges from 8,800 to 13,600 acre-feet in 2025 *(See Figure 5-3).*

Figure 5-3 **Historical and Projected Agricultural Demands SCAMA**



5.1.3 Supply Variability

A large portion of the water supply in the SCAMA is derived from streambed recharge along the Santa Cruz River. However, streamflow which feeds streambed recharge is highly variable and difficult to project. In Table 8-1, stream bed recharge is estimated using a statistical analysis of the historic Santa Cruz flow records to develop a statistically generated variable streambed recharge data set under typical (not affected by climate change) conditions. In addition to the natural stream bed recharge, the River is enjoys the benefit of approximately 14,000 acre-feet per year of reclaimed water discharge,. It is estimated that approximately 7,000 acre-feet per year of this supply is recharged into aquifers downstream of the point of discharge and the balance leaves the SCAMA, flowing into the TAMA.

The future of this reclaimed water is uncertain as most of the volume is derived from sewer flows from Nogales, Sonora in Mexico and, by International Treaty, Mexico has the right to retain the Nogales, Sonora portion of the reclaimed water. While recent indications are that a portion of this supply is going to be diverted for treatment at the new Los Alisos Wastewater Treatment Plant, the assumption is made in these projections that the reclaimed water discharge will continue as it is today. Note that the projected streambed recharge is a combination of both natural flow and reclaimed water discharge and that the natural components of streambed recharge were not projected separately and then added to the assumption of reclaimed water discharge that infiltrates into the aquifer. See *Appendix 1* for more detail on the assumptions used in projecting the supply.

5.1.4 User Interviews

During the development of the scenarios, staff conducted user interviews of academic, government and private sector experts. Staff also reviewed public documents such as intergovernmental agreements. These interviews and reviews were done in order to gain more insight regarding population growth, the potential for new water users (such as mines, power plants and golf courses), the potential for changes in current water use projections and supply sources are used, the addition of new sources, and changes in urbanization.

6. PROJECTED DEMANDS AND WATER BALANCE

ADWR has prepared comparisons of projected supplies and demands for the SCAMA through 2025. *Table 6-1* shows the pattern of projected surpluses and deficits on an AMA-wide scale for Scenarios One, Two, and Three using three different assumptions for demand. Each water demand sector was projected using the assumptions described in Section 5.1.2., above. Supply was projected using statistical analysis for stream channel recharge based on continuation of the historical pattern described in Appendix 1. Projected ET and groundwater inflow and outflow vary based on the volume of projected stream channel recharge. See *Appendix 1* for a discussion of how the natural components were projected and then disaggregated into each sub-geographic area. *Appendices 3 – 7* outline the assumptions made to project Municipal, Industrial and Agricultural water demand for the three scenarios.

The columns under “Net Balance” show the surplus or deficit for each scenario. If the number is negative it means the projection assumptions result in a deficit, where the demand exceeds the supply (net natural and incidental recharge). In these years, the water demands in excess of the supply are being met by depleting the aquifer storage. A positive number in the “Net Balance” columns indicates a surplus, where the net natural and incidental recharge are greater than the demand. In these years, aquifer storage is being replenished.

Scenario One has the lowest volume of overdraft of the three scenarios, because it has the lowest water demand. Also due to the lower demand in Scenario One, there is a greater volume of surplus than in the higher demand scenarios, because less of the potential replenishing supply is being consumed. Scenario Three has the greatest volume of overdraft because it has the highest water demand of the three scenarios. Similarly, when there is a surplus, there is less of a surplus in Scenario Three than in the other scenarios, because more water is being withdrawn leaving less of the surplus available to replenish the aquifer. During years of surplus stream channel flow and groundwater outflow into the TAMA are projected to be greater than in deficit years.

Table 6-1 Projected AMA Demand/Supply and Surplus/Deficit 2010-2025 (acre-feet/year)

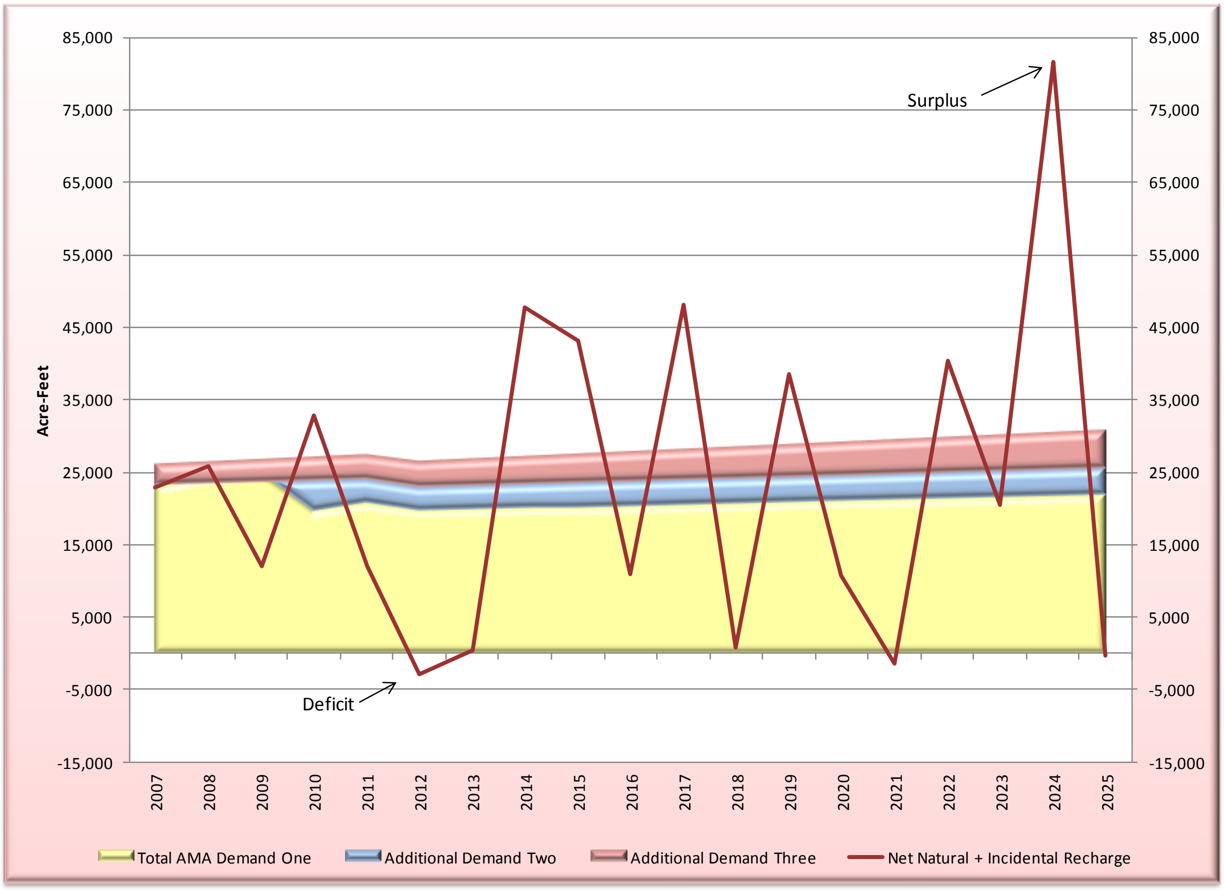
Year	Supply	Demand			Net Balance		
		Scenario One	Scenario Two	Scenario Three	Scenario One	Scenario Two	Scenario Three
2007	22,933	20,709	23,312	26,162	2,224	-355	-3,138
2008	25,878	20,672	23,495	26,488	5,206	2,407	-519
2009	11,993	20,636	23,678	26,814	-8,643	-11,661	-14,730
2010	32,878	20,599	23,862	27,139	12,279	9,040	5,830
2011	11,993	20,780	24,047	27,464	-8,787	-12,030	-15,380
2012	-2,921	19,741	23,013	26,568	-22,662	-25,910	-29,398
2013	462	19,922	23,201	26,893	-19,460	-22,715	-26,340
2014	47,684	20,103	23,389	27,217	27,580	24,318	20,558
2015	43,077	20,128	23,579	27,541	22,949	19,541	15,646
2016	10,846	20,309	23,770	27,864	-9,464	-12,881	-16,909
2017	48,093	20,491	23,962	28,188	27,602	24,174	20,015
2018	809	20,673	24,156	28,512	-19,864	-23,304	-27,593
2019	38,494	20,855	24,351	28,835	17,639	14,186	9,769
2020	10,647	21,037	24,547	29,159	-10,390	-13,858	-18,402
2021	-1,416	21,197	24,745	29,483	-22,613	-26,119	-30,789
2022	40,366	21,357	24,945	29,807	19,009	15,464	10,669
2023	20,435	21,517	25,146	30,131	-1,082	-4,668	-9,586
2024	81,565	21,677	25,348	30,455	59,888	56,260	51,220
2025	-387	21,838	25,552	30,780	-22,225	-25,896	-31,057

6.1 Projected Summary Water Balance

Comparing Surplus and Deficit for the SCAMA as a whole to each of the four sub-geographic areas within the AMA demonstrates that local conditions can vary significantly in their pattern of projected surpluses and deficits from the pattern for the SCAMA as a whole. Some local areas may experience greater shortages, and sustained depletions from aquifer storage, due to their greater dependency on stream flow.

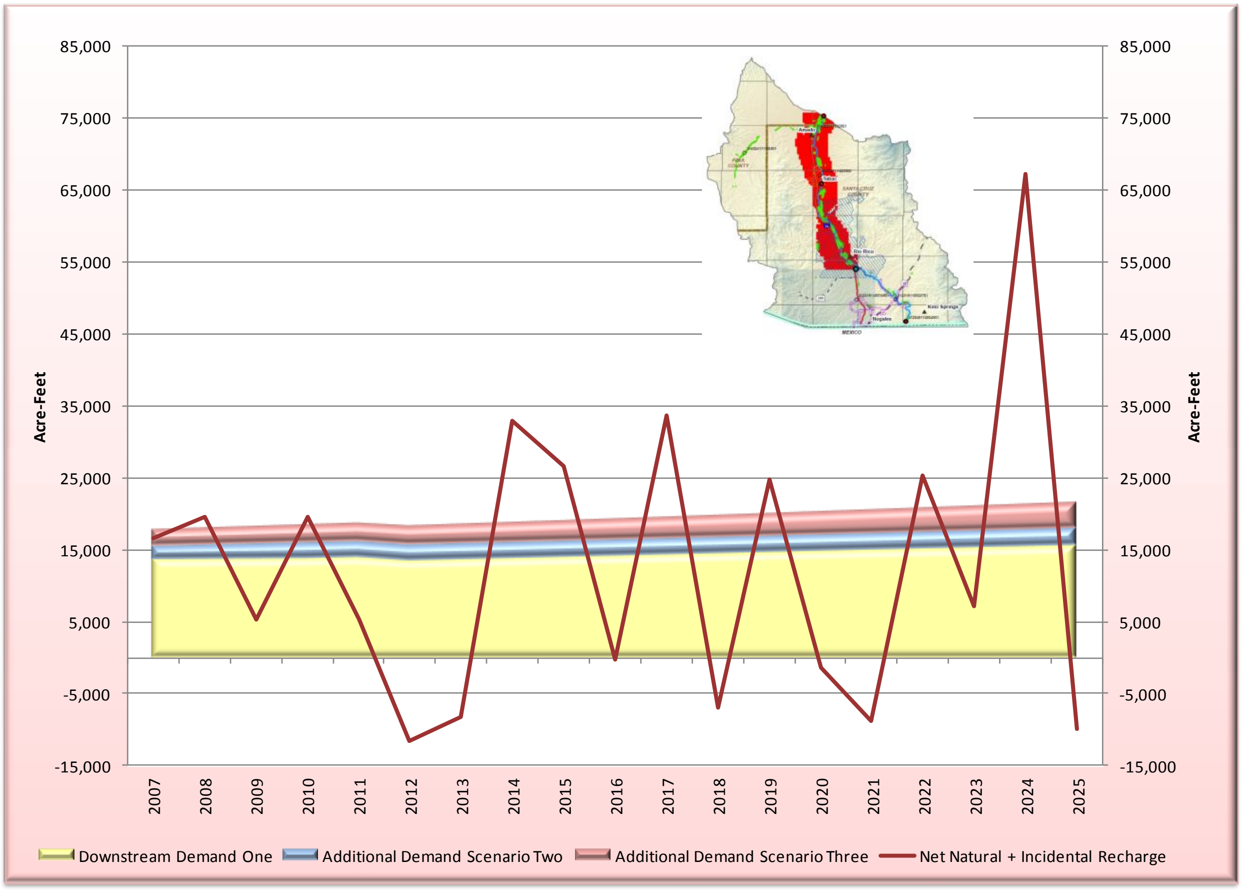
Figure 6-1 below shows the projected AMA wide water balance for Scenario One. The yellow shaded area on the graph is the total projected demand for Scenario One. Additional demand above the volume projected in Scenario One is depicted on the blue and red shaded areas on the chart. These areas correspond to the additional demand above Scenario One, projected in Scenario Two and Scenario Three. The statistically generated net natural recharge plus incidental recharge is shown as a red line in the chart. Incidental recharge, that component of recharge that results from irrigation and landscape watering that infiltrates back into the aquifer, is actually greater in Scenarios Two and Three due to increased demand in the Agricultural and Industrial sectors. However, because it is only about 100 acre-feet more than incidental recharge in Scenario One, it does not add a significant supply and cannot be distinguished when graphed at this scale. With these AMA-wide level assumptions, there are few years where the AMA is projected to be in a negative supply situation (overdrafting) – (See the years 2012 and 2021 in the chart below). The same water supply is used in all three scenarios, however, with increased demands in Scenario Two and Scenario Three, there is less surplus supply in surplus years and greater deficit in the deficit years.

Figure 6-1 Projected Water Balance - AMA Wide



The projected water balances for each sub-geographic area with the demand for the three Scenarios and projected water supply within the sub-geographic area are shown in the charts below. All water balance charts have been prepared using the same scale to provide a consistent visual impression of their relative magnitude to the full AMA balance. Similar to the AMA-wide figure, the simulated supply shown includes projected incidental recharge from Scenario One, as the increase in incidental recharge in Scenarios Two and Three in each geographic sub-area is not apparent at the scale of these figures and is less than 100 acre-feet per year.

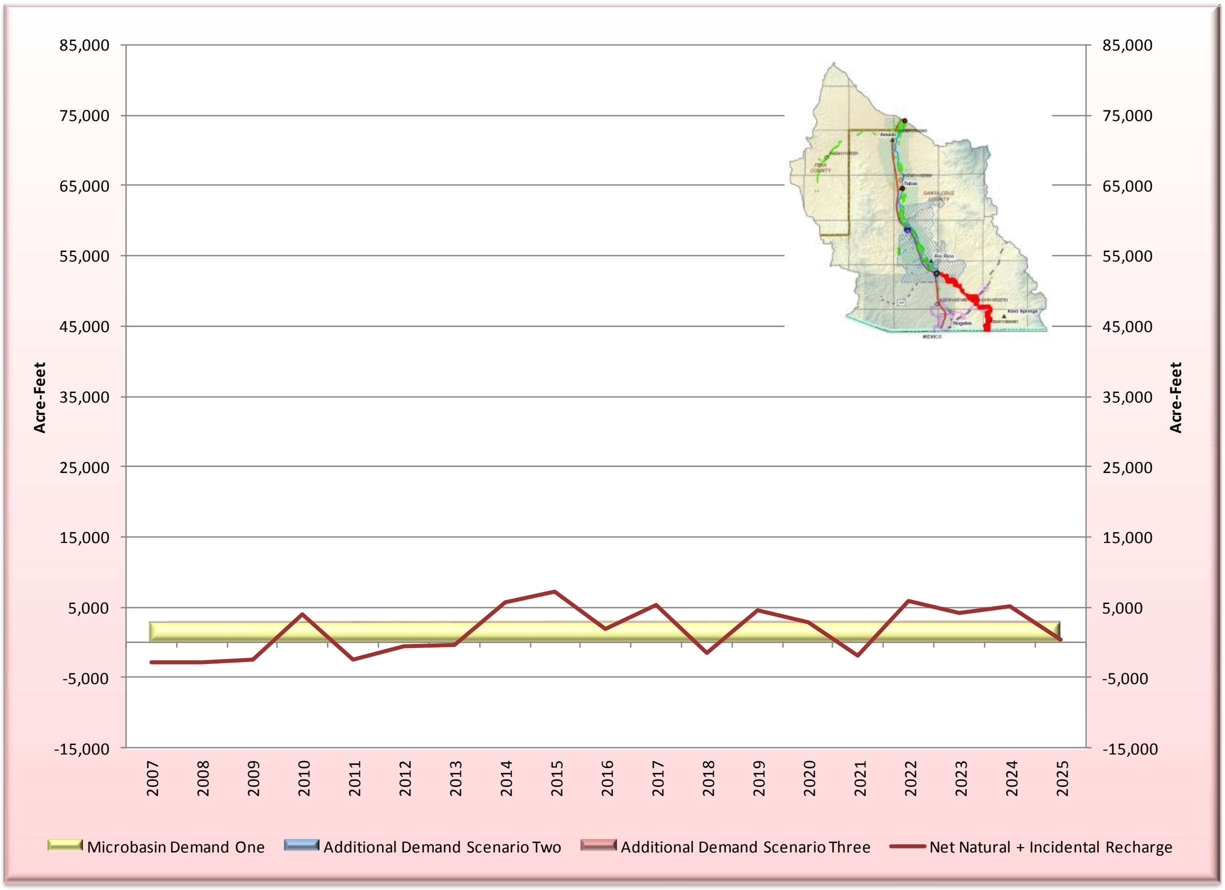
Figure 6-2 Projected Water Balance - Downstream Area



The projected sum of Net Natural and Incidental Recharge Line in the Downstream Area, shown in *Figure 6-2* is very similar in shape to the line for projected Net Natural and Incidental Recharge for the entire SCAMA. This is because most of the AMA projected demand occurs, and projected supplies are located in the Downstream Area. However the magnitude of the surpluses is less and volume of deficits greater in the Downstream AMA compared to the entire AMA as a whole. This is because there are supplies in other sub-geographic areas within the AMA that are not available to the Downstream Area directly, and in those other areas, demand is frequently less than supply (surplus conditions often exist).

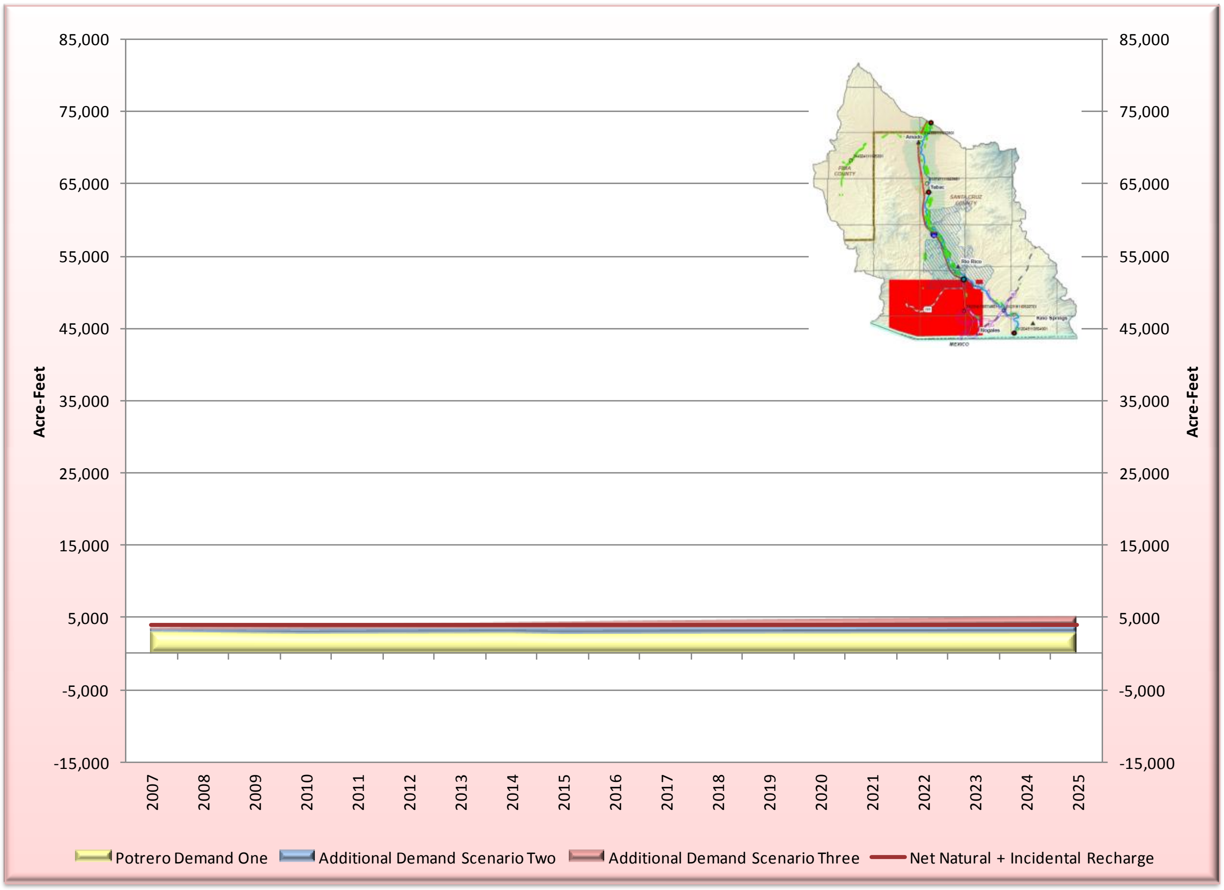
Figure 6-3 shows the projected water balance for the Microbasin Area. The projected supply line (Net Natural and Incidental Recharge) still varies in the Microbasin Area, but not nearly to the degree as it does in the Downstream Area. Also, in many years in the Microbasin Area projected demand is less than projected supply, indicating a surplus. However, the volume of surpluses, when they do occur, is not nearly as great as in the Downstream Area. These surpluses either refill the available storage space in the Microbasins or flow to the Downstream Area.

Figure 6-3 Projected Water Balance - Microbasin Area



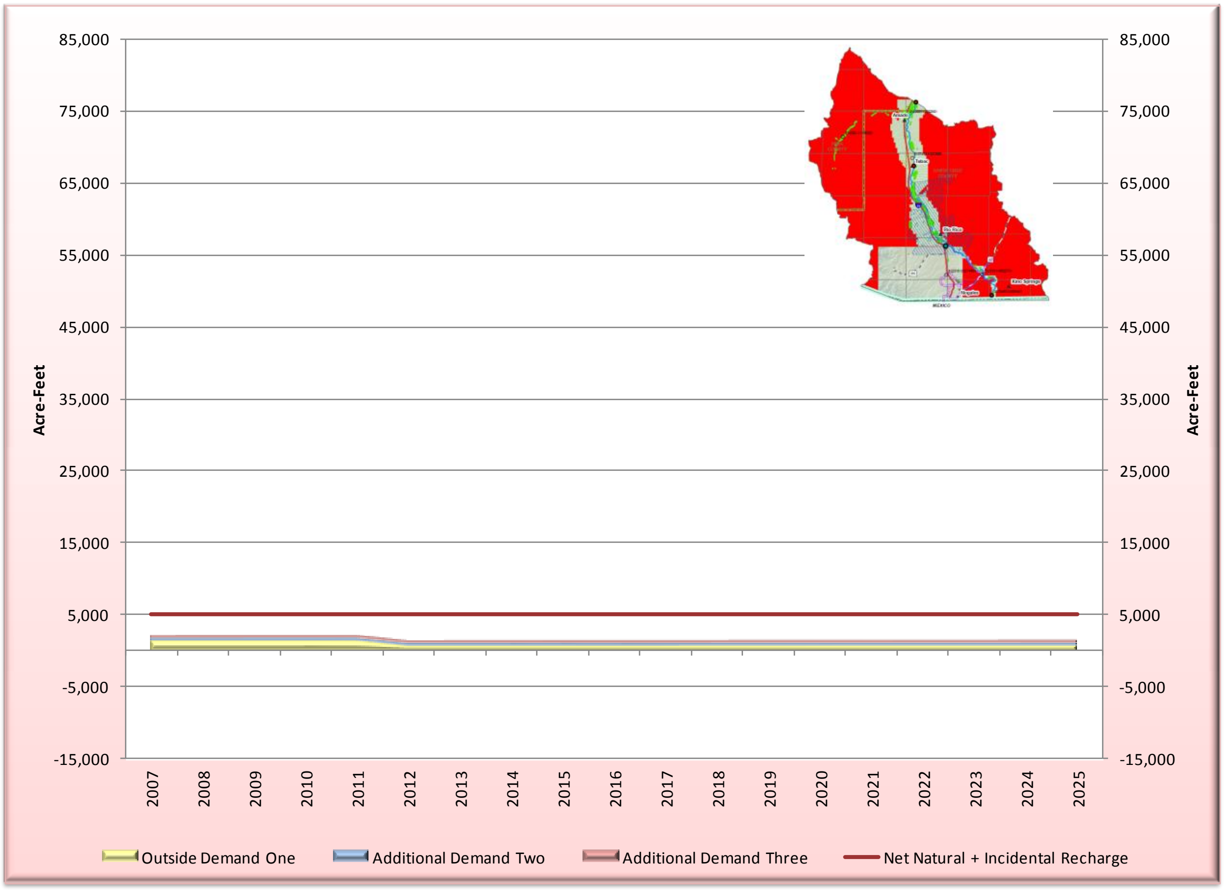
In the Potrero Area, both the projected supply and demand are fairly flat. However, as the demand increases over time it eventually exceeds the static supply assumption, and, in Scenario Three, the demand is greater than the supply after about the year 2017. See *Figure 6-4*.

Figure 6-4 Projected Water Balance - Potrero Area



In the remainder of the AMA, the Outside Area, like the Potrero Area ADWR has assumed a constant supply based on an assumption of a constant annual value for mountain front recharge. But unlike the Potrero Area the projected demand under any of the three scenarios is not anticipated to exceed the supply (See *Figure 6-5*). However, localized demands (served by individual or groups of wells) may exceed available groundwater supplies. Declining aquifer water levels provided evidence of such conditions. Excess supplies from the Outside Area are assumed to flow in response to groundwater gradients and contribute to the supplies of the other SCAMA sub-areas and the TAMA.

Figure 6-5 Projected Water Balance - Outside Area



7. FUTURE RECHARGE POTENTIAL

No artificial recharge was projected in any of the three scenarios. However, it is possible that a recharge project could be permitted and constructed in the SCAMA prior to 2025. With limited storage capacity in the near-stream alluvium, where the majority of water withdrawals occur, artificial recharge could assist the AMA in establishing a buffer against periods of limited flow in the Santa Cruz River. Suitable locations for artificial recharge would be areas with the potential to maintain adequately high infiltration rates. Should recharge basins be developed, special attention to managing such sites would be needed, to avoid clogging the soil surface which would minimize recharge of increased river flows, and where water stored would not flow out of the AMA and be available for future use. Injection wells offer another possible method of recharge. This recharge method is typically far more costly and must also be carefully managed as injection wells tend to clog. Treatment of supplies to a higher quality for injection well recharge vs. recharge basins is likely. Recharging water in areas that are most stressed during periods of low flow and drought would assist the AMA in meeting the local portion of its water management goal. However, an additional source of supply that could be stored would need to be identified and secured. Additionally, recharging in these areas may interfere with the natural replenishment inherent in the existing system by filling saturated sediments that would otherwise be available to accept stormwater infiltration.

8. ADDITIONAL SCENARIOS

8.1 Scenario Descriptions

8.1.1 Drought

Climatic variability is endemic in the region. The climatic and water supply record in the SCAMA clearly exhibits this variability, with periods of both above and below average precipitation and streamflow. Existing users in the AMA have adapted to this variability, either shifting pumping away from inner valleys of the Santa Cruz River when well yields decline, or curtailing uses. While this situation has been manageable for water providers in the region, recent water level declines have been observed in wells in the Potrero Area, where much of the City of Nogales' pumping has shifted in response to limited production from their Microbasin Area wells. Such conditions may be further exasperated by either deepening drought or increases in demand in the SCAMA.

In response to potential climate change impacts, this Assessment includes three additional scenarios incorporating projected reductions in surface water supplies, resulting in supply shortages. The consensus opinion of an international panel of climate science experts, the International Panel on Climate Change (IPCC), is that the southwestern United States is likely to experience significant impacts from global-scale warming, particularly in the water resources sector (Intergovernmental Panel on Climate Change, 2007). IPCC predicts with high confidence that average temperatures will continue to increase. There is now also a strong indication of the potential for reductions in winter precipitation in northern Mexico and the southern portions of the southwestern United States. This means that even if total precipitation increases on average across the globe, drought is likely to become an even greater problem in the region than it is today, perhaps becoming the new "normal" (Seagar & Ting, 2007). The IPCC findings also conclude that the intensity of precipitation is likely to increase in future climate scenarios for the southwestern United States. Therefore, both extremes of precipitation – floods and droughts – will increasingly challenge water managers in the region. Increases in temperature, particularly in summer, will affect demand for water in Arizona. Higher temperatures lead to more demand for electricity for air conditioning; more water required to support agriculture, landscaping, and ecosystems; and more evaporative losses from reservoirs.

Runoff predictions from a strong majority of the 22 global climate models are that stream flow in the western United States will be reduced over the next century, where other parts of the country may see increased precipitation and streamflow. These predicted reductions in flow for the desert southwest are primarily a result of drying caused by higher temperatures (reduced soil moisture, increased ET and reservoir losses). As the streambed recharge of the Santa Cruz River is the primary source of supply for water users in the SCAMA, any reductions in flow will have consequences for water managers reliant on the Santa Cruz River as a source. Additionally, within Arizona, predicted losses of snowpack in high elevation areas will likely change the volume and timing of peak runoff and may impact downstream users and habitat (Jacobs, 2009).

Several climate change models exist for the southwestern region of the U.S., but at this time, they are not localized enough to be useful for the purposes of advising this Assessment. Instead, ADWR incorporated a statistically generated period of reduced surface water availability by using actual historical supply records as described below.

8.1.2 Dry Conditions Projection Methodology

Demand was not assumed to be altered for any of the shortage projection scenarios. ADWR hydrologic modeling staff generated net streamflow recharge rates along the Santa Cruz River based on examination of two different 19-year intervals, including one "average" recharge period and one relatively "dry" period,. For additional details and assumptions associated with the statistically generated streamflow and the groundwater flow models see Appendix 1. Streamflow realizations are also discussed, analyzed and presented in ADWR Model Report #21 (Nelson, 2010).

Streamflow recharge, as simulated in the efforts, operates along a head-dependant boundary. As a result, stresses and model conditions assigned to the simulated groundwater flow system may impact groundwater recharge and groundwater discharge rates spatially and temporally. For these scenarios, "basecase" and "base" model conditions/assumptions, including all initial conditions, ET parameter distributions, stream-aquifer boundary conditions, pumping rates, and lateral boundary conditions - as defined in Model Report #21 - were applied. Although evaluating "average" and "dry" conditions over a continuous 19-year period does not provide the degree of statistical rigor as compared to evaluating the collective ensemble, it nonetheless demonstrates the possible range of variability in streamflow recharge that could be expected in the hydrologic system.

Results of this effort predict mean "average" and "dry" streamflow recharge rates of 30,838 and 20,914 acre-feet/year, respectively. The standard deviation associated with "average" and "dry" streamflow recharge rates for the 19-year period are 23,150 and 16,860 acre-feet per year, respectively. The projected streamflow recharge availability and shortage volumes from the sequences selected are shown in *Table 8-1*, below.

Table 8-1 **Simulated SCR Stream Channel Recharge, "Average" and "Dry" Conditions SCAMA**

"Average" Stream Recharge, years 1-19		**"Dry" Stream Recharge, years 72-90**	
Simulation Years	Recharge along Santa Cruz River (AF/year)	Simulation Years	Recharge Along Santa Cruz River (AF/year)
1	46,498	72	19,089
2	8,318	73	9,166
3	9,745	74	16,839
4	53,006	75	8,041
5	55,775	76	26,968
6	26,048	77	7,439
7	57,549	78	95,822
8	10,889	79	14,076
9	50,742	80	12,999
10	19,250	81	24,059
11	9,888	82	10,231
12	47,095	83	23,064
13	26,775	84	16,860
14	89,313	85	8,794
15	20,513	86	17,074
16	10,211	87	18,444
17	26,917	88	20,826
18	7,535	89	15,245
19	9,825	90	32,330
Statistical Summaries			
Mean	**30,836**	**Mean**	**20,914**
Standard deviation	**23,150**	**Standard deviation**	**19,347**
Median	**26,048**	**Median**	**16,860**
Maximum	**89,313**	**Maximum**	**95,822**
Minimum	**7,535**	**Minimum**	**7,439**

8.1.3 Drought Projection Results

Table 8-1 shows the projected impact of the statistically generated drought on the AMA water balance. Although periodic flood events would still occur in the drought scenario, they would occur less often with more intervening years where demand exceeds the volume of replenishing supply. Compare the "Net Balance" columns in Table 8-2 to the "Net Balance" columns in Table 6-1. The result of a long-term drought in SCAMA is that the AMA would not be able to maintain equilibrium of long-term supply and would experience more supply shortfalls more frequently than under conditions of greater and more frequent stream flow. Implications of this would be longer periods of demand curtailment without implementation of additional water management strategies to protect against more frequent, longer and more intense droughts.

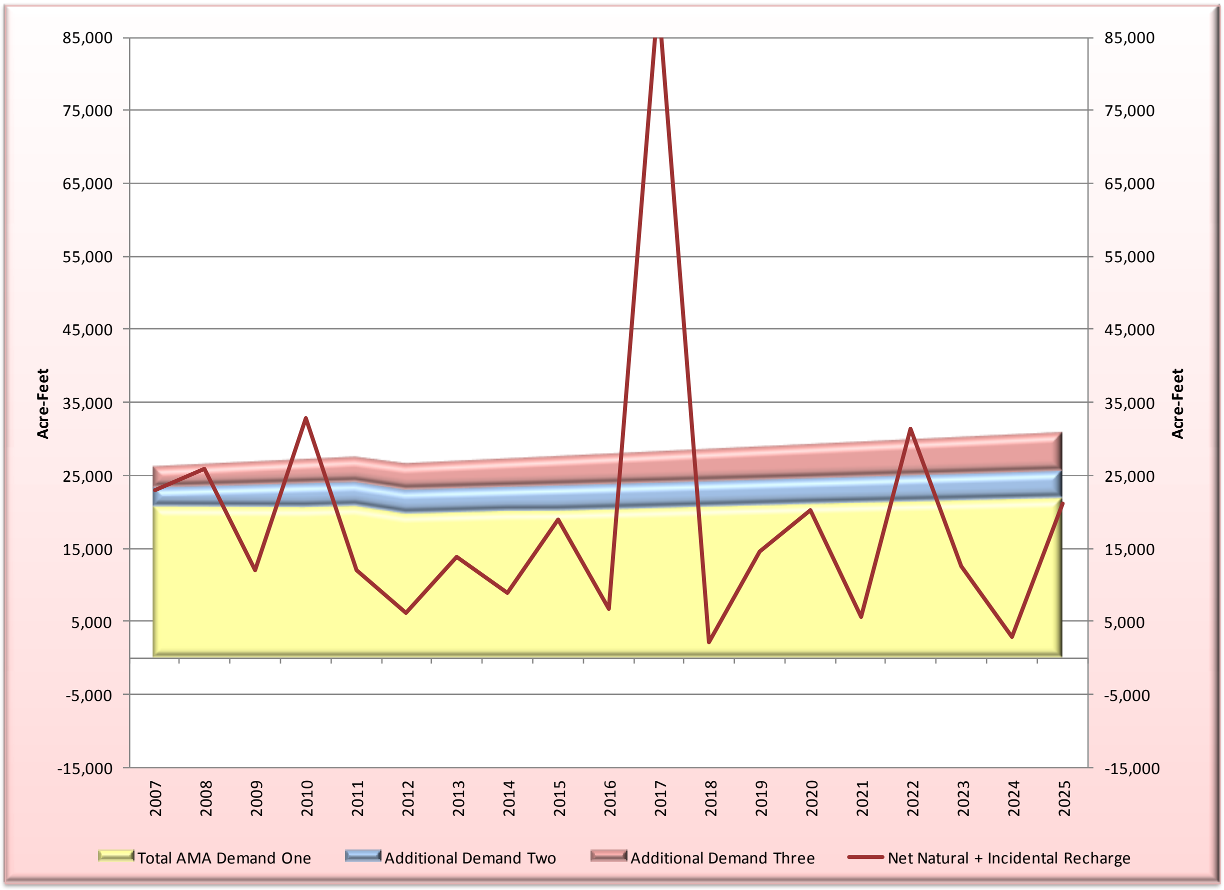
Similar to the "normal" conditions scenario analysis, the higher demand in Scenarios Two and Three above the projected demand in Scenario One results in a deeper deficit under dry conditions.

Table 8-2 Projected AMA Demand/Supply and Surplus/Deficit 2010-2025 (acre-feet/year)

		Demand			Net Balance		
Year	**Supply**	Scenario One	Scenario Two	Scenario Three	Scenario One	Scenario Two	Scenario Three
2007	22,933	20,709	23,312	26,162	2,224	-355	-3,138
2008	25,878	20,672	23,495	26,488	5,206	2,407	-519
2009	11,993	20,636	23,678	26,814	-8,643	-11,661	-14,730
2010	32,878	20,599	23,862	27,139	12,279	9,040	5,830
2011	11,993	20,780	24,047	27,464	-8,787	-12,030	-15,380
2012	6,227	19,741	23,013	26,568	-13,514	-16,763	-20,250
2013	13,755	19,922	23,201	26,893	-6,167	-9,422	-13,047
2014	8,915	20,103	23,389	27,217	-11,188	-14,450	-18,211
2015	18,919	20,128	23,579	27,541	-1,209	-4,617	-8,512
2016	6,675	20,309	23,770	27,864	-13,634	-17,052	-21,079
2017	90,465	20,491	23,962	28,188	69,974	66,546	62,387
2018	2,134	20,673	24,156	28,512	-18,539	-21,979	-26,268
2019	14,608	20,855	24,351	28,835	-6,247	-9,700	-14,117
2020	20,285	21,037	24,547	29,159	-752	-4,219	-8,764
2021	5,560	21,197	24,745	29,483	-15,637	-19,142	-23,813
2022	31,305	21,357	24,945	29,807	9,948	6,403	1,608
2023	12,631	21,517	25,146	30,131	-8,886	-12,472	-17,390
2024	2,849	21,677	25,348	30,455	-18,828	-22,456	-27,496
2025	21,061	21,838	25,552	30,780	-777	-4,448	-9,609

The water balance under Dry Conditions for the AMA as a whole is graphed in *Figure 8-1*, followed by figures showing the impact of potential Dry Conditions in each sub-geographic area. Using the same scale as the other charts in this section, the surplus in 2017 is off the scale. The statistically generated value in that year is 90,465 acre-feet.

Figure 8-1 Projected Water Balance DRY CONDITONS - AMA-Wide



This figure demonstrates how persistent dry conditions, such as a long-term drought, would result in demand for several years consecutively in excess of supply, meaning that more water would be drawn from aquifer storage, water levels would decline further, and overdraft would increase.

Comparing the figures below for each sub-geographic area to the figure for the AMA as a whole shows how local conditions can vary significantly from the AMA-wide balance, which can be exasperated further by dry conditions.

In *Figure 8-2* it is evident the Downstream Area still mimics the general pattern at the AMA-wide scale, as in the normal conditions charts above. However, note that much of the peak surplus moves through the Downstream Area, and that dry conditions in this sub-geographic area result in many consecutive years where demand exceeds the supply, even in Scenario One.

Figure 8-2 Projected Water Balance DRY CONDITONS - Downstream Area

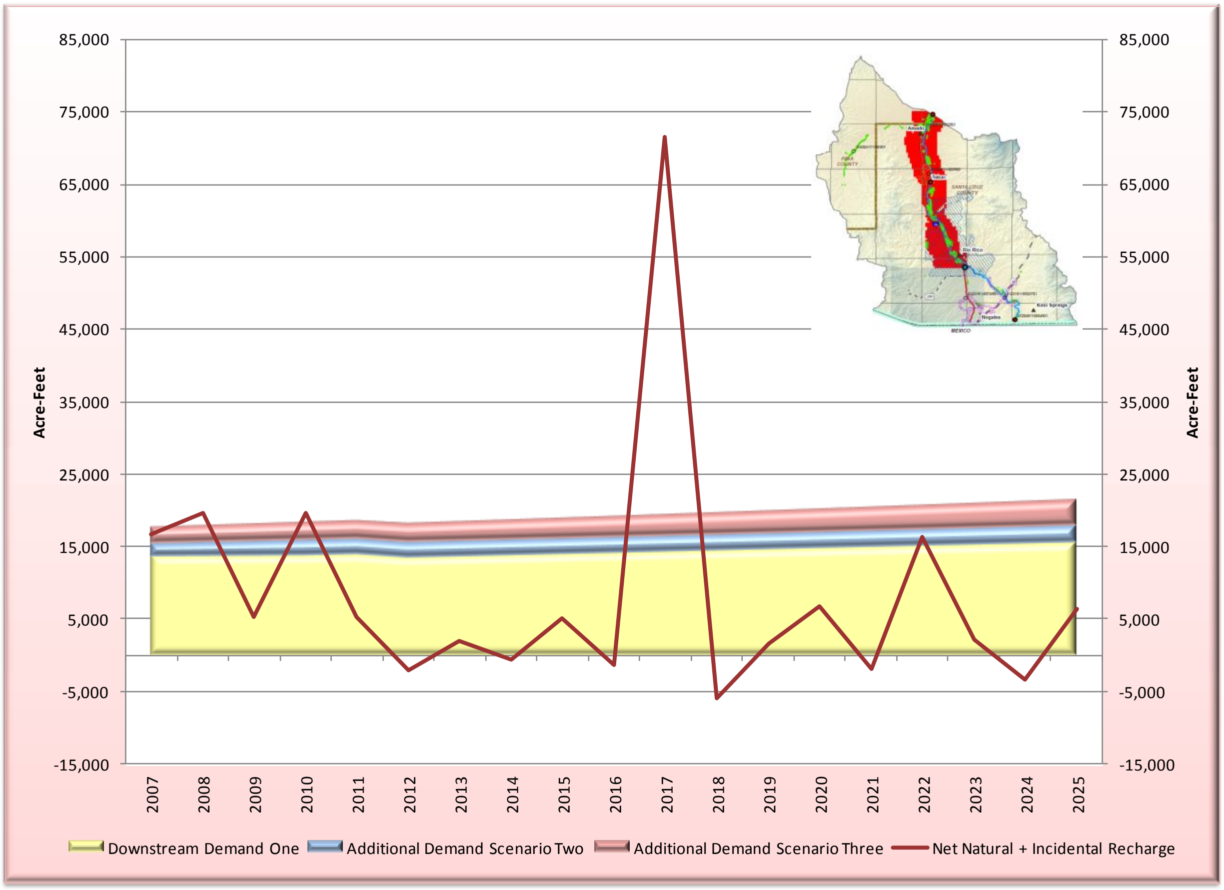
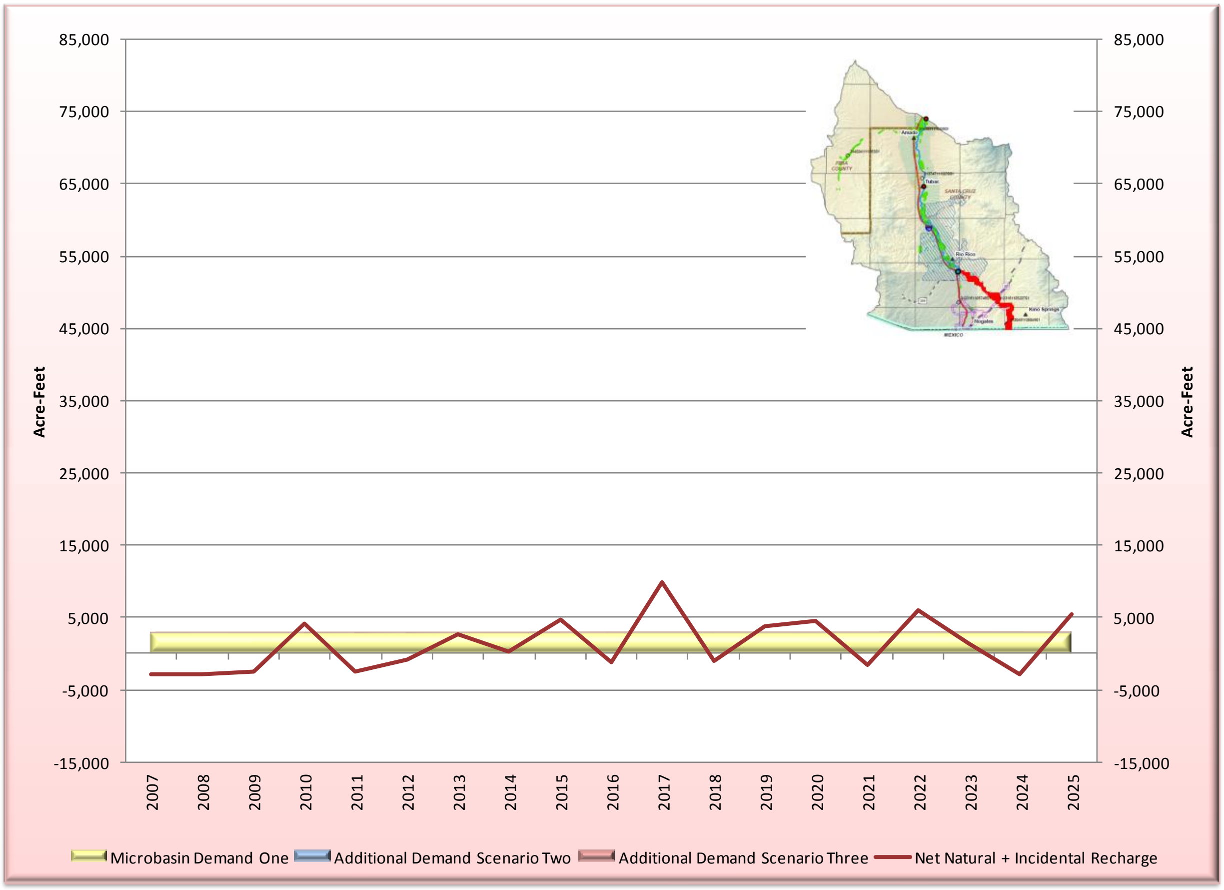


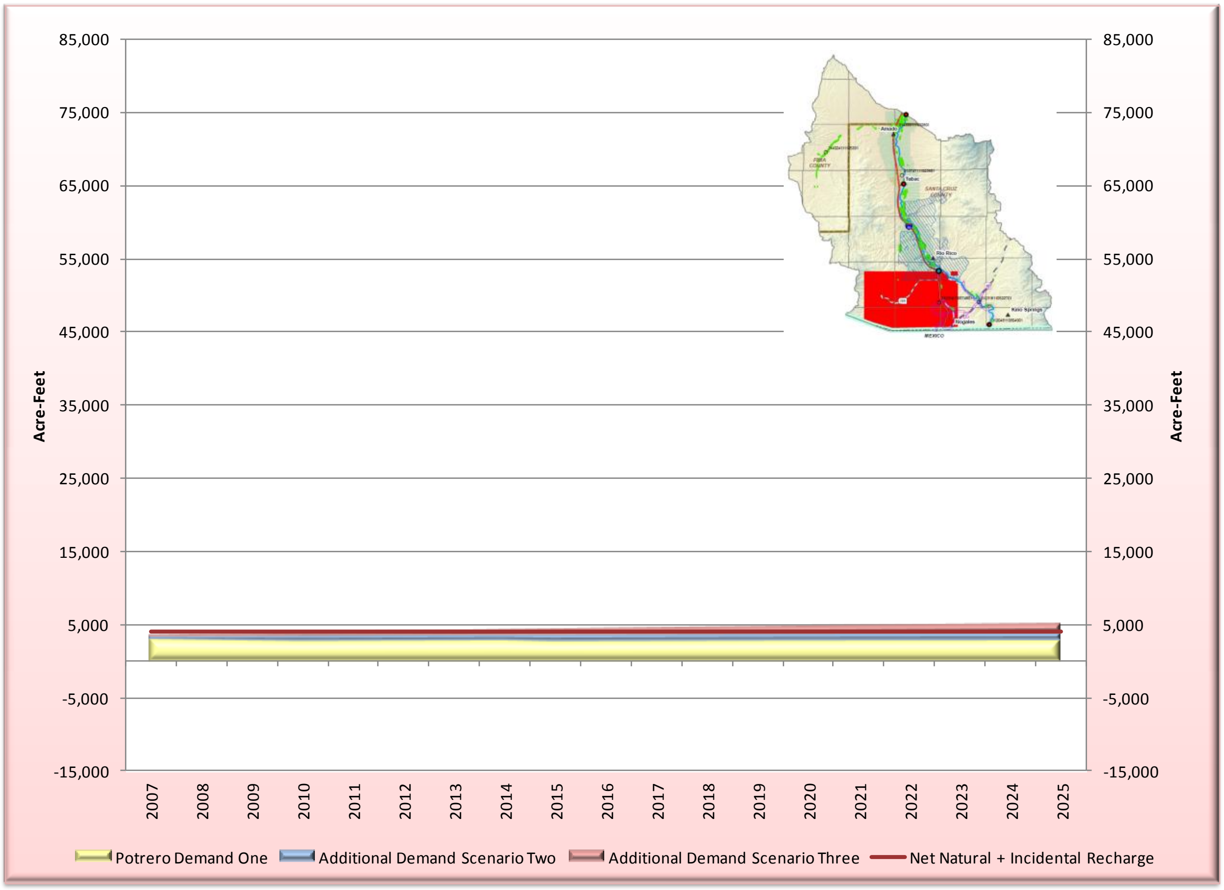
Figure 8-3 demonstrates the impact of dry conditions in the Microbasin Area. The magnitude of deficits and surpluses is volumetrically less in the Microbasin Area than in the Downstream Area. Although the City of Nogales has the option of shifting to its Potrero wellfield to make up the difference in demand and supply during extended dry conditions, not all water users in the Microbasin Area have that option. Nogales' Portero supply needs to remain capable of meeting demands for this management strategy to remain viable.

Figure 8-3 Projected Water Balance DRY CONDITONS - Microbasin Area



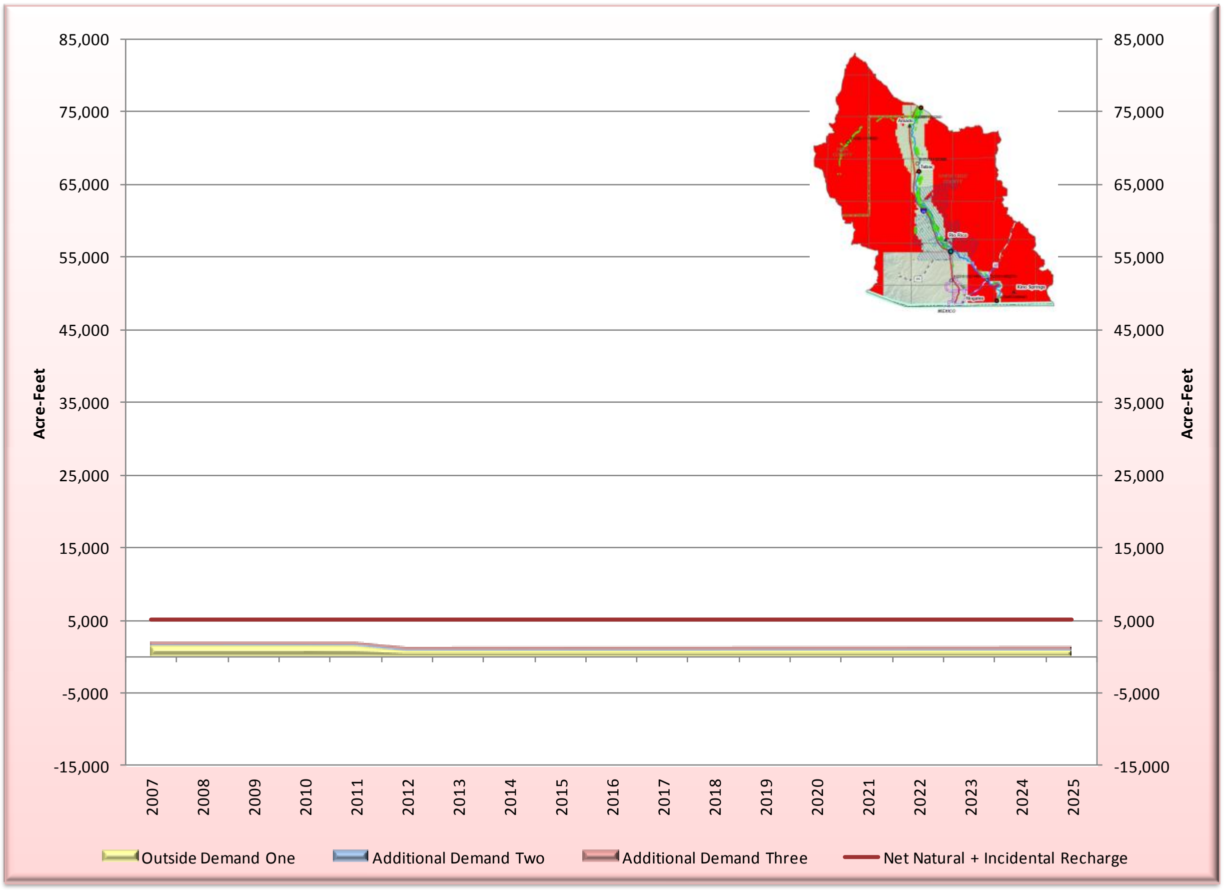
Because the main source of supply in the Potrero area is mountain front recharge, the magnitude of which is calculated, not measured, the supply is assumed to remain static under dry conditions based on the Dry Conditions Scenario. It is unclear how several consecutive years of pumping in Potrero would impact the supply over the long-term *(See Figure 8-4). H*owever, the historical period increased pumpage data from the Potrero Area and the declining water level in the Potrero hydrograph may indicate how long-term dry conditions would affect this sub-geographic area. It is also unknown how quickly this area would recover once dry conditions abated and pumping was largely shifted back to the Microbasins.

Figure 8-4 Projected Water Balance DRY CONDITONS - Potrero Area



As shown in *Figure 8-5*, similarly to the Potrero Area, the remainder of the AMA – the Outside Area - relies on mountain front recharge for its supply, and in the Dry Conditions Scenario assumptions, remains static. Because projected demand never exceeds the estimated mountain front recharge for this area, there is never a year in which deficit conditions occur during the projected period. However, localized pumping may not fully access its share of this supply, resulting in water level declines in portions of the Outside Area.

Figure 8-5 Projected Water Balance DRY CONDITONS - Outside Area



8.1.4 Mexico Retains Excess Wastewater

Although not included in this Assessment, ADWR is interested in a model scenario where the volume of reclaimed water that comes from Nogales, Sonora that exceeds the 9.9 mgd limit is instead retained by Mexico and treated at the new Los Alisos WWTP. This scenario would attempt to evaluate whether this would cause any reduction in riparian demand or reduction in physical availability of water for current or projected demand in the Downstream Area and the AMA as a whole.

8.1.5 Increased Agricultural and/or Mining Demand along the SCR in Mexico

Another possible scenario ADWR would like to model is an increase in agricultural and/or mining demand in Mexico along the Santa Cruz River to attempt to evaluate possible reduction in surface flow and groundwater inflow to the SCAMA as a result.

8.2 Drought Implications

ADWR's projections are not deterministic findings, but rather an examination of potential future conditions. Assuming the projected drought materializes, the demand sectors would need to either curtail demand or augment supply. However, a source for supply augmentation in the SCAMA has yet to be identified. Drought has a quick and significant impact on supply availability in the SCAMA because most of the highest producing wells in the AMA, which meet the majority of the AMA's demand, are located in or near the Santa Cruz River. Historically, this supply has varied annually as well as seasonally, however, as demand increases fluctuations in the supply may impact more people and water users for longer periods of time.

A drought could be further exacerbated by the retention of reclaimed water in Mexico and treated at the LAWWTP, and on future urban development along the Santa Cruz River in Mexico and changes in agricultural and mining uses. Reclaimed water discharge from the NIWWTP and stream channel recharge could be reduced. Mexican officials plan to expand the pumping capacity at the Santa Barbara and Mascarenas well fields which are located upstream from the AMA along the Santa Cruz. ADWR does not have authority to regulate pumping activity in Mexico, or the volume of reclaimed water retained in Mexico. Consequently, increased demand within the SCAMA, coupled with increased demand in Mexico and a reduction in reclaimed water from Mexico treated and discharged at the NIWWTP, coupled with drought conditions and the lack of a back-up augmentation supply is a significant water management issue in the SCAMA.

PART IV THE FOURTH MANAGEMENT PLAN PROCESS

The Groundwater Code requires ADWR to develop Management Plans for each AMA to assist the AMA in achieving its management goal. The Management Plans contain conservation requirements for the Municipal, Industrial and Agricultural sectors. While the Management Plans provide requirements for reductions in water use – it is not the only tool available to ADWR for achieving the management goals and should not be viewed as such.

ADWR has developed Management Plans for each of the previous management periods using similar, yet increasingly more complicated approaches. The 1MP (1984 – 1990) was the first comprehensive attempt to manage groundwater within the AMAs. Development of the mandatory conservation requirements used a very straightforward approach, based on water supply and demand quantification.

The 2MP (1990 – 2000) employed a more advanced supply and demand analysis incorporating current and future conditions. In the development of conservation requirements ADWR put more emphasis on aggressive and cutting-edge conservation practices for the three main water use sectors. Water supply augmentation was also integrated into the water management strategies in addition to a newly created Conservation and Augmentation Assistance grants program.

The 3MP (2000-2010) was the mid-point of the 45-year timeframe from the inception of the Code in 1980 to the year 2025 by which safe-yield was to be attained. The 3MP recognized the impacts of the other water management programs not addressed through the Management Plans, including the AWS Rules and the Underground Storage and Recovery Program. Because of the recognition of these additional management programs, supply and demand analysis vastly improved. However, the conservation requirements included in the 3MP were strikingly similar to the 2MP.

The 3MP for the AMAs, as well as the findings of the subsequently formed local AMA “Safe-Yield Task Force” (or other similarly named stakeholder groups) and the Governor’s Water Management Commission in 2001, made a series of observations that should frame the development of future water management strategies. Although these observations recognized certain differences among the AMAs, there were fundamental similarities. The principal observations were:

1) While significant progress has been made since the enactment of the Code, it is unlikely that the statutory goals of the AMAs will be met, given the current authorities granted to ADWR;
2) While it is projected that most AMAs will continue to make progress toward achievement of their goals as currently unused renewable water supplies become utilized, we may begin to move in the opposite direction if increased demands outstrip the availability of renewable supplies.
3) Localized areas within AMAs are and will continue to experience water management problems disproportionate to those of the AMA as a whole due to infrastructure and renewable water supply access, continued allowable groundwater pumping by grandfathered uses, and recovery of long term storage credits outside the areas of impact of the recharge facilities.

These observations are a mixture of “good news/bad news”. It is good news from the standpoint that the existing programs and authorities have served this State, most specifically the AMAs, well. We should all be proud of the work accomplished and the progress made to date. The bad news is that with the current authorities, it may not be possible to meet the management goals, and may over time move us farther away. These goals are the fundamental underpinnings to ensuring a long-term sustainable water supply for the State of Arizona. The 4MP must emphasize ensuring sustainable water supplies and the effective and efficient management of the State's most precious resource for Arizona to thrive.

So what should the 4MP look like? The Management Plans to date have served us well; however, they are not really planning tools that provide succinct options for future water management decisions. They are excellent tools in identifying current and projected water use, mandatory conservation requirements, and potential directions and initiatives that could be pursued to move toward goal achievement and wise, long-term water management. The Management Plans should provide more concise direction regarding what is needed to get to the ultimate goal.

ADWR will approach the 4MP more as a Plan for success than a document that simply identifies the statutory requirements for the main water using sectors. In this Plan ADWR, in cooperation with the public, will build on past successes but recognize that additional observations should be considered, including:

1) Conservation will only get us so far. We will continue to address meaningful conservation requirements, but also will review the "incentives" for utilization of renewable water supplies, reduce the complexity and the administrative workload necessary to implement these programs, and be diligent in their enforcement.
2) Have serious discussions regarding the AMA goals and the implications to the State of not reaching them.
3) Consider different approaches to water management among the AMAs, recognizing local conditions and community values.
4) Address the limitations of the Management Plans and underlying authorities as we determine what course of action to follow.
5) Recognize sub-area issues and consider alternative management strategies to address areas where conditions are positive and conditions are negative.
6) Develop, in cooperation with local water users and other water resource entities, a long-term water management strategy to get the AMAs where we need them to be by identifying what specific actions/steps we need to take and what resources will be required to accomplish this strategy.

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APPENDICES

Appendix 1 Simulated Hydrologic Components by Sub-Geographic Area

ADWR Internal Memorandum

To: Pam Muse
From: Keith Nelson
Date: December 19th, 2011
Subject: SCAMA Assessment, Net Stream Recharge Along Santa Cruz River, SCAMA and long-term average (Uniform) Recharge Rates

Name of file: Simulated_Water_Budgets_1985_2025_Ins_and_Outs_12_19_2011.docx
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This memo updates the previous memo – on simulated recharge along the Santa Cruz River (variable) - written on 10/18/2011; see attached below. This memo also includes presentation and discussion MFR and tributary recharge, as well as two natural outflow water budget components including 1) ET and 2) underflow from the SCAMA to the TAMA.

In addition this memo will discuss and document four different hydrologic zones associated with the Santa Cruz AMA. Included are two "inner valley" zones that respond strongly to variable (seasonal; annual and long-term) recharge patterns along the Santa Cruz River Valley in the

1) Northern portion of the SCAMA model (Northern SCAMA Area); and
2) Micro-Basin (the Micro-basins Area)

The other two areas are currently understood to be areas where groundwater levels respond to long-term changes; these include the

3) Potrero and Nogales Wash area (The Potrero area), and

4) Areas outside the inner valleys (Outside areas); these include area both inside and outside current model domains. **See Figure 1.**

This memo documents simulated net natural streamflow recharge rates along the Santa Cruz River in the Micro-basin area and the SCAMA-North model area; note that these rates are variable over time. Further, rates of uniformly-applied simulated natural recharge – both inside and outside currently modeled areas - are also estimated. Simulated and estimated recharge information will be used in the Santa Cruz AMA Water Budget Assessment.

Depending on the relevant time frame, some rates will be based on:
1) The calibration period (1997-2002);
2) Inferred recharge rates based on observed weather patterns
   prior to calibration period (1985-1996) and
   after the calibration period (2003-2011)
   SCAMA-to-TAMA underflow rates based on the Tucson model (which is effectively consistent with the SCAMA-North model
3) Projected rates (2012-2025), based on two 19-year periods of the stochastic model including
   One "dry" period (realization #2, years 72-90, or 72-86) and
   One "average" period (realization #2, years 1-19, or 1-15)

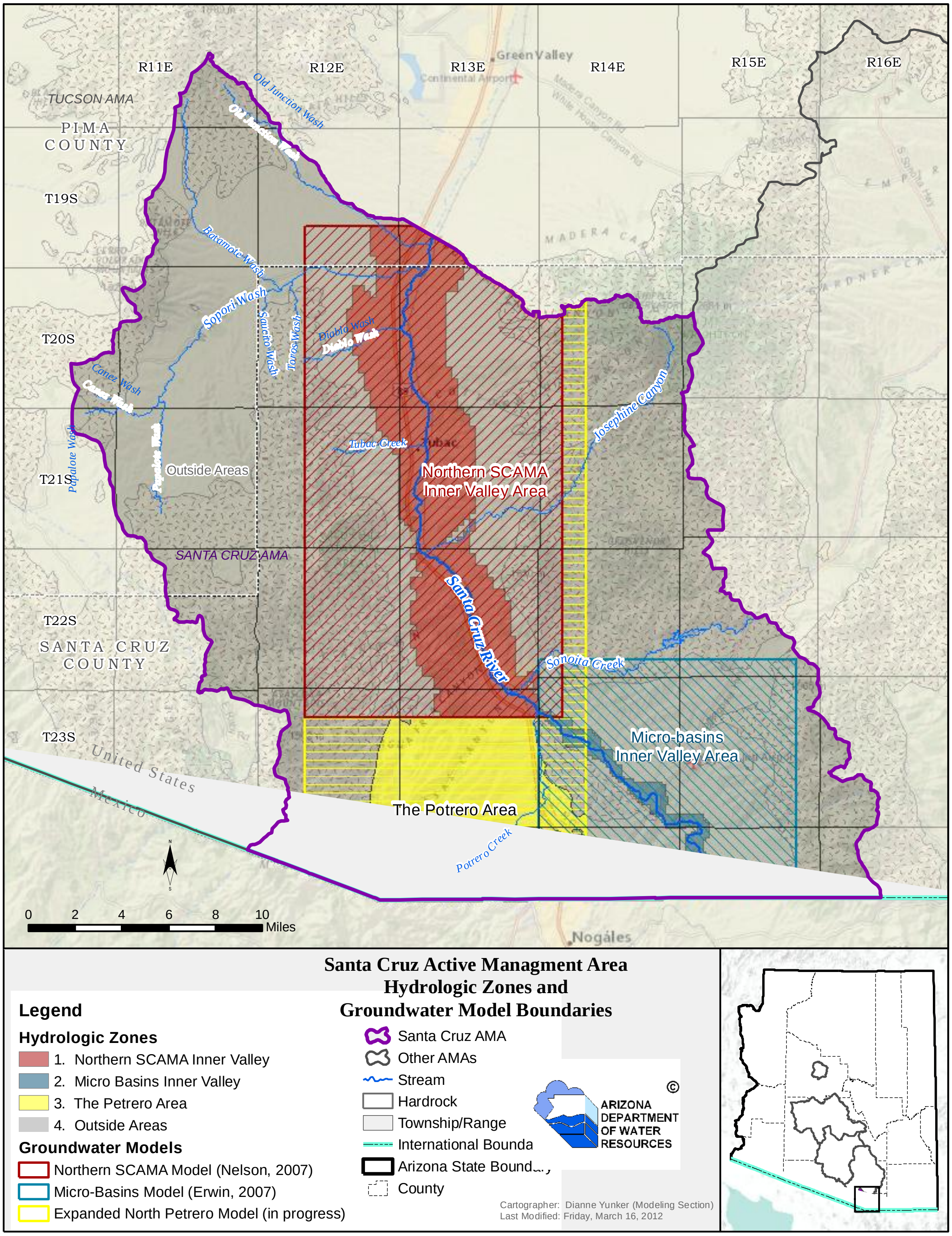

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Figure 6. Hydrologic Zones and Groundwater Model Boundaries

Thus areas 1 and 2 generally have variable natural recharge rates and are subject to significant induced recharge (induced recharge potential), while areas 3 and 4 can be generally represented by assigning uniform natural recharge rates. Again note that areas 1 and 2 cover areal extents where groundwater levels change on seasonal, annual and long-term basis, and are strongly associated with stream recharge (or lack of stream recharge). While groundwater levels in areas 3 and 4 may also fluctuate over time based on natural weather patterns, changes in these areas are slower, and for current water management purposes, can be represented by long-term uniform rates. An exception to "outside" areas maybe the central Sopori Wash area **(Figure 2),** located about 5 miles west of the Santa Cruz/Sopori Wash Confluence, where available data groundwater levels are in direct connection with the inner valley, despite its peripheral location; nonetheless this area will responds to long-term changes from the inner Santa Cruz River Valley near Amado.

Maps are presented below showing the locations of variable stream cells, uniformly-applied MFR and tributary recharge cells, and "Inner Valley" areas in the Santa Cruz AMA. All variable (contributing) stream recharge cells occur within "Inner Valley" areas (upper Sopori is a placeholder). In general, tributary recharge cells occur within Inner Valley areas; the only exceptions are: one tributary recharge cell located along the upper end of Cottonwood Canyon, and 8 tributary recharge cells located along upper Sopori Wash. All MFR cells occur outside inner valley areas.

In addition this memo documents outflow components associated with ET and underflow from SCAMA to TAMA. These outflow rates are presented in the context of the aforementioned four geographical areas. Miscellaneous information – note that modeled rates differ from calendar years in that the simulated rates are based on the water year from October 1 through September 30th.

Northern SCAMA and Micro-basin "Inner-Valley" Areas (Figure 3) are subject to significant groundwater level fluctuations (colored cells). For Northern SACAM area the "Inner Valley" extent is consistent with areal coverage of layer 2 Koal_RR, Koal_North and Koal_Tub_East (See Nelson, 2007, page 60). For Micro-Basins area the "Inner Valley" extent is consistent with areal coverage of active layer 1. (See Erwin, 2007).

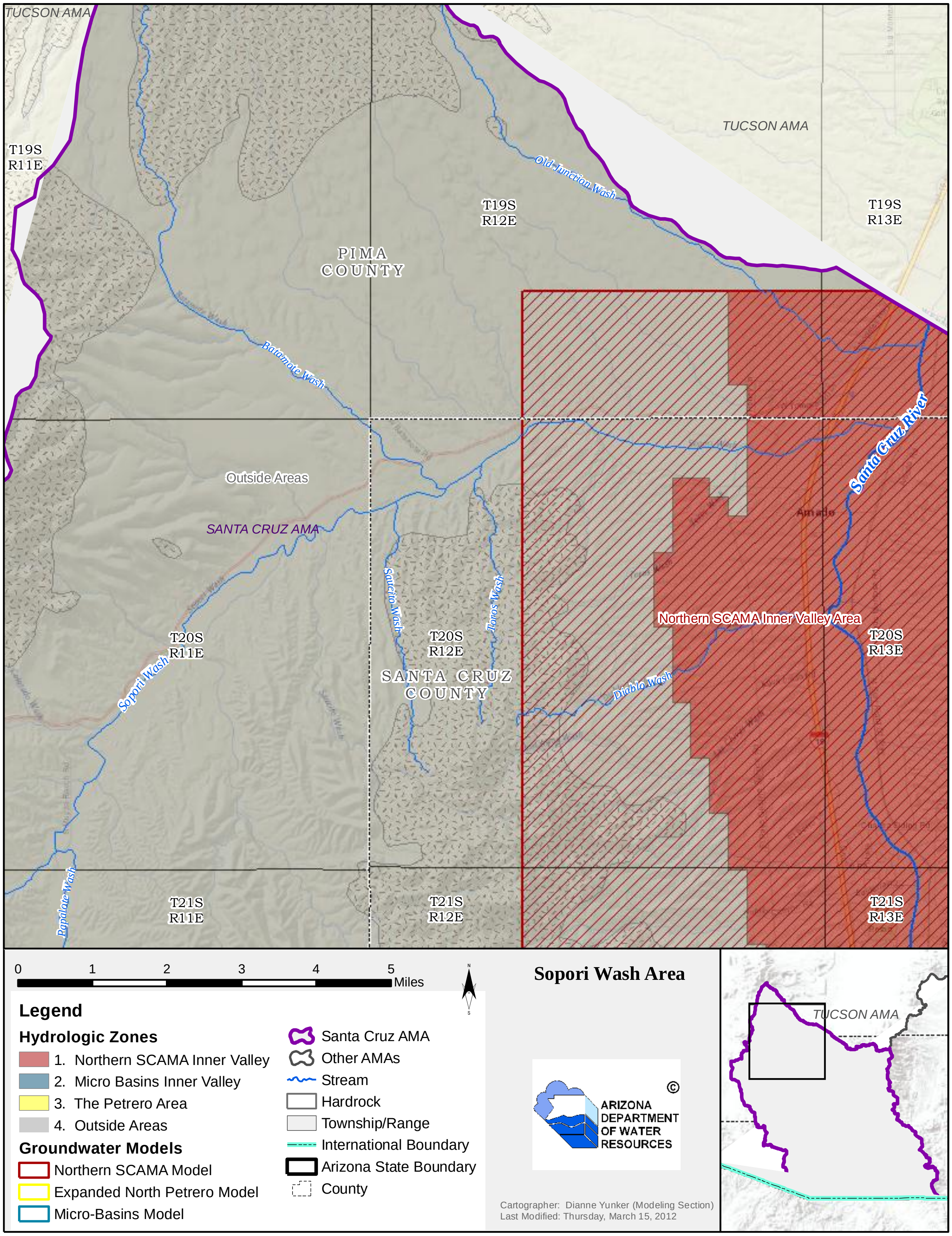

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Figure 7. Sopori Wash Area

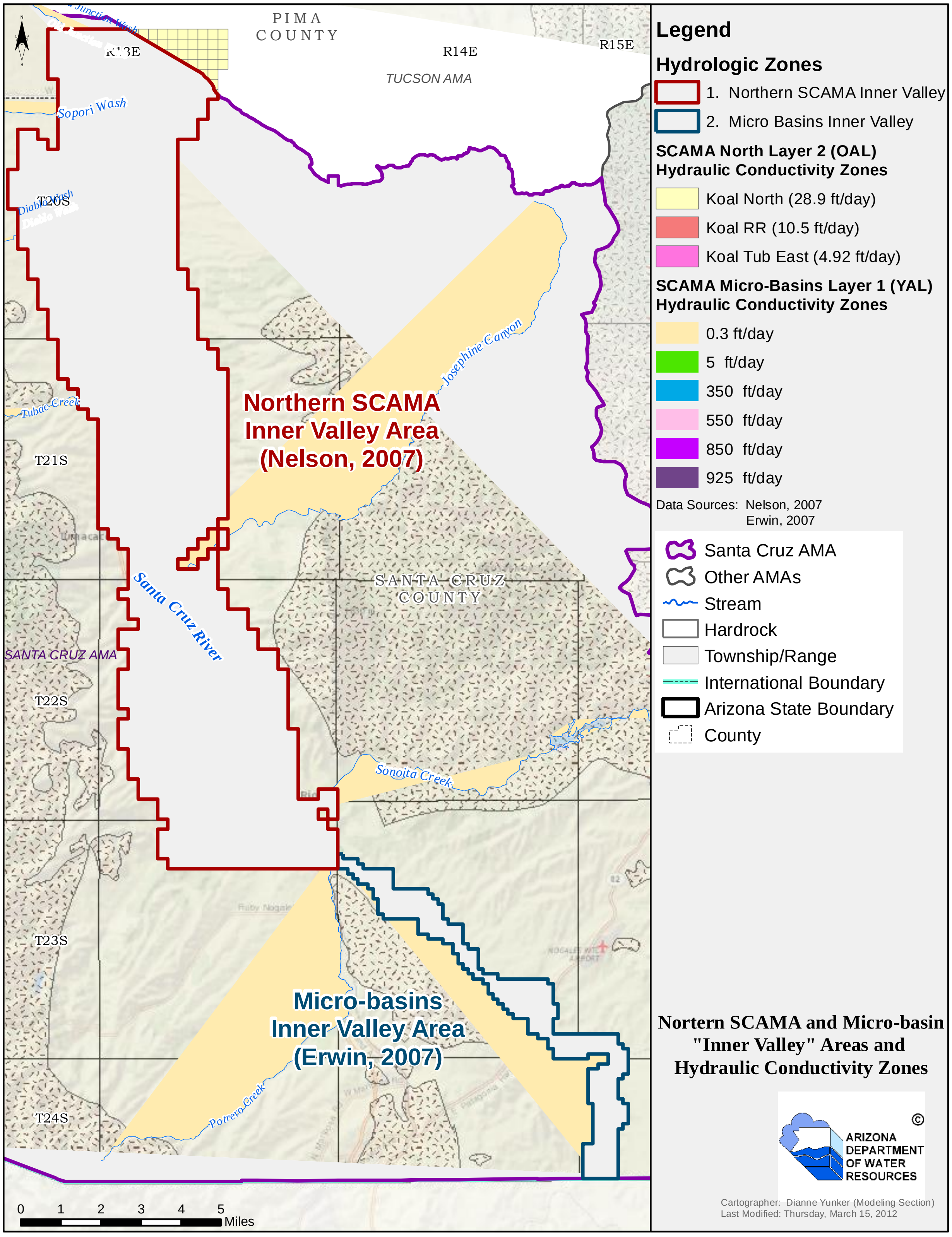

Figure 8. Northern SCAMA and Micro-basin Inner Valley Areas

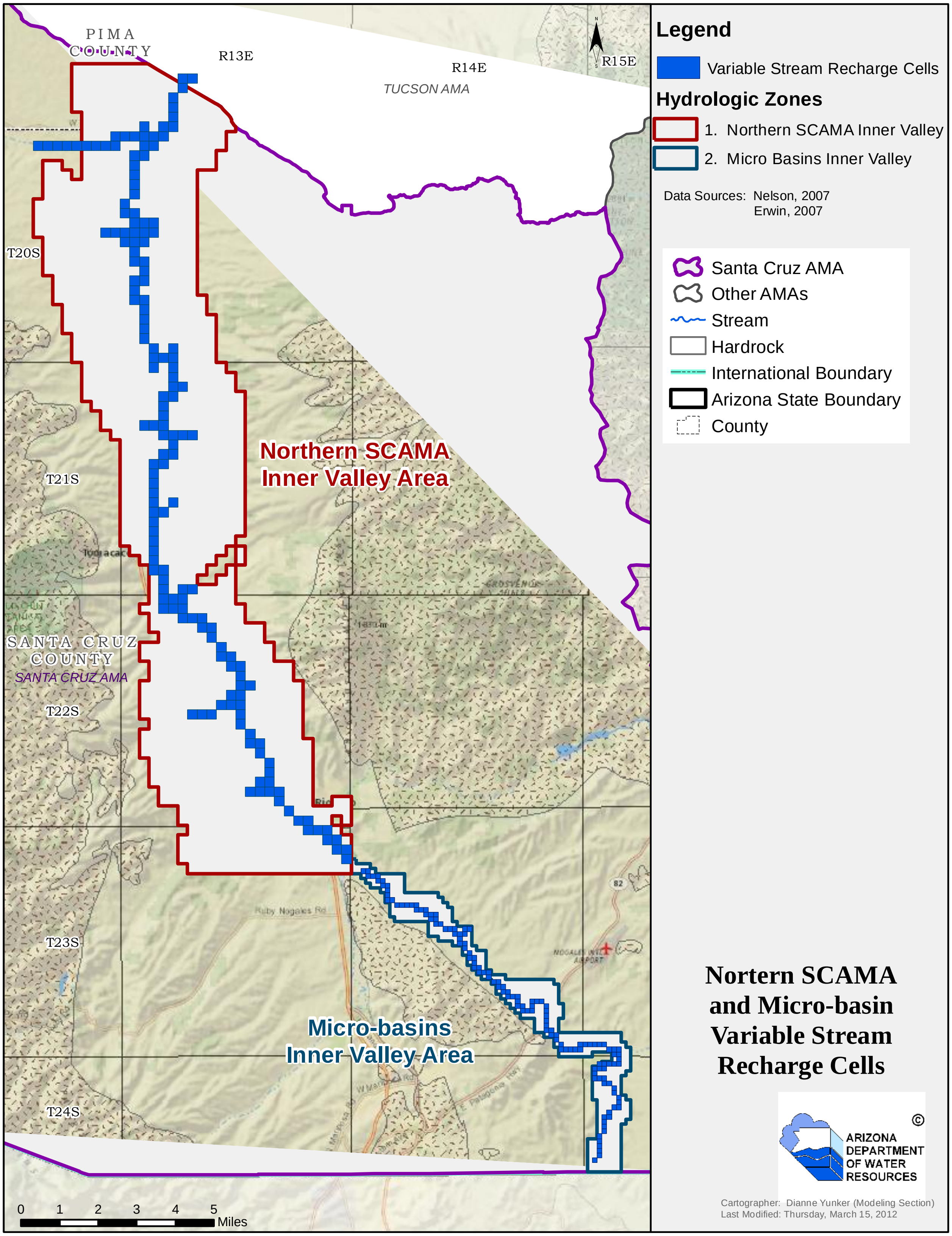

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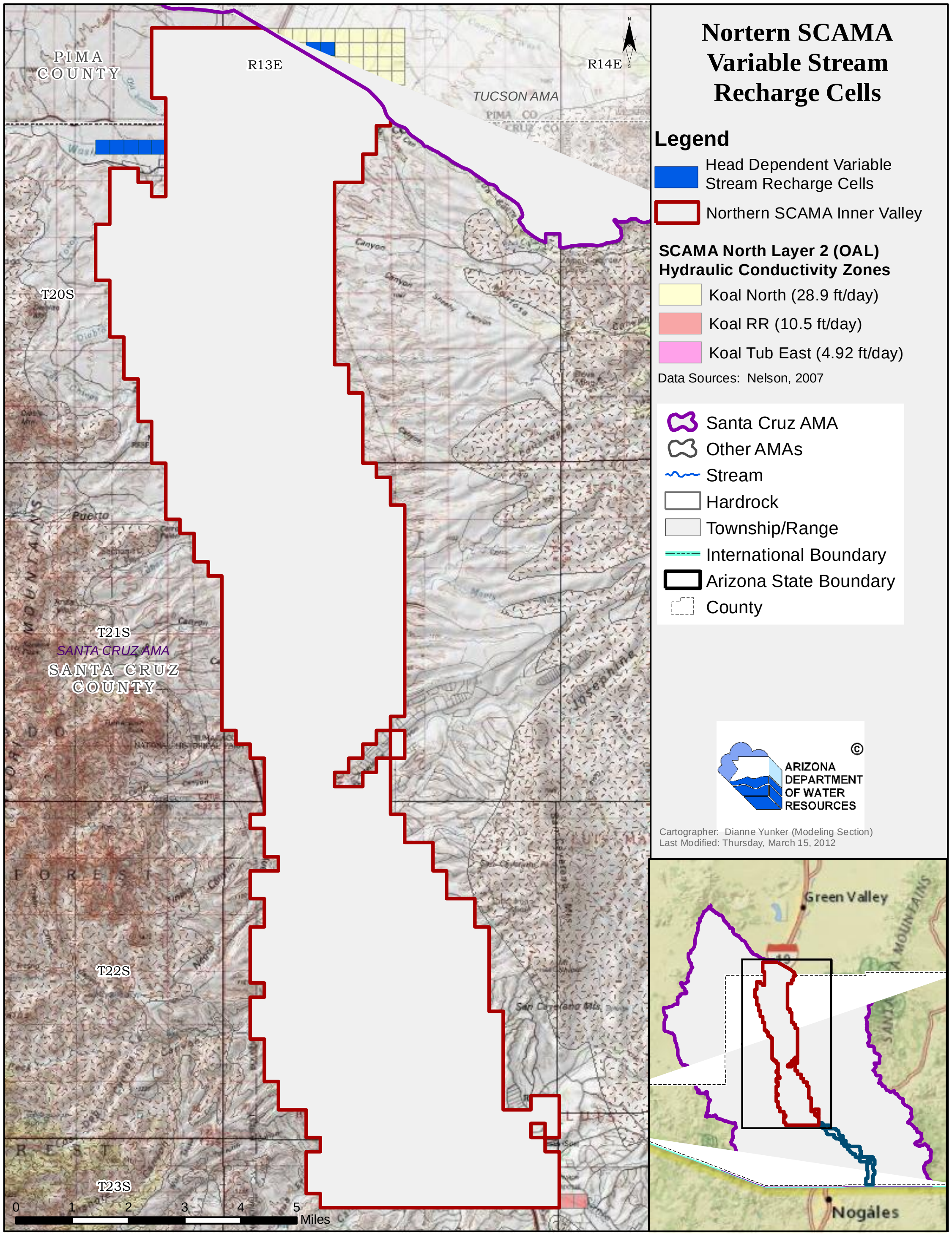
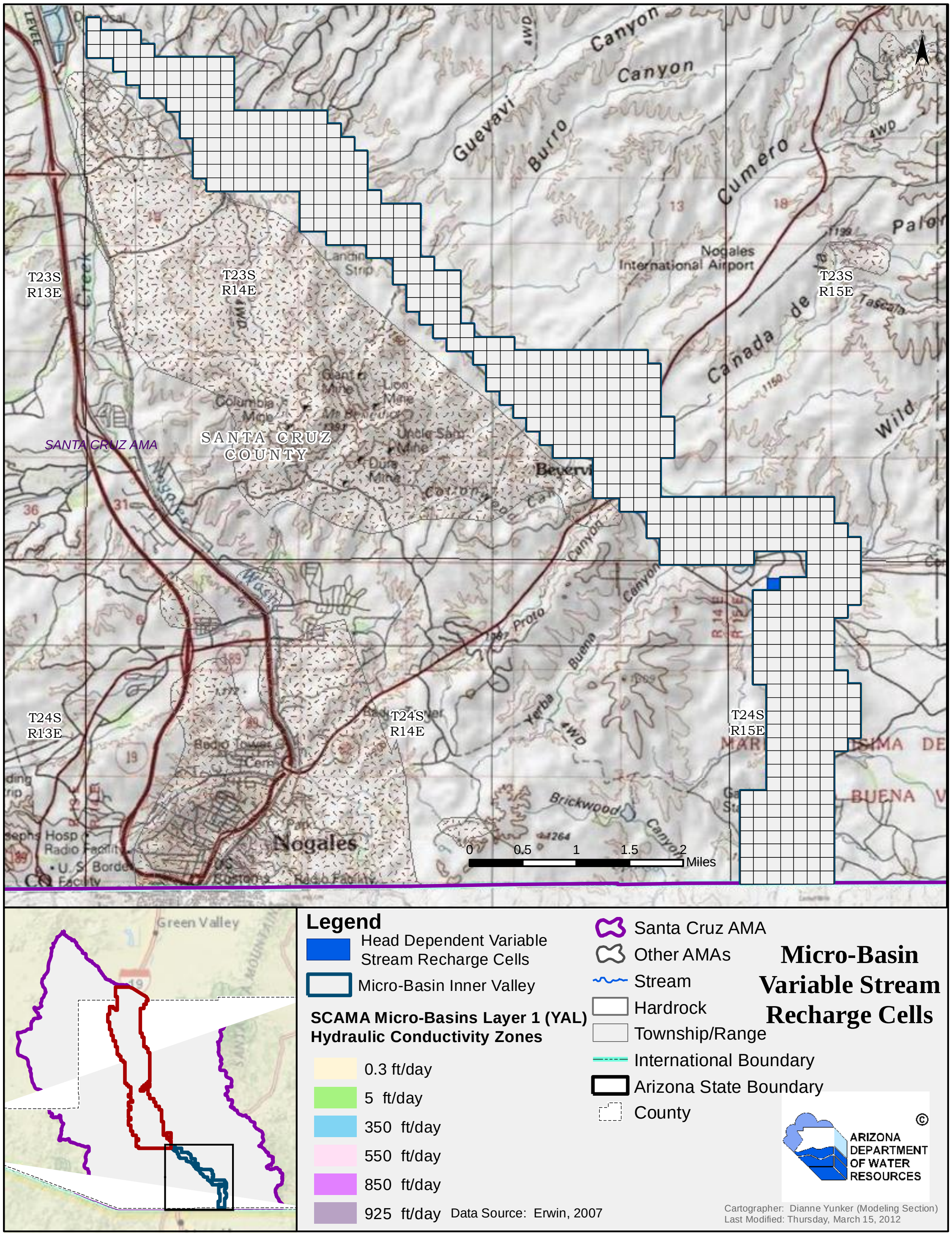
Figure 9. Variable Stream Recharge Cells



Path: U:\WorkSpaces\Hydrology\Modeling\Models\SantaCruz\SCAMA_ASSESMENT_12_13_2011\March2012_UPDATE\GIS\Maps\NorthernSCAMAVariableStreamRecharge.mxd

Figure 10. Northern SCAMA Inner valley area and variable stream recharge cells

Recharge cells are dark blue. Note that Koal_RR=10.5 feet/day; Koal_North = 28.9 feet/day and Koal_Tub_East =4.92 feet/day.



Path: U:\WorkSpaces\Hydrology\Modeling\Models\SantaCruz\SCAMA_ASSESMENT_12_13_2011\March2012_UPDATE\GIS\Maps\MicroBasin_VariableStreamRecharge.mxd

Figure 11. Micro-Basins "Inner Valley" Area

This area is associated with active layer 1 extent, and variable stream recharge cells (blue).

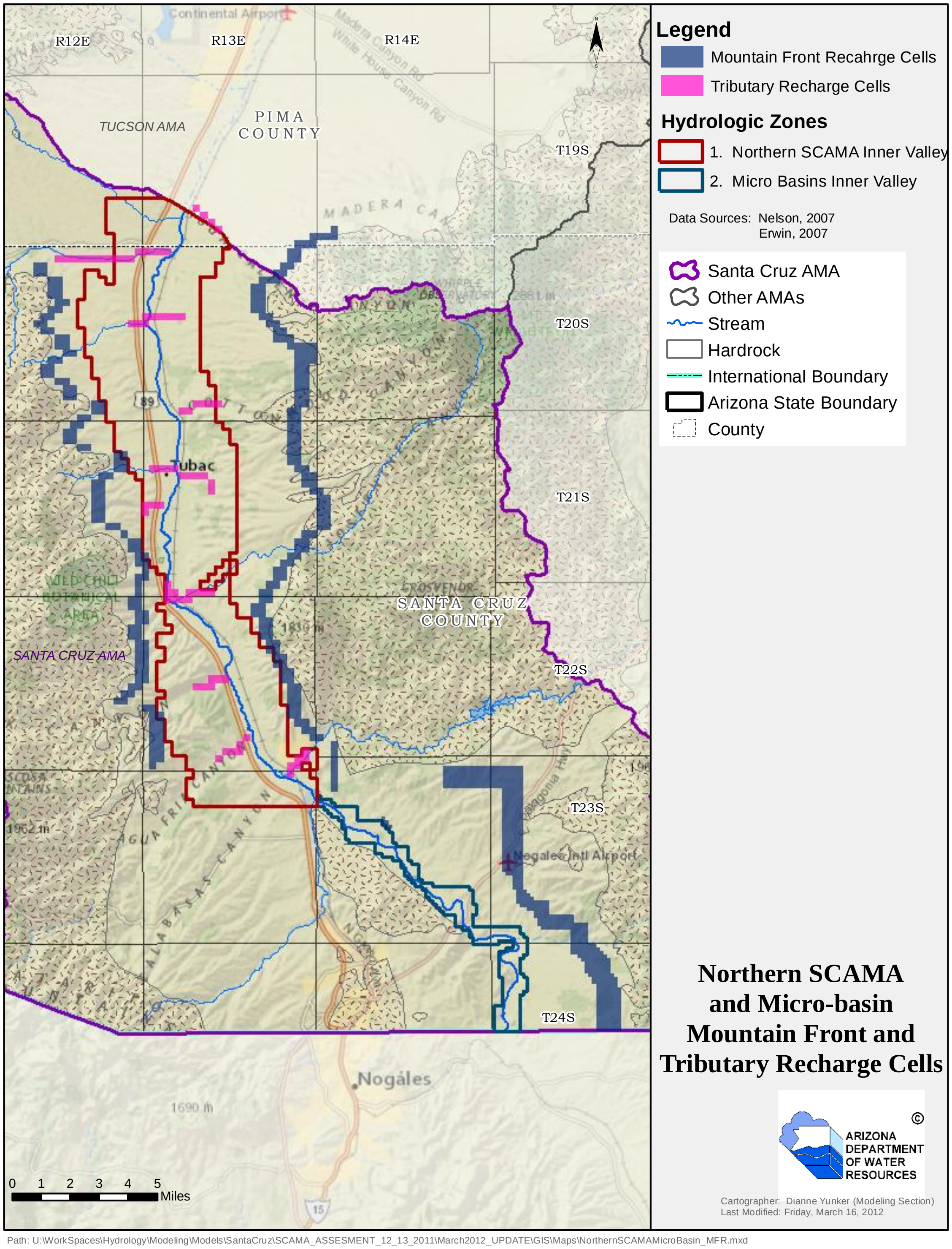


Figure 12. Northern SCAMA and Micro-Basin MF and Trib. Recharge Cells

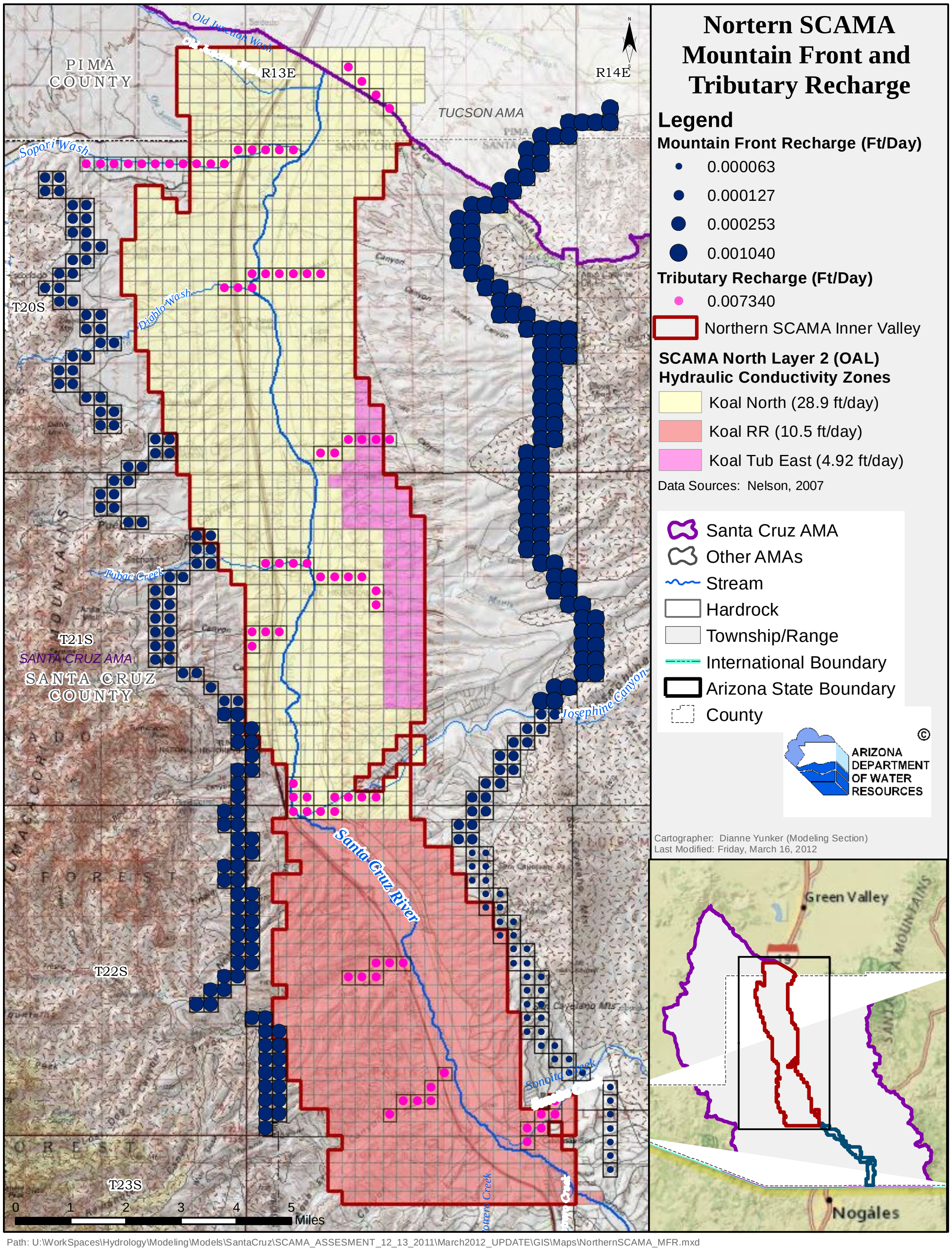
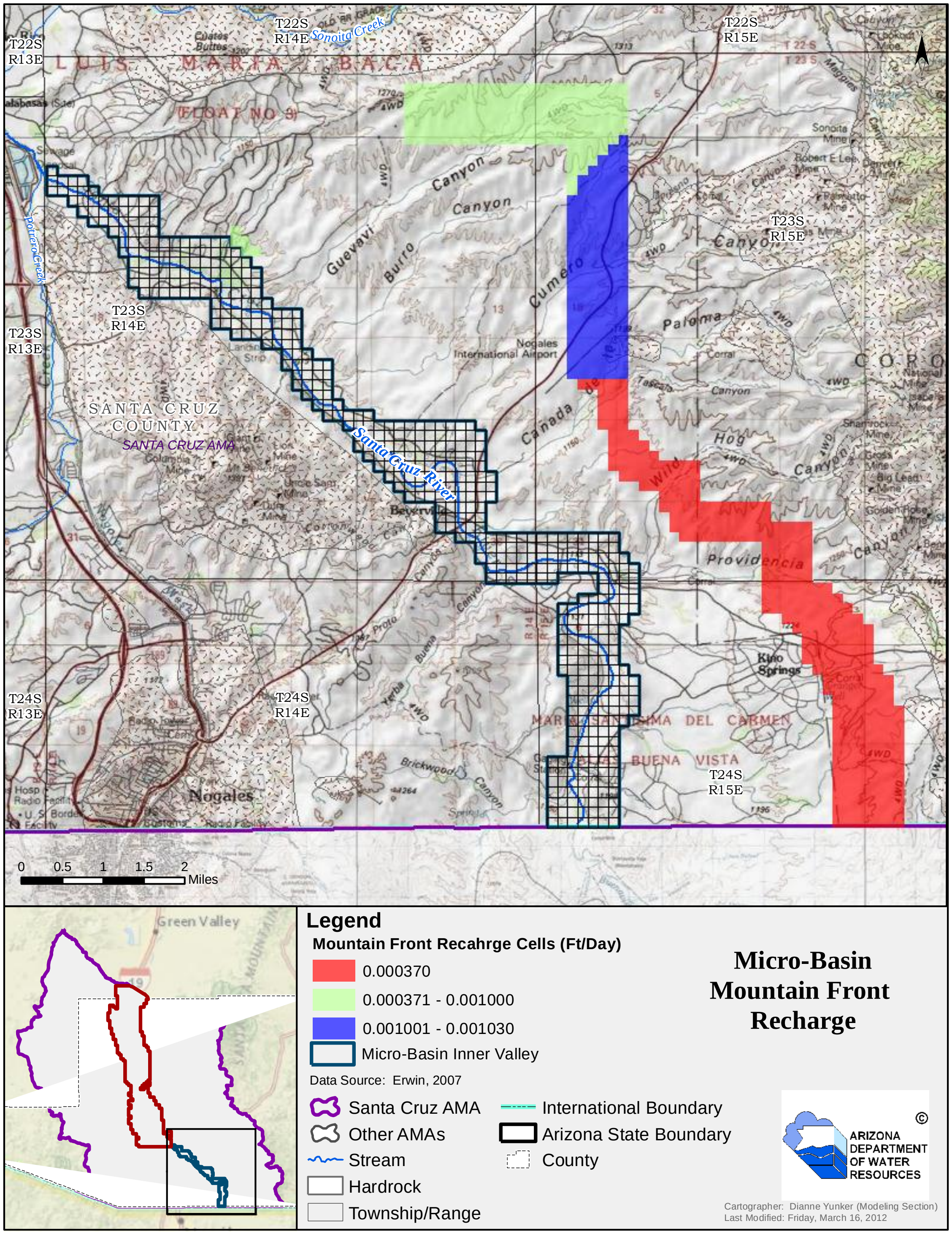


Figure 13. Northern SCAMA inner valley area

Tributary cells are located mostly within inner valley with the exception upper Sopori Wash (8 cells) and Cottonwood Canyon (one cell); MFR cells located exclusively outside inner valley.



Path: U:\WorkSpaces\Hydrology\Modeling\Models\SantaCruz\SCAMA_ASSESMENT_12_13_2011\March2012_UPDATE\GIS\Maps\MicroBasin_MFR.mxd

Figure 14. Uniformly-assigned MFR cells in Micro-Basin area

MFR cells are light green, blue and red. Note that all MFR cells are located outside “Inner Valley” Areas in the Micro-basin area.

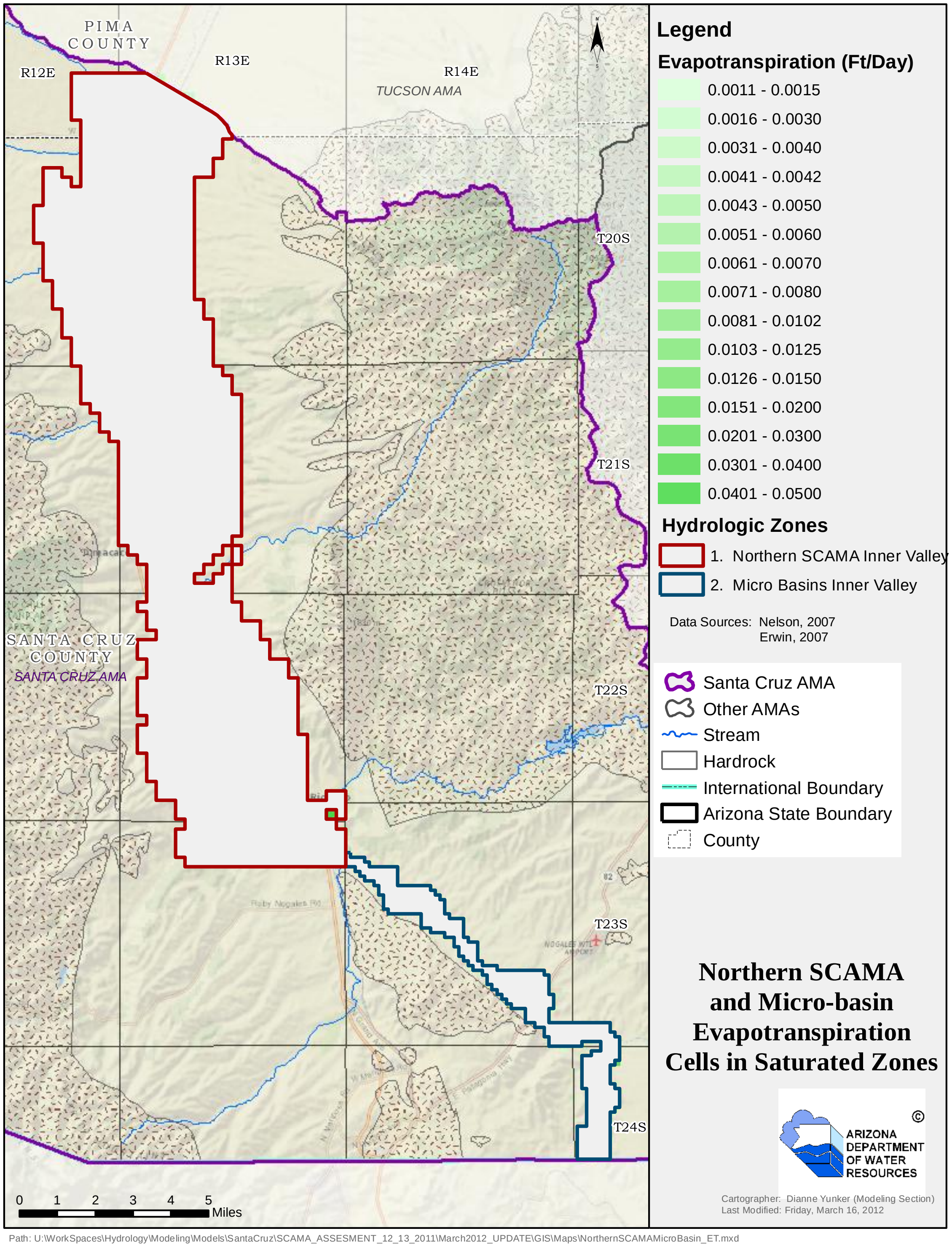


Figure 15. Northern SCAMA and Micro-basin ET

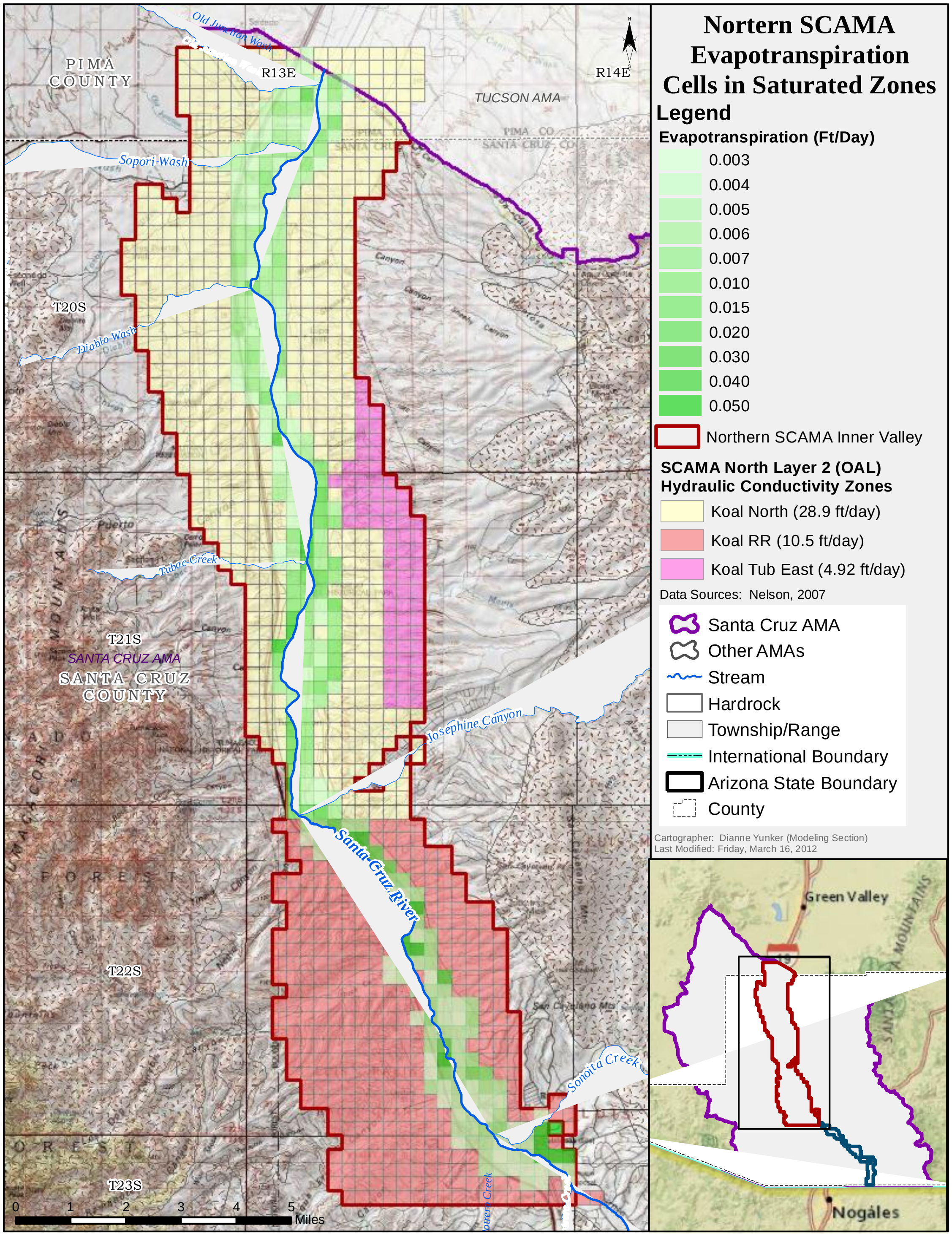
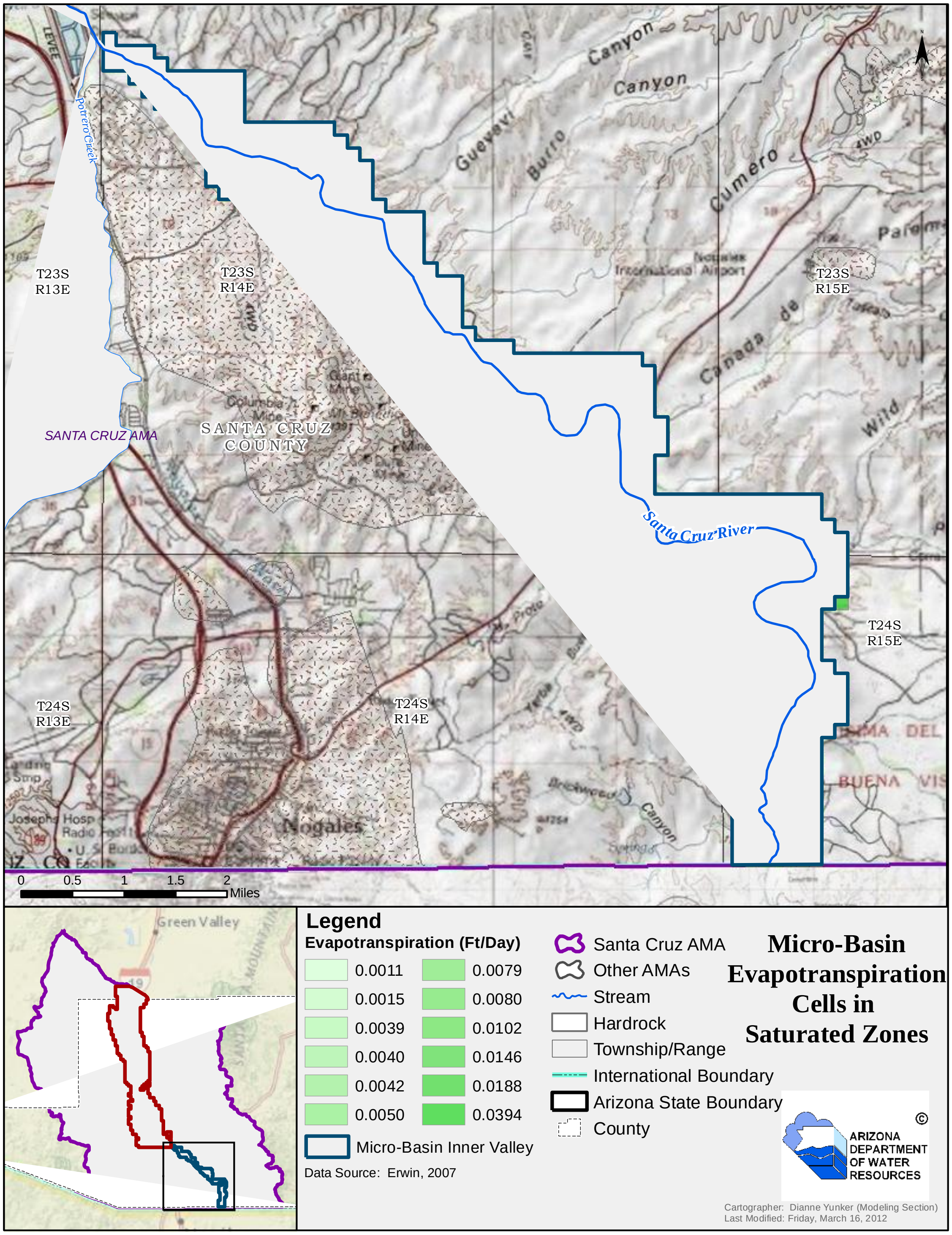


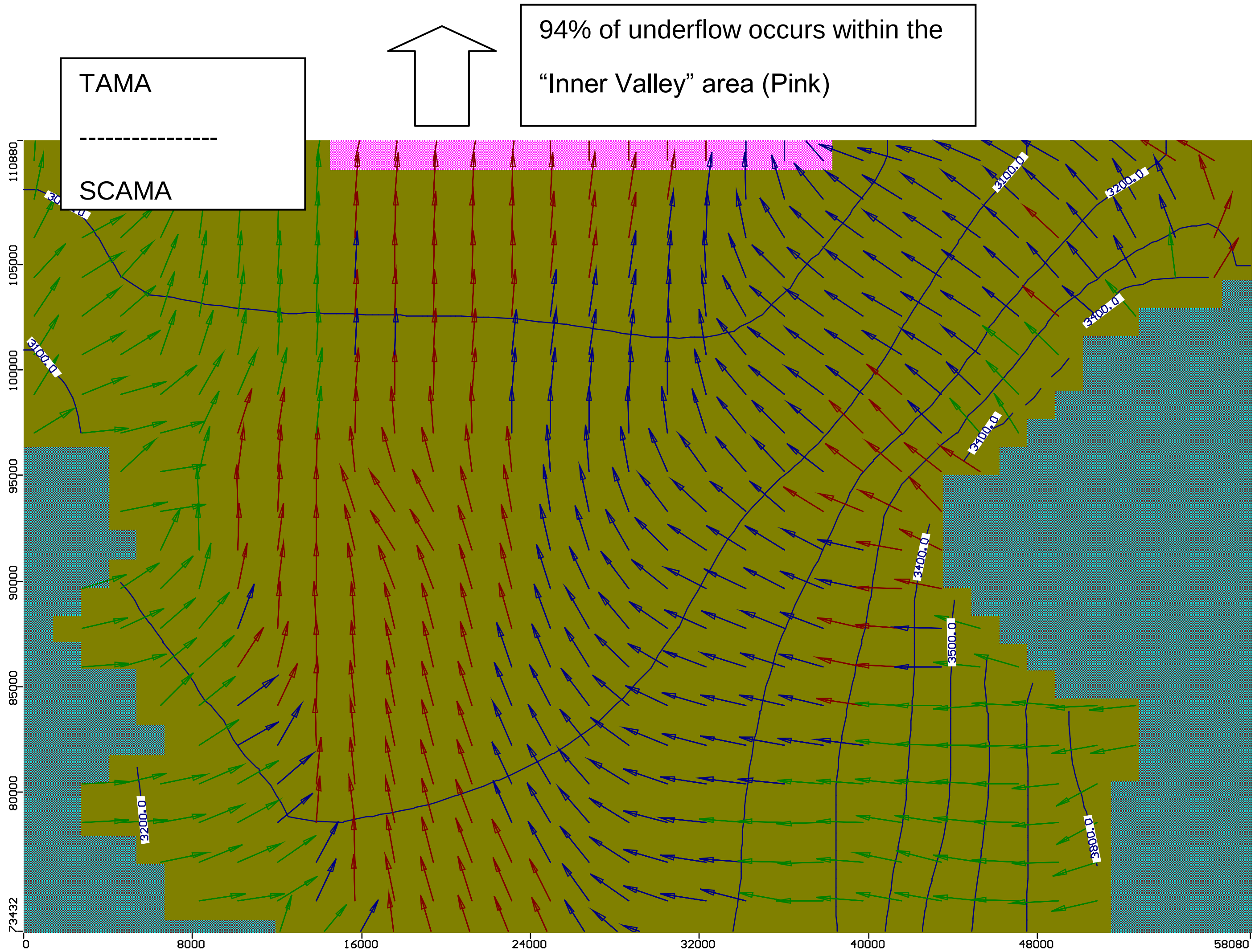
Figure 16. SCAMA-North Inner Valley and ET cells in the saturated zone

All ET cells (saturated zone) are located within the Inner Valley area.

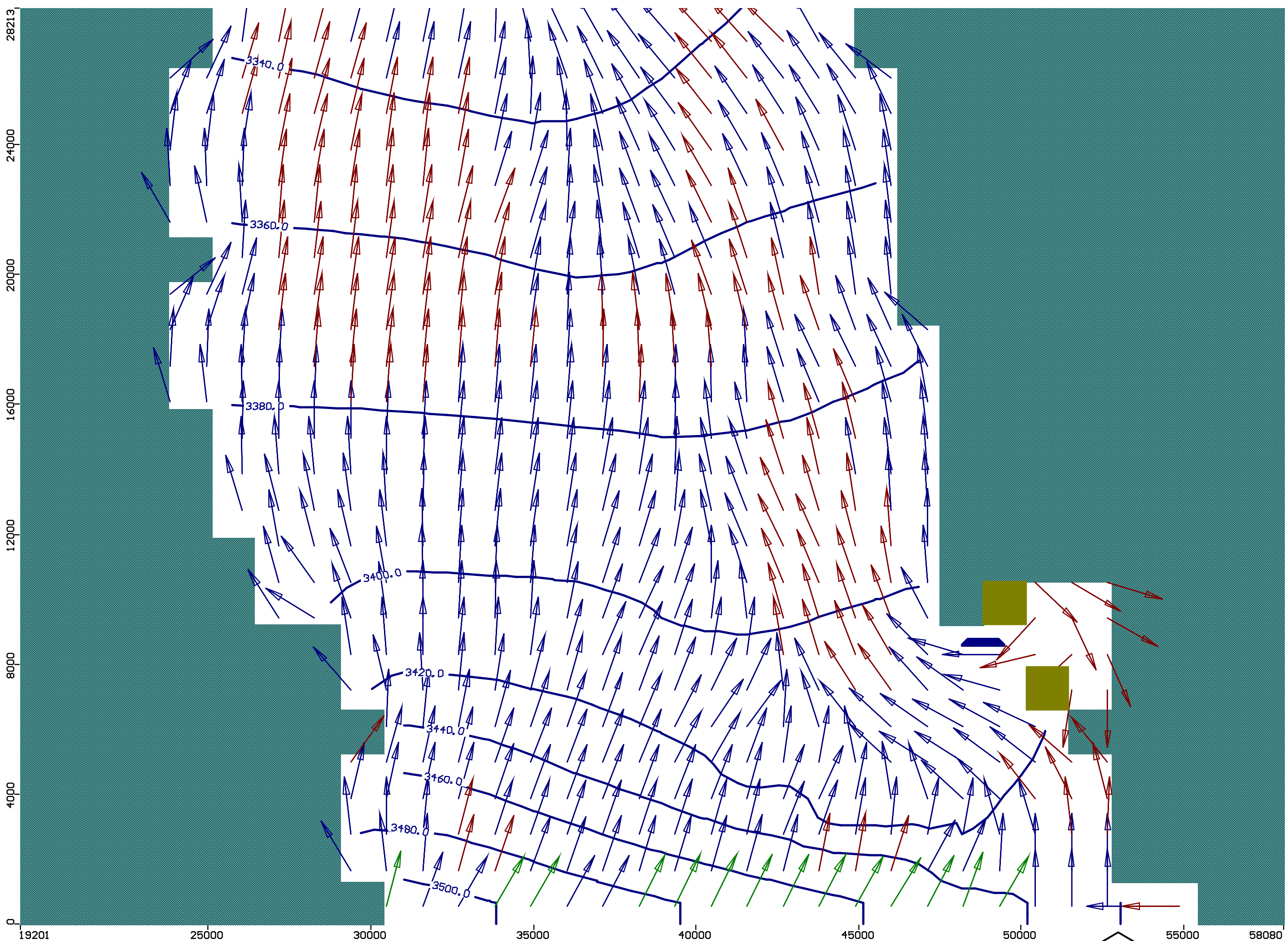


Path: U:\WorkSpaces\Hydrology\Modeling\Models\SantaCruz\SCAMA_ASSESMENT_12_13_2011\March2012_UPDATE\GIS\Maps\MicroBasin_ET.mxd

Figure 17. Micro-Basin Inner Valley ET (all ET located within Inner Valley)



Steady Underflow from SCAMA to TAMA; Inner Valley zone (pink) defining underflow from SCAMA to TAMA: 94% of underflow from SCAMA to TAMA occurs within Inner Valley (Pink, layers 1, 2 and 3), while the remaining 6% occurs in outside areas within model domain. It is assumed that insignificant underflow (out of SCAMA) occurs outside of the current SCAMA-model domains.



Conceptual Model of Underflow Into The Northern SCAMA Model Area from the Potrero area (left-side) – estimated at 4,000 AF/YR and the Micro-Basins area (right-side) – estimated at 4,500 AF/YR. The next SCAMA-North model update will refine underflow rates from the General Potrero/Nogales Wash area, the Micro-Basins, and will include MFR and Nogales Wash recharge, as well as underflow from Mexico.

4,000 AF/YR

Underflow

From Potrero & Nogales Wash Area primarily Layer 2 and 3

4,500 AF/YR

Underflow

from

Micro-Basin, Layer 1 (Yal), Layer 2 (Oal) and Layer 3 (Nog).

Water Budget Analysis and Discussion
This water budget analysis and discussion supersedes information reported in the following spreadsheet, “FMP_Budget_5_16_08_Update_06_22_2011.xlsx. Upon inspection of the budget it was noted that recharge into the Potrero/Nogales Wash area and recharge along the Santa Cruz River were – in effect – double counted. That is, modeling results (see Model Report #21) and field data (see recent Clear Creek report) increasingly show that significant underflow probably occurs in the in the Micro-Basins area (perhaps into the Sonoita Creek confluence area). Therefore the source of underflow from the Micro-basins into SCAMA north largely occurs as recharge into the Micro-basins area. It is assumed that an estimated 4,000 AF/yr of underflow flows from the Micro-basins to the Northern SCAMA Model area, and that an estimated 4,000 AF/yr of underflow moves from the general Potrero/Nogales Wash area into the Northern SCAMA Model area. Further, it is assumed that the approximate 4,000 AF/yr of underflow from the Potrero/Nogales Wash area is effectively equal to the long-term upgradient MFR rate (MFR in Mexico; recharge along the Nogales Wash, etc.). Net stream recharge rates calculated from the modified Micro-basin model (see Model report #21 for details) were used for the 1998-2002 calibration period.

Miscellaneous notes on Micro-basins. The GHB external head elevations and associated conductance assigned at Micro-basin northern boundary are fixed, and as such, occasionally conduct relatively large rates of underflow into the SCAMA north model domain, due to high projected (stochastic) upstream stream recharge rates. Long-term underflow rates out of the Micro-basin model average about 4,600 AF/yr. The primary outflow sources in the Micro-basin model are 1) pumpage (2,800 AF/YR); 2) ET (3,140 AF/YR) and 3) GHB underflow (4,560 AF/yr) totaling about 10,500. The primary inflow sources are 1) stream recharge (8,100 AF/yr); 2) MFR (1,260 AF/YR) and 3) net underflow from Mexico into the US (1,280 AF/yr), totaling about 10,640 AF/yr. The difference for realizations #2, which is a predominantly “dry” streamflow recharge realization, is the net change-in-storage, which over the course of the 105 year simulation is only about 140 AF/yr. The limited stream recharge rates simulated during the calibration period (even with the modified model, which allows higher rates of stream recharge) probably reflect unconditioned starting heads, which were not modified in the updated Micro-basin model. After an extended simulated time, the collective system starts to reflect a more dynamic equilibrium condition, and thus heads equilibrate to dynamic pulses and storage changes; accordingly, the model heads eventually become conditioned to the system. Note the lack of steady state conditions – even temporary, seasonal, steady conditions – effectively, precluded a steady state calibration in the Micro-Basin area.

Very preliminary model up-date results, which extend the SCAMA-North model domain south through the Potrero-Nogales Wash area to the US-Mexican border (effectively creating another ACM), are not inconsistent with previous SCAMA-North model results. The preliminary results for every tested ACM, indicate that rates of about 4,000 AF/yr of underflow occur from the general Nogales Wash/Potrero area into SCAMA North. These results infer that the remaining balance of the required total underflow is approximately 4,500 AF/yr, originating from the Micro-basin, Santa Cruz River/Sonoita Creek-confluence area. The long-term simulated underflow rate out of the Micro-Basins for the modified Micro-Basin model for realization #2 was **4,558 AF/YR**, consistent with the new conceptualization. Note that a total underflow of about 8,500 AF/YR into the SCAMA-North model is required for an effective calibration. See Model Report #14 for a discussion about spatial parameter correlation between subsurface sources into SCAMA north between the Micro-basins, Potrero and Nogales Wash and Sonoita Creek.

Regarding the southern Micro-Basin model boundary (based on the modified Micro-Basin model – see Model Report #21), the long term net underflow rate (realization #2) from Mexico into the U.S. is **1,315 AF/YR**. Note that this rate is higher than previous estimates of about 400 AF/yr. To account for the new modified Micro-basin model parameters, updated stream recharge estimates have been provided herein. That is, stream recharge estimates from the stochastic model have been used to provide guidance for the assignment of historical stream recharge during periods outside present calibration periods. In other words high stream recharge periods from the stochastic model have been categorically inferred to historical “wet” periods (i.e., 1993), while relatively low stream recharge periods from the stochastic model have been categorically inferred to historical “dry” periods (i.e., 1996).

Observed Streamflow Data near Nogales, USGS 09480500

The annual mean long-term streamflow along the Santa Cruz River, recorded near Nogales is 25.8 cfs (18,823 AF/YR). The median streamflow is 16.85 cfs (1914-2011). For long-term streamflow patterns (time series analysis), see Shamir et al (2005). Table below shows streamflow (not stream recharge rates); note that streamflow rates may correlate with stream recharge rates, when aquifer storage space exists.

1914	18	13104	1953	7	5242	1984	116	83691
1915	66	47565	1954	41	29827	1985	114	82532
1917	19	13828	1955	77	56035	1986	26	18606
1918	6	4394	1956	10	6892	1987	11	8036
1919	18	13031	1957	7	5249	1988	15	10715
1920	23	16506	1958	27	19837	1989	4	3200
1921	66	47782	1959	21	15131	1990	26	19040
1922	7	5242	1960	36	25701	1991	32	22877
1930	37	26570	1961	8	6139	1992	31	22153
1931	54	39384	1962	21	15420	1993	61	43800
1932	44	31565	1963	23	16362	1994	4	2679
1933	10	6878	1964	37	26859	1995	34	24760
1934	5	3967	1965	8	5553	1996	2	1491
1935	93	67112	1966	95	68994	1997	2	1332
1936	20	14624	1967	15	10570	1998	11	8036
1937	22	16072	1968	61	43945	1999	12	8470
1938	11	8253	1969	18	13321	2000	3	2259
1939	25	18389	1970	16	11366	2001	53	38587
1940	13	9629	1971	24	17086	2002	1	825
1941	9	6559	1972	11	7819	2003	1	934
1942	11	8036	1973	28	20054	2004	0	304
1943	13	9484	1974	23	16289	2005	4	2997
1944	5	3309	1975	29	20633	2006	10	7240
1945	7	4945	1976	22	15710	2007	7	4981
1946	23	16362	1977	5	3931	2008	3	2230
1947	7	5314	1978	110	79709	2009	0	279
1948	12	8688	1979	123	88758	2010	19	13466
1949	19	13973	1980	3	2461	2011	2	1325
1950	28	20054	1981	13	9267	Mean	26	18823
1951	7	4807	1982	4	3113			
1952	8	5509	1983	91	65519			

Three generalized categories have been defined for estimating recharge for historical periods outside the current calibration period (1985-1997; 2003-2011) along the Santa Cruz main stem (and contributions from major tributaries near confluence areas) in the Northern SCAMA model area.

Listed below are two tables showing the breakdown of natural recharge for the four designated areas including: 1) Northern-SCAMA Inner Valley; 2) the Micro-Basins Inner Valley; 3) the General Potrero Area (including Nogales Wash); and 4) all areas outside inner valleys and Potrero (Outside areas). The first table uses an “average” stream recharge period for projective purposes, while the second table uses “dry” stream recharge projections. A third table provides statistics associated with the projected periods associated with realization #2 including years 1-19; and years 72-90.

[Note that observation data (seepage data) collected from 2003 to 2010, shows minimal (if any) effluent recharge in the Northern-SCAMA area. Effluent during this period may have supported unsaturated ET along stream channel. The NIWTP upgrade may have led to improvements in effluent infiltration. The projection simulations included herein, do not explicitly “contain” effluent, which is normally added in stream segment #2 of the stream-aquifer boundary package. Assignment of the conductance term – for projection purposes – when effluent is included, carries difficult assumptions because of the clogging layer, flood-induced scour, higher hydraulic connections along/during gaining reaches; lower hydraulic connection along losing reaches. See model report #21 for further discussion. Therefore for projection purposes, if effluent recharge is assumed to occur during any of the projection period (2012-2025), then effluent recharge could be added to the budget independently, of the natural recharge rates, discussed herein, along the main-stem of the Santa Cruz River.]

Estimated natural stream recharge rates for years 1985-1997 and 2003-2011 (total of 22 years) was based on “wet”, average” and “dry” years. For “wet” years (2 years), streamflow recharge was estimated at 54,640 and 12,000 AF/YR, respectively, for the SCAMA-North and Micro-basins area. For “average” years (5 years) streamflow recharge was estimated at 35,755 and 8,000 AF/YR, respectively, for the SCAMA-North and Micro-basins area. For “dry” years (15 years) streamflow recharge was estimated at 16,870 and 1,000 AF/YR, respectively, for the SCAMA-North and Micro-basins area. While the relative categorizations (dry, average and wet) between the SCAMA-North area and the Micro-Basins areas were similar, they were defined to be identical, due to different contributions from major tributaries (Sonoita Creek; Nogales Wash, etc.), located downstream from Micro-basins reaches. For example, the summer stream recharge events from 2006 had a more significant impact in the northern area, due to large contributions from the Sonoita Creek watershed.

Note: There are many water budgets are presented below. However, many of the presented water budgets below have no direct application to requested GWM purposes. Rather, some of the water budgets below were developed for self-consistency-purposes, and sub-regional water budget checking purposes. Furthermore, the flow of the memo is complicated and not structured well; in the future I hope to improve and economize the memo’s structure/flow so that it is more understandable. In general, the water budget rates provided below have been bolded for simulated periods, and are in italics for the projected period.

Natural Recharge: Calibrated (1998-2002); Estimated (1985-1997; 2003-2011); Projected (2012-2025)

Year	**Micro-Basin Inner Valley** Does NOT include 1,315 AF/yr of underflow from Mex	**Northern SCAMA Inner Valley** Variable stream recharge; Inner Valley also includes tributary recharge from Northern SCAMA Base model (8,350 AF/yr) minus 9*107 AF/yr (Cottonwood (1) and Upper Sopori (8)		**Outside Areas** MB MFR=1266; plus Base Model MFR 1900 plus 9*107 tributary plus 1,000 estimated for Hardrock MFR outside model areas	**Potrero** Potrero Nogales Wash Recharge; will update when model is extended	**Total Simulated Natural Stream Recharge**
	Variable		*Uniform*			
	NET Stream	**NET Stream**	**Tributary**	**MFR + Tributary**	**MFR=Flux**	***variable***
1985	12000	54640	7383	5133	4000	83156
1986	1000	16870	7383	5133	4000	34386
1987	1000	16870	7383	5133	4000	34386
1988	1000	16870	7383	5133	4000	34386
1989	1000	16870	7383	5133	4000	34386
1990	8000	35755	7383	5133	4000	60271
1991	8000	35755	7383	5133	4000	60271
1992	8000	35755	7383	5133	4000	60271
1993	12000	54640	7383	5133	4000	83156
1994	1000	16870	7383	5133	4000	34386
1995	8000	35755	7383	5133	4000	60271
1996	1000	16870	7383	5133	4000	34386
1997	1000	16870	7383	5133	4000	34386
1998	**7929**	**37870**	**7383**	**5133**	**4000**	**62315**
1999	**6557**	**30610**	**7383**	**5133**	**4000**	**53683**
2000	**2745**	**18270**	**7383**	**5133**	**4000**	**37531**
2001	**6131**	**54640**	**7383**	**5133**	**4000**	**77287**
2002	**956**	**16870**	**7383**	**5133**	**4000**	**34342**
2003	1000	16870	7383	5133	4000	34386
2004	1000	16870	7383	5133	4000	34386
2005	1000	16870	7383	5133	4000	34386
2006	1000	35755	7383	5133	4000	53271
2007	1000	35755	7383	5133	4000	53271
2008	1000	35755	7383	5133	4000	53271
2009	1000	16870	7383	5133	4000	34386
2010	8000	35755	7383	5133	4000	60271
2011	1000	16870	7383	5133	4000	34386
Projection Realizations # 2; years: 1-15 (Ital)					7383	5133
2012	***3721***	***4597***	***7383***	***5133***	***4000***	***24834***
2013	***4364***	***5382***	***7383***	***5133***	***4000***	***26262***
2014	***9443***	***43666***	***7383***	***5133***	***4000***	***69625***
2015	***12533***	***43342***	***7383***	***5133***	***4000***	***72391***
2016	***7683***	***18369***	***7383***	***5133***	***4000***	***42568***
2017	***10553***	***47089***	***7383***	***5133***	***4000***	***74158***
2018	***4733***	***6160***	***7383***	***5133***	***4000***	***27409***
2019	***10267***	***40539***	***7383***	***5133***	***4000***	***67322***
2020	***8038***	***11213***	***7383***	***5133***	***4000***	***35767***
2021	***4391***	***5497***	***7383***	***5133***	***4000***	***26404***
2022	***10715***	***36388***	***7383***	***5133***	***4000***	***63619***
2023	***9257***	***17519***	***7383***	***5133***	***4000***	***43292***
2024	***11111***	***78533***	***7383***	***5133***	***4000***	***106160***
2025	***8122***	***12392***	***7383***	***5133***	***4000***	***37030***

Year	Micro-Basin Inner Valley Does NOT include 1,315 AF/yr of underflow from Mex	Northern SCAMA Inner Valley Variable stream recharge; Inner Valley also includes tributary recharge from Northern SCAMA Base model (8,350 AF/yr) minus 107 AF/yr		Outside Areas MB MFR=1266; plus Base Model MFR 1900 plus 107 tributary plus 1,000 estimated for MFR outside model areas	Potrero Potrero Nogales Wash Recharge will update when model is extended	Total Simulated Natural Stream Recharge
	Variable		*Uniform*			
	NET Stream	NET Stream	Tributary	MFR + Tributary	MFR=Flux	***variable***
1985	12000	54640	7383	5133	4000	83156
1986	1000	16870	7383	5133	4000	34386
1987	1000	16870	7383	5133	4000	34386
1988	1000	16870	7383	5133	4000	34386
1989	1000	16870	7383	5133	4000	34386
1990	8000	35755	7383	5133	4000	60271
1991	8000	35755	7383	5133	4000	60271
1992	8000	35755	7383	5133	4000	60271
1993	12000	54640	7383	5133	4000	83156
1994	1000	16870	7383	5133	4000	34386
1995	8000	35755	7383	5133	4000	60271
1996	1000	16870	7383	5133	4000	34386
1997	1000	16870	7383	5133	4000	34386
1998	**7929**	**37870**	**7383**	**5133**	**4000**	**62315**
1999	**6557**	**30610**	**7383**	**5133**	**4000**	**53683**
2000	**2745**	**18270**	**7383**	**5133**	**4000**	**37531**
2001	**6131**	**54640**	**7383**	**5133**	**4000**	**77287**
2002	**956**	**16870**	**7383**	**5133**	**4000**	**34342**
2003	1000	16870	7383	5133	4000	34386
2004	1000	16870	7383	5133	4000	34386
2005	1000	16870	7383	5133	4000	34386
2006	1000	35755	7383	5133	4000	53271
2007	1000	35755	7383	5133	4000	53271
2008	1000	35755	7383	5133	4000	53271
2009	1000	16870	7383	5133	4000	34386
2010	8000	35755	7383	5133	4000	60271
2011	1000	16870	7383	5133	4000	34386
Projection Realizations # 2; years: 72-86(Ital)						
2012	***3953***	***4892***	***7383***	***5133***	***4000***	***25361***
2013	***6923***	***8528***	***7383***	***5133***	***4000***	***31967***
2014	***4272***	***5296***	***7383***	***5133***	***4000***	***26084***
2015	***8312***	***10364***	***7383***	***5133***	***4000***	***35192***
2016	***2747***	***3383***	***7383***	***5133***	***4000***	***22646***
2017	***16605***	***88090***	***7383***	***5133***	***4000***	***121211***
2018	***4057***	***4999***	***7383***	***5133***	***4000***	***25572***
2019	***7969***	***9896***	***7383***	***5133***	***4000***	***34381***
2020	***9077***	***13859***	***7383***	***5133***	***4000***	***39452***
2021	***3103***	***3848***	***7383***	***5133***	***4000***	***23467***
2022	***10200***	***21921***	***7383***	***5133***	***4000***	***48637***
2023	***6383***	***7858***	***7383***	***5133***	***4000***	***30757***
2024	***1144***	***1400***	***7383***	***5133***	***4000***	***19060***
2025	***9003***	***11206***	***7383***	***5133***	***4000***	***36725***
Years 1998-2002 calibrated rates; years 1985-1997 and 2003-2011 stream recharge rates inferred from flow data and antecedent aquifer conditions; ***years 2012-2025 projected stream recharge based in part on stochastic model***.						

Simulated Stream Projections & Statistics, Realization #2: Years 1-19; and 72-90

Summary of Total Simulated NET Streamflow along Santa Cruz River – variable along HDB Streamflow Realization #2 (See ADWR Modeling Report #21 for modeling assumptions). Units: AF/YR							
Real -2	Micro-Basin	SCAMA-North	Total Stream	Real - 2	Micro-Basin	SCAMA-North	Total Stream
1	***13583***	***32902***	***46485***	72	***3953***	***4892***	***8845***
2	***3721***	***4597***	***8318***	73	***6923***	***8528***	***15451***
3	***4364***	***5382***	***9746***	74	***4272***	***5296***	***9568***
4	***9443***	***43666***	***53109***	75	***8312***	***10364***	***18676***
5	***12533***	***43342***	***55874***	76	***2747***	***3383***	***6130***
6	***7683***	***18369***	***26052***	77	***16605***	***88090***	***104695***
7	***10553***	***47089***	***57643***	78	***4057***	***4999***	***9056***
8	***4733***	***6160***	***10893***	79	***7969***	***9896***	***17866***
9	***10267***	***40539***	***50805***	80	***9077***	***13859***	***22936***
10	***8038***	***11213***	***19251***	81	***3103***	***3848***	***6950***
11	***4391***	***5497***	***9888***	82	***10200***	***21921***	***32121***
12	***10715***	***36388***	***47103***	83	***6383***	***7858***	***14240***
13	***9257***	***17519***	***26776***	84	***1144***	***1400***	***2544***
14	***11111***	***78533***	***89644***	85	***9003***	***11206***	***20209***
15	***8122***	***12392***	***20514***	86	***7396***	***9122***	***16518***
16	***4565***	***5647***	***10212***	87	***15189***	***7182***	***22372***
17	***8423***	***18495***	***26918***	88	***3509***	***10136***	***13645***
18	***3369***	***4167***	***7536***	89	***10911***	***4334***	***15244***
19	***4409***	***5417***	***9826***	90	***9257***	***23073***	***32330***
Mean	***7857***	***23017***	***30873***		***7369***	***13126***	***20495***
Stndev	***3209***	***20571***	***23216***		***4110***	***19030***	***21906***
Min	***3369***	***4167***	***7536***		***1144***	***1400***	***2544***
Max	***13583***	***78533***	***89644***		***16605***	***88090***	***104695***

The table below presents simulated recharge estimate statistics from the calibrated period (1998-2002); the inferred historical periods (1985-1997; 2003-2011) and the projected periods compare.

Simulated Natural Stream Recharge Statistics for an **“average”** stream recharge period (**Real # 2, years 1-19)**		
Period	**Mean Simulated Natural Recharge**	**Standard Deviation**
1985-1997 – estimated	49,850	19,000
1998-2002 – calibrated	**53,000**	**17,800**
2003-2011 – estimated	43,600	11,100
2012-2025 – projective	***51,200***	***24,500***
1985-2025	48,800	19,300
Simulated Natural Stream Recharge Statistics for a **“dry”** stream recharge period (**Real # 2, years 72-90)**		
Period	**Mean Simulated Natural Recharge**	**Standard Deviation**
1985-1997 – estimated	49,850	19,000
1998-2002 – calibrated	**53,000**	**17,800**
2003-2011 – estimated	43,600	11,100
2012-2025 – projective	***37,200***	***25,400***
1985-2025	43,500	21,200

SCAMA Natural Outflow Water Budget Components

This section discusses the natural water budget outflows components associated with 1) ET and 2) underflow from SCAMA to TAMA.

SCAMA Natural ET Outflow Water Budget Components

Note that the ET values shown in the tables below represent ET exclusively within the saturated zone for currently-modeled areas associated with the Micro-basins and in SCAMA-North. For the collective Santa Cruz AMA, the total ET demand in both the saturated and unsaturated zones was estimated to be 25,800 AF/yr (Sharon Masek – mid-1990's). The difference between ET rates listed below and the total estimated SCAMA ET of 25,800 AF/yr is assumed to be due to ET: 1) outside the currently-model domains, in both the saturated and unsaturated zones; and 2) ET in the unsaturated zones within current model areas. Thus it is assumed that there is no ET in the saturated zone, *outside* Inner Valley zones.

The ET rate in the saturated zone was estimated by the SCAMA models for years 1998-2002. For the years 1985-1997 and 2003-2011, ET in the modeled-area saturated zones was estimated by assigning one of three categorical rates based on either "wet" (17,000 AF/YR), "average (15,500 AF/yr)" or "dry" (14,000 AF/yr) conditions; these rates were generalized on modeled ET rates with the saturated ET for the combined SCAMA-North and Micro-basins model areas. Years 1998-2002 were based on calibrated ET rates. Years 2012-2025 were based on projected rates from stochastic model (realization #2 years 1-19; and years 72-90).

SCAMA Natural Underflow/Outflow Water Budget Components

Estimated underflow for years 1985-1997 and 2003-2007 was based on the Tucson Model (Mason).

Estimated underflow for year 1998-2002 was based on the SCAMA-North model calibration (Nelson, 2007).

Estimated SCAMA to TAMA underflow rates for years 2008-2011, was categorically-based on three conditions including: "Wet" years (25,000 AF/YR); "average" years 21,500 AF/YR; and "dry" year = 18,000 AF/yr.

Estimated underflow for years 2012-2025 was based on the stochastic model (first table - realization #2 years 1-15); and second table – realization #2 years 72-86).

Based on steady state flow conditions, it is assumed that 94% of underflow from SCAMA to TAMA occurs within the defined "Inner Valley". Thus 6% of underflow from SCAMA to TAMA occurs outside of the "Inner Valley" area. These proportions have been extended to transient years accordingly because steady state is assumed to be equal to long-term dynamic equilibrium conditions.

Projection Realizations # 2; "**Average" years: 1-15 (2012-2025)**					
Year	ET North+MB	Total Underflow SCAMA to TAMA	Inner Valley Underflow SCAMA to TAMA	Outside Underflow SCAMA to TAMA	Total ET + Underflow
1985	17000	26432	24846	1586	43432
1986	14000	25583	24048	1535	39583
1987	14000	24488	23019	1469	38488
1988	14000	23894	22460	1434	37894
1989	14000	23746	22321	1425	37746
1990	15500	24362	22900	1462	39862
1991	15500	24920	23425	1495	40420
1992	15500	24635	23157	1478	40135
1993	17000	25144	23635	1509	42144
1994	14000	26330	24750	1580	40330
1995	15500	27555	25902	1653	43055
1996	14000	26963	25345	1618	40963
1997	14000	25631	24093	1538	39631
1998	**16414**	**22150**	**20821**	**1329**	**38564**
1999	**15609**	**22880**	**21507**	**1373**	**38489**
2000	**15050**	**22590**	**21235**	**1355**	**37640**
2001	**16074**	**26380**	**24797**	**1583**	**42454**
2002	**16216**	**25950**	**24393**	**1557**	**42166**
2003	14000	23788	22361	1427	37788
2004	14000	23842	22411	1431	37842
2005	14000	24030	22588	1442	38030
2006	14000	24285	22828	1457	38285
2007	15500	24445	22978	1467	39945
2008	15500	21500	20210	1290	37000
2009	14000	18000	16920	1080	32000
2010	15500	21500	20210	1290	37000
2011	14000	18000	16920	1080	32000
2012	***15351***	***22011***	***20690***	***1321***	***37362***
2013	***14607***	***20800***	***19552***	***1248***	***35407***
2014	***13144***	***18404***	***17300***	***1104***	***31548***
2015	***14905***	***23997***	***22557***	***1440***	***38902***
2016	***15529***	***25781***	***24234***	***1547***	***41310***
2017	***15041***	***20612***	***19375***	***1237***	***35653***
2018	***16133***	***20055***	***18852***	***1203***	***36188***
2019	***15182***	***23234***	***21840***	***1394***	***38416***
2020	***15074***	***19634***	***18456***	***1178***	***34708***
2021	***15439***	***21969***	***20651***	***1318***	***37408***
2022	***13893***	***18948***	***17811***	***1137***	***32841***
2023	***14783***	***17662***	***16602***	***1060***	***32445***
2024	***15276***	***18907***	***17773***	***1134***	***34183***
2025	***17979***	***29026***	***27284***	***1742***	***47005***

Projection Realizations # 2; **"Dry" years: 72-86 (2012-2025)**					
Year	ET MB+North	Total Underflow SCAMA to TAMA	Inner Valley Underflow SCAMA to TAMA	Outside Underflow SCAMA to TAMA	Total ET + Underflow
1985	17000	26432	24846	1586	43432
1986	14000	25583	24048	1535	39583
1987	14000	24488	23019	1469	38488
1988	14000	23894	22460	1434	37894
1989	14000	23746	22321	1425	37746
1990	15500	24362	22900	1462	39862
1991	15500	24920	23425	1495	40420
1992	15500	24635	23157	1478	40135
1993	17000	25144	23635	1509	42144
1994	14000	26330	24750	1580	40330
1995	15500	27555	25902	1653	43055
1996	14000	26963	25345	1618	40963
1997	14000	25631	24093	1538	39631
1998	**16414**	**22150**	**20821**	**1329**	**38564**
1999	**15609**	**22880**	**21507**	**1373**	**38489**
2000	**15050**	**22590**	**21235**	**1355**	**37640**
2001	**16074**	**26380**	**24797**	**1583**	**42454**
2002	**16216**	**25950**	**24393**	**1557**	**42166**
2003	14000	23788	22361	1427	37788
2004	14000	23842	22411	1431	37842
2005	14000	24030	22588	1442	38030
2006	14000	24285	22828	1457	38285
2007	15500	24445	22978	1467	39945
2008	15500	21500	20210	1290	37000
2009	14000	18000	16920	1080	32000
2010	15500	21500	20210	1290	37000
2011	14000	18000	16920	1080	32000
2012	***13064***	***15677***	***14736***	***941***	***28741***
2013	***12773***	***15046***	***14143***	***903***	***27819***
2014	***12148***	***14629***	***13751***	***878***	***26777***
2015	***11556***	***14308***	***13450***	***858***	***25864***
2016	***11524***	***14040***	***13198***	***842***	***25564***
2017	***15283***	***25056***	***23553***	***1503***	***40339***
2018	***13680***	***19351***	***18190***	***1161***	***33031***
2019	***12561***	***16807***	***15799***	***1008***	***29368***
2020	***13188***	***15575***	***14641***	***935***	***28763***
2021	***12617***	***14887***	***13994***	***893***	***27504***

2022	***12462***	***14468***	***13600***	***868***	***26930***
2023	***13094***	***14631***	***13753***	***878***	***27725***
2024	***11511***	***14300***	***13442***	***858***	***25811***
2025	***11294***	***13971***	***13133***	***838***	***25265***

Year	ET: SCAMA-North plus Micro-Basins (Real#2: 1-15)	ET: SCAMA-North	ET: Micro-Basins
1985	17000	14000	3000
1986	14000	12000	2000
1987	14000	12000	2000
1988	14000	12000	2000
1989	14000	12000	2000
1990	15500	13000	2500
1991	15500	13000	2500
1992	15500	13000	2500
1993	17000	14000	3000
1994	14000	12000	2000
1995	15500	13000	2500
1996	14000	12000	2000
1997	14000	12000	2000
1998	**16414**	**13240**	**3173**
1999	**15609**	**12880**	**2809**
2000	**15050**	**12170**	**2880**
2001	**16074**	**14020**	**2054**
2002	**16216**	**12360**	**3856**
2003	14000	12000	2000
2004	14000	12000	2000
2005	14000	12000	2000
2006	14000	12000	2000
2007	15500	13000	2500
2008	15500	13000	2500
2009	14000	12000	2000
2010	15500	13000	2500
2011	14000	12000	2000
2012	***15351***	***12471.65***	***2879.042***
2013	***14607***	***11638.01***	***2968.913***
2014	***13144***	***10416.36***	***2727.931***
2015	***14905***	***11783.05***	***3122.227***
2016	***15529***	***12238.47***	***3290.963***

2017	***15041***	***11774.74***	***3266.377***
2018	***16133***	***12703.27***	***3429.903***
2019	***15182***	***11883.97***	***3298.028***
2020	***15074***	***11901.65***	***3172.495***
2021	***15439***	***12023.47***	***3415.87***
2022	***13893***	***10702.73***	***3190.303***
2023	***14783***	***11544.98***	***3238.318***
2024	***15276***	***11853.78***	***3421.915***
2025	***17979***	***14457.61***	***3521.341***

Year	ET: SCAMA-North plus Micro-Basins (Real#2: 72-86)	ET: SCAMA-North	ET: Micro-Basins
1985	17000	14000	3000
1986	14000	12000	2000
1987	14000	12000	2000
1988	14000	12000	2000
1989	14000	12000	2000
1990	15500	13000	2500
1991	15500	13000	2500
1992	15500	13000	2500
1993	17000	14000	3000
1994	14000	12000	2000
1995	15500	13000	2500
1996	14000	12000	2000
1997	14000	12000	2000
1998	**16414**	**13240**	**3173**
1999	**15609**	**12880**	**2809**
2000	**15050**	**12170**	**2880**
2001	**16074**	**14020**	**2054**
2002	**16216**	**12360**	**3856**
2003	14000	12000	2000
2004	14000	12000	2000
2005	14000	12000	2000
2006	14000	12000	2000
2007	15500	13000	2500
2008	15500	13000	2500
2009	14000	12000	2000
2010	15500	13000	2500
2011	14000	12000	2000
2012	***13064***	***10067***	***2997***
2013	***12773***	***9716***	***3058***
2014	***12148***	***9209***	***2940***
2015	***11556***	***8832***	***2724***
2016	***11524***	***8686***	***2837***
2017	***15283***	***11990***	***3293***
2018	***13680***	***10515***	***3166***
2019	***12561***	***9697***	***2864***
2020	***13188***	***10000***	***3188***
2021	***12617***	***9594***	***3023***
2022	***12462***	***9649***	***2813***
2023	***13094***	***9959***	***3135***
2024	***11511***	***8799***	***2712***
2025	***11294***	***8699***	***2595***

SCAMA-North (Base Model domain) Natural Inflows and Natural Outflows (Realization #2, years 1-15)							
Year	Natural Inflow				Natural Outflows		
	Under-flow	Net Stream	MFR Plus Tributary	**Total**	ET	Underflow	**Total**
1985	8000	54640	10250	72890	14000	26432	40432
1986	8000	16870	10250	35120	12000	25583	37583
1987	8000	16870	10250	35120	12000	24488	36488
1988	8000	16870	10250	35120	12000	23894	35894
1989	8000	16870	10250	35120	12000	23746	35746
1990	8000	35755	10250	54005	13000	24362	37362
1991	8000	35755	10250	54005	13000	24920	37920
1992	8000	35755	10250	54005	13000	24635	37635
1993	8000	54640	10250	72890	14000	25144	39144
1994	8000	16870	10250	35120	12000	26330	38330
1995	8000	35755	10250	54005	13000	27555	40555
1996	8000	16870	10250	35120	12000	26963	38963
1997	8000	16870	10250	35120	12000	25631	37631
1998	**8546**	**37870**	**10250**	**56666**	**13240**	**22150**	**35390**
1999	**8120**	**30610**	**10250**	**48980**	**12880**	**22880**	**35760**
2000	**8255**	**18270**	**10250**	**36775**	**12170**	**22590**	**34760**
2001	**10065**	**54640**	**10250**	**74955**	**14020**	**26380**	**40400**
2002	**7992**	**16870**	**10250**	**35112**	**12360**	**25950**	**38310**
2003	8000	16870	10250	35120	12000	23788	35788
2004	8000	16870	10250	35120	12000	23842	35842
2005	8000	16870	10250	35120	12000	24030	36030
2006	8000	35755	10250	54005	12000	24285	36285
2007	8000	35755	10250	54005	13000	24445	37445
2008	8000	35755	10250	54005	13000	21500	34500
2009	8000	16870	10250	35120	12000	18000	30000
2010	8000	35755	10250	54005	13000	21500	34500
2011	8000	16870	10250	35120	12000	18000	30000
2012	***7999***	***4597***	***10250***	***22846***	***12472***	***22011***	***34483***
2013	***8376***	***5382***	***10250***	***24008***	***11638***	***20800***	***32438***
2014	***7656***	***43666***	***10250***	***61572***	***10416***	***18404***	***28820***
2015	***8712***	***43342***	***10250***	***62304***	***11783***	***23997***	***35780***
2016	***9037***	***18369***	***10250***	***37656***	***12238***	***25781***	***38019***
2017	***8597***	***47089***	***10250***	***65936***	***11775***	***20612***	***32387***
2018	***9331***	***6160***	***10250***	***25741***	***12703***	***20055***	***32758***
2019	***9045***	***40539***	***10250***	***59834***	***11884***	***23234***	***35118***
2020	***8523***	***11213***	***10250***	***29986***	***11902***	***19634***	***31536***
2021	***9388***	***5497***	***10250***	***25135***	***12023***	***21969***	***33992***
2022	***8249***	***36388***	***10250***	***54887***	***10703***	***18948***	***29651***
2023	***8388***	***17519***	***10250***	***36157***	***11545***	***17662***	***29207***
2024	***9155***	***78533***	***10250***	***97938***	***11854***	***18907***	***30761***
2025	***10829***	***12392***	***10250***	***33471***	***14458***	***29026***	***43484***
Average	8348	27481	10250	46079	12367	23172	35540
Sim Average	**8751**	**27839**	**10250**	**46840**	**12214**	**22157**	**34371**
Streamflow recharge rates for un-calibrated periods (1985-1997; 2003-2011) divided into wet, average and dry years; underflow for un-calibrated periods (2008-2011) divided into wet, average and dry years. Underflow from SCAMA to TAMA for 1985-1997; 2003-2011 based on TAMA model. See text. Projected stream recharge (2012-2025), in italics, does not include effluent recharge. MFR and tributary recharge equal long-term rates.							

SCAMA-North (Base Model domain) Natural Inflows and Natural Outflows (Realization #2, years 72-86)							
Year	Natural Inflow				Natural Outflows		
	Under-flow	Net Stream	MFR Plus Tributary	**Total**	ET	Underflow	**Total**
1985	8000	54640	10250	72890	14000	26432	40432
1986	8000	16870	10250	35120	12000	25583	37583
1987	8000	16870	10250	35120	12000	24488	36488
1988	8000	16870	10250	35120	12000	23894	35894
1989	8000	16870	10250	35120	12000	23746	35746
1990	8000	35755	10250	54005	13000	24362	37362
1991	8000	35755	10250	54005	13000	24920	37920
1992	8000	35755	10250	54005	13000	24635	37635
1993	8000	54640	10250	72890	14000	25144	39144
1994	8000	16870	10250	35120	12000	26330	38330
1995	8000	35755	10250	54005	13000	27555	40555
1996	8000	16870	10250	35120	12000	26963	38963
1997	8000	16870	10250	35120	12000	25631	37631
1998	**8546**	**37870**	**10250**	**56666**	**13240**	**22150**	**35390**
1999	**8120**	**30610**	**10250**	**48980**	**12880**	**22880**	**35760**
2000	**8255**	**18270**	**10250**	**36775**	**12170**	**22590**	**34760**
2001	**10065**	**54640**	**10250**	**74955**	**14020**	**26380**	**40400**
2002	**7992**	**16870**	**10250**	**35112**	**12360**	**25950**	**38310**
2003	8000	16870	10250	35120	12000	23788	35788
2004	8000	16870	10250	35120	12000	23842	35842
2005	8000	16870	10250	35120	12000	24030	36030
2006	8000	35755	10250	54005	12000	24285	36285
2007	8000	35755	10250	54005	13000	24445	37445
2008	8000	35755	10250	54005	13000	21500	34500
2009	8000	16870	10250	35120	12000	18000	30000
2010	8000	35755	10250	54005	13000	21500	34500
2011	8000	16870	10250	35120	12000	18000	30000
2012	**8368**	***4892***	***10250***	***23510***	**10067**	***15677***	***25744***
2013	**7791**	***8528***	***10250***	***26569***	**9716**	***15046***	***24762***
2014	**7606**	***5296***	***10250***	***23152***	**9209**	***14629***	***23838***
2015	**7447**	***10364***	***10250***	***28061***	**8832**	***14308***	***23140***
2016	**7632**	***3383***	***10250***	***21265***	**8686**	***14040***	***22726***
2017	**10102**	***88090***	***10250***	***108442***	**11990**	***25056***	***37046***
2018	**8509**	***4999***	***10250***	***23758***	**10515**	***19351***	***29866***
2019	**7852**	***9896***	***10250***	***27998***	**9697**	***16807***	***26504***
2020	**8048**	***13859***	***10250***	***32157***	**10000**	***15575***	***25575***
2021	**8330**	***3848***	***10250***	***22428***	**9594**	***14887***	***24481***
2022	**8044**	***21921***	***10250***	***40215***	**9649**	***14468***	***24117***
2023	**8476**	***7858***	***10250***	***26584***	**9959**	***14631***	***24590***
2024	**7836**	***1400***	***10250***	***19486***	**8799**	***14300***	***23099***
2025	**7467**	***11206***	***10250***	***28923***	**8699**	***13971***	***22670***
Average	8109	23209	10250	41568	11587	21263	32850
Sim Average	**8236**	**18621**	**10250**	**37107**	**10531**	**18037**	**28567**
Streamflow recharge rates for un-calibrated periods (1985-1997; 2003-2011) divided into wet, average and dry years; underflow for un-calibrated periods (2008-2011) divided into wet, average and dry years. Underflow from SCAMA to TAMA for 1985-1997; 2003-2011 based on TAMA model. See text. Projected stream recharge (2012-2025), in italics, does not include effluent recharge. MFR and tributary recharge equal long-term rates.							

Micro-Basin (model domain) Natural Inflows and Natural Outflows (Realization #2, years 1-15)							
Year	Natural Inflow				Natural Outflows		
	Underflow	Net Stream	MFR	Total	ET	Underflow	Total
1985	1315	12000	1266	14581	3000	4000	7000
1986	1315	1000	1266	3581	2000	4000	6000
1987	1315	1000	1266	3581	2000	4000	6000
1988	1315	1000	1266	3581	2000	4000	6000
1989	1315	1000	1266	3581	2000	4000	6000
1990	1315	8000	1266	10581	2500	4000	6500
1991	1315	8000	1266	10581	2500	4000	6500
1992	1315	8000	1266	10581	2500	4000	6500
1993	1315	12000	1266	14581	3000	4000	7000
1994	1315	1000	1266	3581	2000	4000	6000
1995	1315	8000	1266	10581	2500	4000	6500
1996	1315	1000	1266	3581	2000	4000	6000
1997	1315	1000	1266	3581	2000	4000	6000
1998	**1315**	**7929**	**1266**	**10510**	**3173**	**4546**	**7719**
1999	**1315**	**6557**	**1266**	**9138**	**2809**	**4120**	**6929**
2000	**1315**	**2745**	**1266**	**5326**	**2880**	**4255**	**7135**
2001	**1315**	**6131**	**1266**	**8712**	**2054**	**6065**	**8119**
2002	**1315**	**956**	**1266**	**3537**	**3856**	**3992**	**7848**
2003	1315	1000	1266	3581	2000	4000	6000
2004	1315	1000	1266	3581	2000	4000	6000
2005	1315	1000	1266	3581	2000	4000	6000
2006	1315	1000	1266	3581	2000	4000	6000
2007	1315	1000	1266	3581	2500	4000	6500
2008	1315	1000	1266	3581	2500	4000	6500
2009	1315	1000	1266	3581	2000	4000	6000
2010	1315	8000	1266	10581	2500	4000	6500
2011	1315	1000	1266	3581	2000	4000	6000
2012	***1315***	***3721***	***1266***	***6534***	***2879***	***3999***	***6878***
2013	***1315***	***4364***	***1266***	***9504***	***2969***	***4376***	***7345***
2014	***1315***	***9443***	***1266***	***6853***	***2728***	***3656***	***6384***
2015	***1315***	***12533***	***1266***	***10893***	***3122***	***4712***	***7834***
2016	***1315***	***7683***	***1266***	***5328***	***3291***	***5037***	***8328***
2017	***1315***	***10553***	***1266***	***19186***	***3266***	***4597***	***7863***
2018	***1315***	***4733***	***1266***	***6638***	***3430***	***5331***	***8761***
2019	***1315***	***10267***	***1266***	***10550***	***3298***	***5045***	***8343***
2020	***1315***	***8038***	***1266***	***11658***	***3172***	***4523***	***7695***
2021	***1315***	***4391***	***1266***	***5684***	***3416***	***5388***	***8804***
2022	***1315***	***10715***	***1266***	***12781***	***3190***	***4249***	***7439***
2023	***1315***	***9257***	***1266***	***8964***	***3238***	***4388***	***7626***
2024	***1315***	***11111***	***1266***	***3725***	***3422***	***5155***	***8577***
2025	***1315***	***8122***	***1266***	***11584***	***3521***	***6829***	***10350***
Average	1315	5323	1266	7904	2664	4348	7012
Sim Average	**1315**	**8122**	**1266**	**9437**	**3521**	**4751**	**7893**
Streamflow recharge rates for un-calibrated periods (1985-1997; 2003-2011), may underestimate induced recharge - depending on aquifer storage space, application of pumpage. Note Sim Average = years 1998-2002; 2012-2025.							

Micro-Basin (Model domain) Natural Inflows and Natural Outflows (Realization #2, years 72-86)							
Year	Natural Inflow				Natural Outflows		
	Underflow	Net Stream	MFR	Total	ET	Underflow	Total
1985	1315	12000	1266	14581	3000	4000	7000
1986	1315	1000	1266	3581	2000	4000	6000
1987	1315	1000	1266	3581	2000	4000	6000
1988	1315	1000	1266	3581	2000	4000	6000
1989	1315	1000	1266	3581	2000	4000	6000
1990	1315	8000	1266	10581	2500	4000	6500
1991	1315	8000	1266	10581	2500	4000	6500
1992	1315	8000	1266	10581	2500	4000	6500
1993	1315	12000	1266	14581	3000	4000	7000
1994	1315	1000	1266	3581	2000	4000	6000
1995	1315	8000	1266	10581	2500	4000	6500
1996	1315	1000	1266	3581	2000	4000	6000
1997	1315	1000	1266	3581	2000	4000	6000
1998	1315	**7929**	1266	**10510**	**3173**	**4546**	**7719**
1999	1315	**6557**	1266	**9138**	**2809**	**4120**	**6929**
2000	1315	**2745**	1266	**5326**	**2880**	**4255**	**7135**
2001	1315	**6131**	1266	**8712**	**2054**	**6065**	**8119**
2002	1315	**956**	1266	**3537**	**3856**	**3992**	**7848**
2003	1315	1000	1266	3581	2000	4000	6000
2004	1315	1000	1266	3581	2000	4000	6000
2005	1315	1000	1266	3581	2000	4000	6000
2006	1315	1000	1266	3581	2000	4000	6000
2007	1315	1000	1266	3581	2500	4000	6500
2008	1315	1000	1266	3581	2500	4000	6500
2009	1315	1000	1266	3581	2000	4000	6000
2010	1315	8000	1266	10581	2500	4000	6500
2011	1315	1000	1266	3581	2000	4000	6000
2012	**1315**	**3953**	**1266**	**6534**	**2997**	**4368**	**7365**
2013	**1315**	**6923**	**1266**	**9504**	**3058**	**3790**	**6848**
2014	**1315**	**4272**	**1266**	**6853**	**2940**	**3604**	**6544**
2015	**1315**	**8312**	**1266**	**10893**	**2724**	**3444**	**6168**
2016	**1315**	**2747**	**1266**	**5328**	**2837**	**3628**	**6465**
2017	**1315**	**16605**	**1266**	**19186**	**3293**	**6097**	**9390**
2018	**1315**	**4057**	**1266**	**6638**	**3166**	**4503**	**7669**
2019	**1315**	**7969**	**1266**	**10550**	**2864**	**3845**	**6709**
2020	**1315**	**9077**	**1266**	**11658**	**3188**	**4040**	**7228**
2021	**1315**	**3103**	**1266**	**5684**	**3023**	**4321**	**7344**
2022	**1315**	**10200**	**1266**	**12781**	**2813**	**4034**	**6847**
2023	**1315**	**6383**	**1266**	**8964**	**3135**	**4465**	**7600**
2024	**1315**	**1144**	**1266**	**3725**	**2712**	**3824**	**6536**
2025	**1315**	**9003**	**1266**	**11584**	**2595**	**3454**	**6049**
Average	1315	4806	1266	*7387*	2576	4107	6683
Sim Average	**1315**	**6214**	**1266**	***8795***	**2953**	**4231**	**7184**
Streamflow recharge rates for un-calibrated periods (1985-1997; 2003-2011), may underestimate induced recharge – depending on aquifer storage space, application of pumpage. Note Sim Average = years 1998-2002; 2012-2025.							
Natural System Inflows using Projection years 72-86 (Real#2) for 2012-2025 (Unit AF/yr)							

	Inner Valleys							
	Micro-Basins	Northern Area		Outside				
	MB Stream IN	Northern Stream IN	N Tributary In	Outside MFR IN	Potrero In	From Mexico Into MB In	*Total IN*
1985	12000	54640	7383	5133	4000	1315	*84471*
1986	1000	16870	7383	5133	4000	1315	*35701*
1987	1000	16870	7383	5133	4000	1315	*35701*
1988	1000	16870	7383	5133	4000	1315	*35701*
1989	1000	16870	7383	5133	4000	1315	*35701*
1990	8000	35755	7383	5133	4000	1315	*61586*
1991	8000	35755	7383	5133	4000	1315	*61586*
1992	8000	35755	7383	5133	4000	1315	*61586*
1993	12000	54640	7383	5133	4000	1315	*84471*
1994	1000	16870	7383	5133	4000	1315	*35701*
1995	8000	35755	7383	5133	4000	1315	*61586*
1996	1000	16870	7383	5133	4000	1315	*35701*
1997	1000	16870	7383	5133	4000	1315	*35701*
1998	**7929**	**37870**	**7383**	**5133**	**4000**	**1315**	***63630***
1999	**6557**	**30610**	**7383**	**5133**	**4000**	**1315**	***54998***
2000	**2745**	**18270**	**7383**	**5133**	**4000**	**1315**	***38846***
2001	**6131**	**54640**	**7383**	**5133**	**4000**	**1315**	***78602***
2002	**956**	**16870**	**7383**	**5133**	**4000**	**1315**	***35657***
2003	1000	16870	7383	5133	4000	1315	*35701*
2004	1000	16870	7383	5133	4000	1315	*35701*
2005	1000	16870	7383	5133	4000	1315	*35701*
2006	1000	35755	7383	5133	4000	1315	*54586*
2007	1000	35755	7383	5133	4000	1315	*54586*
2008	1000	35755	7383	5133	4000	1315	*54586*
2009	1000	16870	7383	5133	4000	1315	*35701*
2010	8000	35755	7383	5133	4000	1315	*61586*
2011	1000	16870	7383	5133	4000	1315	*35701*
2012	***3953***	***4892***	***7383***	***5133***	***4000***	**1315**	**26676**
2013	***6923***	***8528***	***7383***	***5133***	***4000***	**1315**	**33282**
2014	***4272***	***5296***	***7383***	***5133***	***4000***	**1315**	**27399**
2015	***8312***	***10364***	***7383***	***5133***	***4000***	**1315**	**36507**
2016	***2747***	***3383***	***7383***	***5133***	***4000***	**1315**	**23961**
2017	***16605***	***88090***	***7383***	***5133***	***4000***	**1315**	**122526**
2018	***4057***	***4999***	***7383***	***5133***	***4000***	**1315**	**26887**
2019	***7969***	***9896***	***7383***	***5133***	***4000***	**1315**	**35696**
2020	***9077***	***13859***	***7383***	***5133***	***4000***	**1315**	**40767**
2021	***3103***	***3848***	***7383***	***5133***	***4000***	**1315**	**24782**
2022	***10200***	***21921***	***7383***	***5133***	***4000***	**1315**	**49952**
2023	***6383***	***7858***	***7383***	***5133***	***4000***	**1315**	**32072**
2024	***1144***	***1400***	***7383***	***5133***	***4000***	**1315**	**20375**
2025	***9003***	***11206***	***7383***	***5133***	***4000***	**1315**	**38040**

(Note – the updated memo may have slightly different rates than the October 18th, 2010 memo below.)

ADWR Internal Memorandum

To: **Pam Nagel**

From: **Keith Nelson**

Date: **October 18th, 2010**

Subject: **Net Stream Recharge Along Santa Cruz River, Santa Cruz AMA**

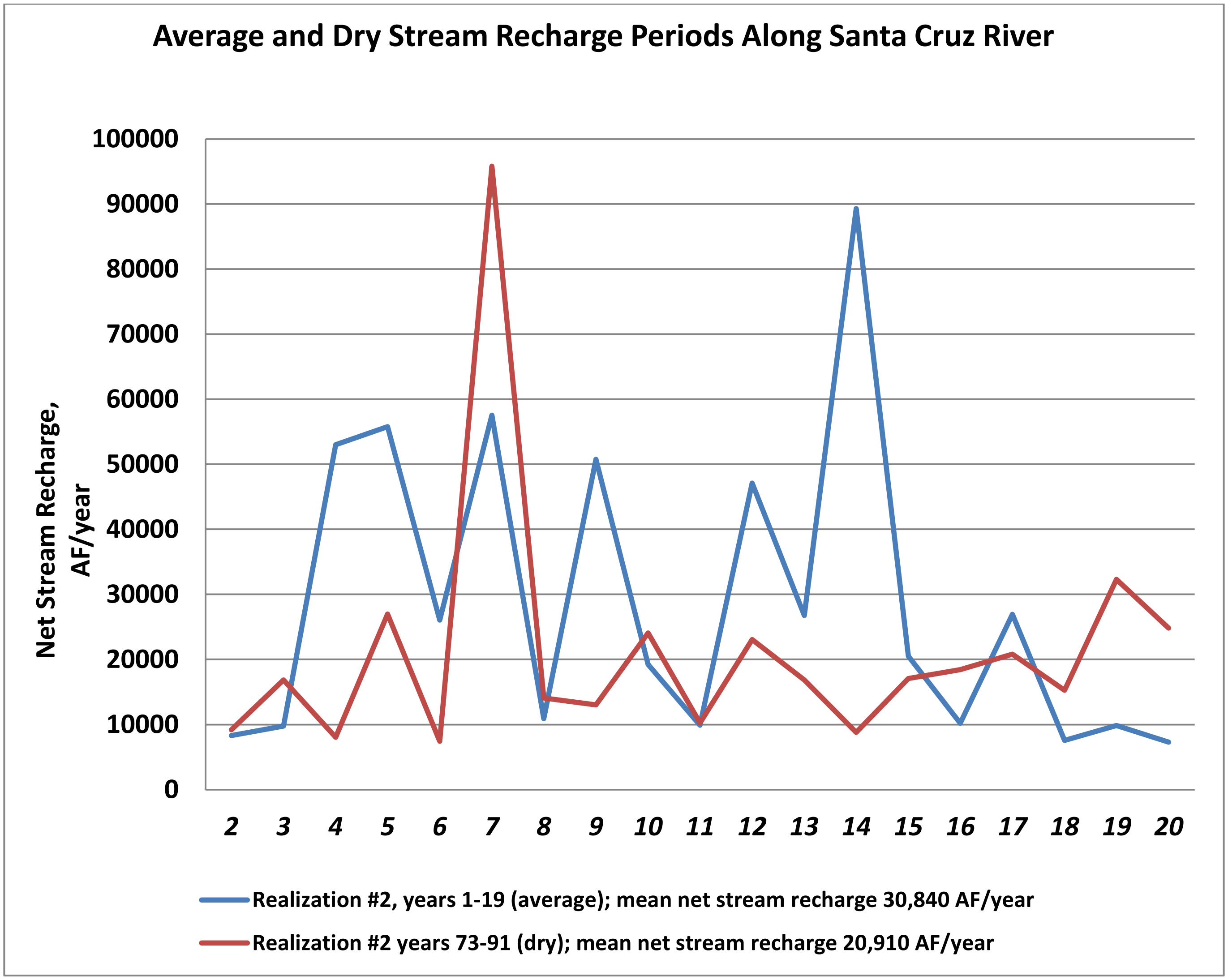
The purpose of this memo is to describe and present simulated, net streamflow recharge rates along the Santa Cruz River. As requested, two different 19-years intervals were examined including one “average” recharge period, and one relatively “dry” period.

For this analysis, streamflow realization #2 was examined over two different time intervals: “Average” streamflow recharge conditions were represented by years 1-19, while “dry” streamflow recharge conditions were represented by simulation years 72-90. Note that streamflow realization #2 is one of 100, 100-year statistically independent, equally-likely streamflow realizations, and the “average” and “dry” periods were subjectively selected. For additional details and assumptions associated with the groundwater flow models and the stochastic streamflow model see ADWR modeling report’s #14, #15 and #21 and associated references, i.e., Shamir et al (2005). Note that streamflow realization #2 is also discussed, analyzed and presented in model report #21 for reference.

Note that streamflow recharge, as simulated herein, operates along a head-dependant boundary. As a result stresses and model conditions assigned to the simulated groundwater flow system may impact groundwater recharge and groundwater discharge rates over space and time. For these scenarios “basecase” and “base” model conditions/assumptions, including all initial conditions, ET parameter distributions, stream-aquifer boundary conditions, pumping rates, and lateral boundary conditions - as defined in model report #21 - were applied. Although evaluating “average” and “dry” conditions over a continuous 19-year period does not provide the degree of statistical rigor as compared to evaluating the collective ensemble, it nonetheless demonstrates the variability in streamflow recharge in the hydrologic system.

Results show that the mean “average” and “dry” streamflow recharge rates are 30,838 and 20,914 acre-feet/year, respectively. The standard deviation associated with “average” and “dry” streamflow recharge rates for the 19-year period are 23,150 and 19,347 acre-feet/year, respectively.

"Average" Stream Recharge, years 1-19		"Dry" Stream Recharge, years 72-90	
Simulation Years	Recharge along Santa Cruz River (AF/year)	Simulation Years	Recharge Along Santa Cruz River (AF/year)
1	46498	72	19089
2	8318	73	9166
3	9745	74	16839
4	53006	75	8041
5	55775	76	26968
6	26048	77	7439
7	57549	78	95822
8	10889	79	14076
9	50742	80	12999
10	19250	81	24059
11	9888	82	10231
12	47095	83	23064
13	26775	84	16860
14	89313	85	8794
15	20513	86	17074
16	10211	87	18444
17	26917	88	20826
18	7535	89	15245
19	9825	90	32330
Mean	**30,836**	**Mean**	**20,914**
Standard deviation	**23,150**	**Standard deviation**	**19,347**
Median	**26,048**	**Median**	**16,860**
Maximum	**89,313**	**Maximum**	**95,822**
Minimum	**7,535**	**Minimum**	**7,439**


Average and Dry Stream Recharge Periods Along Santa Cruz River
Net Stream Recharge, AF/year
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Realization #2, years 1-19 (average); mean net stream recharge 30,840 AF/year
Realization #2 years 73-91 (dry); mean net stream recharge 20,910 AF/year

Appendix 2 Incidental Recharge SCAMA

SCAMA - SURVEYED IGFRS - EFFICIENCIES AND INCIDENTAL RECHARGE - 1994

Right#	Allotment	Irrigation Acres	Irrigation Method	Crop	Crop IR	Irr. Acres w/ Double Cropped	Irr. Acres w/o Double Cropped	Total IR	Water Use	%Eff.	Inc. Rechg. at 100%	Inc. Rechg. at 80%	Weighted % Efficiency
100054	166.6	35	slope	P.Pasture	3.95	22.5	35	118.025	80.15	1.4725515			0.0310864
				Bermuda	2.7	7.5							
				Grapes	1.78	5							
102086	126.13	30.8	slope	P.Pasture	3.95	30	30	118.5	129.9	0.9122402	11.40	9.12	0.0312115
Critchlow													
102961	521.65	116.5	slope	Bermuda	2.7	36.5	73	146.365	386.78	0.3784193	240.42	192.33	0.0385508
Parker				N.Pasture	1.31	36.5							
103105	182.16	47	slope	Bermuda	2.7	40	40	108	75.05	1.4390406			0.0284459
Donau													
103495	653.66	98	slope	Bermuda	2.7	80	90	366.8	628.13	0.4320762	261.33	209.06	0.0966107
Troyer				P.Pasture	3.95	10							
				Winter Mix	1.59	70							
103795	317.85	70	slope	Alfalfa	3.78	32.5	65	242.4	312.69	0.7752087	70.29	56.23	0.0638453
Reeve				Bermuda	2.7	32.5							
				Winter Mix	1.59	20							
103908	618.52	195	slope	P.Pasture	3.95	10	80	415.4	425.97	0.975186	10.57	8.46	0.1094114
Rowley				Alfalfa	3.78	70							
				Winter MIx	1.59	70							
104889	132.03	28	slope	Alfalfa	3.78	10	27	104.02	92.2	1.1281996			0.0273976
Clark				Bermuda	2.7	10							
				S.Grass	1.06	7							
				Winter Mix	1.59	20							
105926	239.61	52	slope	Vegetables	1.78	12	12	29.31	52.18	0.5617095	22.87	18.30	0.0077199
Lowe				Winter MIx	1.59	5							
105951	1456.21	312	slope	Vegetables	1.78	25	102	166.93	349.69	0.4773657	182.76	146.21	0.0439674
Crebbs				Winter Mix	1.59	77							
106682	143.91	44	slope	Bermuda	2.7	22	44	142.56	131.16	1.0869167	-11.40	-9.12	0.0375486
Ellinwood				Alfalfa	3.78	22							
109607	323.56	50	slope	Sorghum	1.73	50	50	166	283.89	0.5847335	117.89	94.31	0.0437224
Sedgewick				Winter Mix	1.59	50							
111260	306.36	72	sprinkler	P.Pasture	3.95	69	69	272.55	260.11	1.0478259			0.0717864
Baffert													
112022	393.47	77	slope	Bermuda	2.7	50	50	135	143.2	0.9427374	8.20	6.56	0.0355574
Karam													
112732	307.53	68	slope	S. Grass	1.06	68	68	180.2	181.05	0.9953052	0.85	0.68	0.0474625
Peachy				Winter Mix	1.59	68							
112967	212.56	38	slope	Sorghum	1.73	38	38	126.16	264.53	0.4769213	138.37	110.70	0.033229
Sedgewick				Winter Mix	1.59	38							

Right#	Allotment	Irrigation Acres	Irrigation Method	Crop	Crop IR	Irr. Acres w/ Double Cropped	Irr. Acres w/o Double Cropped	Total IR	Water Use	%Eff.	Inc. Rechg. at 100%	Inc. Rechg. at 80%	Weighted % Efficiency
TOTALS EXC. RIO RICO	6101.81	1021.3				1214	873	2838.22	3796.68	0.7475531	1053.55	842.84	0.75
112480	6433.31	1164	slope	Alfalfa	3.78	700	735	3821.3	9918	0.3852894	6096.70	4877.36	
RR (Bales)				Winter Mix	1.59	700							
112480	partial	90	slope	Vegetables	1.78	35							
RR (LaMirage)													
TOTAL EXC RIO RICO	6101.81	1021.3				1214	873	2838.22	3796.68	0.7475531	1053.545	842.836	
TOTALS FOR RIO RICO	6433.31	1254				1435	735	3821.3	9918	0.3852894	6096.7	4877.36	
TOTAL 17 Surveyed	12535.12	2275.3				2649	1608	6659.52	13714.68	0.485576	7150.245	5720.196	
9 Other IGFRs	7219.95	1411				819.4	497.5	1914.9	1864.7	1.0269212	225.4	180.4	
26 Rights Surveyed	19755.07	3686.3				3468.4	2105.5	8574.42	15579.38	0.5503698	7375.645	5900.596	
TOTALS FOR ALL IGFRS	26653	*(5469)							15889				

Total water use for all active IGFRs for 1994 = 15,889.26 AF

Total 63 active large rights, 17 rights were surveyed for data, 20 rights had no water use in 1994

Total Double cropped acres (26 rights): (3468.4-2105.5) = 1,362.9 Acres

Land Utilization SCAMA (17 surveyed):= (1608/2275.3) = 70.7%

%eff of SCAMA (17 surveyed exc Rio Rico): 2838.22/3796.68= 75%

%eff of SCAMA (17 surveyed): 6659.52/13714.68 = 49%

%eff of the 26 rights: (8574.42/15579.38)= 55%

SUMMARY INFORMATION:

Total SCAMA (17 Surveyed)	Acres	% acre	IR	Tot IR	% H2O	(Exc Rio Rico)	Acres	% acre	IR	Tot IR	%H2O
P.Pasture	141.5	5.3%	3.95	558.925	8.4%	P.Pasture	141.5	11.7%	3.95	558.925	19.7%
Bermuda	278.5	10.5%	2.7	751.95	11.3%	Bermuda	278.5	22.9%	2.7	751.95	26.5%
Winter Mix	1118	42.2%	1.59	1777.62	26.7%	Winter Mix	418	34.4%	1.59	664.62	23.4%
Alfalfa	834.5	31.5%	3.78	3154.41	47.4%	Alfalfa	134.5	11.1%	3.78	508.41	17.9%
Vegetables	72	2.7%	1.78	128.16	1.9%	Vegetables	37	3.0%	1.78	65.86	2.3%
Sudan	75	2.8%	1.06	79.5	1.2%	Sudan	75	6.2%	1.06	79.5	2.8%
Sorghum	88	3.3%	1.73	152.24	2.3%	Sorghum	88	7.2%	1.73	152.24	5.4%
Native Pasture	36.5	1.4%	1.31	47.815	0.7%	Native Pasture	36.5	3.0%	1.31	47.815	1.7%
Grapes	5	0.2%	1.78	8.9	0.1%	Grapes	5	0.4%	1.78	8.9	0.3%
Total	2649	100.0%	* 2.511	6659.52	100.0%	Total	1214	100.0%	* 2.337	2838.22	100.0%

Total SCAMA (26 surveyed)	Acres	% acre	IR	Tot IR	% H2O	(Exc Rio Rico)	Acres	% acre	IR	Tot IR	%H2O
P.Pasture	237.4	6.8%	3.95	937.73	10.9%	P.Pasture	237.4	11.7%	3.95	937.73	19.7%
Bermuda	466.1	13.4%	2.7	1258.47	14.7%	Bermuda	466.1	22.9%	2.7	1258.47	26.5%
Winter Mix	1400.2	40.4%	1.59	2226.318	26.0%	Winter Mix	700.2	34.4%	1.59	1113.318	23.4%
Alfalfa	925.4	26.7%	3.78	3498.012	40.8%	Alfalfa	225.4	11.1%	3.78	852.012	17.9%
Vegetables	96.6	2.8%	1.78	171.948	2.0%	Vegetables	61.6	3.0%	1.78	109.648	2.3%
Sudan	125.8	3.6%	1.06	133.348	1.6%	Sudan	125.8	6.2%	1.06	133.348	2.8%
Sorghum	147	4.2%	1.73	254.31	3.0%	Sorghum	147	7.2%	1.73	254.31	5.3%
Native Pasture	61.1	1.8%	1.31	80.041	0.9%	Native Pasture	61.1	3.0%	1.31	80.041	1.7%
Grapes	8.3	0.2%	1.78	14.774	0.2%	Grapes	8.3	0.4%	1.78	14.774	0.3%
Total	3467.9	100.0%	* 2.469	8574.951	100.0%	Total	2032.9	100.0%	* 2.337	4753.651	100.0%

* Weighted, per acre average IR

Appendix 3 Assumptions Used for Large Municipal Providers

Category	Scenario
Demand	**SCENARIO ONE**: The Department of Commerce and Pima Association of Governments projections were used. The large provider projection was broken out of the total AMA projection by maintaining large providers at the same percent of the total AMA population that they were in 2006. This large provider sum was then broken down to each large provider by adjusting each provider's population down by the percent that the Baseline Scenario One large provider population projection sum is less than the Baseline Scenario Two large provider population projection sum for each year, 2007-2025. The population for each large provider x the TMP conservation requirement for each provider equals large provider demand.
	SCENARIO TWO: Statistical trend lines for each provider x the 2000-2006 average GPCD for each provider equals large provider demand.
	SCENARIO THREE: The 2000-2006 average number of people added to the AMA each year was used to develop an overall AMA population. Then the percent difference between the AMA total Baseline Scenario Three and the AMA total Baseline Scenario Two projection was multiplied by each large provider's projected population in the Baseline Scenario Two projection to result in a Baseline Scenario Three population for each provider. The Baseline Scenario Three population for each provider x the 2000-2006 average GPCD for each provider equals large provider demand.
Supply	Nearly 100% water withdrawn from wells, except for a few direct use reclaimed water facilities and a new development using a portion of surface water. For purposes of this Assessment, the assumption is made that supplies are generally 100% water withdrawn from wells.

Appendix 4 Assumptions Used for Small Municipal Providers

Category	Scenario
Demand	**SCENARIO ONE:** The Department of Commerce and Pima Association of Governments projections were used. Small providers maintained the same percent of the AMA population that they were in 2006. The Baseline Scenario One small provider population projection x 2000-2006 average GPCD for small providers equals small provider demand.
	SCENARIO TWO: The 1985-1999 average growth rate was used to project small provider population x 2000-2006 average GPCD for small providers equals small provider demand.
	SCENARIO THREE: The 2000-2006 average number of people added to the AMA each year was used to develop an overall AMA population. Then the percent difference between the AMA total Baseline Scenario Three and the AMA total Baseline Scenario Two projection was multiplied by total small provider population in the Baseline Scenario Two projection to result in a Baseline Scenario Three population for small providers. The Baseline Scenario Three population for small providers x the 1985-2006 average GPCD for small providers equals small provider demand.
Supply	100% water withdrawn from wells.

Appendix 5 Assumptions Used for Exempt Well Users

Category	Scenario
Demand	**SCENARIO ONE**: Exempt well population is the remainder of the Department of Commerce and Pima Association of Governments total AMA population after large provider and small provider projections are subtracted from it. The exempt well population, the TMP single family models for new development and the 2000 Census average persons per household for Santa Cruz County were used to project exempt well demand for each year, 2007-2025.
	SCENARIO TWO: Exempt well population was projected by using the 2000-2006 average growth rate for Santa Cruz County. The projected exempt well population, the TMP single family models for new development, and the 2000 Census average persons per household for Santa Cruz County were used to calculate projected exempt well demand for each year, 2007-2025.
	SCENARIO THREE: The 2000-2006 average number of people added to the AMA each year was used to develop an overall AMA population. Then the percent difference between the AMA total Baseline Scenario Three and the AMA total Baseline Scenario Two projection was multiplied by exempt well projected population in Baseline Scenario Two to result in a Baseline Scenario Three exempt well population projection. The exempt well population, the TMP single family models for new development, and the 2000 Census average persons per household for Santa Cruz County were used to calculate projected exempt well demand for each year, 2007-2025.
Supply	100% water withdrawn from wells.

Appendix 6 Assumptions Used for Industrial Demand and Supply Projections

Category	Scenario
Demand	**SCENARIO ONE**: For golf, assumed both courses use less than their maximum conservation limits; no new courses built. For sand and gravel, assumed current demand would decline to zero in 2015 as demand is met with 100% reclaimed water. For other uses, historical average was held constant.
	SCENARIO TWO: For golf, same as Scenario One. For sand and gravel, historical average held constant. For other uses, same as Scenario One.
	SCENARIO THREE: For golf, both courses use their full allotments. No new courses built. For sand and gravel maximum of total allotments for two sand and gravel facilities are used. For other uses, same as Scenario One.
Supply	100% water withdrawn from wells.

Appendix 7 Assumptions Used for Agricultural Projections

	Category	Scenario	Assumption
Demand Factors	Maximum GW Allotment (>10 acres)	**ALL**	Assumptions based on AMA staff review of individual IGFRs
Demand	IGFRs > 10 AC	**ONE**	Average of Historical use minus one standard deviation, with reductions due to AMA Staff review of individual IGFRs.
		TWO	Average of Historical use, with reductions due to AMA Staff review of individual IGFRs.
		THREE	Average of Historical use plus one standard deviation, with reductions due to AMA Staff review of individual IGFRs.
	IGFRs < 10 AC	**ALL**	Not projected, since use wasn't reported after 1993. This demand component is negligible.
	Canal & other losses	**ALL**	N/A
Supply		**ALL**	100%water withdrawn from wells
Incidental Recharge		**ALL**	25% of total demand.