CHAPTER

2

Overview of Water Resources

2.1 INTRODUCTION

The Santa Cruz Active Management Area (AMA) covers 716 square miles in the Upper Santa Cruz Valley River Basin. It is principally concentrated around a 45-mile reach of the Santa Cruz River from the international border to the Continental gaging station, located a few miles north of the Santa Cruz/Pima County line. The drainage area of the Santa Cruz River upstream from Continental is about 1,680 square miles. From its headwaters in the San Rafael Valley, the river flows southward into Mexico, flows for 25 miles through Mexico, bends northward, and enters Arizona again five miles east of Nogales. Surface water flow within the Santa Cruz AMA is extremely variable (Putman, et al., 1983). The river can be generally characterized as ephemeral or intermittent with some perennial reaches. An effluent-dominated perennial reach exists immediately downstream from the Nogales International Wastewater Treatment Plant (NIWWTP).

Major tributaries which feed the Santa Cruz River within the Santa Cruz AMA include Nogales Wash, Sonoita Creek, and Sopori Wash, as well as Peck, Agua Fria, and Josephine Canyons. Sonoita Creek and Nogales Wash are the largest tributaries to the Santa Cruz River in the AMA.

The Santa Cruz AMA watershed has been subject to dry and wet climatic cycles. The longest dry period included several years up to 1954. Figures 2-1 and 2-2 show the long-term annual precipitation at Tumacacori, Arizona and Nogales, Arizona, respectively. In Tumacacori, the average annual rainfall from 1948 to 1995 was 15.7 inches. Nogales averaged 18.4 inches of precipitation from 1953-1995. Fluctuations in wet and dry cycles have generally occurred over 30 year intervals. The shallow depth of its aquifers and the high transmissivity of the alluvium make many portions of the Younger Alluvium of the Santa Cruz River responsive to precipitation events and susceptible to droughts. Figure 2-3 graphs the surface flow at the United States Geological Survey (USGS) streamgage at Buena Vista at the southern edge of the AMA and water level changes at nearby Santa Fe Ranch and the City of Nogales Highway 82 wellfield.

FIGURE 2-1
SANTA CRUZ ACTIVE MANAGEMENT AREA

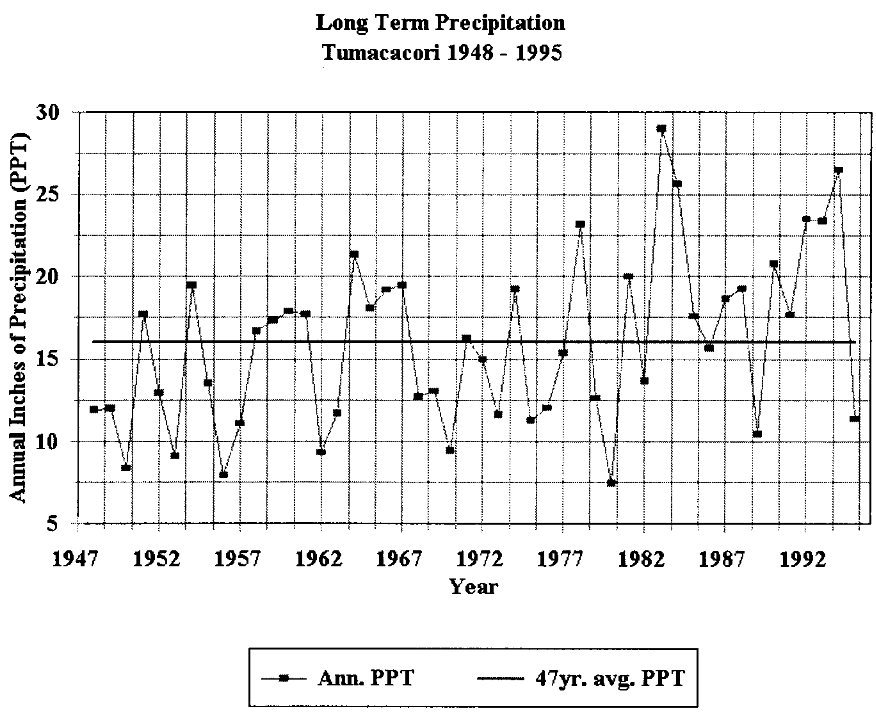
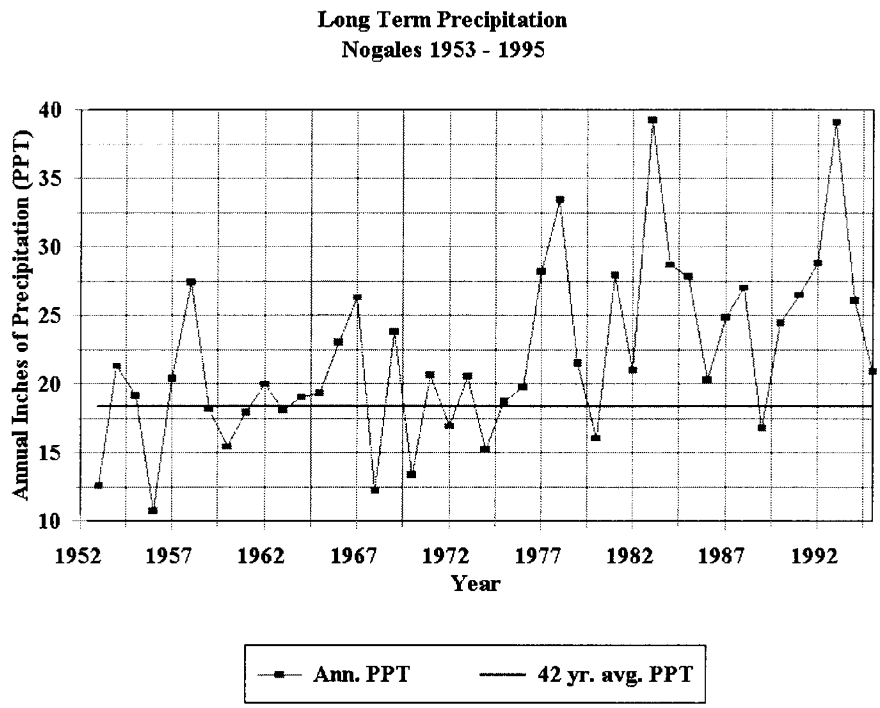


FIGURE 2-2
SANTA CRUZ ACTIVE MANAGEMENT AREA



More detailed information on factors affecting water supply conditions in the AMA and a description of available supplies are discussed in the following sections:

- Data sources
- Geologic and aquifer characteristics
- Hydrologic conditions
- Hydrologic analysis
- Availability and utilization of renewable supplies

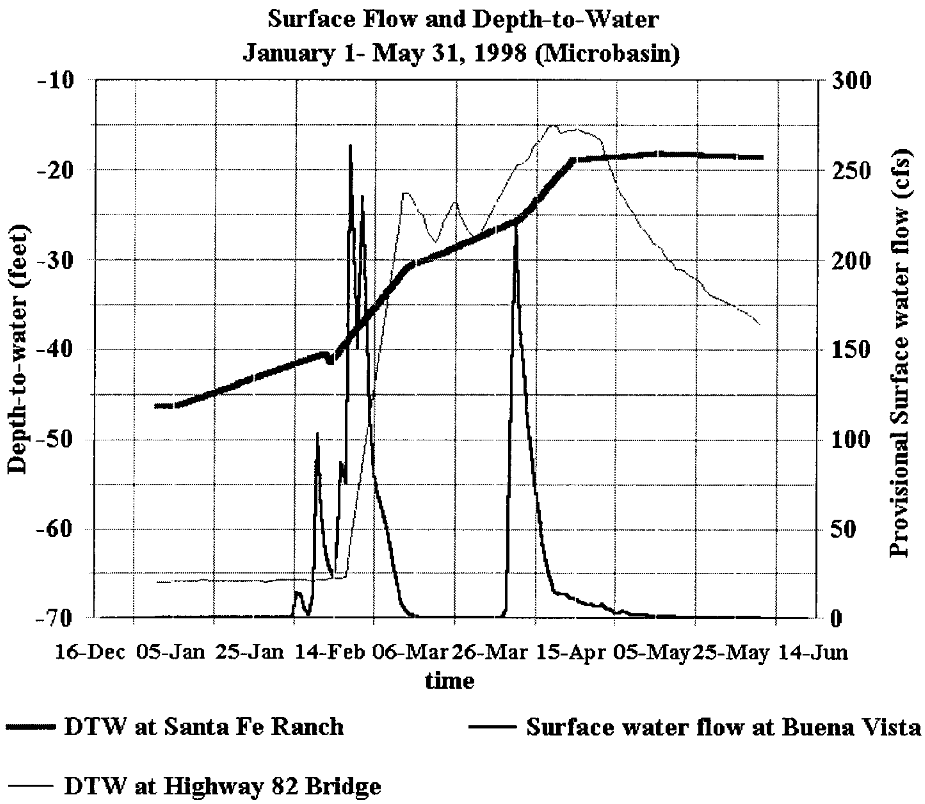
2.2 DATA SOURCES

Data sources describing hydrologic conditions in the AMA are available from the Arizona Department of Water Resources (Department), other state agencies, federal agencies, and water utilities. Some of the major data sources are described below.

2.2.1 Arizona Department of Water Resources Basic Data and Hydrology Divisions

Beginning in 1997, the Department started collecting monthly streamflow measurements along the Santa Cruz River. Water levels are also measured monthly at about 40 index well locations. Data collected is being used in developing a hydrologic computer model for the Santa Cruz AMA. Continuous, regular monitoring provides information on seasonal change that cannot be easily or accurately deduced from less frequent data gathering. The continuation of monitoring activities such as these will ensure that the Santa Cruz AMA has current information available to support its water management efforts.

FIGURE 2-3
SANTA CRUZ ACTIVE MANAGEMENT AREA



2.2.2 Arizona Department of Water Resources Computer Model

Dual water management goals guide the Santa Cruz AMA. Safe-yield conditions must be maintained, and long-term declines in local water tables must be prevented. In order to evaluate the achievement of these goals, a very good technical understanding of the hydrologic system of the basin is needed. The Department's Hydrology Division is developing a regional hydrologic model that will provide input in understanding and managing the water resources of the Santa Cruz AMA.

The Santa Cruz AMA hydrologic model will be used as a tool to help explore water management alternatives for the Santa Cruz AMA for the third management period (2000-2010). The model will support the Assured Water Supply Program (AWS Program) by helping to identify the physical availability of water resources. The model may also address issues such as the effect of diminished availability of effluent on the riparian system and other water users downstream of the NIWWTP.

The hydrologic model of the Santa Cruz AMA will provide:

- a regional look at the hydrologic system
- a tool to integrate the effects of numerous stresses on the hydrologic system
- a tool to explore alternative management concepts
- a tool to educate Department staff and the public
- a database containing hydrologic information to support other studies, and programs (AWS)

Questions that the model would be expected to help answer are:

- What effect will various levels of municipal and industrial growth have on the goals of the AMA? How much growth can occur under safe-yield conditions?
- What effect would retirement of agricultural land have on the maintenance of AMA goals?
- Will recharge programs be effective in mitigating undesired effects due to water withdrawals? Would such programs allow higher levels of development? If so, where would recharge projects be useful?
- What are the probable effects of a prolonged drought on Santa Cruz AMA hydrologic conditions?
- Do opportunities exist for a better use of the binational watershed?

It is not expected that the model will provide sufficient spatial or temporal definition to be able to answer questions on the effect of small, single wells due to the regional nature of the model and the lack of data. The Department does not have the authority to collect water withdrawal information from wells with pump capacities of 35 gallons per minute (gpm) or less.

The Santa Cruz AMA hydrologic modeling process began in 1997 with Phase 1, data collection and review of prior studies. A groundwater flow model has been built using the USGS model code MODFLOW. Currently, the model is in the calibration phase where the goal is to replicate historical water level conditions. Once the model has been calibrated it will be used to evaluate future water management scenarios.

The model will address questions concerning meeting the AMA water management goals. The model will also assist in understanding the consequences of effluent recharge downstream from Rio Rico, interactions between continued water demand, varying river flows, the changing riparian system, and the effects of future growth on the hydrologic system.

The hydrologic system of the basin is heavily dependent on the highly variable surface flow of the Santa Cruz River and larger tributaries such as Sonoita Creek and Sopori Wash. These types of hydrologic conditions call for a model that deals well with seasonality and annual fluctuations in total precipitation as well as the intensity and duration of precipitation, along with interactions between different hydrologic segments and alluvial components.

2.2.3 Other Agencies and Reports

The Santa Cruz AMA model will incorporate data provided by other agencies as well as data collected and analyzed specifically for the model. Government entities in Mexico have graciously provided data on the Santa Cruz River watershed across the International Boundary. Additional data has been collected by the Department within Santa Cruz county to assist in the technical analysis necessary for managing water resources in the AMA.

The Department has also conducted a study to examine the historic riparian system of the Santa Cruz River. Studies of effluent recharge and riparian use are important to properly understand the hydrology of the Santa Cruz AMA because effluent recharge comprises a large and relatively consistent input to the hydrologic system and because the riparian habitat is the largest water demand in the basin. In addition, geologic studies by the Department will better define the hydrogeology of the Santa Cruz AMA.

2.3 GEOLOGIC AND AQUIFER CHARACTERISTICS

Basin-fill sediments along the Santa Cruz River north of the City of Nogales to Amado form three aquifer units. Listed in ascending order, they are: the Nogales Formation, the Older Alluvium, and the Younger Alluvium. Both alluvial units are generally unconfined, hydraulically connected, and yield water to wells, although the Older Alluvium aquifer does exhibit semi-confined and confined conditions in some places, most notably in Potrero Creek. The Nogales Formation is not generally considered an aquifer, although local exceptions may occur. It is better referred to as "hydrologic bedrock." Figure 2-4 displays the geologic units which are located in the Santa Cruz AMA.

2.3.1 The Nogales Formation

Although few wells penetrate the Nogales Formation, it is believed to underlie the Older Alluvium in many parts of the Santa Cruz AMA. The Nogales Formation generally underlies the basin and is composed of well-consolidated conglomerates with some interbedded volcanic tufts and is estimated to be at least 5,000 feet thick (Simons, 1974). The Nogales Formation generally has poor water bearing characteristics and has not been widely developed as a source of water. Groundwater occurs primarily in fracture zones and unconsolidated layers within the formation. Well yields of several hundred gallons per minute have been obtained from this formation; however, average yields are less than 30 gpm.

2.3.2 The Older Alluvium

The Older Alluvium consists of locally stratified lenses of boulders, gravel, sand, silt, and clays with cemented zones or caliche (Anderson, 1956; Schwalen and Shaw, 1957; Putman, et al., 1983). Although this basin-fill alluvium stores large amounts of water and is the most extensive geologic unit within the Santa Cruz AMA, its transmissivity is generally low and well yields are often small. The thickness of the Older Alluvium in the Santa Cruz AMA ranges from a few feet along the mountain ranges to about 1,000 feet or more in the north-central portion of the AMA.

2.3.3 The Younger Alluvium

The Younger Alluvium, sometimes referred to as the floodplain or stream alluvium, is present along the Santa Cruz River and some of its larger tributaries. Depth ranges from 40 to 150 feet and floodplain width varies from about 0.3 miles at the border with Mexico to 2.5 miles near the northern boundary of the Santa Cruz AMA. It is comprised of unconsolidated sands, gravels, and boulders and is usually more coarse grained than the Older Alluvium (Schwalen and Shaw, 1957). These stream channel and floodplain deposits have large hydraulic conductivities and, consequently, are the most productive and widely used aquifer in the region. Some wells tapping this aquifer yield over 1,000 gpm.

A majority of the water withdrawn from wells in the Santa Cruz AMA originates from the Younger Alluvium. Generally, the thickness and width of the Younger Alluvium increases in a northerly direction following the path of the Santa Cruz River.

2.4 HYDROLOGIC CONDITIONS

Hydrologic maps showing water level changes over different periods of time generally provide insights into trends in water storage and water level recovery. The highly seasonal nature of surface water flow, the high transmissivity of the Younger Alluvium of the Santa Cruz River, and the discharge of effluent from the NIWWTP complicate the analysis of water level change and make water level change maps less useful in the Santa Cruz River alluvium. To assist Santa Cruz AMA water management efforts, the hydrologic maps included show the location of wells with a long history of water level measurement. Hydrographs of these wells showing seasonality and annual fluctuations in water levels associated with natural components of the system follow the map and provide information on long and short-term water level trends. The hydrographs provide useful information about past and present hydrologic conditions in the Santa Cruz AMA. Figure 2-8 shows the locations of hydrograph data.

SANTA CRUZ AMA

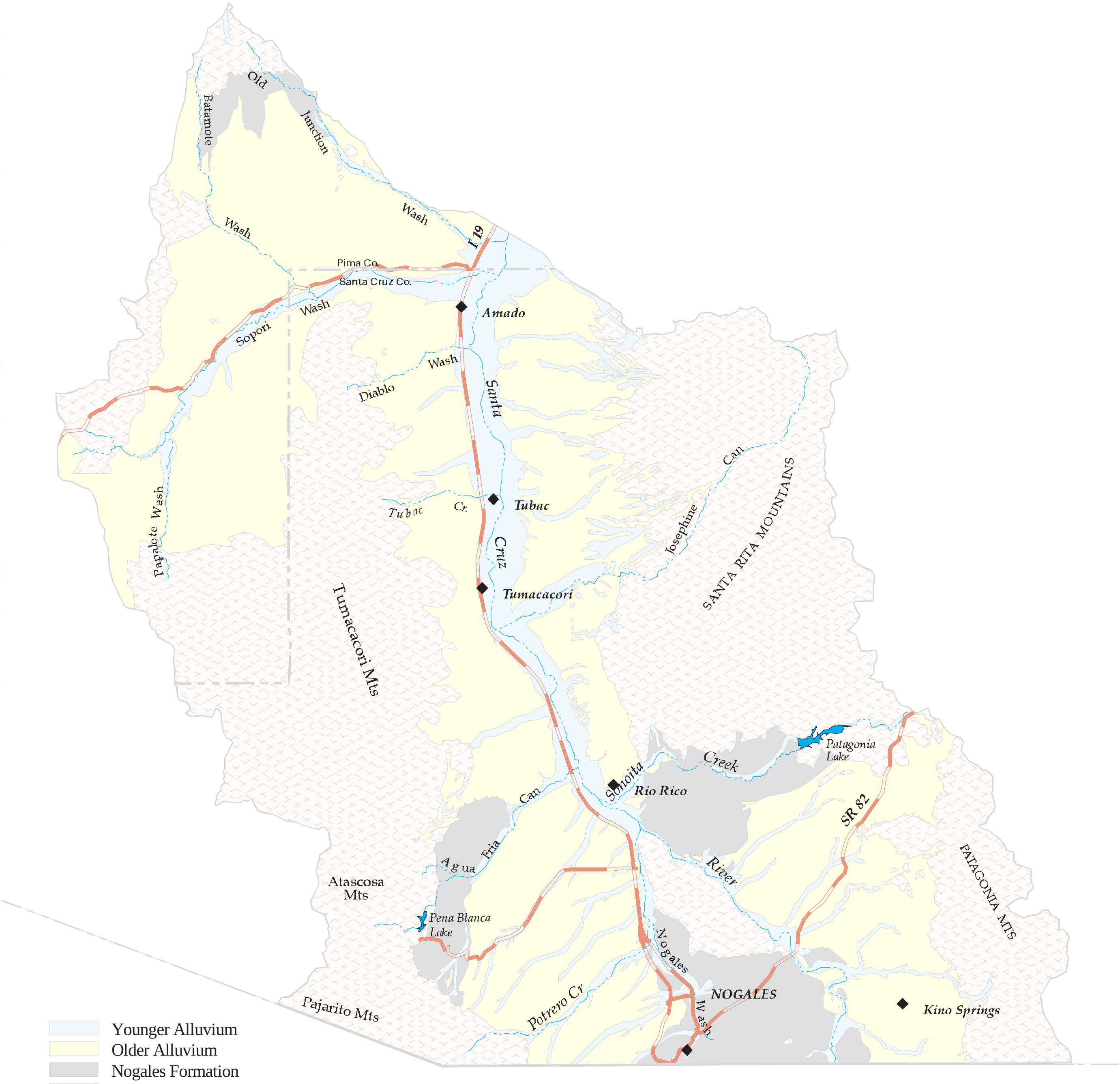


Figure 2- 4

Geologic Units

ORIGINAL SOURCE
United States Geological Survey

Water level elevation maps show the elevation of the water table above mean sea level. The general direction of groundwater flow in an aquifer is indicated by the orientation of the contours on a water level elevation map. A general rule of thumb when interpreting these maps is that groundwater flows from higher elevations to lower elevations, and the direction of flow is generally at right angles to the water level elevation contours. Figure 2-5 depicts Santa Cruz AMA water level elevations from 1952, while Figure 2-6 displays water level elevations in 1982 and Figure 2-7 depicts the 1995 water level elevations.

2.4.1 Santa Cruz River

2.4.1.1 Overview

Changes in human activity have changed flow characteristics along the Santa Cruz River. At the beginning of the century, water withdrawals in the AMA were characterized by direct surface water diversions from the river channel. A major change occurred during the 1920s and 1930s, particularly in the Rio Rico area, when irrigation wells withdrawing water from the subflow zone of the Santa Cruz River gradually replaced direct surface water diversions (Halpenny, 1998).

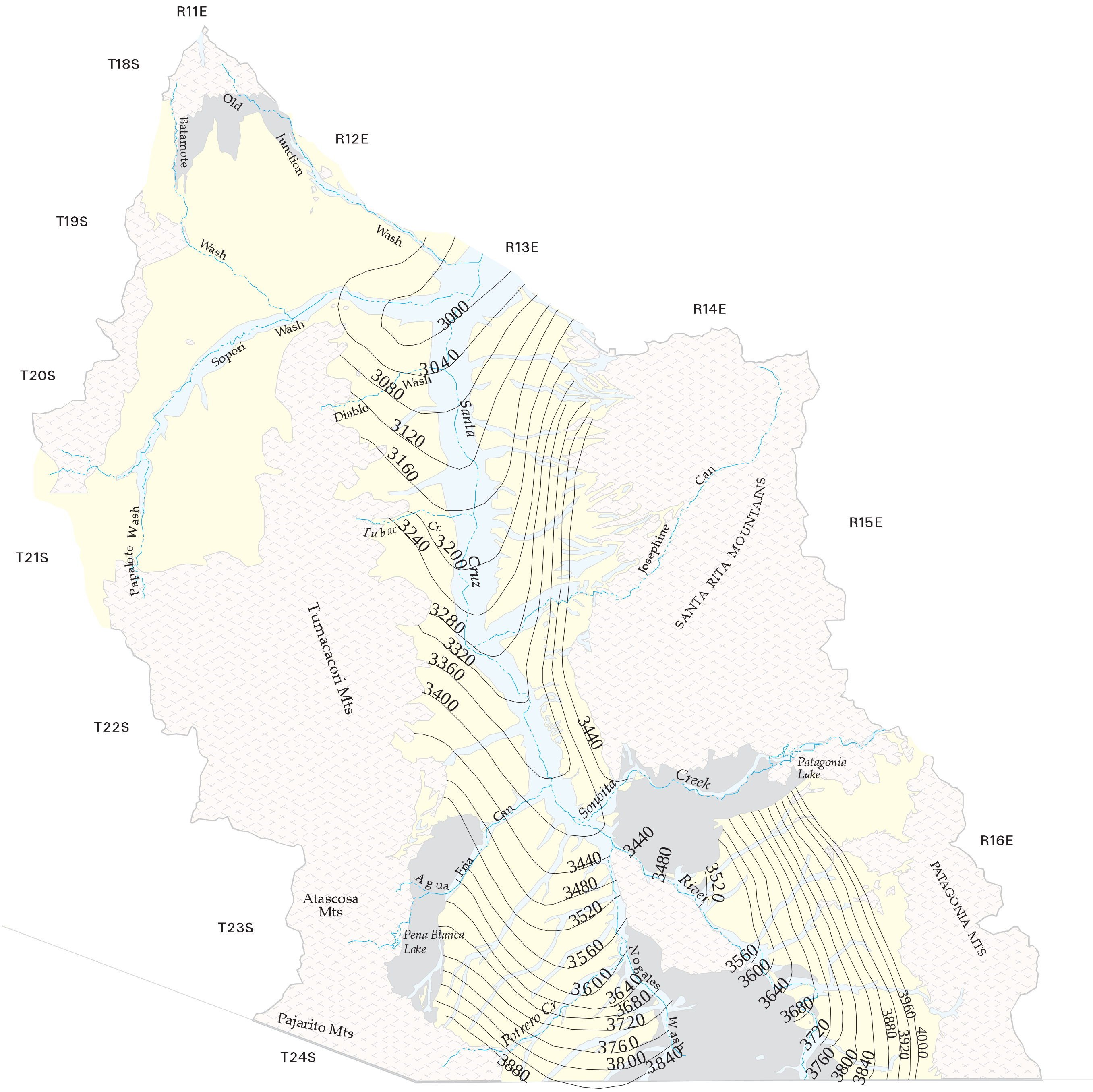
Pumping stations started withdrawing water along the Santa Cruz River near the Nogales area (Ambos Nogales). Wastewater generated from Ambos Nogales was discharged into the Nogales Wash and subsequently flowed back into the river. The later addition of groundwater from the Potrero wellfield to the municipal supply added another supply component to the effluent generated (Halpenny, 1998).

In 1951, a small wastewater treatment plant began operation for the City of Nogales, Arizona handling limited quantities of raw sewage. In 1972, the NIWWTP began treating the increasing volume of wastewater from Nogales, Arizona and from Nogales, Sonora. The resulting effluent is discharged into the Santa Cruz River.

Water levels downstream from the NIWWTP have increased in part due to effluent discharge. A nearly perennial reach has developed between the NIWWTP and Tubac, although there are locations where the channel is dry in the summer along this reach. However, water levels along the effluent-dominated perennial reach have gradually stabilized in recent years. The riparian habitat along the Santa Cruz River has expanded due to effluent discharge and the recent higher than normal precipitation and natural surface flow. As the aquifer deepens close to the Tucson AMA boundary, the effect of effluent discharge on water levels appears to diminish.

Increased demand has resulted from the large population increase over the past decade in Ambos Nogales. Recent economic growth along the border has increased municipal water use and placed a greater burden on the small, isolated aquifers along the Santa Cruz River upstream from the NIWWTP and at Potrero Creek municipal wellfield. Future inflow into the Santa Cruz AMA could be reduced if the population expansion continues at its current rate in Nogales, Sonora. This situation is complicated by the local hydrogeology, which is susceptible to short-term drought to a varying extent throughout the Santa Cruz AMA.

As noted previously in the chapter, surface flow within the Santa Cruz AMA is extremely variable and can be characterized generally as ephemeral or intermittent with some perennial reaches. Perennial reaches in this area result from either sub-surface geologic barriers which force water to the surface, or effluent discharge from the NIWWTP. Currently, however, the only perennial reach along the Santa Cruz River is the effluent-dominated segment which extends about 12 miles downstream from the NIWWTP discharge site.



Santa Cruz AMA
Water Elevation Feet Above Mean Sea Level
Hardrock
Nogales Formation
Older Alluvium
Younger Alluvium
Rivers

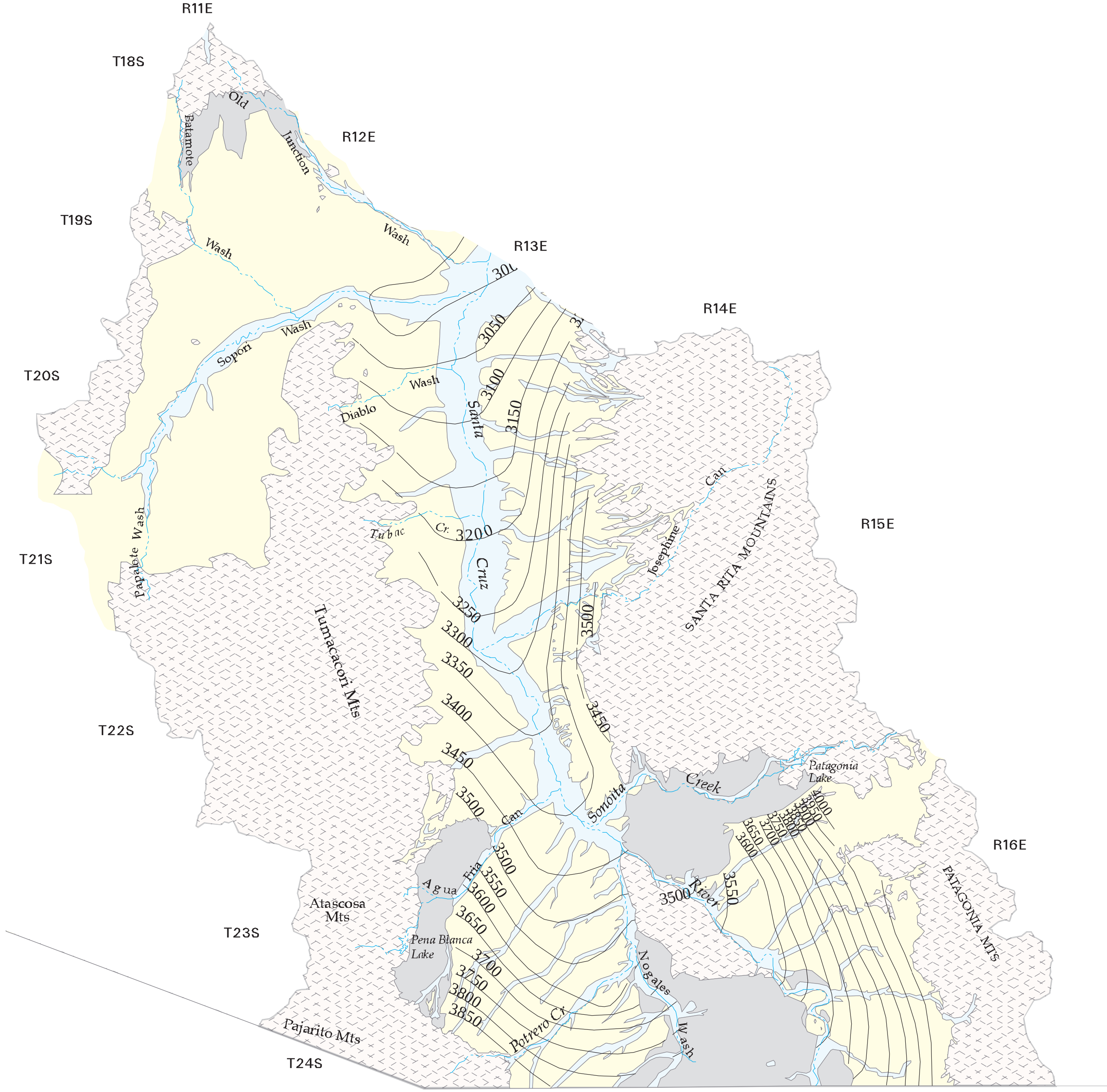
Figure 2- 5

Water Level Elevations

1952

0 1 2 3 4 5
Miles
North

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division



Santa Cruz AMA
Water Elevation Feet Above Mean Sea Level
Hardrock
Nogales Formation
Older Alluvium
Younger Alluvium
Rivers

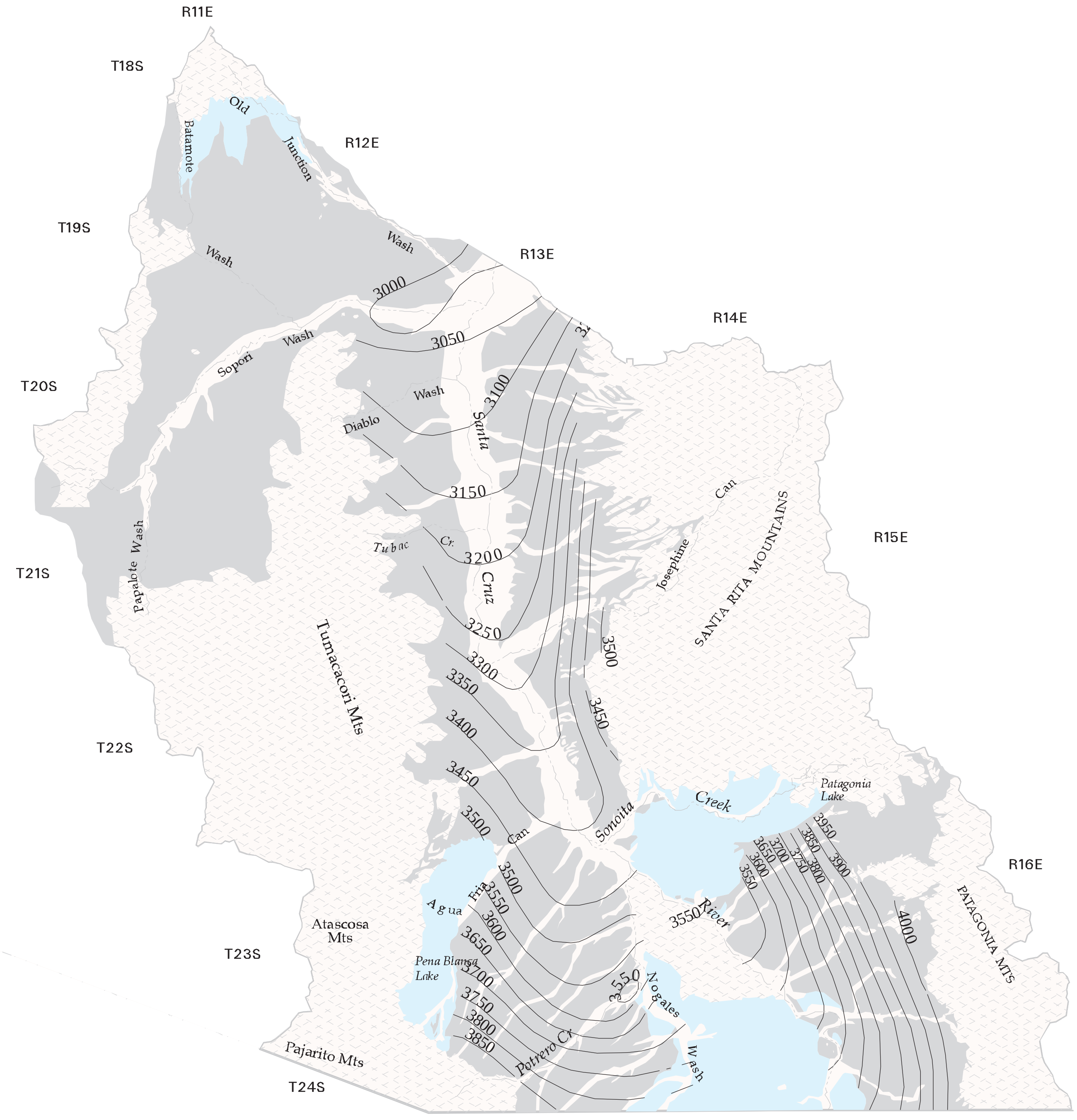
Figure 2- 6

Water Level Elevations

1982

0 1 2 3 4 5
Miles
North

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division



Santa Cruz AMA
Water Elevation Feet Above Mean Sea Level
Hardrock
Nogales Formation
Older Alluvium
Younger Alluvium
Rivers

Figure 2- 7

Water Level Elevation

1995

0 1 2 3 4 5
Miles
North

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division

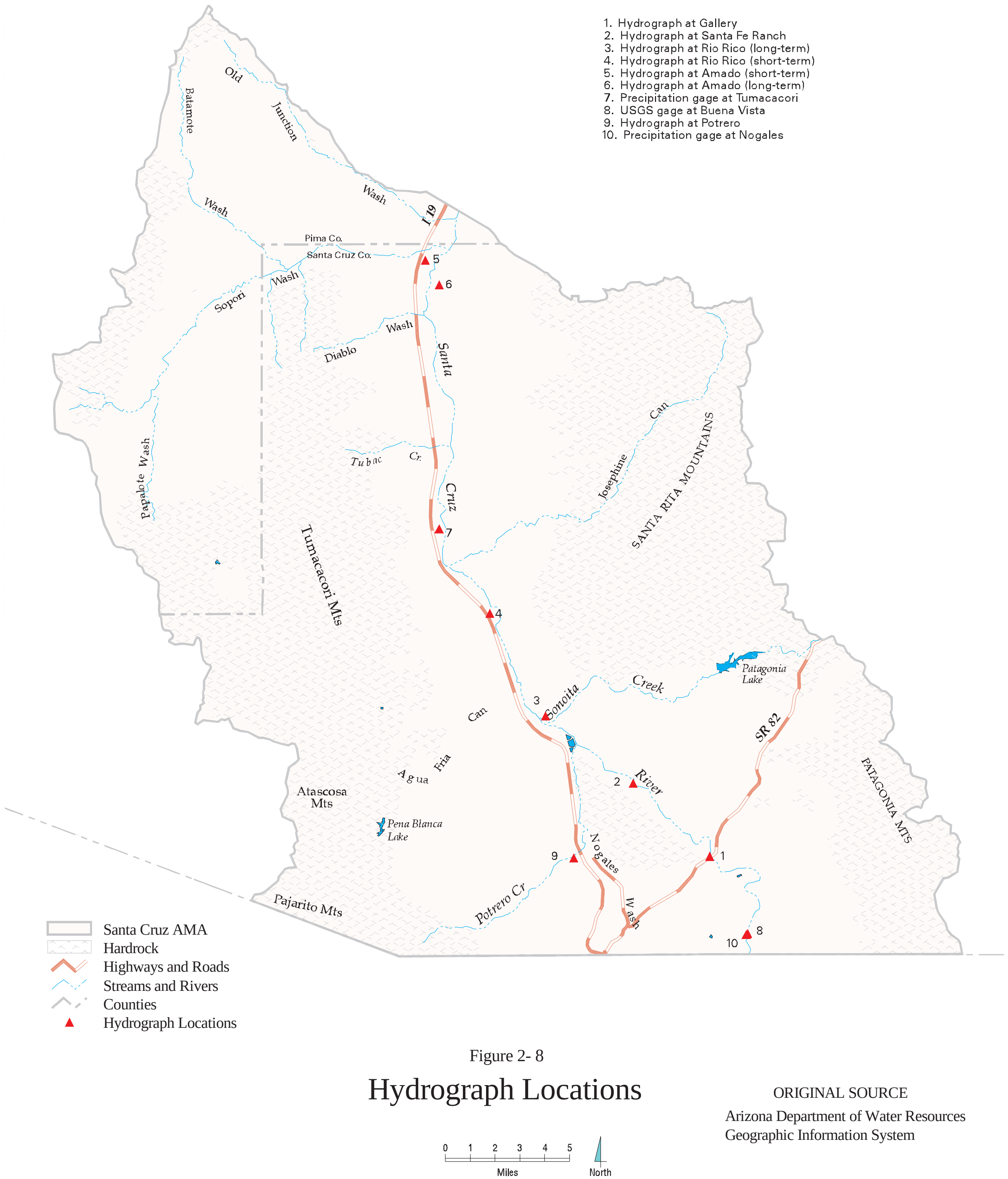


Figure 2- 8

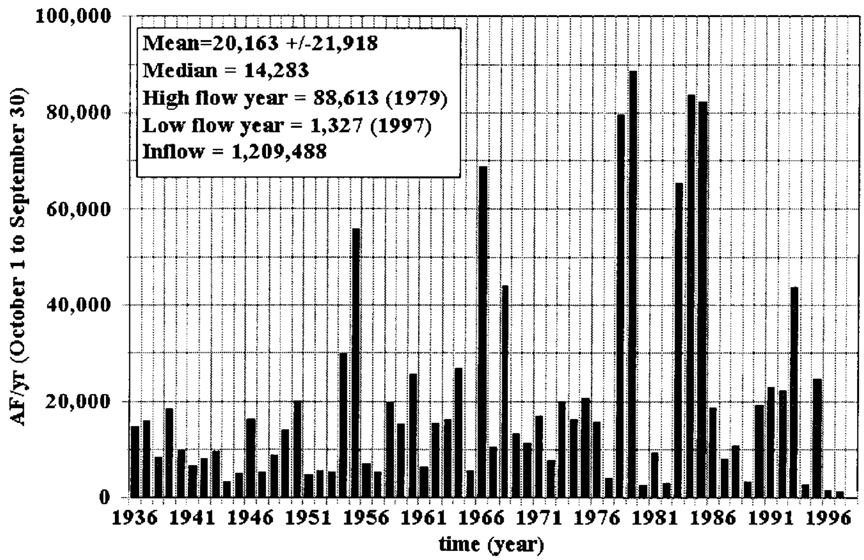
Hydrograph Locations

ORIGINAL SOURCE
Arizona Department of Water Resources
Geographic Information System

The Santa Cruz River serves as a major source of recharge for the Younger Alluvium. As long as streamflow is available, water levels in the Younger Alluvium remain relatively constant. When water withdrawals exceed recharge from surface flow, water levels in the Younger Alluvium decline. Figure 2-9 shows the variability in surface water flow at the USGS Buena Vista gage. Between 1935 and 1997 considerable fluctuations in annual streamflow have occurred. Only 1,327 acre-feet of flow was measured at the Buena Vista gage in 1997. Whereas in 1979 over 88,000 acre-feet of flow was recorded. This tremendous range of values results in a wide range in the amount of natural recharge that occurs within the Younger Alluvium in any given year. The median flow for the period from 1935 to 1997 was 14,283 acre-feet, but using this value to predict future flows or expecting this flow to occur year after year is not a sound assumption. NIWWTP effluent discharge and surface runoff along several tributaries of the Santa Cruz River, most notably Sonoita Creek and Sopori Wash, also contribute recharge to the Younger Alluvium.

FIGURE 2-9
SANTA CRUZ ACTIVE MANAGEMENT AREA

Surface Water Flow at Buena Vista
U.S.G.S. Gage 1935-97 (Water year)



The Department's water management efforts in the Santa Cruz AMA recognize the binational character of the subbasin. As water management issues are resolved on this side of the international border, Mexican officials are also dealing with problems of water supply, distribution, and demand. As solutions are implemented in Mexico, the volume of effluent treated at the NIWWTP could change. In addition, inflow from the Santa Cruz River could change based on water management efforts across the international line. The Department's water management efforts must be strong enough to ensure a continuous water supply is available for current and committed demands in the Santa Cruz AMA, while at the same time being flexible enough to adjust for changes in the water management efforts of Mexico.

2.4.1.2 International Boundary to NIWWTP

Upstream from the NIWWTP the Santa Cruz River flows through a series of four microbasins filled with younger alluvial deposits (Halpenny, 1964). Each of these microbasins contain a long, narrow band of alluvium bordered by consolidated rocks on the margins. These microbasins are analogous to four bathtubs arranged in a row. The four microbasins include: (1) the Buena Vista microbasin, which extends from the international border to the Buena Vista Narrows; (2) the Kino Springs microbasin, which extends from the Buena Vista Narrows to the Kino Springs Narrows; (3) the Highway 82 microbasin, which extends from Kino Springs Narrows to the Guevavi Narrows; and (4) the Guevavi microbasin, located between the Guevavi and Eagan Narrows.

Each microbasin receives water at the upstream end and flows out on the downstream end. Water withdrawals from one "tub" will generally only cause water level declines in that specific subbasin and not the others. However, each of the microbasins contains limited storage and can be rapidly overdrafted. Generally, the subflow in this area converges along the river, which indicates that the Older Alluvium, and possibly the Nogales Formation, are hydrologically connected to the Younger Alluvium.

The presence of shallow subsurface bedrock constricts the subflow between adjacent microbasins. This effectively limits the available water storage within an individual microbasin. The depth to the water table in the Younger Alluvium is closely tied to the elevation of the streambed of the Santa Cruz River because flow in the river serves as a principle source of recharge. Periods of above normal precipitation and runoff serve to maintain or replenish shallow aquifers. During periods of low flow, however, the microbasins may not be completely recharged.

The thickness of the Younger Alluvium varies from about 40 to 100 feet along this portion of the river. Depth-to-water is generally less than 10 feet below land surface along most of the reach. However, during times of low precipitation and low surface water runoff, this depth may exceed 40 to 50 feet in areas where significant withdrawals occur, such as the City of Nogales wellfield along the Santa Cruz River near State Route 82.

In the microbasin reach of the Santa Cruz River, the natural recharge and discharge of water has been highly variable. To understand water level change in the microbasin reach, seasonal variability versus long-term annual change must be examined. Figure 2-10 shows water level changes at Highway 82 in the microbasin reach in response to seasonal surface flows and water withdrawals. The microbasins are dependent on stream flows to replenish them. Figure 2-11 shows the annual water level change in this location for an extended period of time.

During 1997, water levels in the State Route 82 microbasin dropped to very low levels, due to low surface flow and increased withdrawals to meet municipal demand. The municipal wellfield at this location is one of two primary sources of water for the City of Nogales. Recent drought conditions resulted in a lack of sufficient surface flow recharge to offset withdrawals, resulting in dropping water levels. Winter precipitation in early 1998 has partially replenished this portion of the aquifer. Although water levels recovered by mid-1998 in the area of the Highway 82 wellfield, the overall cycle of depletion and replenishment continues. Changes in pumping regimes and the implementation of additional water conservation measures within water service areas will help to reduce demand from this area and help to maintain the supply.

2.4.1.3 NIWWTP to Tucson AMA Boundary

Downstream of Eagan Narrows and the NIWWTP, in the vicinity of the confluence of Sonoita Creek and Nogales Wash with the Santa Cruz River, the floodplain alluvium of the Santa Cruz River increases in width. Between the NIWWTP and the Josephine Canyon area, the floodplain varies from about 0.8 to 1.2 miles in width. Between Josephine Canyon and Amado, the floodplain also averages about 1.5 miles in width. North of Amado, the floodplain alluvium expands to about 2.5 miles in width at the Santa Cruz AMA northern boundary. Thickness of both the Younger and Older Alluvium increases significantly below this point, particularly in the vicinity of the northern Santa Cruz AMA boundary. Between the NIWWTP and the Pima-Santa Cruz County line the thickness of the Younger Alluvium ranges from about 50 to 150 feet.

FIGURE 2-10
SANTA CRUZ ACTIVE MANAGEMENT AREA

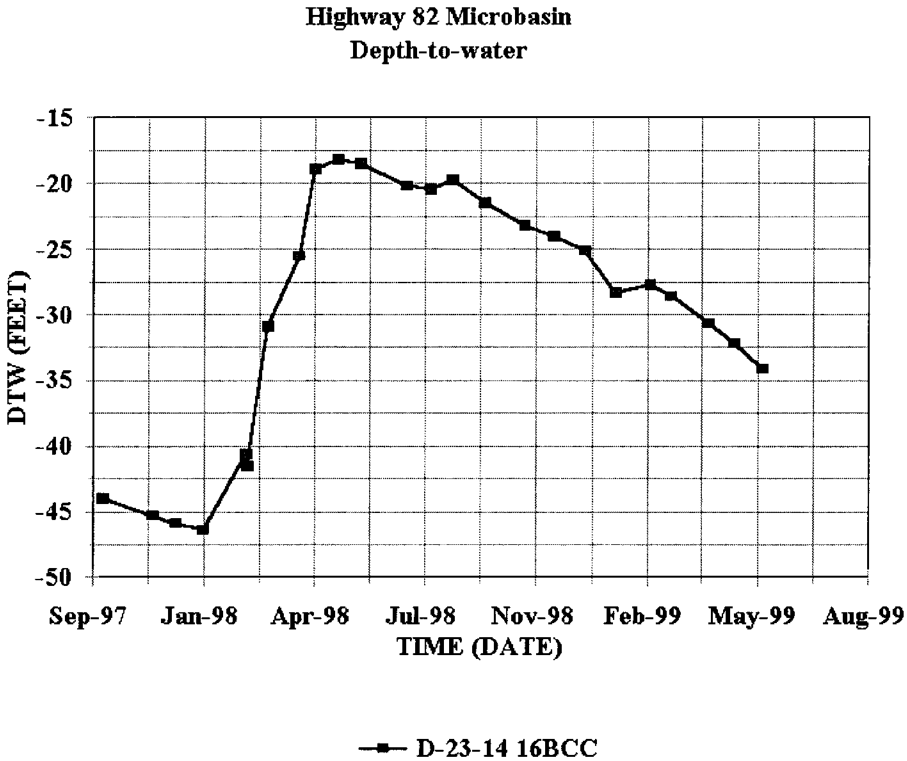
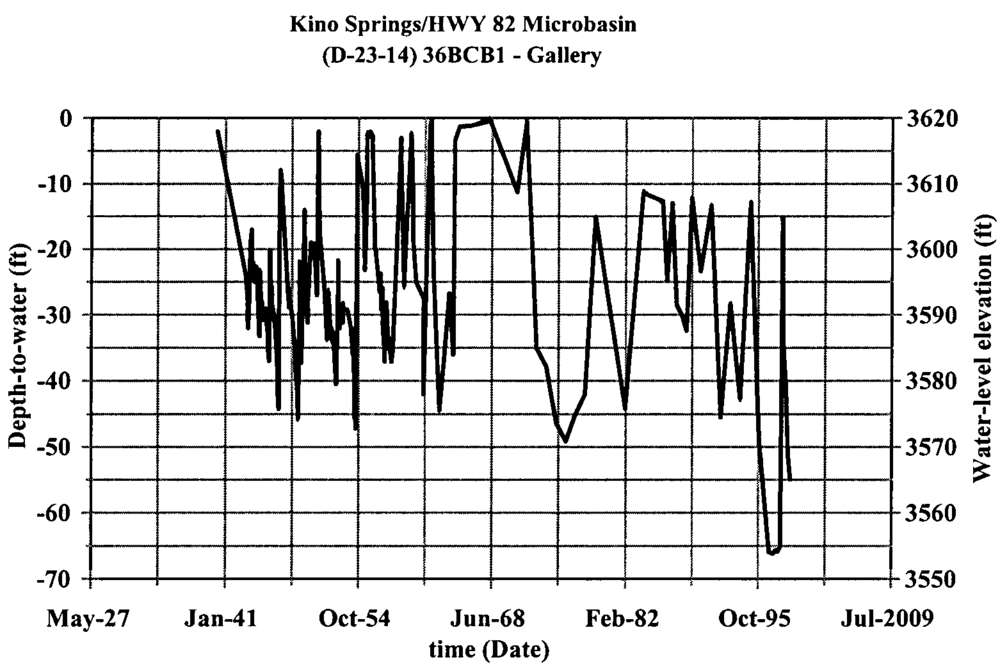


FIGURE 2-11
SANTA CRUZ ACTIVE MANAGEMENT AREA



Mountain front recharge is a major component of recharge to the hydrologic system in this area. The mountain front recharge flows through the regional aquifer toward the Santa Cruz River and eventually joins the subflow in the younger alluvial aquifer. Other recharge components include irrigation seepage, effluent discharge from the NIWWTP, and natural surface water flow (Anderson, 1956; Cella Barr Associates, 1991). A quantification of each recharge component, however, is complicated by the commingled sources of NIWWTP effluent discharge and naturally recharged water along the effluent-dominated perennial reach of the Santa Cruz River.

Recent water level data indicates that the average depth-to-water is less than 10 feet in roughly the first five to six miles below the NIWWTP, to the Peck Canyon area. Depth to water increases to a range of 10 to 20 feet below land surface from near Peck Canyon to the northern AMA boundary.

Hydrographs in Figures 2-12 and 2-13 show seasonal water level changes at Rio Rico and Amado. Long-term hydrographs are also shown for Rio Rico and Amado in Figures 2-14 and 2-15. Although seasonal fluctuations in water levels are characteristic of the Younger Alluvium of the Santa Cruz River, a long-term trend in water levels is observed between Rio Rico and Tubac. Water levels have risen in this area between 1952 and 1982. An additional rise occurred between 1982 and 1995. Recharge from NIWWTP effluent discharge and flood events, and reduced withdrawals for agricultural irrigation are mainly responsible for these water level rises. Water storage in this area is nearly at a maximum and water levels are not expected to increase much higher.

In 1995, depth-to-water ranged from surface flow to as deep as 20 feet below the surface, with the depth to water gradually increasing farther downstream and farther away from the river channel. At Amado, the basin becomes much broader and the alluvial deposits thicken significantly, increasing the local storage potential. Water levels have recovered significantly in this area. However, future development in the Amado area will increase water withdrawals in the area. Consequently, local water levels may again experience declines. The seasonal variation in effluent-dominated flow in the Santa Cruz River further compounds water supply concerns for this area.

2.4.2 Potrero Creek

Potrero Creek is located northwest of the City of Nogales. The City relies on this site as one of its two main water supply sources. The municipal wellfield taps into the regional aquifer, withdrawing water mainly from the Older Alluvium. A cone of depression has developed in the Potrero Creek wellfield. From 1982 and 1995 water level declines in excess of 20 feet have been documented in this area. Hydrogeologic analysis indicates that a dual aquifer system exists in this area. A shallow perched aquifer which rests on top of a semi-permeable clay layer supplies the flow of Potrero Creek and a surrounding wetland area. A deeper basin-fill aquifer supplies the City of Nogales municipal wellfield. At this time, the degree of hydraulic connection between the shallow aquifer and the lower aquifer is uncertain. The lower aquifer is a source of potable water for the City of Nogales. Figure 2-17 is a hydrograph of water level changes over the long-term in Potrero Canyon.

As future growth occurs, the demand at this source will increase. The City of Nogales will probably alternate pumping from this wellfield with pumping at the State Route 82 wellfield to compensate for periods of limited capacity in the microbasin reach.

FIGURE 2-12
SANTA CRUZ ACTIVE MANAGEMENT AREA

Rio Rico: Younger Alluvium
Depth-to-water

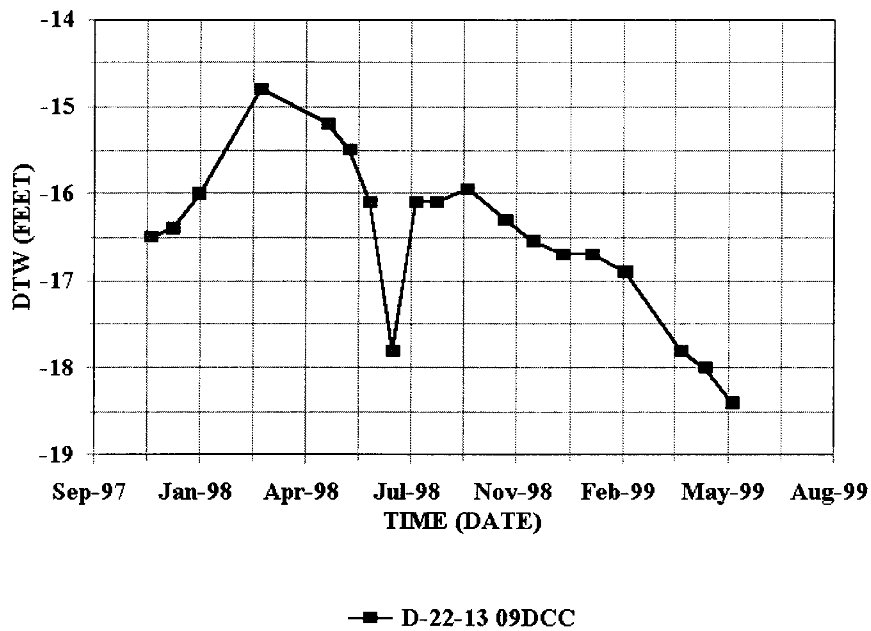


FIGURE 2-13
SANTA CRUZ ACTIVE MANAGEMENT AREA

Amado: Younger Alluvium
Depth-to-water

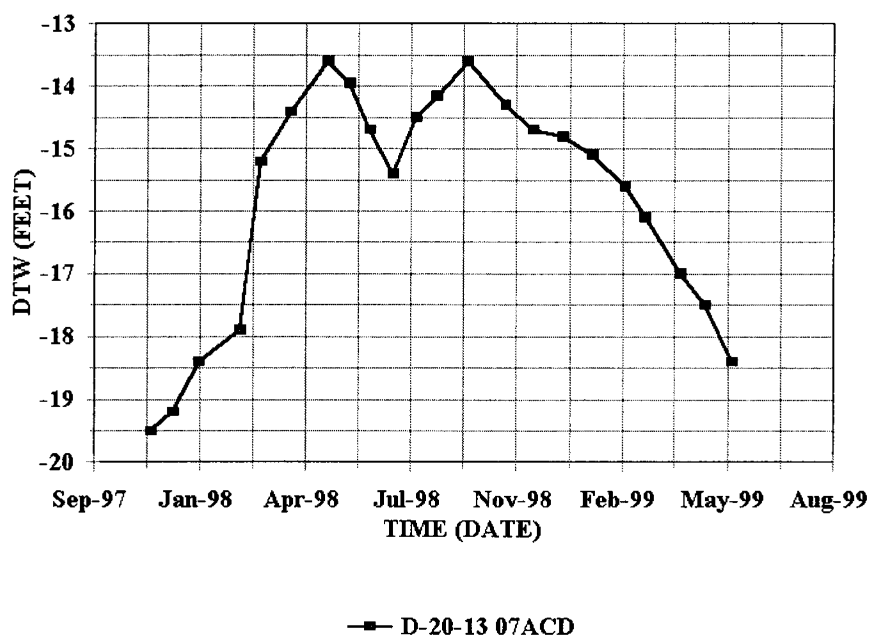


FIGURE 2-14
SANTA CRUZ ACTIVE MANAGEMENT AREA

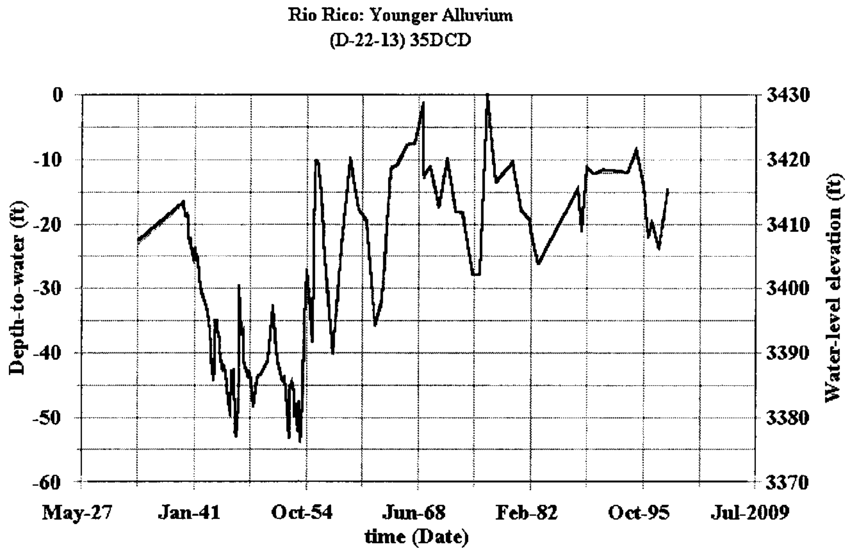
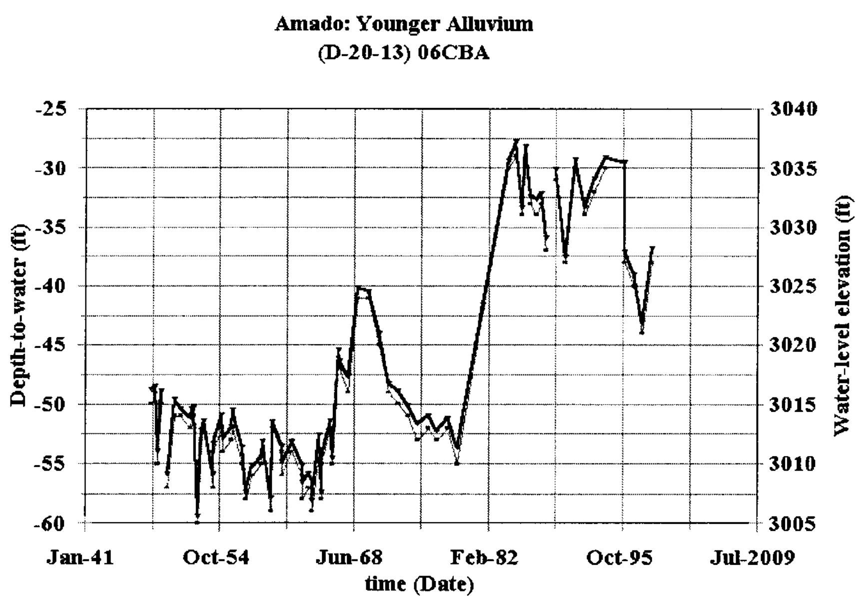


FIGURE 2-15
SANTA CRUZ ACTIVE MANAGEMENT AREA



2.4.3 Sopori Wash

The long-term diversion of spring flow and the pumping of water to support cattle grazing and forage crops has created a depression along Sopori Wash west of the confluence with the Santa Cruz River. Current depth to water in this area is 20-60 feet. Closer to the confluence of the wash and the river, water levels have risen 10 to 20 feet since 1982. Depth to water ranged from 100-160 feet in the confluence area in 1995.

2.4.4 Nogales Wash

Depth-to-water along this wash was about 30 feet in 1995. Some of this water level rise may have been attributable to recent leaks in water and sewer lines in Ambos Nogales. Nogales, Sonora has started making improvements to both the potable water and sewer system, repairing leaks and replacing aging infrastructure. System improvements have also occurred in Nogales, Arizona. The results of these improvements may reduce the water level rises observed in Nogales Wash; however, water quality in the wash will be improved, inflow into the NIWWTP will increase, and potable quality supplies will be more efficiently distributed on both sides of the International Boundary.

2.5 WATER SUPPLY COMPONENTS

2.5.1 Introduction

This section provides a description of the water supply components which are included in the water resource analysis contained in Chapter 11 of this plan. This analysis will assist in developing an understanding of the fluctuating supply characteristics of the Santa Cruz AMA and the impact of this condition on the AMA's water management goals. The information contained in chapters 2 and 11 of this plan will be updated as new data becomes available. Demand components are contained in Chapter 3 of this plan.

2.5.2 Water Storage in the Younger Alluvium

An estimate of the volume of water in storage is provided for seven segments of the Younger Alluvium that correspond to specific reaches along the Santa Cruz River at locations where the Department currently measures stream flow on a monthly basis. Water in storage in the Younger Alluvial Aquifer of the Santa Cruz River was estimated by simple tank analysis, a method which is often used by hydrologists in making groundwater storage estimates. Tank analysis is accomplished by making simplifying assumptions regarding the size, shape, and hydraulic properties of the aquifer. It is, of course, important to consider these assumptions when using the estimates for planning purposes.

The volume of water in storage in the Younger Alluvial Aquifer was estimated for each river segment. This was accomplished by first multiplying the measured surface area of Younger Alluvium by the average saturated thickness of Younger Alluvium for each river segment. This calculation provided an estimate of the total volume of saturated Younger Alluvium for each segment. This figure will be refined as additional hydrologic data is collected and analyzed. The resulting estimates of groundwater storage for each segment of the Younger Alluvial Aquifer are listed in Table 2-1. The length and surface area of each segment is also listed in Table 2-1 to further describe the segment. In addition, acres of land associated with current or potential water demand are also listed for information. These acreages include riparian area, irrigated agricultural areas, and Type 1 non-irrigation grandfathered right areas. Figure 2-16 displays the seven segments which were chosen in calculating water storage for Table 2-1.

TABLE 2-1
INVENTORY OF GROUNDWATER STORAGE IN SEGMENTS OF THE YOUNGER ALLUVIAL AQUIFER ALONG THE SANTA CRUZ RIVER
SANTA CRUZ ACTIVE MANAGEMENT AREA

	Segment Description	Length (miles)	Y. Alluvial Area (acres)	Riparian Area (acres)	IGFR Area (acres)	Type 1 GFR Area (acres)	Storage* (acre-feet)
1	United States Border - SR 82	5.9	970	580	140	0	9,000
2	State Route 82 - NIWWTP	7.6	950	690	200	0	9,400
3	NIWWTP - Santa Gertrudis Lane	10.1	5,850	1,380	1,480	0	60,100
4	Santa Gertrudis - Tubac Bridge	3.9	2,980	1,080	940	290	22,900
5	Tubac Bridge - Chavez Siding	2.3	2,300	1,080	10	0	13,600
6	Chavez Siding - Amado	4.6	3,320	690	450	450	20,900
7	Amado - Tucson AMA Boundary	3.1	3,980	750	890	0	23,600
	Totals	**37.5**	**20,350**	**490**	**4,110**	**740**	**159,500**

* Storage volumes are based on a storage coefficient of .17, which may be revised for each segment as the hydrologic model is further refined.

2.5.3 Maximum and Minimum Natural Recharge Components

2.5.3.1 Organization of Inflow Components

An analysis of probable inflow, outflow, and recharge, along with a table of the pumpage by water use sector and estimated riparian water consumption for the Santa Cruz AMA is presented in Chapter 11. This information illustrates the maximum amount of water that may move through the Santa Cruz AMA without being put to use based on current demands, as well as the amount of demand that would need to be offset with water augmentation and replenishment during a minimum flow year, based on current demands. It is important to note that this information reflects overall demand and supply conditions for the AMA as a whole, but in reality, some areas of the AMA may experience critical supply situations during dry years when other portions of the AMA are in a steady state.

Outflows from the Santa Cruz AMA hydrologic system are described in Chapter 3, along with additional system demands. Outflow includes water leaving the AMA as underflow, water below the surface of the land.

Inflows to the system are comprised of both recharge and underflow components. Recharge is derived from four elements including: (1) main channel natural flow, (2) main channel effluent, (3) mountain front and tributary recharge, and (4) incidental recharge from agricultural irrigation. Inflow from underflow includes underflow that enters from Mexico at the Santa Cruz River and west of Nogales.

2.5.3.2 Sources of Data and Range of Estimates

The hydrologic components presented in Table 2-2 have been compiled from a variety of data sources and estimates. This subsection provides more information on the water supply data and estimates.

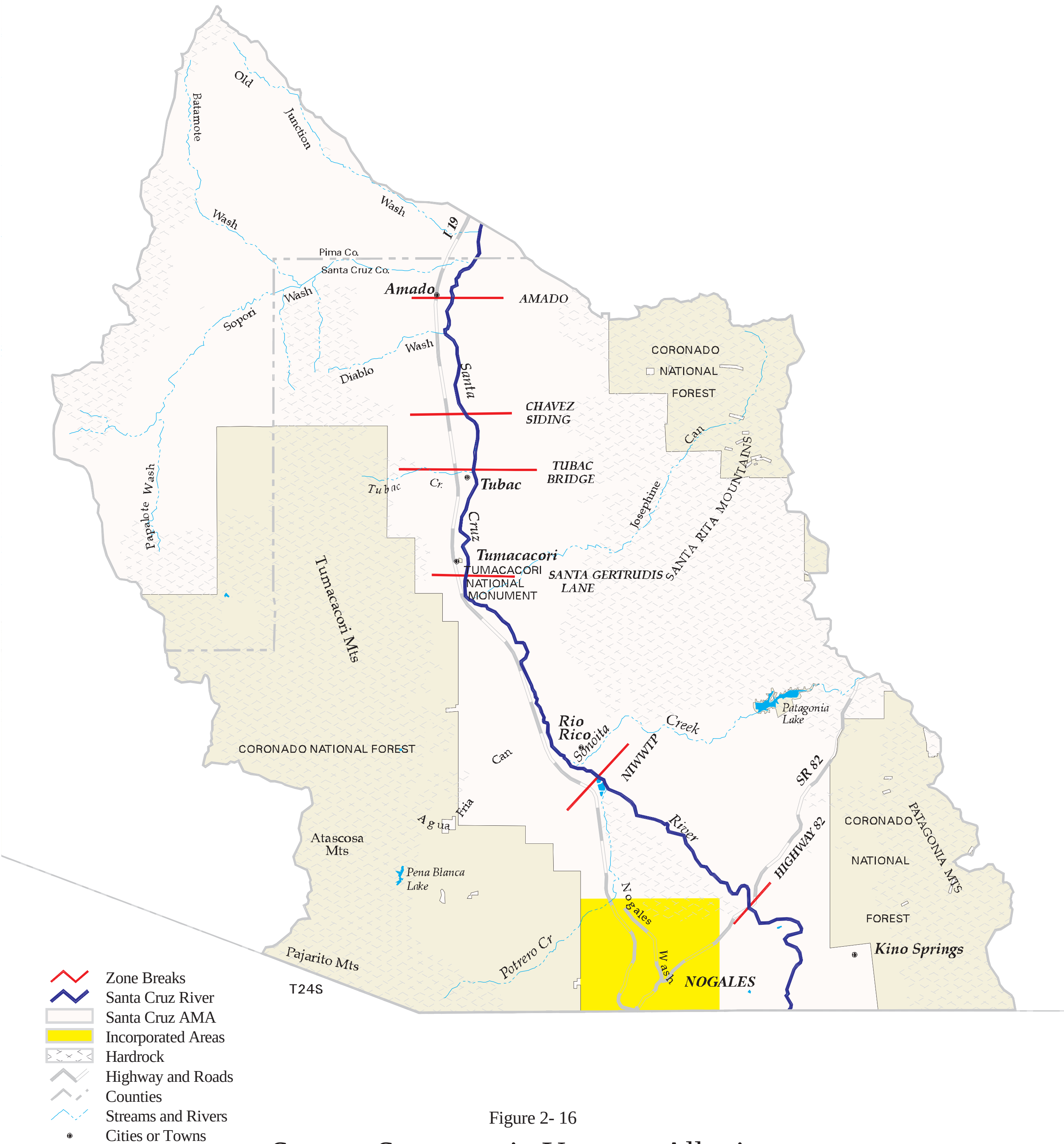
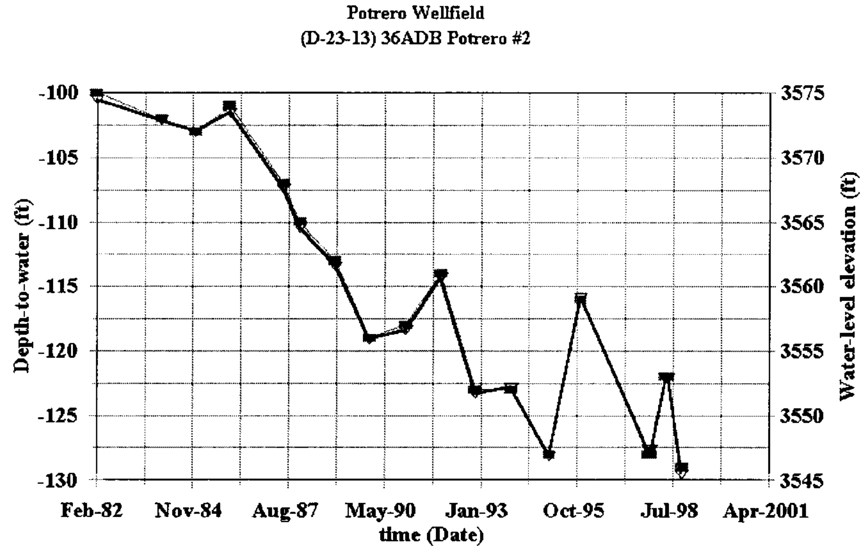


Figure 2- 16

Storage Segments in Younger Alluvium

ORIGINAL SOURCE
Arizona Department of Water Resources
Hydrology Division

FIGURE 2-17
SANTA CRUZ ACTIVE MANAGEMENT AREA



2.5.3.2.1 Effluent Data

Influent and effluent data for the NIWWTP was supplied from annual reports and other data provided by the International Boundary and Water Commission (IBWC). According to the IBWC reports, influent to the NIWWTP varied from about 6,800 acre-feet in 1982 to a high of about 16,700 acre-feet in 1995. Influent in 1996 and 1997 was less than the 1995 figure.

NIWWTP effluent data was obtained for 1992 through 1995. The ratio of reported NIWWTP effluent to influent varies greatly. For example, in 1992 the plant influent was about 14,740 acre-feet, while plant effluent was about 14,860. By contrast, the reported 1995 NIWWTP effluent was about 13,400 acre-feet, or about 80 percent of reported plant influent of 16,700.

Theoretically, evaporation and removal of solids should cause some reduction in the volume of water passing through the NIWWTP. Influent and effluent measurement error may be partially responsible for the wide variation between annual influent-to-effluent ratios. This possibility is further supported by the results of recent stream gaging measurements made by the USGS immediately downstream of the NIWWTP discharge point to the Santa Cruz River. These measurements indicate the plant discharge measuring device may under report effluent discharge by as much as 15 percent (Scott, 1996). The IBWC may subsequently have replaced any meters that were under-registering. Although there appears to be some under reporting of NIWWTP effluent discharge, there was also a large increase in the annual volume of effluent released from the plant during the 1982-1995 period.

2.5.3.2.2 Recharge Estimates

Main Channel Surface Water Flow

Main channel surface water flow is shown for the Buena Vista gage in Table 2-2. The volume of the annual flow that infiltrates depends, among other things, on the available storage capacity in the aquifer, the duration of the flow, and the infiltration rate of each segment of the river.

TABLE 2-2
RANGE IN ANNUAL WATER SUPPLIES
SANTA CRUZ ACTIVE MANAGEMENT AREA
(Figures Rounded to Nearest 100 Acre-Feet)

COMPONENT	RANGE IN ACRE-FEET
INFLOWS	
Main Channel Natural Flow (Santa Cruz River)	1,300 - 88,600
RECHARGE	
Main Channel Effluent	13,400
Major Tributary[1]	5,200 - 41,300
Mountain Front and Minor Tributary	11,400
Incidental (Agricultural and Industrial)	3,900
Total Recharge	**33,900 - 70,000**
UNDERFLOW (estimated)	
Santa Cruz River at Mexico/US Border	100 - 500
West of Nogales Mexico/US Border	200 - 1,200
Total Underflow	**300 - 1,700**
TOTAL INFLOWS	**35,500 - 160,300**

[1] These figures are very rough estimates. As the hydrologic model is further developed, these figures may be adjusted.

Upstream from the NIWWTP main channel surface water recharge is due solely to natural surface flow. Downstream from the NIWWTP it was assumed that recharge from natural flow supplies the difference between the total estimated main channel surface water recharge and the total effluent recharge.

Mountain Front and Tributary Recharge

Estimates of mountain front recharge and minor tributary recharge are included as a supply. The source of these estimates is Osterkamp's 1973 report on groundwater recharge in the Tucson area. It should be noted that the estimates of mountain front and tributary recharge were increased from the Osterkamp estimates to balance the estimated riparian evapotranspiration losses along Sonoita Creek, Nogales Wash, and Sopori Wash. Conceptually, this water is initially recharged along the mountain fronts and minor ephemeral streams which border and transect the older alluvial deposits of the Santa Cruz River Valley. Eventually the groundwater in the Older Alluvium flows into the younger alluvial aquifer. It should be noted that mountain front and minor tributary recharge is equivalent to the regional aquifer recharge mentioned by Scott (1996).

Incidental Agricultural Recharge

Incidental recharge from the over-application of agricultural irrigation water represents a significant source of recharge in some areas. The volume of agricultural recharge is estimated to be 34 percent of the average annual agricultural pumpage. This means that on average, 66 percent of the water applied for agricultural irrigation is used by the plants and 34 percent recharges the aquifer.

The 34 percent recharge or inefficiency factor is also generally supported by the observed ratio between reference crop consumptive use and total pumpage (Scott, 1996). Although this ratio is not a direct measure of agricultural recharge, it is believed to be a close approximation. According to the 1996

University of Arizona study, the calculated irrigation efficiency ranges from about 44 percent to more than 100 percent of the reported monthly agricultural pumpage in 1995. The average ratio of reference crop consumptive use to total agricultural pumpage is about 66 percent for the three summer months when the most intense agricultural pumpage occurred (June-August).

Groundwater Underflow Estimates

The estimates of main channel water underflow into the Santa Cruz AMA at the international border ~~range~~ have been estimated from about 410 acre-feet per year to about 580 acre-feet per year (Halpenny, 1964; Putman et al., 1983). Underflow west of Nogales entering the AMA was estimated at between 200-1,200 acre-feet per year and is derived from 1997 data collected as part of the Department's Santa Cruz AMA Groundwater Modeling Study. The modeling study also estimated underflow at the Santa Cruz River between 100-500 acre-feet per year.

2.6 AVAILABILITY AND UTILIZATION OF RENEWABLE SUPPLIES

2.6.1 Overview

All demand sectors rely on water withdrawn from wells. Indirectly, the combination of effluent, surface water, mountain front recharge, and incidental recharge all contribute to the replenishment of the younger alluvial aquifer. Shallow well pumpage is therefore comprised of water originating from several sources. An AMA-wide water monitoring system may help to identify specific volumes of renewable supplies which are put to beneficial use. However, using information currently available, it is difficult to make the distinction between groundwater and surface water withdrawn from wells.

2.6.2 Renewable Supply Use Trends

2.6.2.1 Central Arizona Project Water

The City of Nogales and Rio Rico Utilities transferred their Central Arizona Project (CAP) allocations, 3,949 acre-feet and 2,683 acre-feet per year respectively, to the City of Scottsdale. Any attempt to transport CAP water to the Santa Cruz AMA would have involved building pipelines and lift stations to transport the water uphill over a substantial distance and at great expense. Both Rio Rico and the City of Nogales have utilized funds from the transfer of their CAP allocations to retire former agricultural land in order to utilize the water rights to meet future demands and will continue to do so.

2.6.2.2 Surface Water Lakes

The City of Nogales may use up to 4,200 acre-feet of surface water from Patagonia Lake, although this volume is presently reserved solely for emergency use. To retrieve this potential supply, city planners would need to design and construct a potable water delivery and treatment system. If the City were to build a delivery system connected to Patagonia Lake, they would be statutorily limited to the use of this water supply only during times of emergency.

Peña Blanca Lake has experienced water quality problems discovered with the detection of mercury in its fish population. However, mercury has not been detected in water samples taken to date. Consequently, it possible that this problem concerns sediment contamination and its impact on the local food chain. Surface water rights or claims associated with this lake are primarily owned by the United States Forest Service and the Arizona Game and Fish Department. Additional legal arrangements would need to be made for a water provider in the Santa Cruz AMA to obtain an allotment from Peña Blanca Lake, if it is physically and economically possible to deliver this water for municipal use.

2.6.2.3 Effluent

2.6.2.3.1 Indirect Uses

In 1996, 14,301 acre-feet of influent (untreated wastewater) flowed into the NIWWTP, the vast majority of which was subsequently discharged into the Santa Cruz River (IBWC, 1997). Since the construction and initial operation of the NIWWTP, the riparian area in the Santa Cruz River has expanded and additional development has occurred resulting in an increase in municipal water demand. The Department begins to address water management challenges such as maintaining sufficient water supplies to meet current and other committed demands with the adoption of consistency with management goal criteria for the Assured Water Supply Rules (AWS Rules) for the Santa Cruz AMA. The Third Management Plan helps to outline the water management concerns of the AMA by providing hydrologic information and detailing current water use trends. Because the effluent generated by the NIWWTP is owned in part by Mexico, water management strategies will need to be developed which address the interrelated nature of supplies and demands on both sides of the international border.

As more development occurs in the Amado-Tubac area, water use will increase and the need for recharge of effluent will be an important component of maintaining safe-yield conditions. The Department encourages the construction of centralized wastewater facilities, such as the Arivaca Junction Wastewater Treatment Pond, which could generate effluent to meet some the local demands, such as agricultural irrigation, and preserve the quality of the water supply in this region.

2.6.2.3.2 Direct Uses

Effluent has not been directly used in the past. The City of Nogales has indicated its intention to use effluent in the future for watering turf at Palo Duro municipal golf course. Rio Rico and Tubac represent two communities in addition to the City of Nogales that may have the potential to utilize effluent for golf course turf watering in the future.

2.6.3 Factors Affecting Renewable Supplies

Water management efforts by the Sonoran government could impact water levels in the Santa Cruz River downstream from the International Boundary. Sonora is proposing to replenish effluent in the Los Alisos basin to help supply that area, reducing demand in the Santa Cruz basin. These concepts are being explored further in the Wastewater Facilities Planning Process coordinated by the IBWC.

Water supplies could also be impacted locally if the City of Nogales or Rio Rico were to obtain and recover effluent recharge credits for their share of NIWWTP effluent discharge into the Santa Cruz River. This could change the point at which the water is replenished and recovered, which may help to manage local water table levels.

2.7 SUMMARY AND CONCLUSIONS

The dual water management goal of Santa Cruz AMA is to maintain safe-yield conditions and prevent local water table levels from experiencing long-term declines. However, local water table levels fluctuate with variations in weather patterns, water withdrawals within the Santa Cruz River basin (in Mexico and in the United States), and incidental recharge from agricultural irrigation and wastewater treatment plant discharge.

The Department is currently calibrating a hydrologic model for the region which will assist in water management planning and the development of rules and requirements that will allow for the achievement of the AMA's dual goal.

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