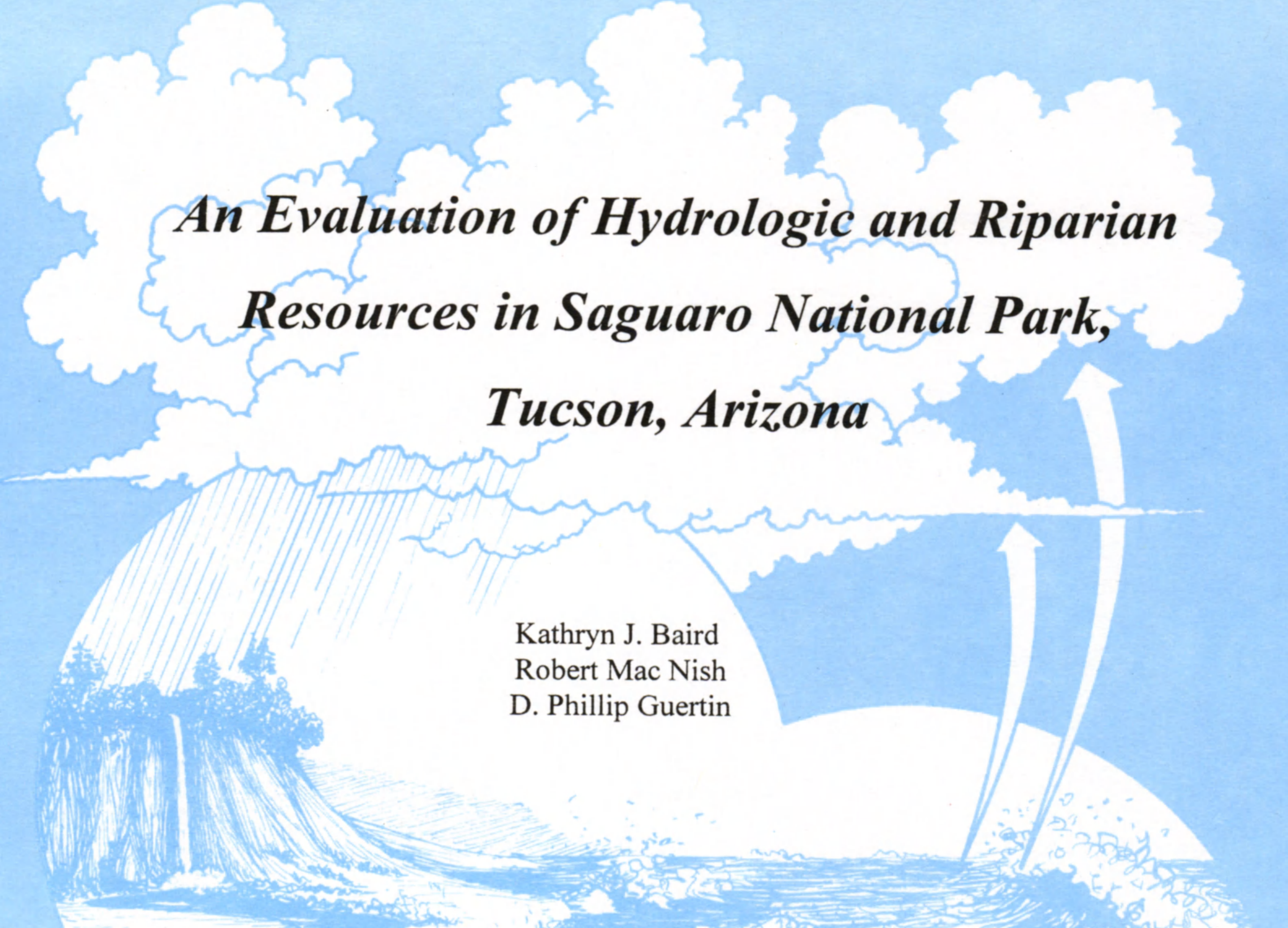
HWR No. 01-010

An Evaluation of Hydrologic and Riparian Resources in Saguaro National Park, Tucson, Arizona



Kathryn J. Baird
Robert Mac Nish
D. Phillip Guertin

Department of Hydrology and Water Resources, and
University of Arizona Research Laboratory for Riparian Studies
University of Arizona
Tucson, Arizona 85721

Cooperation Agreement No. CA 8000-2-9001
Work Order No. 8039-2-9001

TABLE OF CONTENTS

List of Figures

List of Tables

Executive Summary

SETTING:

Within Saguaro National Park only Rincon Mountain District contains significant riparian areas. The geologic framework of the Tanque Verde Ridge and Rincon Valley exerts strong control on the hydrology of these riparian systems. Pantano fault constitutes a line of hydrogeologic separation between the occurrence and utilization of groundwater in the Rincon Valley and the main Tucson basin. No known, comparable fault isolates the upper Tanque Verde Creek alluvium from downstream pumping effects. However, east of the confluence with Agua Caliente Wash, the highly permeable alluvial materials are much thinner, and serve to dampen such downstream effects. Therefore, the ground water reservoirs supporting the riparian areas within Rincon Mountain District are not directly connected to the Tucson basin aquifer.

In what is described herein as upper basin areas, high gradient tributary streams to Tanque Verde Creek and Rincon Creek have discontinuous bodies of shallow alluvium interspersed with bedrock channel. Alluvium has accumulated behind small faults or resistant bedrock ledges and contains shallow ground water basins that support small pockets of riparian or xeroriparian vegetation. The ground water in these small basins is sustained by seeps or springs, and by runoff from precipitation and is not likely to be connected to a regional ground water system.

In what we have characterized as middle basin areas, the stream gradients are less than 25m/km. In these low gradient reaches, the alluvial floodplain sediments are continuous, though not thick, as ledges of more resistant bedrock formations appear in the stream channel. These low gradient reaches contain larger volumes of ground water than the high gradient basins and support more robust riparian vegetation. The ground water in the low gradient reaches is believed to be connected to the regional ground water system. Such a low gradient reach exists in a tributary to Tanque Verde Creek about 1.4 km east of Wentworth Road and extends about 1.6 km into the Park. A similar low gradient reach occurs along Rincon Creek in the Expansion Area, and at the mouths of Chiminea and Madrona Creeks.

EXISTING RIPARIAN CONDITIONS:

The high gradient tributaries of Rincon and Tanque Verde Creeks support a combination of mixed narrow leaf community dominated by such species as mesquite, catclaw, desert willow, and mixed scrub. Considered a xeroriparian community, this habitat type is an important resource to the Park. Below 1000 meters, these reaches are dominated by a more typical riparian community of sycamore and cottonwood.

The lower portions of Chiminea, Madrona and Rincon Creek through the X9 ranch area to Sentinel Butte support the finest and most extensive riparian habitat remaining in the Park. At these lower elevations, the stream channels widen slightly and modest deposits of saturated alluvium supply limited groundwater storage capacity to the system. This allows for the development of a band of riparian habitat dominated by cottonwoods, willows, and sycamores along the streambank. This stretch of habitat is one of two areas critically threatened by increased groundwater development. The second threatened habitat is the mesquite bosque growing along the northern boundary of the Park in a tributary of Tanque Verde Creek. This bosque is supported by flows from several tributaries as they converge just above their confluence with Tanque Verde Creek.

These habitats posses high wildlife values and are crucial to the functioning of Saguaro National Park. The long-term health and survival of these habitats depends upon an assured groundwater source for daily water requirements and a natural surface flooding regime for recruitment events. However, current groundwater development is placing considerable stress upon these systems. Field investigations reveal signs of water stress in mature trees, as well as a lack of seedling/sapling recruitment. This coupled with the transition to a more xeric community that is occurring away from the creek bank should be taken as a serious warning signal.

THREATS:

The principal threats to the upper basin riparian areas in order of severity are: (1) Prolonged drought resulting in the drying up of springs and seeps and a reduction in surface runoff to replenish the ground water. (2) Hillslope erosion along the lateral edges of the small basins depositing sediment in the riparian areas thus raising the land surface above the water table. (3) Trespass livestock.

The principal threats to the middle basin riparian areas are: (1) The possible development of increased ground water withdrawals from the floodplain alluvium or aquifers which are in hydraulic connection with that aquifer. (2) The continuation of present ground water withdrawals in these areas.

MANAGEMENT ALTERNATIVES:

The passive management alternative includes the implementation of monitoring programs to detect changes in the ground water levels of the middle basin riparian areas. In both the middle and upper basin areas, transects should be established to monitor the health of the riparian vegetation and evaluate the accumulation of sediments.

Pro-active management alternatives include: (1) Taking legal and/or administrative actions to prevent further development of ground water supplies in the middle basin areas. (2) Encouraging expansion of the Tucson Water Service Area to include the middle basin areas of both Tanque Verde and Rincon Creeks bringing an additional source of water to augment the natural supply. (3) Encourage retention of septic systems and leach fields in the middle basin areas to keep natural and any additional water supplies contributing to ground water replenishment. (4) Investigate the feasibility of using treated waste water from a regional treatment plant to augment ground water recharge at the upstream ends of the middle basin reaches.

INTRODUCTION

Saguaro National Park in Tucson, Arizona encompasses two geographically distinct areas: Rincon Mountain District and Tucson Mountain District. Of the two, only the Rincon Mountain District (Park) has significant riparian habitat due to Tanque Verde Ridge, which reaches 2641 meters in elevation. The higher elevations in this area receive more precipitation than the basin floor and the Tucson Mountain District area. The runoff from the precipitation infiltrates the alluvial materials covering the floors of the washes draining Tanque Verde Ridge and sustains riparian corridors in the middle reaches of Tanque Verde and Rincon Creeks. The scope of this study includes Rincon Creek, its tributary riparian areas and Tanque Verde Creek riparian tributary areas within or immediately adjacent to the Park (Mac Nish and Guertin, 1997). Both of these creeks have riparian resources that will likely be impacted by proposed development adjacent to the Park boundaries.

The Rincon Creek watershed is located in Rincon Valley on the southwest side of the Rincon Mountains. It is formed by Tanque Verde Ridge and Mica Mountain to the north and Rincon Peak to the east and drains about 19,100 hectares. The Rincon Creek drainage area covers about one third of the Rincon Mountain District. Approximately one half of the Rincon Creek watershed lies within Saguaro National Park, while a small portion on the eastern end is located in Coronado National Forest (Briggs et al., 1996).

Rincon Creek drains a large portion of the southwestern side of the Rincon Mountains and borders Saguaro National Park along its southern edge (Figure 1). It flows almost due west through the Rincon Valley to its confluence with Pantano Wash. Short reaches of Rincon, Madrona, and Chimenea Creeks flow from park land, across private land and enter the Park's expansion area (Briggs et al., 1996). Within the expansion area, Rincon Creek is intermittent or ephemeral. However, the high groundwater table in portions of the expansion area supports good quality riparian habitat along its banks.

Tanque Verde Creek flows for 25 km from its headwaters in the Rincon Mountains to its confluence with Pantano Wash. The lower ten-kilometer stretch of Tanque Verde Creek is a relatively low gradient ephemeral creek. Remnant mesquite bosques line the wide sandy channel (Stromberg et al., 1992). With a mean elevation of 1,323 meters, Tanque Verde basin receives a mean annual precipitation of 424.2 mm. While Tanque Verde Creek proper lies outside of Saguaro National Park, numerous tributaries lie within the Park. Several of these tributaries support important riparian/mesquite bosque communities (Figure 2).

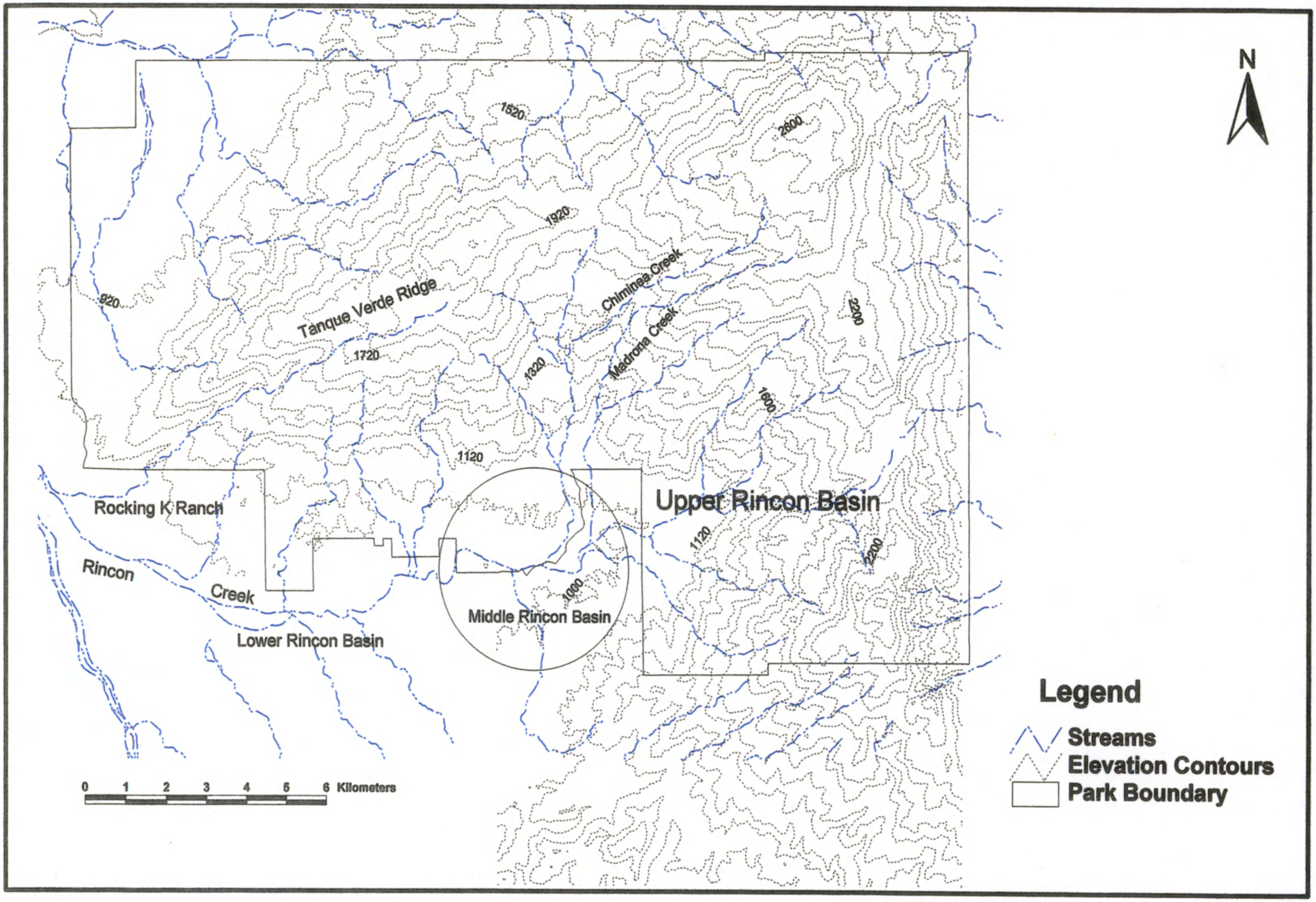


Figure 1. Saguaro National Park, East and associated portions of Rincon Creek.

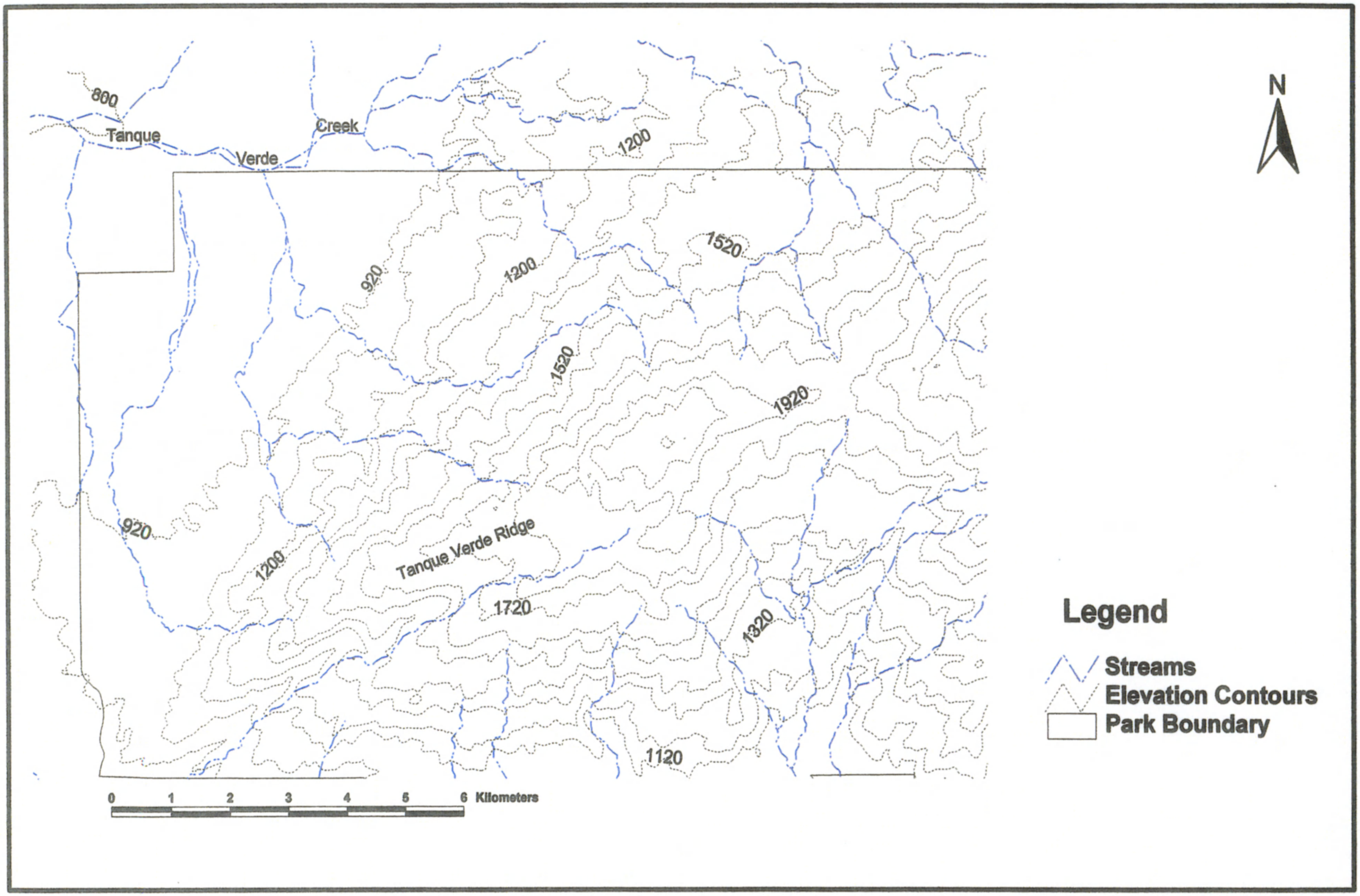


Figure 2. Saguaro National Park, East and associated portions of Tanque Verde Creek.

PROBLEM STATEMENT

In Tucson's harsh, desert environment water is a critical resource within the Park and is essential to its biological communities. Springs, seeps, perennial and ephemeral stream reaches, and riparian areas sustain unique habitats important in maintaining the desert ecosystems the park was established to protect. Past land use activities, ongoing groundwater withdrawals, and continued growth in the Tucson area have created major changes in hydrologic processes and riparian landscapes within and adjacent to the park (Mott, 1997).

Historic accounts and records indicate that the hydrology of the Tucson area has changed significantly in the past 100 years. In the mid-1850's, mesquite trees covered the entire valley and cottonwoods, willows and walnuts grew along the major streams. Much of the area was marshy, making malaria a major problem (Smith, 1910; Arnold, 1940). The introduction of cattle, the cutting of trees for fuel and building materials coupled with a drought in the late 1800s lead to downcutting of stream channels and dewatering of streambeds. Wet marsh areas were replaced by deep arroyos that only occasionally filled with water (Hastings and Turner, 1962).

Water table declines have the potential to affect Saguaro National Park's resources through the loss of phreatophytic vegetation, decreased capacity of water supply wells, and fracture dewatering of bedrock with resulting loss of recharge to springs and seeps. The balance between groundwater levels, dependent vegetation, and associated wildlife can be particularly sensitive to alteration. Even small water table declines or increased fluctuation can negatively impact riparian habitats, which are not adapted to repeated or prolonged stress. Excessive extraction of near surface groundwater from areas adjacent to Saguaro National Park is a serious potential threat to the riparian resources of the park. Near boundary water extraction could result in water table declines that extend into park lands and impact vegetative communities dependent on near-surface groundwater (Mott, 1997).

The stream reaches in Saguaro National Park are best separated into one of two physical categories. The first category is comprised of high-gradient (>25m/km.) reaches characterized by alternating outcrops of bedrock channel with alluvial floored stretches. These pockets of alluvium occur upstream from geologic structures that create small, shallow basins that subsequently fill with sediments. All high-gradient reaches are described herein as "upper reaches". The second category is comprised of low-gradient reaches with slopes less than 25m/km. and characterized by continuous alluvial floodplains.

These low-gradient reaches are further described as middle or lower basin areas. The middle basin areas have relatively shallow alluvial sediments and occasional outcrops of bedrock or consolidated sediments, which form sub-surface dams. As the dams force the groundwater close to the stream surface, a shallow depth to groundwater is maintained upstream of these structures. The reach of Rincon Creek from one mile above its confluence with Chimenea Creek through the Expansion Area constitutes a middle basin area. As is Tanque Verde Creek along the northern boundary of the Park, and the lower portion of one of it's tributaries lying within the boundary of the Park. Greater depths of alluvial deposits and generally deeper groundwater resources characterize the lower basin areas. The Tanque Verde lower basin area lies to the west of a point about two kilometers above its confluence with Aqua Caliente Wash and in the Rincon Creek basin the lower basin area lies to the west of Camino Loma Alta.

Specific threats to the riparian areas within the Park come from several sources: groundwater extraction from the middle basin areas and a change in land use in the upper basin areas. The middle and lower basin areas of Rincon Creek within the old Rocking K and to a lesser extent X9 Ranches are experiencing extensive urbanization (Figure 1). Rocking K Ranch development proposes a mixed-use, resort-oriented community to include residential areas, resorts and golf courses, and retail development (Briggs et al., 1996). Further upstream in the X9 Ranch area increased groundwater pumping for residential use outside the area is proposed. The magnitude of depletion and subsequent declines in riparian water tables are a clear threat to the continued existence of the riparian habitat along Rincon Creek (Mott, 1997).

Preservation of the riparian habitat within the park is becoming increasingly critical with the continued loss of riparian habitat in the Tucson basin. Not enough is known about the interactions between ongoing groundwater withdrawals, future developments, and the physical hydrology and biological processes active within the park's riparian areas. If a preservation scheme is successful it must include a means of quantifying and offsetting potential water level declines if these declines are determined to threaten riparian resources (Mac Nish and Guertin, 1997).

The goal of this study was to formulate recommendations for long term monitoring programs and strategies to protect the riparian areas within the Park. In order to achieve these goals, the present hydrology and flora of the riparian areas must be characterized and quantified. Information on the effects of antecedent stresses needs to be developed and the changes in hydrology, climate and land use quantified.

METHODOLOGY

Historical groundwater, well, geological and water resource information was gathered from various sources and analyzed. A literature search of Rincon and Tanque Verde Creeks, and the Tucson basin was conducted and pertinent information summarized (see literature cited). Initially, historical aerial photographs were located, assessed and electronically scanned (see Preliminary Product Review, June 1998 for list of photographs and sources). The scale of the photographs made their use impractical for study purposes. Numerous field surveys were conducted between September 1997 to December 1999 to document current vegetation and hydrologic conditions and assess potential problems. See Appendix A: Riparian Mapping, this report, for a more complete description of the vegetation mapping and current aerial photographic work.

RESULTS: HYDROLOGY

TOPOGRAPHY

North of Rincon Creek, including much of Saguaro National Park, the land rises steeply up to Tanque Verde Ridge in the Rincon Mountains. The land surface north of the creek is predominately rocky and rough. South of Rincon Creek the land rises more gently. The land south of the Creek is an alluvial plain whose surface slopes downward to the west in the southern portion of the plain and to the northwest closer to the apex of land lying between Rincon Creek and Pantano Wash. The inner valley surface is incised 12 meters or more below the level of the alluvial plain, with many small washes draining northward into Rincon Creek. Rincon Creek is an incision of the plain close to the northern edge where the alluvium laps upon bedrock of the Rincon Mountains.

GEOLOGIC STRUCTURE

Rincon Creek Basin

The Rincon Mountains are composed of metamorphic and intrusive igneous rocks and are the largest mass of low-porosity and low-permeability material bounding the Tucson basin. The least porous units are the least permeable and the most resistant; these rocks form the mountain range and the bottom of the sediment-filled basin and restrict the flow of groundwater into or out of the basin. These crystalline intrusive and metamorphic rocks contain water only where the rock is fractured and where rainfall or streamflow are sufficient and frequent enough to provide recharge. Many of the springs at the base of the Rincon Mountains are fed by rain and snow melt that are transmitted by fractures through the rocks and forced to the surface at the contact between the fractured crystalline rock and tightly cemented sedimentary rock down gradient of the spring. Springs in the higher parts are fed by water moving through fractures and the permanence and amount of their flow are dependent on the extent of the fractured system and on the frequency and amount of precipitation (Davidson, 1973).

The geologic framework of Tanque Verde Ridge and Rincon Valley including two major faults exerts strong control on the hydrology of the riparian systems within Saguaro National Park. Pantano Fault is a high angle fault running NNW just east of Pantano Wash (Figure 3). This fault constitutes a line of hydrogeologic separation between the occurrence and utilization of groundwater in the Rincon Valley and the main Tucson basin, and thus has a profound effect in isolating groundwater in the lower basin of Rincon Creek from the effects of pumping in the Tucson basin.

The gently dipping Catalina thrust fault outcrops along the base of the mountain flanks on both sides of Rincon Creek (Figure 3). This fault, formed in late Cretaceous time, may have been reactivated as a glide fault in Miocene time as the crystalline cores of the ridges flanking the Rincon Creek trough rose and the upper plate of the thrust faults slid into the synclinal (downfolded) trough (Thorman and Drewes, 1981). Thorman and Drewes (1981) describe disharmonic faults associated with the thrusts that butt into the thrust from above but do not cross the thrust plane. They hypothesize that these disharmonic faults were formed during thrusting to relieve stresses building up in the upper plate as the thrust faulting moved the upper plate over a gently undulating plane. They also describe the glide faults as both independent structures, and as reactivation of the earlier thrust faults.

Thorman and Drewes (1981) did not map the Rincon Creek area in as much detail as they did mineralized areas. However, their descriptions suggest that either disharmonic faults reactivated during the glide faulting, or imbricate glide faults branched off the Catalina fault when it was reactivated creating a series of small structural basins. These basins extend from the point where the outcrop of the Catalina fault crosses Rincon Creek to Sentinel Butte. Such structures may extend westward beyond Sentinel Butte, but the unconsolidated alluvium deepens to the west and we found no visual evidence to suggest their existence. A hypothetical cross-section of the nature of the structures creating the small structural basins is illustrated in Figure 4. While no attempt was made to map faults during this study, the alternation of bedrock outcrops in the channel of Rincon Creek with alluvial floored channel segments is consistent with the presence of such structures. These features are observed in the middle basin area as far west as Sentinel Butte.

Faults of small displacement along the flanks of the Tanque Verde Ridge anticline, and the alternation of competent layers with less competent layers combine to form a series of basins in some of the tributaries to Tanque Verde and Rincon Creeks. The larger and usually deeper basins have filled with alluvium deposited by the stream and retain shallow groundwater. In many instances the groundwater system in these basins is probably replenished by streamflow resulting from storms in the drainage basin or springs/seeps caused by the same structure that formed the small basin, and not from the regional groundwater system.

In the alternating bedrock and alluvial sediment within the Expansion Area of Rincon Creek channel, groundwater moving down and to the west through the alluvial material is forced to the surface by a series of partially buried bedrock "dams". After crossing such features the stream flows back into the alluvium until it reaches the next downstream barrier. During times of high groundwater flow, as in the spring, stream flow is continuous through this reach, but by early summer, the flow occurs intermittently in the reaches immediately upstream from the bedrock "dams" (Figure 4). The limited data available suggest that the regional groundwater system is in hydraulic connection with the groundwater in the alluvium of the middle basin area of Rincon Creek. Additionally, withdrawals from the Rincon Water Company well would quickly drain the small alluvial aquifer during the dry months of each year unless the alluvium was also receiving recharge from the regional groundwater system (see Historical Well Data, this report).

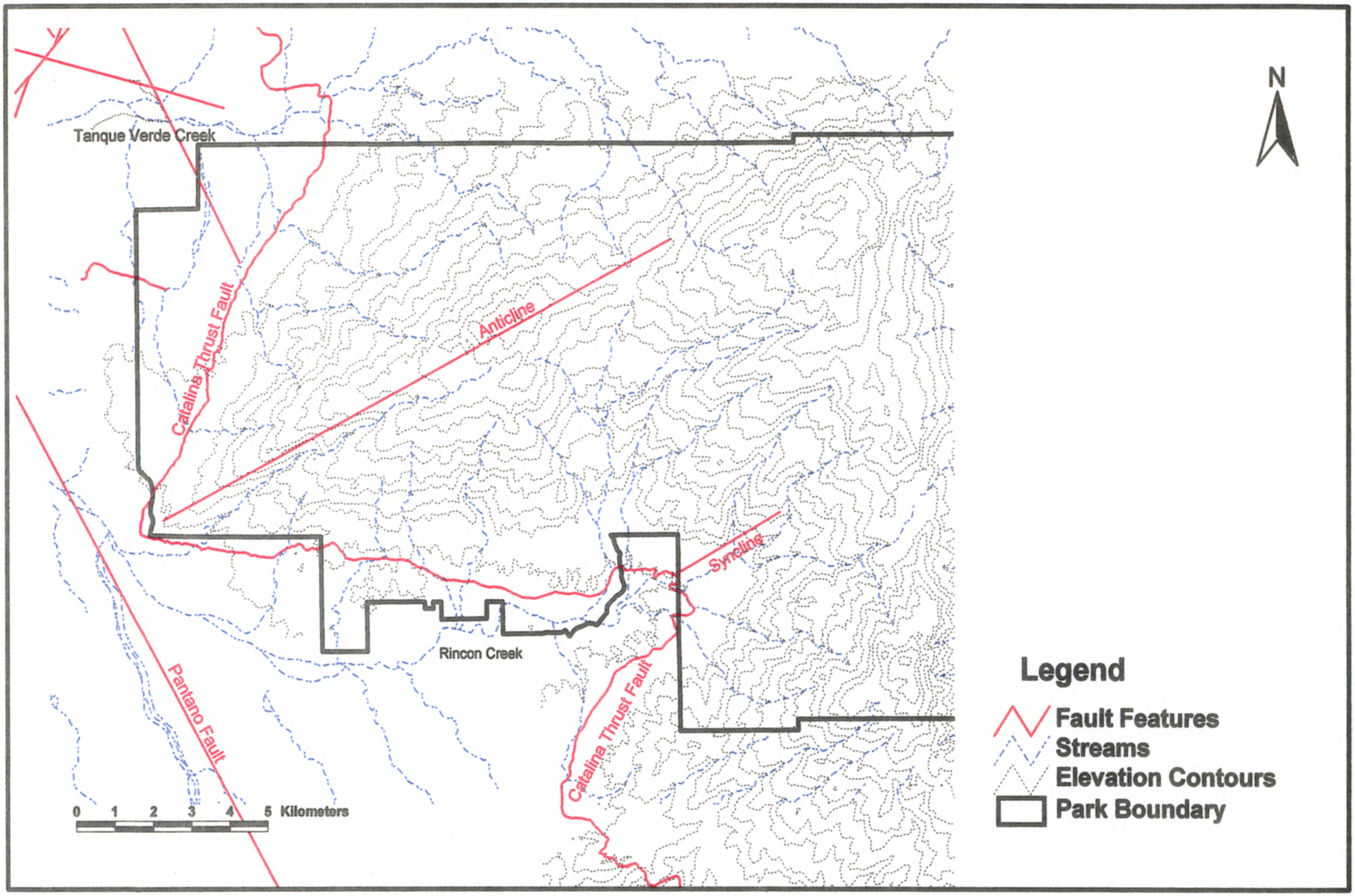


Figure 3. Major Faults in the vicinity of Rincon Creek.

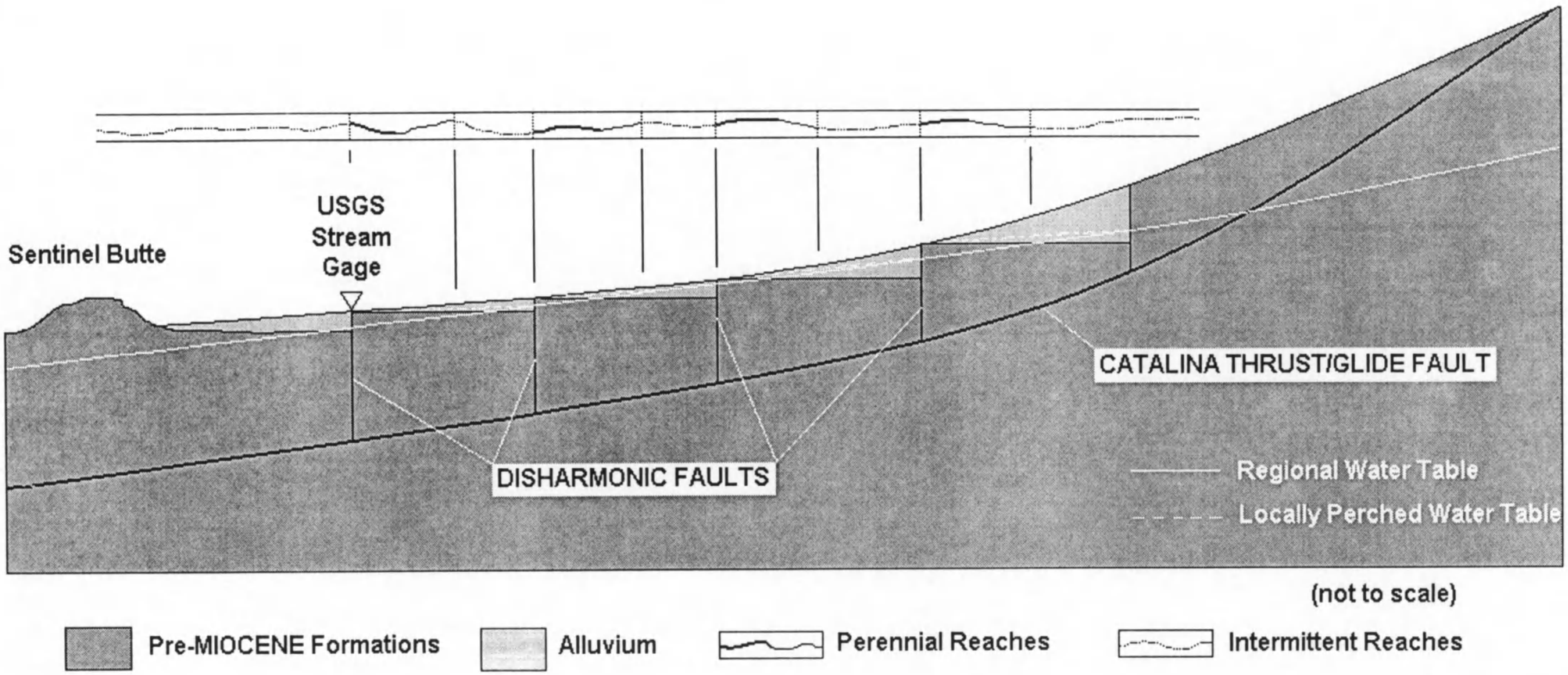


Figure 4. Schematic Cross-section along the axis of the Rincon Valley syncline from Sentinel Butte to the outcrop of the Catalina Fault.

Tucson Basin and Tanque Verde Creek

Southern Arizona lies within the Basin and Range physiographic province. Fine sediments from adjacent highlands were deposited in a relatively low-grade environment during the Eocene and early Oligocene. Although the source areas have mostly eroded away, a major portion of these Tertiary sediments crops out in the Tucson area. The geology of the Tucson basin was influenced by two major Tertiary tectonic events: the mid-Tertiary orogeny and the Basin and Range disturbance. Volcanism, metamorphism, listric faulting and uplift characterized the mid-Tertiary orogeny and contributed in part to the uplift of the Catalina highlands. Sediments derived from mid-Tertiary volcanism and uplift are typically thick sequences of conglomerates, fluvial overbank, and lacustrine deposits (Rogers, 1987).

The Basin and Range disturbance was the most recent major tectonic event to affect the Tucson basin. During this time, block faulting produced subsiding basins into which large volumes of sediments were deposited. This block faulting erased previous drainage and depositional patterns and created the typical horst and graben terrain that is present today. By the middle of the Miocene, the cover of mainly volcanic flows and related sediments had been removed from the Catalina highlands exposing the gneissic core. As faulting continued, increasing percentages of gneissic material were deposited. By the close of the Basin and Range disturbance, depositional sediments in the northern and eastern portions of the Tucson basin contained well over 90 percent Catalina gneiss (Rogers, 1987).

Two episodes of Basin and Range block faulting have been recognized. The main episode of faulting resulted in the formation of a deep north-south trending structural trough and deposition of thousands of feet of sediments and evaporites. Vertical fault movement exceeded depositional rates and closed basins evolved resulting in lacustrine and/or playa conditions in the basin interior in the middle Miocene. Development of exterior drainage systems terminated these southern Arizona lacustrine conditions (Rogers, 1987).

In the late Miocene, a second episode of faulting with renewed uplift of the Santa Catalina, Tanque Verde, and Rincon Mountains occurred. This resulted in the formation of shallow structural troughs imprinted upon the older structures. Basin and Range faulting gradually declined during the early Pliocene and had essentially ceased by the late Pliocene. General tectonic quiescence has since prevailed (Rogers, 1987).

Along the basin margins and mountain fronts extensive pedimentation and truncation of the older deformed sediments followed the end of the faulting. A well-defined pediment surface was formed extending from the Santa Catalina and Rincon Mountain fronts toward the interior of the Tucson basin. Cutting into the deformed Tertiary sediments, this erosional surface formed the base upon which the undeformed and unconsolidated late Pliocene and Pleistocene sediments were deposited (Rogers, 1987).

Basin filling continued well after the Basin and Range block faulting had ceased. By the late Pleistocene, maximum filling of the Tucson basin occurred with the deposition of the Fort Lowell Formation. Sediments of this formation were deposited mainly as a result of climatic effects. Along the basin margins, subsequent episodes of erosion and stream downcutting have stripped away much of the late Pliocene and Pleistocene sediments and exposed older sedimentary units (Rogers, 1987).

Surficial deposits in the northeast area of the Tucson basin consist mainly of Pleistocene and Holocene terrace deposits and localized Holocene stream and flood plain deposits. Characterized by a high degree of weathering, the terrace deposits average ten meters in thickness. Stream deposits consist of loose silty gravelly sand to coarse sandy gravel and the flood plain deposits are typically a loose silt or silty sand. Stream and flood plain deposits occur within and adjacent to the streambeds of Agua Caliente, Pantano, Ventana Canyon, and Rillito washes and Sabino and Tanque Verde creeks. The stream and flood plain deposits adjacent to Tanque Verde streambeds are derived mostly from Catalina Gneiss since it drains primarily from the Santa Catalina and Rincon Mountains (Rogers, 1987).

The hydrogeology of Tanque Verde Creek changes near the confluence with Agua Caliente Wash. Below Agua Caliente Wash is a structural trough of thick, unconsolidated, highly permeable Pliocene and Pleistocene sediments which overlie the older consolidated Miocene and Oligocene rocks. About two kilometers above the confluence, faulting and subsequent erosion have resulted in relatively shallow depth of the older, lower permeability, consolidated sedimentary Miocene and Oligocene rocks. Because of the greater hydraulic conductance and thickness of the younger unconsolidated sediments, the downstream section has been more intensively developed by Tucson Water as a source of high quality, low cost groundwater. (Stromberg et al., 1992)

WATER RESOURCES

There are two contributing sources of water to the Rincon Creek basin. One is mountain front recharge and the other is runoff in Rincon Creek. Groundwater contour maps of the area indicate that the direction of groundwater flow is from northeast to southwest (Osterkamp, 1973). The reach of Rincon Creek in the lower basin area downstream from the expansion area of the park is a line source of groundwater recharge where storm run-off infiltrates into the alluvium and percolates downward to the water table. On an average annual basis the flux through Rincon Valley was estimated to be 4,540 acre-feet per year (5.6 Mm^3). Consisting of 3,500 acre-feet (4.3 Mm^3) as recharge from runoff in Rincon Creek and 1,040 acre-feet per year (afy) (1.3 Mm^3) from mountain front recharge (Osterkamp, 1973). Burkham (1970) found that the infiltration along Rincon Creek from the gauging station to Camino Loma Alta was relatively low but from there to Old Spanish Trails crossing the rate was extremely high. These rates correlate with the geology of Rincon Valley.

Davidson (1973) estimated that only about 3,000 acre-feet (3.7 Mm^3) per year moved as groundwater into the Tucson basin along a 16 km band that crossed the mouths of Rincon Creek and Pantano Wash. United States Geological Survey (USGS) streamflow data indicate that Pantano Wash delivers almost twice the annual flow of Rincon Creek. If one assumes that the amount of groundwater moving in the alluvium of these two streams is in similar proportion and that only a small amount moves in from the adjacent ridges, one might estimate that the groundwater discharge is about 1.1 Mm^3 /y and 2.0 Mm^3 /y from Rincon Valley and Pantano Valley, respectively. The amount of groundwater discharge at the park's western boundary would be smaller, as the area that Davidson's estimate was for 6.5 km to the west. Using the drainage area above the park's western boundary (in the Rincon Valley alluvium) and the drainage area in Rincon Valley above Davidson's line, one could estimate 85% of the 1.1 Mm^3 or 0.94 Mm^3 /y crosses the park's western boundary.

HISTORIC WATER DEMAND

Until about 1980, much of the land along Rincon Creek was irrigated to produce feed for livestock. Historic water demand for uses other than irrigation was minimal. According to the Arizona Corporation Commission (ACC) the following three water companies produced a total of 27.48 acre-feet (33,900 m^3) in 1984: Loma Alta, Rincon Creek and Thunderhead. The total private residential pumpage was only about 2.4 acre-feet per year (2,960 m^3/y). The larger Ranchland Water Company produced 39 acre-feet (48,100 m^3) of groundwater for use by 257 local residents for a total of 135 gallons (511 liters) per capita per day. Downstream use by Ranchland Water Company required that additional 46 acre-feet (56,700 m^3) per year be taken directly from Rincon Creek. Of these four water companies, only Rincon Creek extracted water from within the current study area. Ranchland Water Company occupied the area now known as Rocking K Ranch and utilized water resources further west and downstream (Halpenny and Halpenny, 1985).

The Rincon Creek Water Company service area occupies 437 hectares of mostly very rough terrain underlain by Precambrian and Mesozoic rock. It draws water from wells in the middle basin area upstream of the current United States Geological Survey gauging station on Rincon Creek and several miles upstream from the Precambrian and Mesozoic rock outcrops that separate Tucson basin from "Rincon" basin. This area is within the Park's expansion area and includes the best remaining and most threatened riparian habitat along Rincon Creek. Specific historic pumpage values for Rincon Creek water company were not available; however, in 1984 it only served one customer (Halpenny and Halpenny, 1985).

PRECIPITATION

Precipitation drives the hydrologic system in the Rincon Creek basin. There are no other inputs of groundwater for this basin (both mountain front recharge and creek infiltration start as precipitation). The thickness of the saturated alluvium varies, but the overall storage capacity is orders of magnitude less than the saturated sediments within the Tucson basin (Mott, 1997). Since the depth of alluvial material is not extensive in the middle basin, this area has minimal water storage capacity. Precipitation also drives the hydrologic conditions of the Tanque Verde tributaries. Most of the tributaries are high-gradient washes typical of upper basin areas, with limited if any storage capacity. As with most washes in arid and semi-arid areas, these washes run only in response to rainfall events. This makes the amount and timing of available precipitation and its balance with groundwater extraction critical.

Ideally one would compare long-term basin precipitation data, streamflow and measured groundwater levels. Unfortunately, there is no weather station within Saguaro National Park, east. Precipitation data was collected from Tucson Magnetic Observatory (TMO) located at Tanque Verde Road and Sabino Canyon and at Santa Rita Experimental Range. Appendix B contains a complete list of monthly and annual rainfall amounts for both stations. The Tucson Magnetic Observatory is the closest measurement location and was considered an appropriate data source. Total annual rainfall for TMO was plotted in Figure 5. While not a long-term trend, there appear to be more wet years after 1977 than from 1934 to 1977. If anthropogenic factors weren't present one would expect to see a subtle increase in recruitment and improved riparian conditions as a result of the increased water availability. Yet all available information (literature and field observations) indicate a decrease in riparian plant recruitment and a decline in the overall health of the community.

To get a rough idea of how Rincon Creek responds to precipitation events, monthly precipitation measured at the observatory was graphed against monthly stream flow on Rincon Creek. Several assumptions are inherent in this comparison. The first is that rainfall at TMO reflects conditions on the Rincon Creek watershed. In the winter with the large, slower moving frontal storms common to the Tucson area this isn't a bad assumption. However, summer precipitation falls as a result of very localized convective thunderstorms and conditions can vary greatly from one location to the next. Figure 6 shows three relatively wet years while Figure 7 reflects three drier years. None of these years represent extreme years. In both cases, there is a general pattern of increasing stream flow in response to increased precipitation. Note that on both figures streamflow is calculated on a log-scale that accentuates low flows.

As reported by Halpenny and Halpenny (1985) groundwater levels, especially in areas of shallow alluvium, are tightly coupled to precipitation. From the perspective of keeping the riparian communities intact, water table levels must stay within the rooting zone of the riparian vegetation the majority of time from March to October. The winter rains are critical in recharging the groundwater in the middle basin areas of Tanque Verde and Rincon Creeks, while summer rains help maintain the high-gradient upper basin areas and replenish the soil moisture in the middle basin areas. The small riparian pockets in the upper basin areas have extremely limited water storage capacity and are much more sensitive to short term fluctuations in weather conditions. Groundwater extractions in the middle basin areas must be balanced by recharge on a seasonal basis to keep the riparian communities intact.

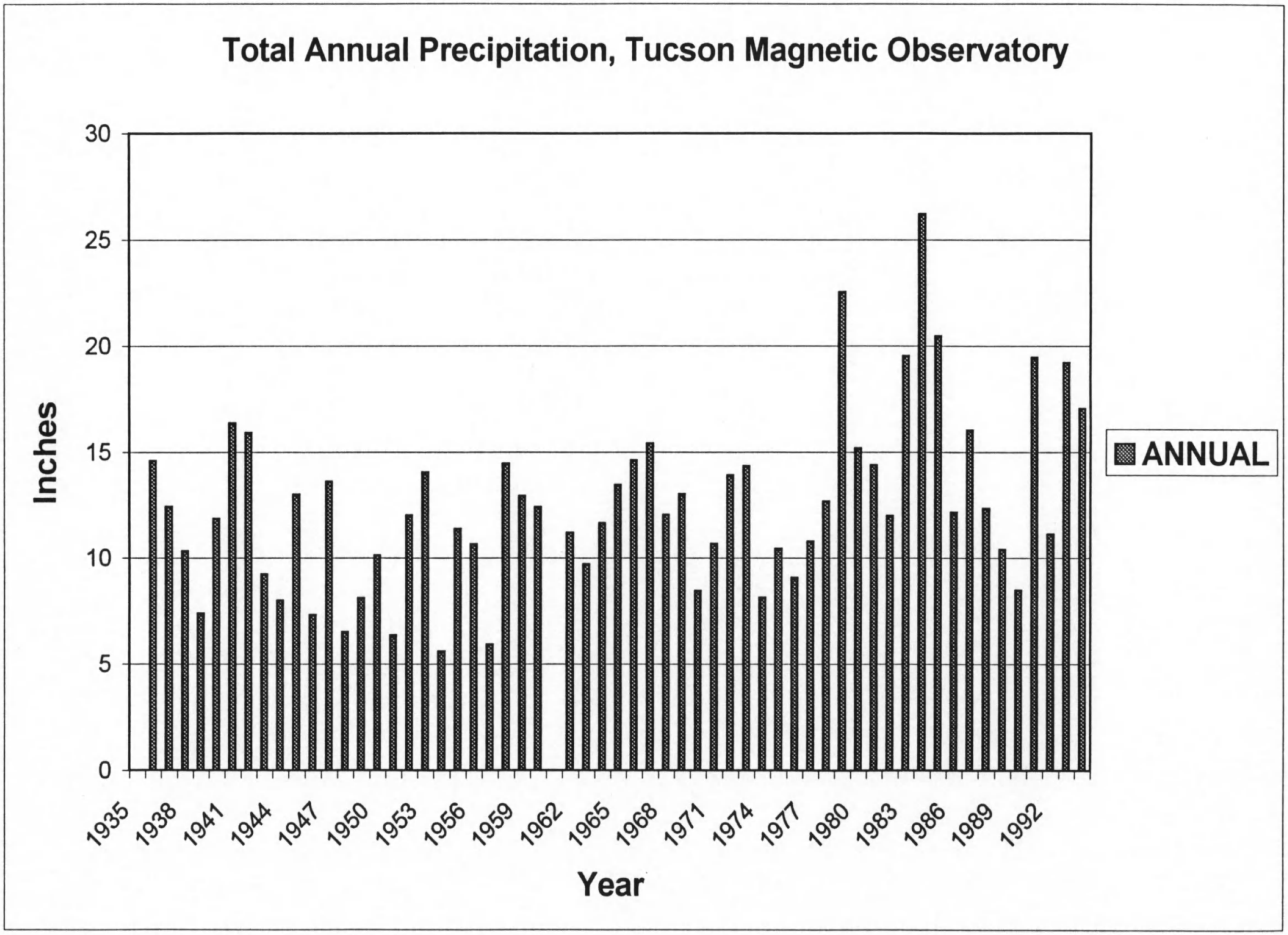
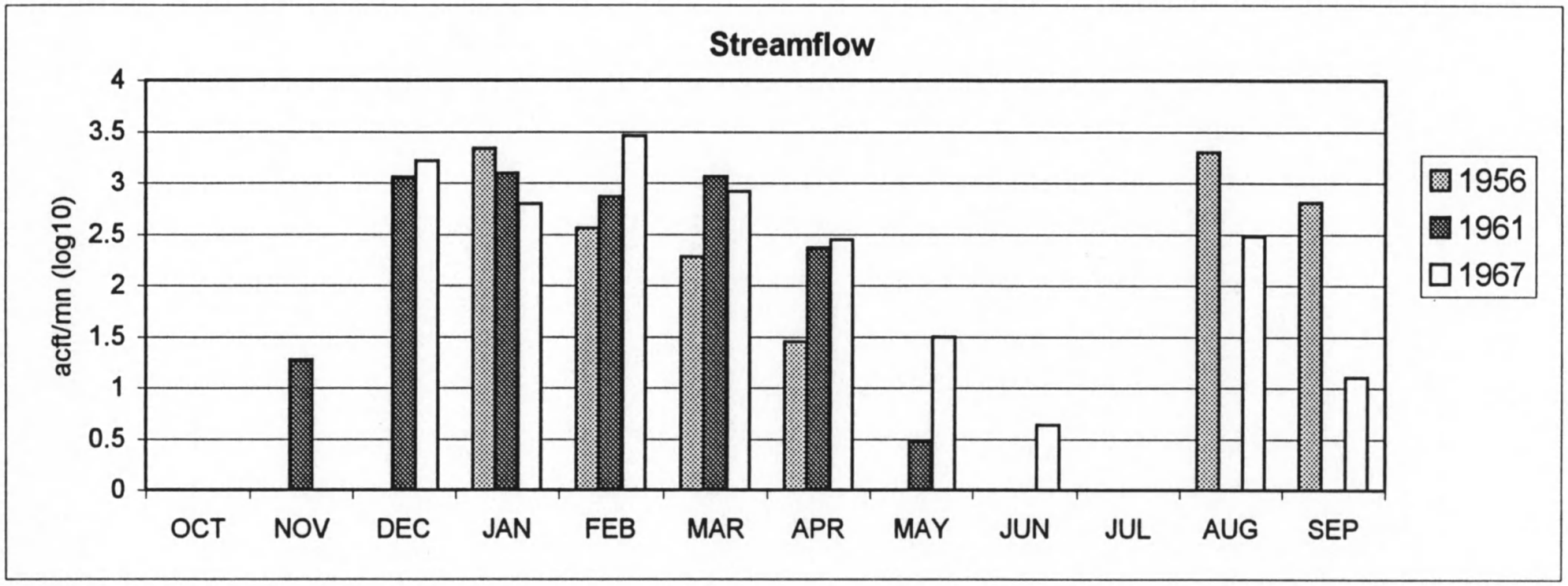


Figure 5. Total annual precipitation in inches, Tucson Magnetic Observatory (1935-1993)



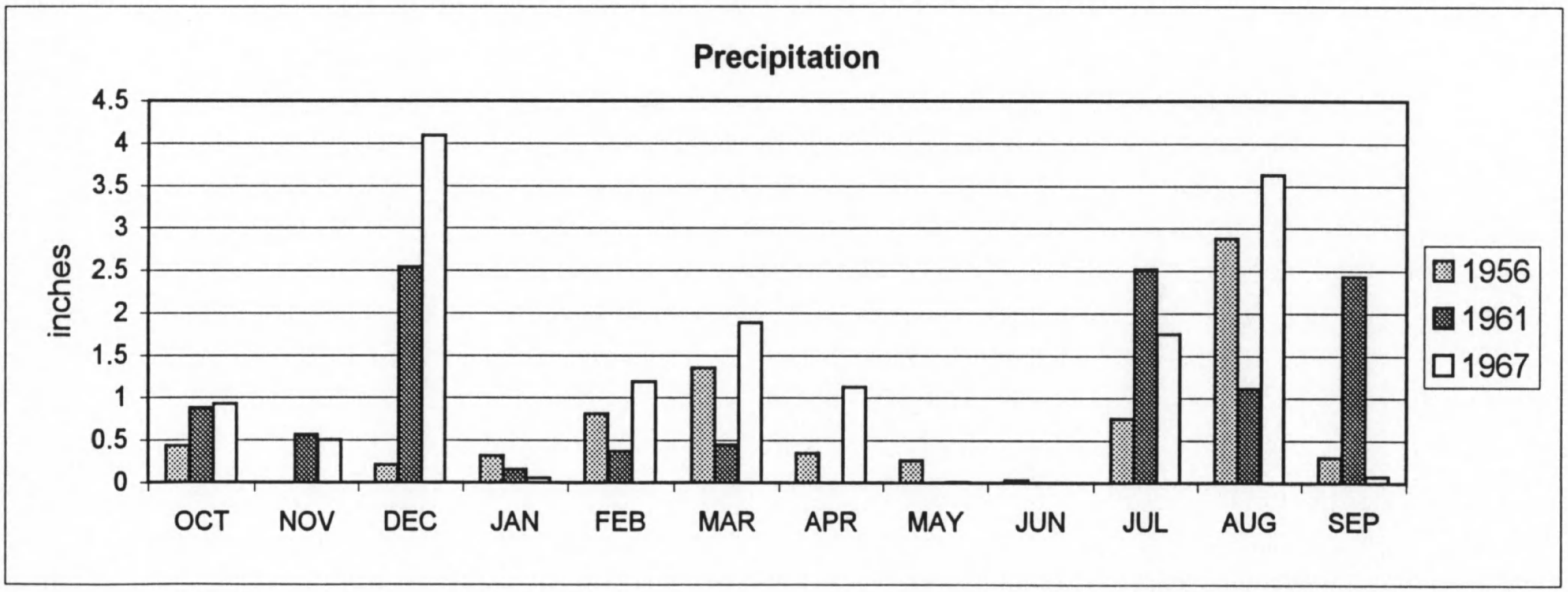
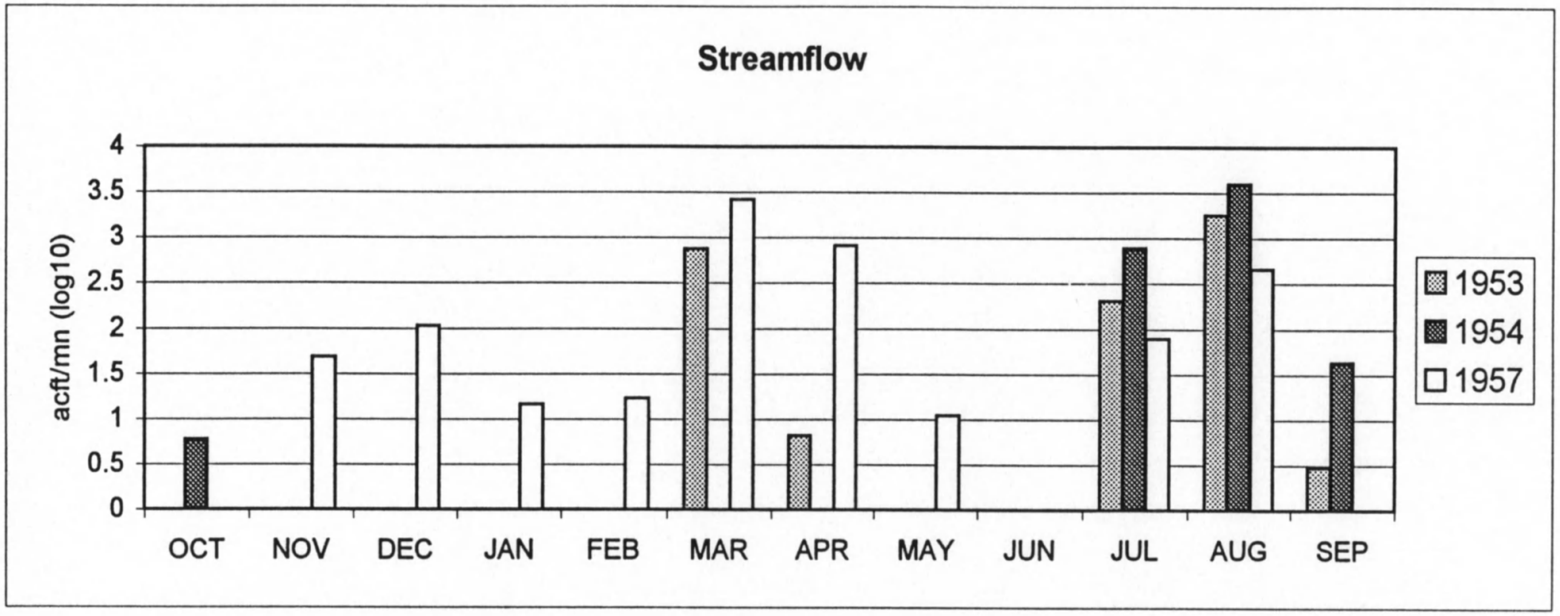


Figure 6. Total monthly precipitation at TMO (top) and total monthly streamflows (acre feet month) Rincon Creek. Data from three relatively wet years.



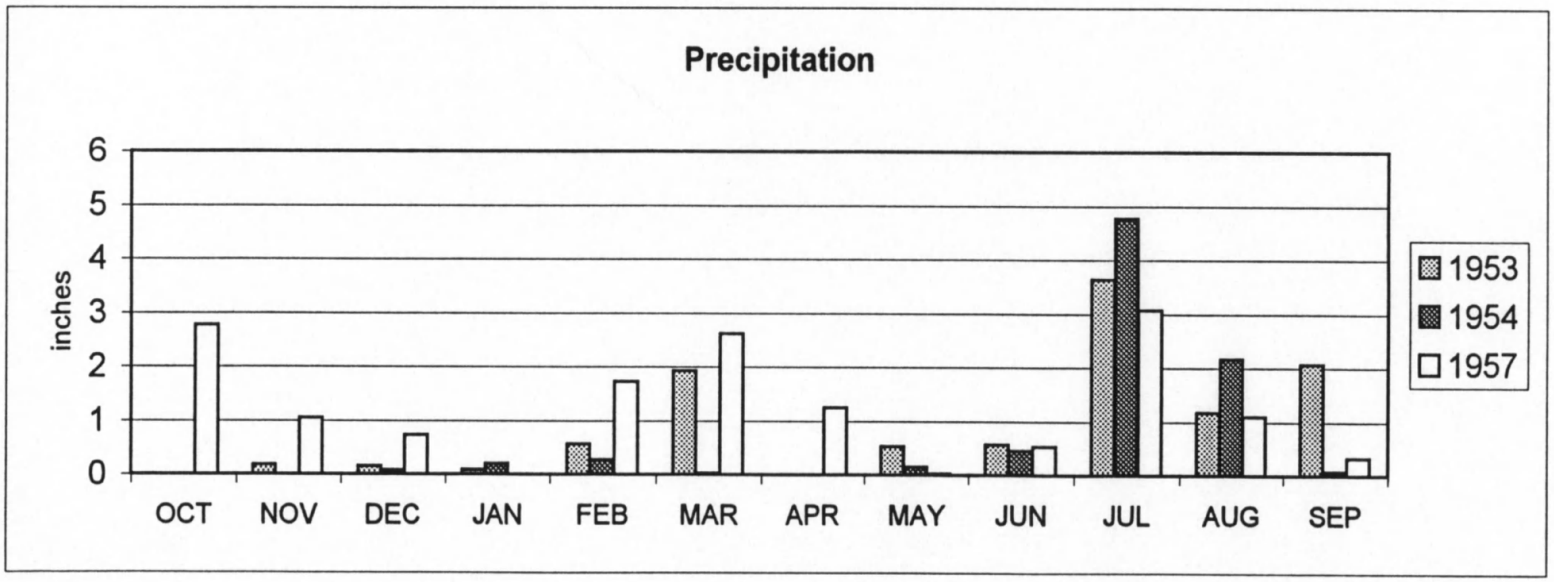


Figure 7. Total monthly precipitation at TMO (top) and total monthly streamflows (acre feet month) Rincon Creek. Data from three relatively dry years.

Rincon Creek Gauging Station

The USGS began operating a gauging station (USGS station number 09485000) on Rincon Creek approximately 300 to 400 meters upstream of Sentinel Butte on October 1, 1952. Through September 30, 1974, the station was operated as a total station measuring total annual runoff and discharge peaks. From October 1, 1974 to Sept 1989 the station was operated as only a crest-stage partial record station. In September of 1989 it was converted back to a total station and has continued as such to present day. Halpenny and Halpenny (1985) reported that the highest peak discharge during the first 32 years of record was 9,660 cubic feet per second (cfs) (274 m^3/s) on August 19, 1971. Peak flows through 1994 are illustrated in Figure 8. USGS has not released more current data. The peak flow of 274 m^3/s still remains the historic peak discharge. A record of USGS historic peak flows for Rincon Creek through 1994 is listed in table 1. No trend or change in peak flows is apparent from these data.

Total annual and average daily flows were calculated for all available years through 1996 (Table 2). Flows for 1974 through 1988 were not measured and therefore not available. The wettest year recorded was 1992 with total annual flow of 29.8 Mm^3 per year (24,172 afy) and a calculated average daily flow of 81,500 m^3/day (66.04 acre-feet/day). This is considerably higher than the remaining wet years: 1965, 1972, and 1994, which averaged 59,400, 40,200 and 52,200 m^3/day respectively. 1955 has the dubious distinction of being the driest year with a total annual flow of only 64,100 m^3 (51.97 afy) or averaging only 173 m^3/day. Out of the 30 years of data available, four years had average daily flows of less than 1233 m^3/day (1 acre-foot/day): 1955, 1966, 1973, and 1995. Three of those years had total annual flows of less than 123,300 m^3 per year (100 afy). Total annual streamflows are illustrated in Figure 9. Indicative of a semi-arid climate there are considerably more dry years than wet years.

Due to the skewed distribution of flows and the high number of no-flow days, it is often more telling to look at the standard deviation around the mean flow. Figure 10 graphically illustrates the wide fluctuations calculated for each mean. The fact that Rincon Creek has years where the calculated average daily flow equaled or exceeded the total annual flow of other years speaks to the extreme variability in hydrologic conditions.

Variable annual streamflow is not the only problem facing riparian communities in the arid southwest. Timing of the streamflow and water availability is critical. Tucson has a bimodal precipitation distribution resulting in the same bimodal distribution in stream flow. Figures 11 through 13 show the monthly streamflow for the 1950s, 1960-1973 and 1989-1996 respectively. Monthly totals vary from year to year but a pattern of wet winters and potentially high flows in the late summer months due to the monsoons is clear. Appendix C contains a complete list of monthly streamflow data for Rincon Creek gauging station.

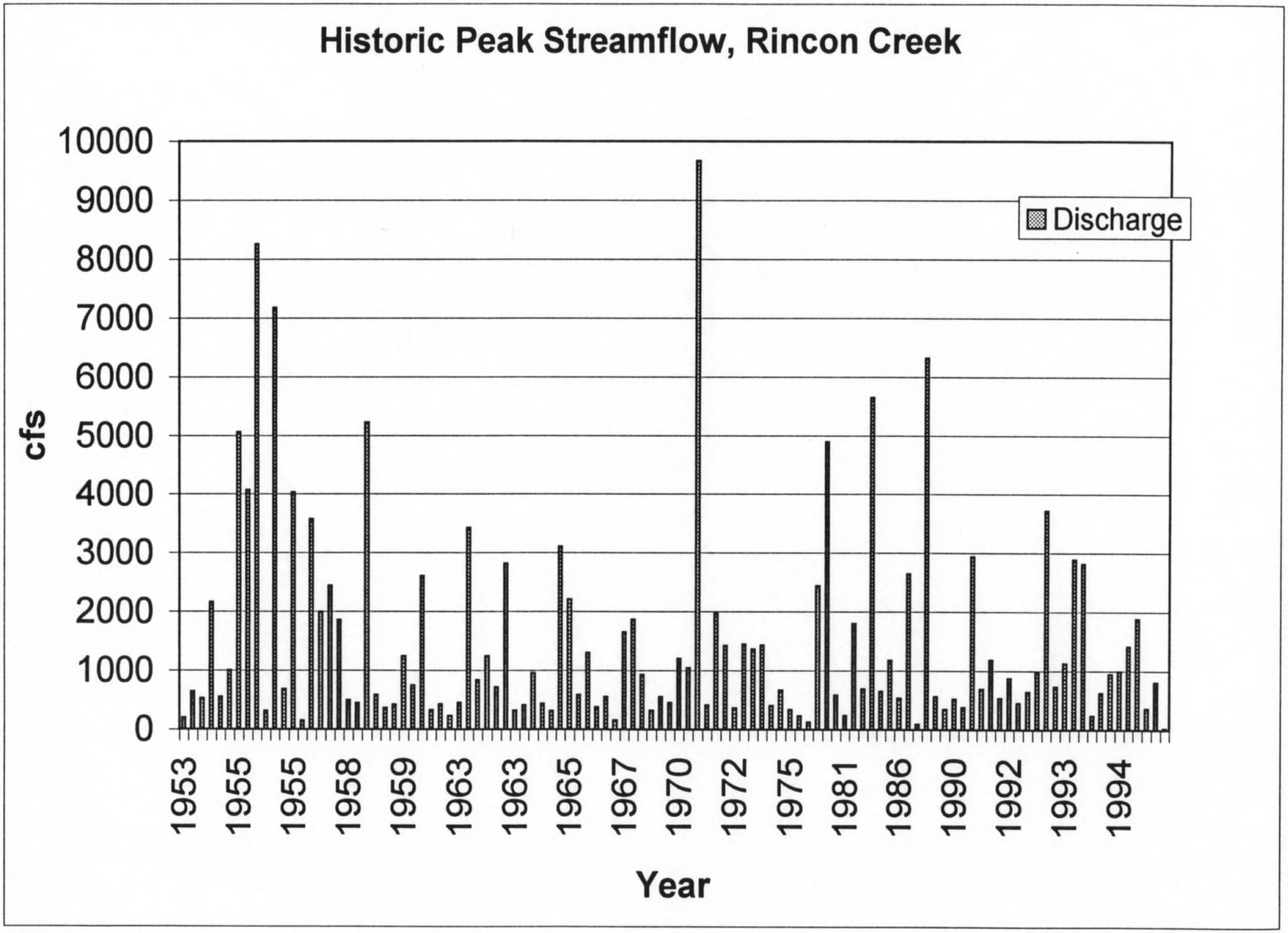


Figure 8. Historic peak streamflows (cubic ft./sec), Rincon Creek.

Table 1. Peak streamflows (cubic feet/second) Rincon Creek, Tucson Arizona.

Year	Month	Discharge (cfs)
1953	7	194
1954	3	640
1954	7	525
1954	8	2160
1954	8	550
1955	7	1000
1955	7	5050
1955	7	4070
1955	8	8250
1955	8	312
1955	8	7170
1955	8	682
1955	8	4030
1956	7	150
1957	1	3570
1957	8	1990
1957	8	2440
1957	8	1850
1958	3	492
1958	8	447
1958	10	5220
1959	8	580
1959	8	357
1959	8	415
1959	8	1240
1960	1	747
1961	8	2600
1961	8	325
1961	9	430
1962	1	227
1963	2	454
1963	8	3420
1963	8	837
1963	8	1240
1963	8	713
1963	8	2810
1963	8	323
1963	9	409
1964	9	948
1964	9	433
1965	8	311
1965	12	3100
1965	12	2210
1965	12	586
1965	12	1300
1966	8	379
1966	9	550
1967	8	157
1967	12	1650
1968	2	1860
1968	8	930
1969	1	323
1969	9	548
1970	7	448
1970	8	1200
1970	9	1040
1971	8	9660
1971	8	410
1971	8	1960
1971	9	1420
1972	7	360
1972	10	1440
1973	2	1360
1973	2	1430
1973	3	406
1974	8	664
1975	9	340
1977		230
1977	1	127
1978	1	2440
1978	12	4890
1980	2	586
1981	8	236
1982	8	1800
1983	1	688
1983	10	5640
1985	1	647
1986	7	1170
1986	12	535
1988	8	2640
1989	7	88
1990	7	6320
1990	7	558
1990	7	343
1990	7	514
1990	7	381
1990	8	2940
1991	1	692
1991	3	1180
1991	12	536
1992	2	871
1992	8	455
1992	12	642
1992	12	964
1993	1	3720
1993	1	731
1993	1	1120
1993	1	2890
1993	8	2810
1994	3	237

Table 2. Total, average, standard deviation and variance of annual streamflow, Rincon Creek gaging station.

Year	Total (acft/year)	Average (acft/day)	Std dev	Variance
1952	591.68	1.62	7.55	56.97
1953	2764.21	7.55	52.37	2742.13
1954	4756.63	13.00	64.92	4214.55
1955	51.97	0.14	0.85	0.73
1956	5406.43	14.77	90.52	8194.04
1957	4160.99	11.37	37.76	1425.92
1958	2227.27	6.09	32.15	1033.80
1959	5680.35	15.52	46.08	2123.46
1960	764.04	2.09	16.37	267.90
1961	4533.69	12.42	24.28	589.62
1962	4366.68	11.96	44.55	1984.48
1963	1238.89	3.38	18.72	350.41
1964	965.37	2.64	5.21	27.13
1965	17589.88	48.19	145.29	21108.42
1966	72.60	0.20	1.43	2.04
1967	6595.69	18.02	88.29	7794.82
1968	988.16	2.71	9.84	96.89
1969	1602.85	4.39	33.18	1101.22
1970	2976.24	8.13	72.35	5234.56
1971	2599.22	7.10	17.95	322.13
1972	11934.44	32.61	128.65	16551.68
1973	279.32	0.76	6.77	45.86
1989	3131.05	8.55	40.90	1672.69
1990	7816.68	21.36	61.91	3832.37
1991	8592.88	23.48	60.81	3697.30
1992	24171.94	66.04	252.08	63542.92
1993	949.54	2.59	14.29	204.07
1994	15477.75	42.29	154.97	24015.60
1995	68.89	0.19	1.79	3.22
1996	551.85	1.51	6.74	45.44

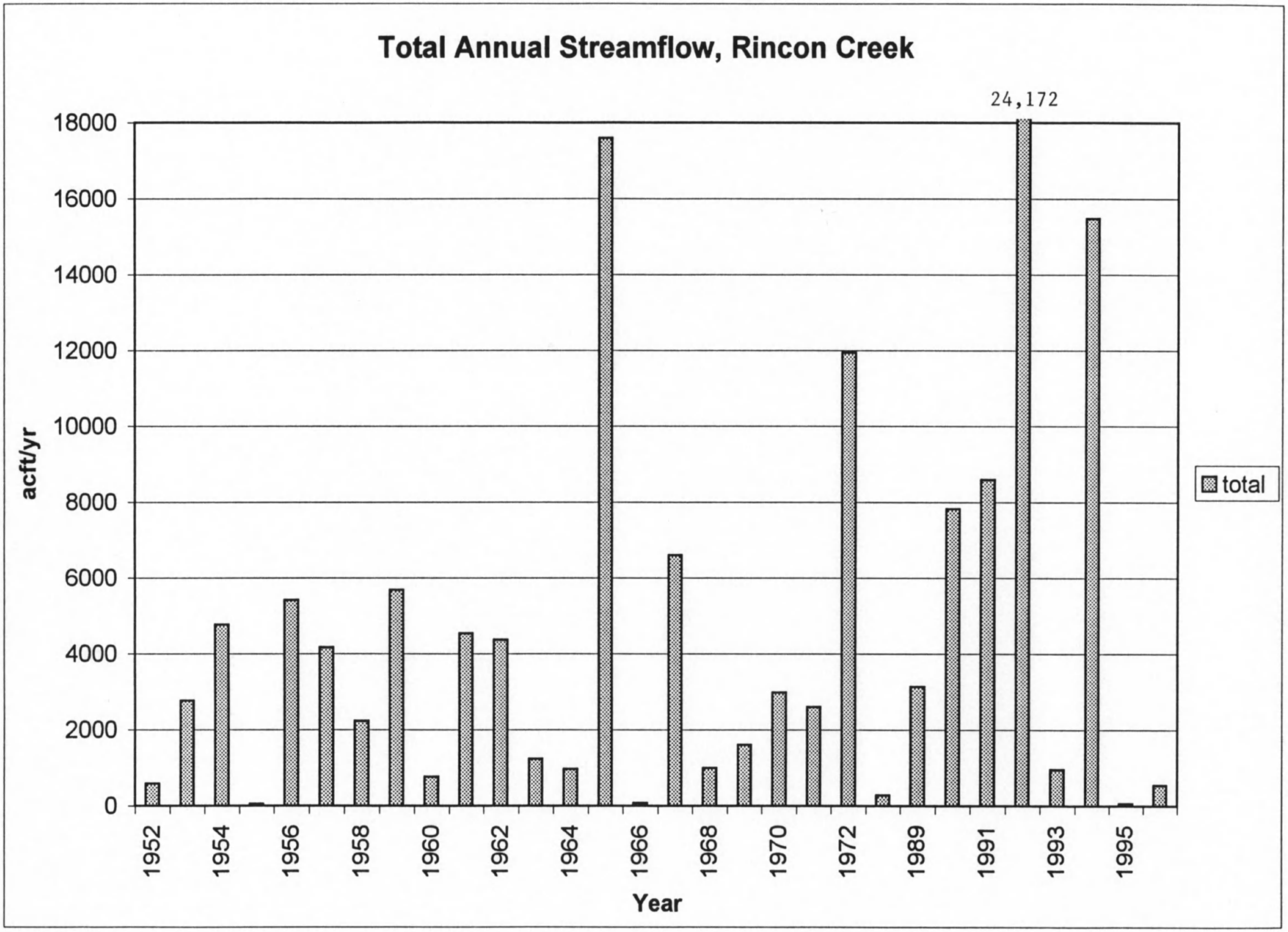


Figure 9. Total annual streamflow (acre-feet/year) for years 1952-1973 and 1989-1996, Rincon Creek.

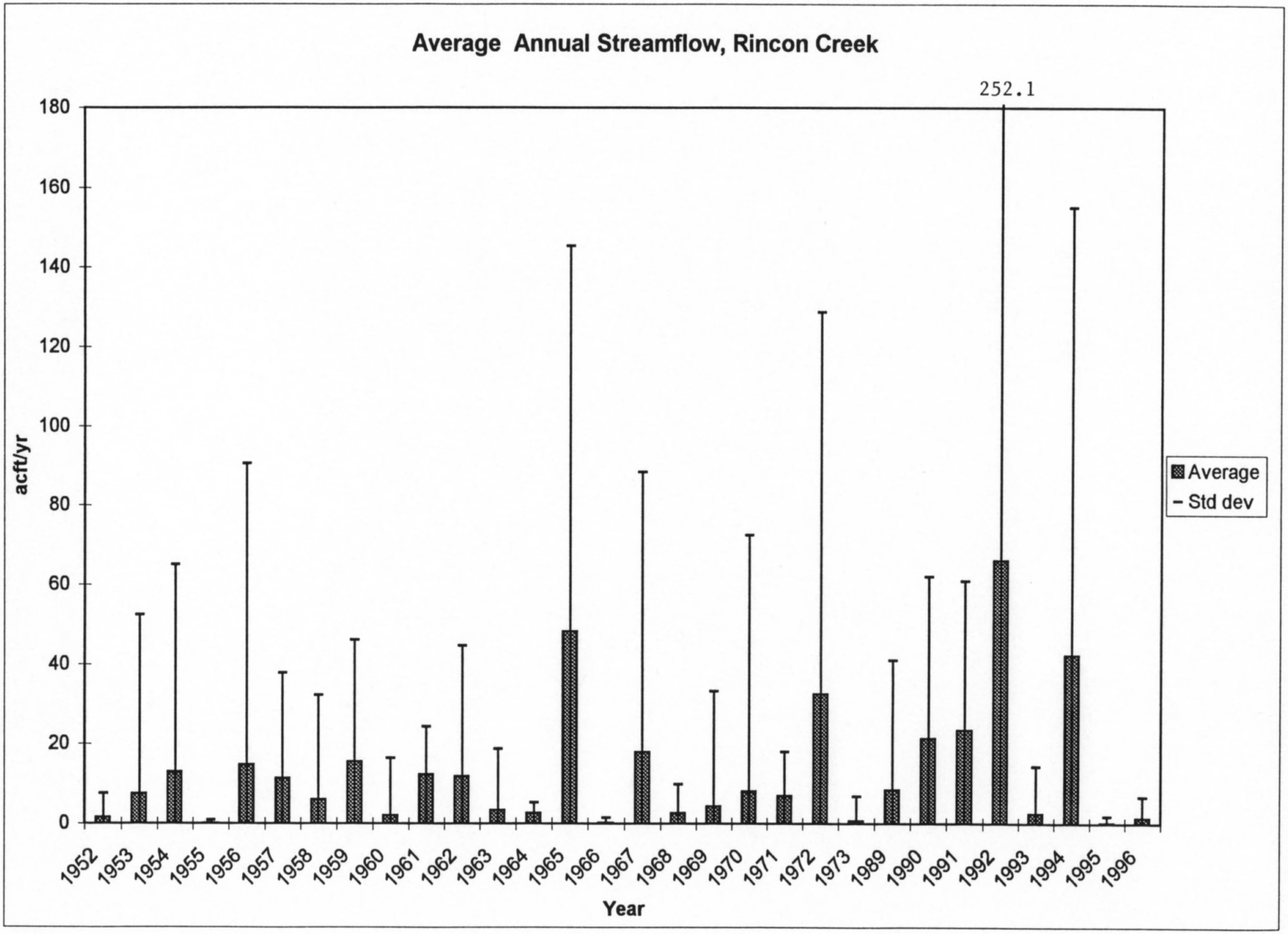


Figure 10. Average annual streamflow plus one standard deviation (acre ft/year), Rincon Creek.

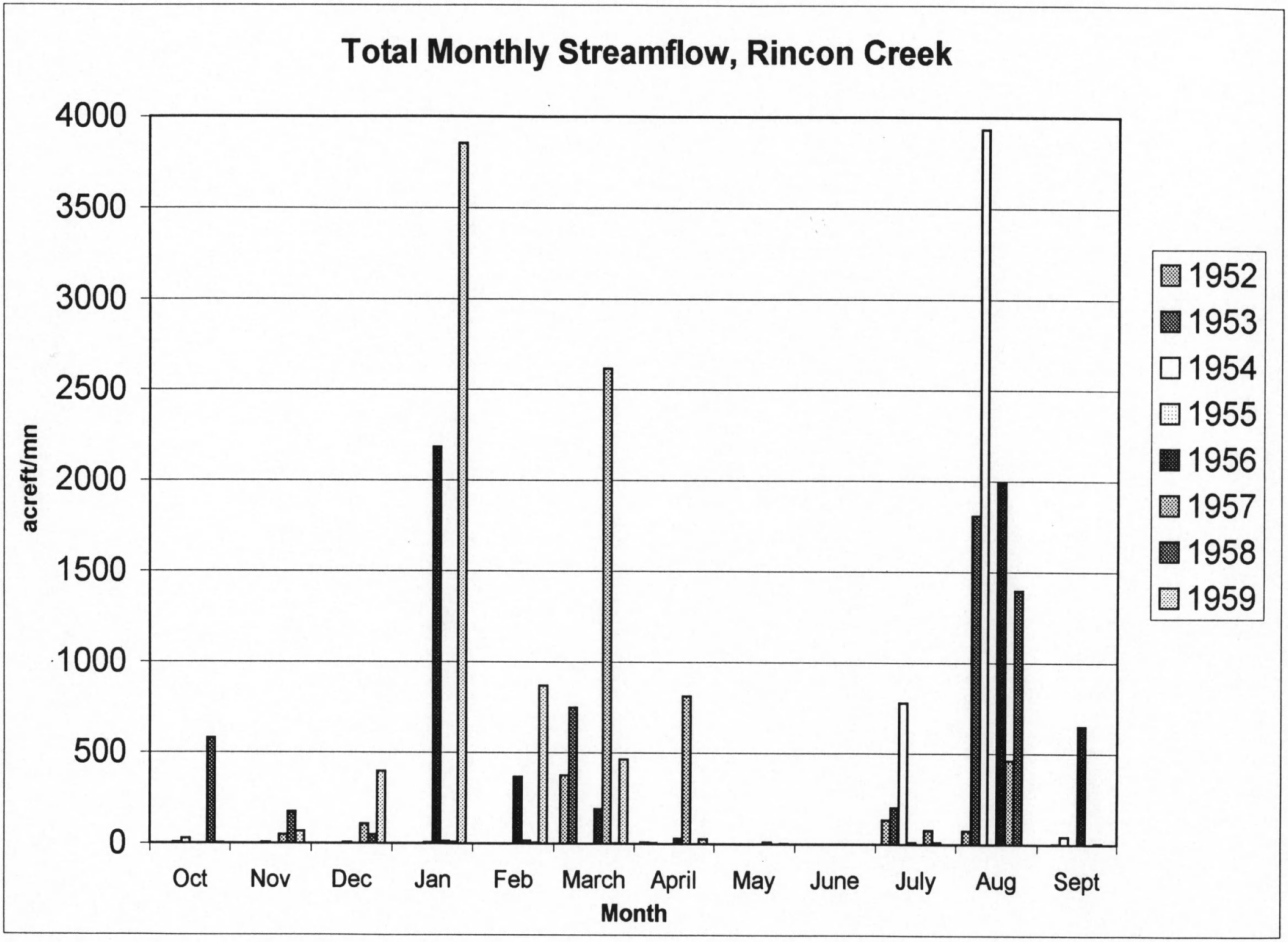


Figure 11. Total monthly streamflow (acre ft/mn) calculated from average daily cfs, Rincon Creek (1950s).

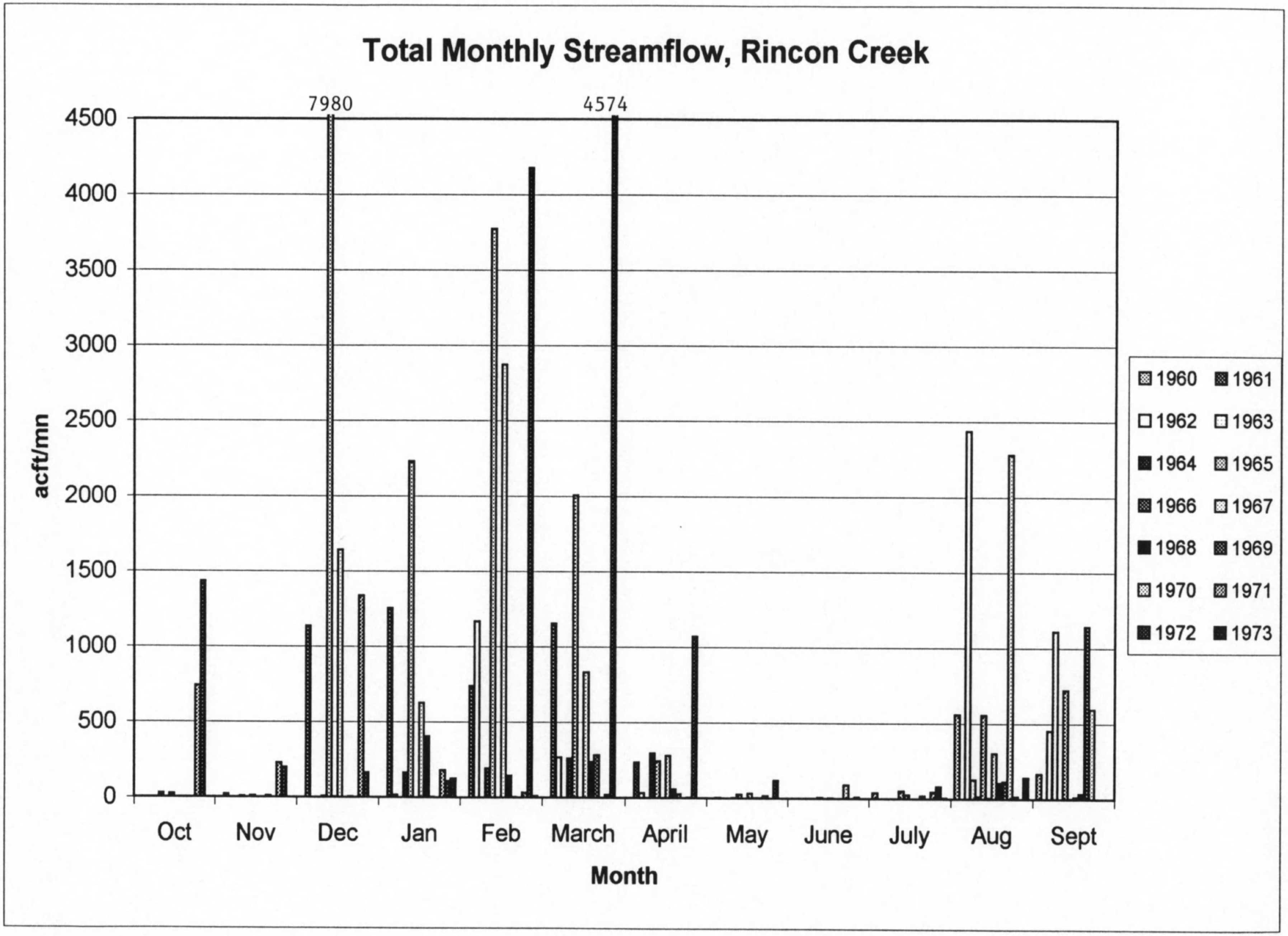


Figure 12. Total monthly streamflow (acre ft/mn) calculated from average daily cfs, Rincon Creek (1960-1973).

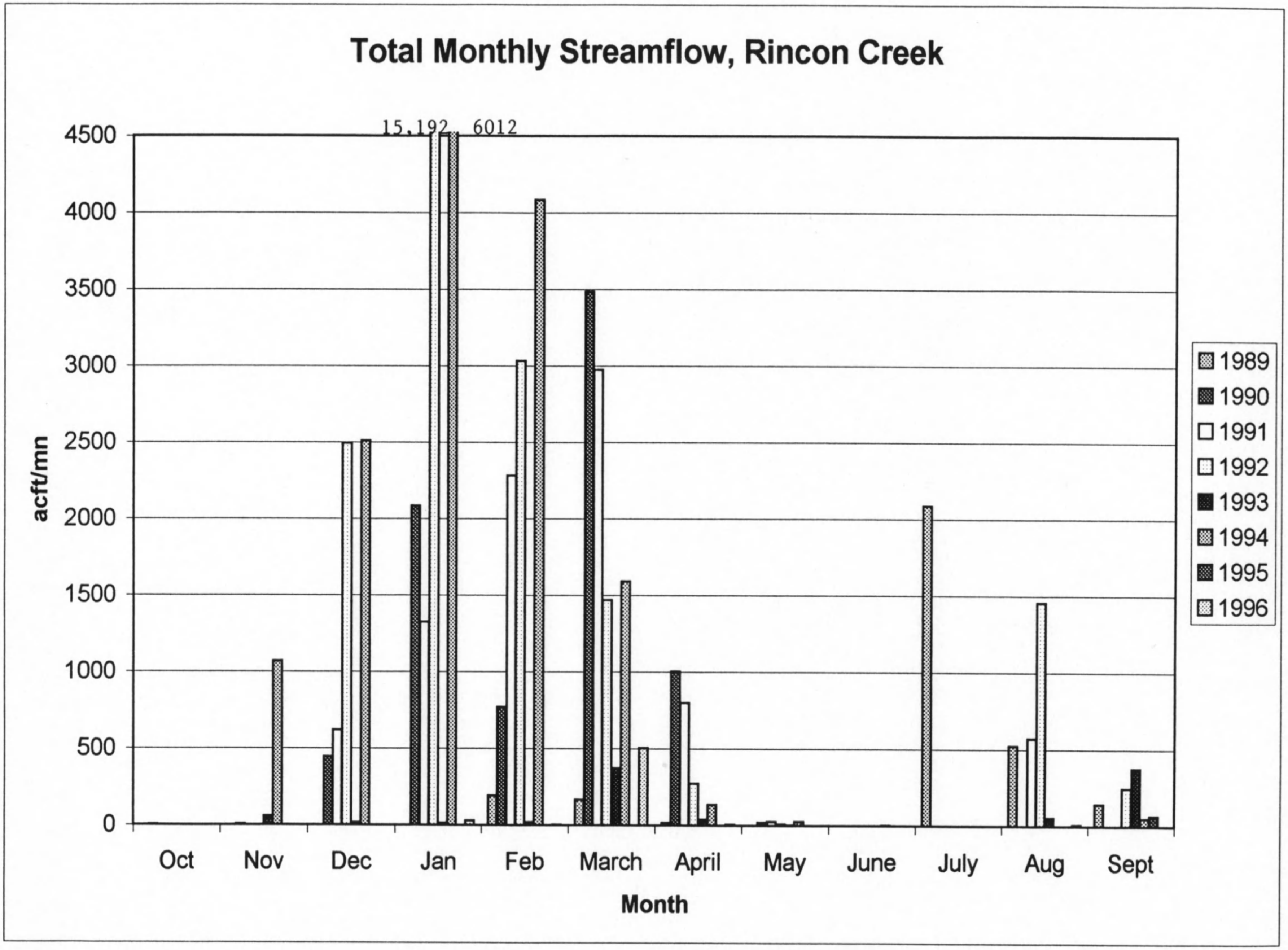


Figure 13. Total monthly streamflow (acre feet/month) calculated from average daily cfs, Rincon Creek (1989-1996).

HISTORIC WELL DATA

Rincon Creek Middle Basin Aquifer

The direction of groundwater movement in the area is predominantly southwestward from Rincon Creek across the Pantano Fault and into the Tucson basin. The groundwater reservoirs supporting the riparian areas within Rincon Mountain District are not directly connected to the Tucson basin aquifer. This is critical since drawdown within Tucson basin is, in most areas, already sufficient to place the water table well beyond the depth of the riparian vegetation. The majority of Rincon Creek flow infiltrates into the ground before reaching the confluence with Pantano Wash. While flows in Pantano Wash are readily recharged, this recharge does not contribute to the groundwater supply of Rincon Valley (Halpenny and Halpenny, 1985).

Water levels in the Rincon Valley have been recorded as early as 1941. Halpenny and Halpenny (1985) using what they considered a plethora of data gathered from 1947-1980 found that the water level in 1980 was slightly lower than when first measured. However, they concluded that the data indicated a general pattern of decline during the dry periods and an increase during wet times. They concluded that the aquifer system was effectively in balance between long-term recharge and long-term natural discharge plus historic (1950 to 1980) withdrawals. Unfortunately, conditions appear to have declined in the succeeding years.

While groundwater levels still respond to both seasonal and long-term fluctuations in precipitation patterns, numerous indicators point to an overall lowering of the water table in both the middle and lower basins. The riparian corridor between the X9 Ranch and Sentinel Butte (within and adjacent to the Park expansion area) contains remnants of a once much larger and more lush riparian forest. Areas once covered by mesquite bosque are now home to desert scrub. The surviving riparian trees line the immediate creek bank and in many cases show signs of long-term water stress. Personal observation and the results of an earlier study conducted by the Rincon Institute suggest that groundwater drops off steeply west of Sentinel Butte. Depth to water approximately 3.2 km down stream was reported at eight meters below the surface (Briggs et al., 1996).

Well data was collected for the entire Saguaro National Park area including the following six USGS township (T) and range (R) parcels: T14SR16E, T14SR17E, T14SR18E, T15SR16E, T15SR17E, and T15SR18E. This information has been forwarded to the Parks. Table 3 lists the wells that lie within or adjacent to the expansion area, the northern section of T15SR17E, and the primary focus of this study. If only one measurement date is given it coincides with the well drilling process. In only five cases were repeat water level measurements taken. Figure 14 illustrates water table elevation and the approximate location of the wells with sufficient location data.

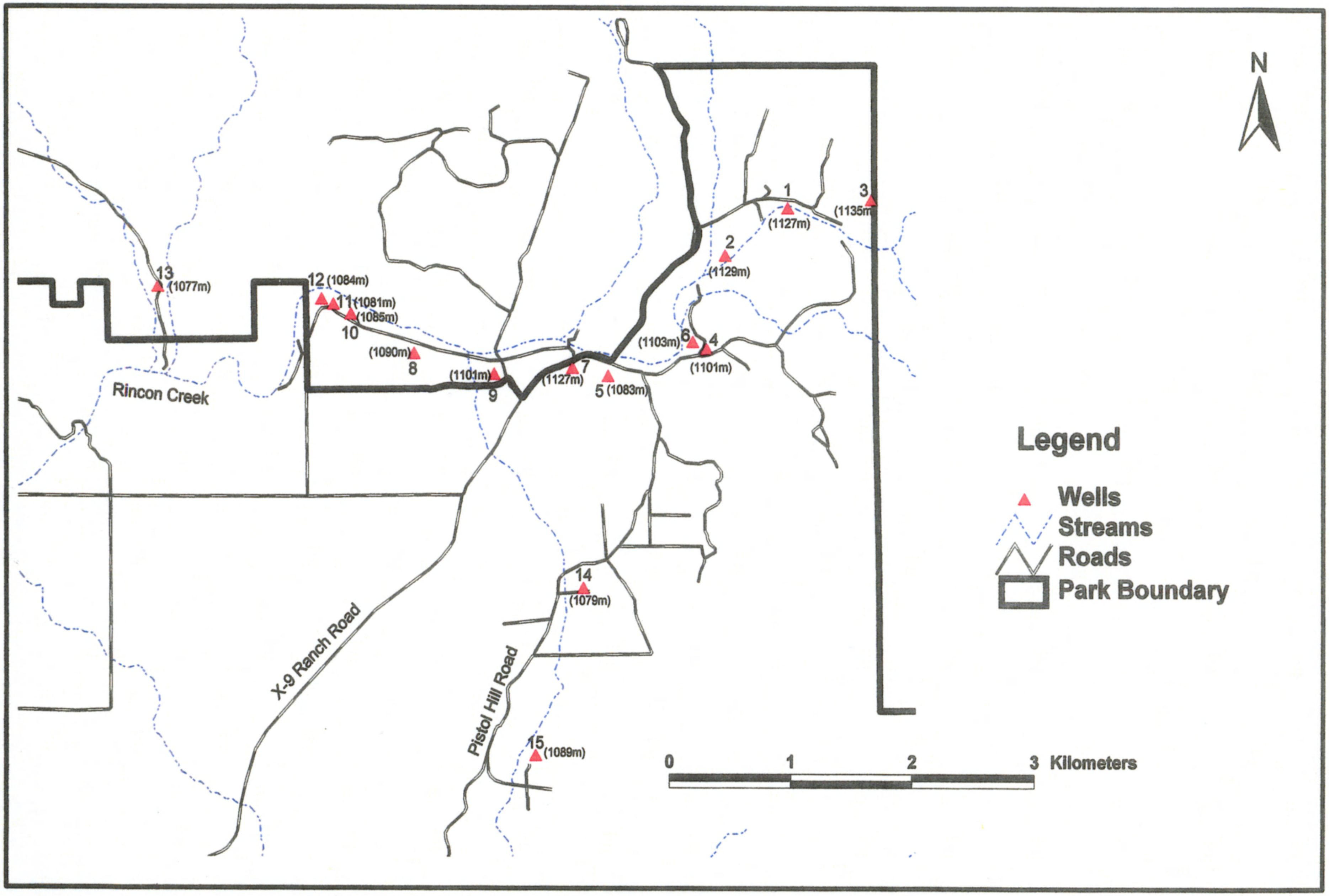


Figure 14. Existing well locations with reported water table elevations (meters above NGD).

The records on file with the Arizona Department of Water Resources are inconsistent between the well registry (55-file) and the Ground Water Site Inventory (gwsi file). Additionally, the water level information in the gwsi file was collected at various times between 1941 and 1995. This limited data suggests that the regional groundwater table is hydraulically connected with the groundwater in the alluvium of the middle basin area of Rincon Creek. The water levels in the wells shown on Figure 14 show a systematic and relatively consistent groundwater gradient to the west. There are three anomalous water levels, with well # 7 and well # 9 being higher than expected and well # 5 being lower than expected. We were not able to determine construction details for well # 7, but well # 9 is 139 meters (455 ft.) deep, and its anomalously high water level suggests an upward gradient indicating the bedrock system is discharging into the alluvium. Well # 5 is an 85 meter (280 ft.) deep Rincon Water Company well, and its anomalously low water level may reflect the effects of recent pumping. This well is in one of a series of small fault-dammed pockets of alluvium in the Rincon Creek middle basin (Figure 4). Withdrawals from this well would quickly drain this small body of alluvium during the dry months of each year unless the groundwater in the alluvium was also being supported by discharge from the regional groundwater system.

It is difficult to say anything more definitive from the sparse data available. Most data is pre-1990s before development of the area and recorded in the winter when water levels are both higher and of less importance to the deciduous riparian community. It is important to note that from a plant community perspective depth to groundwater is the crucial factor. Wells located adjacent to Rincon Creek in the alluvium deposits exhibit relatively high water levels (Wells 7, 8, 9, 10, and 12). Depth to groundwater increases sharply as one moves away from the Creek (Wells 5,14, and 15). Wells located in the smaller tributaries above X 9 Ranch Road have intermediate water levels probably in response to a more limited storage capacity and less water moving through the individual washes (Wells 1, 3, 4, and 6). Monitoring existing groundwater levels along Rincon Creek in the Expansion Area is mandatory to understanding and quantifying the annual and seasonal variability in groundwater behavior as well as its position in relation to the plant community.

Table 3. Groundwater well locations, depth and water table elevations in or near the Saguaro National Park expansion area, Tucson Az.

Well Location	Figure 12 well number	Depth to water Meters (ft)	Water Elevation Meters (ft)	Date measured
T15 R17 8 CDA		22.1 (72.5)	1086 (3123)	1/82
		19.7 (64.7)	1089 (3130)	12/87
		13.9 (45.5)	1096 (3150)	1/95
T15 R17 10 CAD	1	6.8 (22.31)	1127 (3238)	8/66
		7.7 (25.2)	1126 (3235)	12/81
		8.2 (26.8)	1125 (3233)	12/87
T15 R17 10 CC	2	1.8 (5.92)	1129 (3244)	4/41
T15 R17 10 DAD	3	5.4 (17.85)	1135 (3262)	8/66
T15 R17 10 CAA		7 (23)		5/20
T15 R17 15 BCB	4	17.2 (56.45)	1101 (3164)	12/56
T15 R17 15 ADB		4 (13)		1/98
T15 R17 16 ACC	5	23.6 (77.57)	1083 (3113)	4/63
		16.8 (55.2)	1085 (3118)	12/87
		19.4 (63.7)	1088 (3127)	12/81
		22.4 (73.4)	1091 (3136)	4/65
T15 R17 16 ADA	6	9.3 (30.4)	1103 (3170)	12/87
T15 R17 16 BD	7	1.7 (5.48)	1112 (3195)	4/41
T15 R17 16 AAD		86.9 (285)		1/80
T15 R17 16 ACA		70.1 (230)		9/93
T15 R17 16 ACD		24.1 (79)		3/62
T15 R17 16 ADC		19.5 (64)		6/68
T15 R17 16 BAD		3.7 (12)		1/25
		20.4 (67)		2/98
T15 R17 16 BCB		41.1 (135)		2/87
T15 R17 17 ACB	8	2.1 (6.86)	1090 (3132)	8/66
T15 R17 17 ACB		3.7 (12)		6/65
T15 R17 17 ADD	9	2.1 (6.86)	1101 (3163)	8/66
T15 R17 17 BAB	10	2.2 (7.12)	1085 (3118)	8/66
T15 R17 17 BBA	11	5 (16.3)	1081 (3106)	12/81
		3.8 (12.5)	1082 (3110)	12/87
		1.4 (4.7)	1085 (3117)	1/95
T15 R17 17 BBB	12	1.1 (3.64)	1084 (3116)	8/66
T15 R17 17 ADC		4.3 (14)		7/64
T15 R17 17 BBD		3.7 (12)		5/64
T15 R17 17 BBD		3 (10)		6/58
T15 R17 18 BAB	13	9.8 (32)	1077 (3096)	1/95
T15 R17 18 AAD		106.7 (350)		6/96
T15 R17 18 AD		50.3 (165)		
T15 R17 18 AD		4.6 (15)		9/75
T15 R17 18 ADC		25.9 (85)		6/99
T15 R17 21 BDD	14	63.6 (208.6)	1079 (3101)	12/81
		60.3 (197.9)	1083 (3112)	12/87
T15 R17 28 BAC	15	79.7 (261.5)	1089 (3130)	1/95

Tanque Verde Creek

The details of groundwater table declines in the Tanque Verde Creek area are very complex due to variations in both time and space of pumping stress. An analysis of the decline in pumping water levels for 15 wells operated by Tucson Water shows a cumulative average decline of 17.1 m (56 ft.) from September 1994 to September 2000, and an average decline in the past year of 7.3 m (24 ft.) (Table 4). The closest of these large municipal wells to the middle basin area tributary that extends into the Park is over 3.2 km downstream. Stromberg et al. (1992) reported a decline of two meters (6.5 ft.) at Wentworth Road, 1.2 km downstream from the tributary, between January 1986 and January 1990. Further downstream outside of the current study area, in the vicinity of the municipal wells in the lower basin area, they reported declines of 18 meters (59 feet) over the same period of time.

While the distance from the large municipal wells is small enough that the effects of their pumping could be felt on the lower portions of the tributaries, the permeable Pliocene and Pleistocene alluvial sediments become much thinner above the junction of Aqua Caliente Wash with Tanque Verde Creek (Stromberg et al., 1992). This may well dampen the effects of the municipal pumping stress in the vicinity of the tributary in Section 9 as suggested by the differences in the amounts of decline noted above. A private well in the tributary in the NE 1/4 of the NE ¼ of Section 9, within the Park boundary, has a reported drop of 10.1 meters (from 4.6 to 13.7 m) in the past year followed by a rapid recovery to 4 m after heavy, fall rain events (written communication from G. Urias to F. Walker, 8/17/00; verbal communication G. Urias, 11/10/00). This amount and rate of water level decline and recovery seems unusually large if associated with the municipal pumping and is not consistent with the findings of Stromberg et al. (1992) for the area near Wentworth Road.

RESULTS: ECOLOGY

A number of factors including hydrology, elevation, climate, geology and geomorphology interact to produce a great diversity of physical conditions and thus a great diversity of riparian ecosystems differing in size, species composition, and community structure. Groundwater and surface water availability, magnitude and frequency of flood flows, and water quality combine to play a primary role in influencing the composition, structure and abundance of riparian vegetation between and within these ecosystems (Stromberg, 1994).

Depths to groundwater and inundation frequency exert the greatest influence on plant composition within riparian areas. In arid region floodplains, depth to groundwater influences species composition largely due to species differences in rooting depth combined with the fact that shallow groundwater supplies the permanent water source required for tree growth and survival (Stromberg et al., 1996). Climatic factors such as precipitation, temperature, and evaporation rate vary with latitude and longitude and with elevation and influence riparian vegetation by controlling the availability and distribution of water. In Arizona, mid-elevation zones (approximately 1,500 to 2,000 m) are dominated by Arizona walnut (*Juglans major*), velvet ash (*Fraxinus pennsylvanica*), and Arizona sycamore (*Platanus wrightii*). Lower elevations support Fremont cottonwood (*Populus fremontii*), Goodding willow (*Salix gooddingii*) and honey or velvet mesquite (*Prosopis juliflora* or *P. velutina*) (Stromberg, 1994). Two of the more crucial riparian habitat types found within the Park are discussed below.

SONORAN COTTONWOOD- WILLOW ASSOCIATIONS

Forests of Fremont cottonwood and Goodding willow once thrived within the floodplains of low-elevation rivers of Arizona, California, Utah and northern Mexico, historically covering hundreds of kilometers. These cottonwood-willow associations often occur as a mosaic with other riparian types including Sonoran interior marsh, Sonoran riparian scrubland, and Sonoran riparian mesquite. Tree species diversity within cottonwood-willow forests is generally low, but age class and structural diversity is often high. Depending on the past history of flooding or other disturbance the understory can be dense or open and park-like. Most cottonwood-willow stands contain a mix of perennials and annuals, and of exotic and native species (Stromberg, 1993a). Today, Sonoran riparian cottonwood-willow associations are among the most threatened forest types in the United States (Swift, 1984).

Riparian ecosystems develop along floodplains of low gradient alluvial streams where depositional environments of fine-grained alluvial substrates are optimal for riparian forest establishment. Large amounts of viable cottonwood and willow seeds are produced yearly, so propogule source is generally not a limiting factor in recruitment (Johnson, 1994). Recruitment sites for willow and cottonwood seedlings are moist, bare of vegetation and exposed to full sunlight. These conditions are associated with recent sediment events, point bars of meander lobes, and migrating edges of rivers (Bradley and Smith, 1986). Stromberg (1993b) reported that floods with a magnitude equal to at least the seven-year event appeared necessary to remove a sufficient percentage of the competing herbaceous cover and allow cottonwood and willow seedlings to become established in Southern Arizona's riparian systems. In these dry regions, the early establishment and growth of seedlings also requires that seedling roots stay within contact of water tables (Mahoney and Rood, 1992).

Riparian communities are dependent upon specific, dynamic surface water and groundwater requirements for their daily physiological needs (long-term survival) as well as regeneration (Richter, 1992). Quantitative information on the extent and timing of functional responses and mortality of *Populus* and *Salix* to groundwater depletion are rarely matched with information on the rate, depth, and duration of water table declines. The reported mean depths to groundwater for mature *Populus fremontii* and *Salix gooddingii* are 1.5 ± 1 m and 1.4 ± 0.9 m respectively (Stromberg et al 1996). Floodplain accretion or channel incision can increase depth to water over time. While extensive root development in mature trees may allow trees to survive such gradual water table declines, riparian habitats are generally restricted to areas where depth to water table is ≤3.5 meters (Scott et al., 1999).

SONORAN RIPARIAN MESQUITE

Prosopis velutina (velvet mesquite) is a facultative riparian species native to the Sonoran region. Existing as shrubs in arid habitats, mesquite develop into trees reaching their maximum size and cover in riparian habitats. Access to a permanent water source (high groundwater) allows *P. velutina* to form closed-canopy forests or bosques in conjunction with species including *Celtis reticulata*, *Juglans major*, and *Zizpyhus obtusifolia*. The productivity, biomass and diversity of riparian mesquite bosques are an order of magnitude higher than in uplands. Shallow groundwater allows these mesquite trees to escape the normal water limitations of an arid system.

Recognition that the growth form of *Prosopis velutina* varies with water availability is not a new one. As far back as 1884, Harvard noted that where groundwater was within 15 meters of the surface *Prosopis* occurred as a tree rather than a shrub (Stromberg et al., 1993). While in 1927, Meinzer reported that the canopy height of riparian mesquite varied with depth to groundwater (Meinzer, 1927). Historically, bosques covered more land area than any other riparian type in the Southwest. Today in large part due to water development, the few remaining mesquite bosques have been reduced to small, remnant patches (Stromberg et al., 1993).

Riparian mesquite communities experience severe to lethal stress with declining water tables as a result of their dependence on alluvial groundwater. Roots of riparian mesquite typically develop within the upper five meters of the soil surface, extending only into the capillary fringe above the generally shallow phreatic zone. The potentially high growth rate of mesquite roots does not ensure success in response to rapidly declining water tables, as floodplain soils in the arid Southwest often consist of coarse-textured alluvium that does not readily maintain the moist continuum necessary for inducing deeper roots (Stromberg et al., 1992).

Concern over groundwater mining from the basin supporting lower Tanque Verde Creek generated a study on the effects of declining water tables on *Prosopis velutina*. Stromberg et al. (1992) found that predawn and midday plant water potential, leaflet size, leaflet number, tree height, and dead canopy percentage varied linearly with depth to water table, while total vegetation volume varied non-linearly. The authors conclude that the effect of groundwater decline is one of incrementally increasing stress and habitat degradation, ultimately reaching lethal levels. They observed healthy bosque responses only where groundwater levels were <5 meters below the surface. Tree response declined continuously as groundwater receded to 15-18 meters. At greater depths, trees became increasingly stressed. The authors were quick to point out that these results apply only to large, mature trees. Young mesquite trees have limited rooting depths and were noted to be under lethal or sub-lethal stress in areas where mature mesquite trees were only moderately stressed (Stromberg et al., 1992).

EFFECTS OF DROUGHT STRESS

Riparian ecosystems respond to stress by undergoing changes at increasingly larger scales. With low levels of stress, changes often occur at the individual or population levels. Riparian trees experience increases in physiological stress, declines in growth, outbreaks of disease, or increases in mortality and declines in population density. Higher levels of stress cause ecosystems and community-level changes (loss of species), changes in vegetation structure (reduction in canopy cover or replacement of tall forests by shrublands) and reduction in biomass. The reduction or loss of one species can have a cascading effect throughout an ecosystem due to the interdependency of riparian species. Extreme stress levels can result in riparian forests being replaced with desert vegetation or barren soil (Stromberg, 1994).

The response of an individual plant to gradually increasing water stress involves progressive and integrated physiological and morphological responses, beginning with stomatal closure, reduced leaf and canopy development, and ending with death. Plant productivity is reduced as a result of lowered net photosynthesis, and through the death of leaves and fine roots. Under more severe drought conditions trees exhibit reduced radial stem increments, wilting and abscission of leaves, and branch death. Tree mortality may follow directly or as the result of insects or other pathogens. Monitoring annual branch growth may be one of the best indicators of sub-lethal water stress (Scott et al., 1999).

An integrated understanding of surface and groundwater dynamics in relation to the reproduction and maintenance of riparian plant species is required for effective riparian conservation and management (Scott et al., 1999). In conjunction with monitoring groundwater conditions, habitat monitoring is highly recommended. Early signs of habitat degradation or stress can be detected by monitoring these factors at the following scales (Stromberg, 1994).

A) Monitor individual plants for:
- reduction in growth rate
- changes in physiological state (increases in internal plant stress)
- increases in canopy mortality
- increased outbreak of pathogens or disease organisms.

B) Monitor plant populations for:
- reduction in age class diversity
- increases in plant mortality for susceptible age classes.

C). Monitor communities for:

- changes in cover or biomass
- loss of biodiversity
- changes in species composition
- increased abundance of exotic species
- decreased abundance of "keystone" species
- decreased abundance of indicator species that are sensitive to ecosystem changes and serve as early warning detectors of stress.

AREAS OF CONCERN

The long-term health and survival of riparian habitats within Saguaro National Park depends upon an assured water source. Groundwater levels must stay within the rooting zone of the trees for the majority of the growing season, while recruitment events are dependent upon flood events that coincide with high groundwater levels. The first step in determining required groundwater elevations is to establish a critical extinction depth or depth below which the groundwater should not fall. To do this one needs to focus on the zone of groundwater utilization by the riparian trees growing in these areas. The roots of most riparian trees are largely restricted to the upper 6 meters of the soil horizon. Bosque mesquite trees are reported to have taproots down to 9 meters (Judd et al. 1971). Once groundwater levels drop below the root zone, the trees are unable to extract it. If water levels remain below this extinction depth for prolonged periods during the growing season, decline and eventual death of the riparian community follows (Judd et al., 1971; Stromberg et al., 1996; Stromberg et al., 1993).

RINCON CREEK: HIGH GRADIENT REACHES

The upper basin area of Rincon Creek and its tributaries can best be described as high-gradient, bedrock-controlled streams or washes. These are effectively cut-off from the lower alluvial basin by the series of bedrock dams described earlier. Behind these series of bedrock dams small pools develop and support patches of vegetation. While each individual area may not be extensive, together they form a critical resource for the regional wildlife and to the functioning of the Park.

Chimenea, Madrona and upper Rincon Creeks all support valuable habitats (Figure 15). At the higher elevations, 1000-1220 meters, mixed narrow leaf community dominates. This habitat type is characterized by *Prosopis velutina, Acacia greggii, Parkinsonia* spp., *Chilopsis linearis, Celtis spp., Baccharis salicifolia,* and *Cephalanthus occidentalis.* Based on previous mapping efforts *Gossypium thurberi, Jatropha cardiophylla, Muhlenbergia* spp., *Celtis pallida*, and *Lysiloma microphylla* also contribute to this vegetation type. Considered a xeroriparian community, this habitat type is an important resource to the Park. Below 1000 meters, these reaches are dominated by a more typical riparian community of *Platanus wrightii, Fraxinus velutina* and *Populus fremontii* with pockets of just *Fraxinus velutina* interspersed.

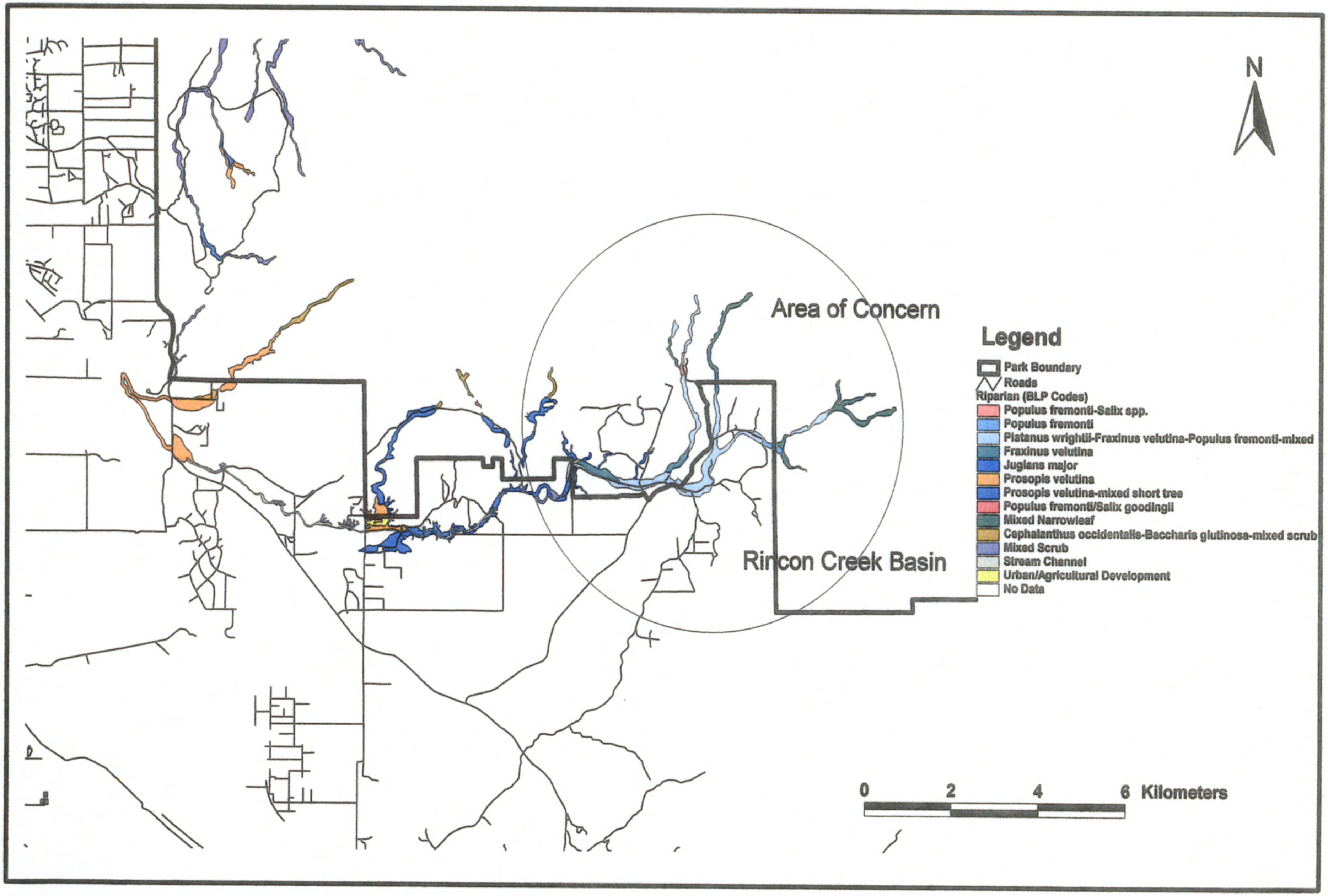


Figure 15. Riparian areas: Rincon Creek and tributaries.

Threats: Groundwater removal in the middle and lower basin areas is not likely to affect these areas. However, these areas are very susceptible to increased sedimentation or erosion caused by changes in land use. Increased numbers of visitors to the areas and/or introduction of mountain bikes will likely trigger increased erosion of the hillslope. Results of our recent field surveys indicate that an erosion problem already exists within the Park. Head cutting and gully formation is occurring along many of the trails as well as on the surrounding hillslopes. Increased sedimentation from the surrounding hills may fill these small pools, displacing the riparian vegetation growing in these areas and eliminating important water sources for wildlife.

TANQUE VERDE TRIBUTARIES

The upper basin area tributaries of Tanque Verde Creek are similar in nature to the Rincon Creek tributaries. The major community type along these tributaries is mixed upland scrub. Patches of *Cephalanthus occidentalis*, *Baccharis glutinosa*, and *Populus fremontii* were located along the tributary adjacent to Douglas Springs trail (Figure 16). However, the riparian community of primary concern is a low elevation mesquite bosque. This bosque is supported by flows from several tributaries as they converge just above their confluence with Tanque Verde Creek (Section 9, T. 12, R. 14). Approximately 60% of the mesquite bosque is located within the Park boundary while the remaining area extends north of the Park's boundary.

Threats: There is extensive development of the groundwater resource in the alluvium in the portion of Tanque Verde Creek which runs from east to west a short distance to the north of the Park boundary. The development includes both private wells for homes and resorts, as well as municipal supply wells operated by Tucson Water. The small riparian areas growing at higher elevations on the northern slope of Tanque Verde Ridge are isolated from effects of this development. However, the riparian bosque is hydraulically connected to the alluvium of Tanque Verde Creek and is being impacted by these groundwater extractions.

RINCON CREEK: MIDDLE REACHES

The lower portions of Chimenea, Madrona and the middle reach of Rincon Creeks support the finest and most extensive riparian habitat remaining in the Park (Figure 17). At these lower elevations, Rincon Creek is a low-gradient alluvial stream. The channel widens slightly and the limited saturated alluvium supplies some groundwater storage capacity to the system and allows for the development of Sonoran cottonwood-sycamore-willow association along the streambank. However, current groundwater development is placing stress upon the system. Field investigations revealed signs of water stress in mature trees, as well as a general lack of seedling recruitment. This coupled with the transition to a more xeric community that is occurring away from the creek bank should be taken as a serious warning signal.

Threats: Fairly extensive groundwater development of the area has already occurred. Private wells for homes exist in the larger alluvial pockets in Chimenea and Madrona Creeks. Numerous private wells now draw water from the alluvium supporting Rincon Creek and as the area continues to develop additional wells may be requested. Groundwater development from the alluvium upstream on the X9 Ranch will diminish the flow through this reach. If most of the water is used for domestic purposes in the X9 development, and the water is returned through septic tanks then much of the water is simply being re-circulated in the groundwater system above the park boundary. However, the timing of the flow through the system is affected particularly in the drier months, as domestic use has a seasonal variation, with more water used in the hotter months. Increased domestic water use during the hot, dry months places additional stress on an already stressed riparian system. The extent and ultimate result of such increased stress will vary with current climatic and groundwater conditions. If however, the water is exported down-valley, groundwater levels will decline and the subsequent loss of riparian habitat is inevitable.

If the habitat is to be preserved, additional water extraction due to development of new wells, increased pumping from existing wells or transfers of water out of the immediate vicinity need to be prevented. If groundwater depths fall below 3.5 meters during a significant portion of the growing season remedial action will be required if the habitat is to survive. If the timing and/or intensity of flood flows in the creek are altered, recruitment events will also be affected. Reductions in either will result in fewer successful recruitment years. In order to preserve future recruitment events, natural surface flow should be preserved.

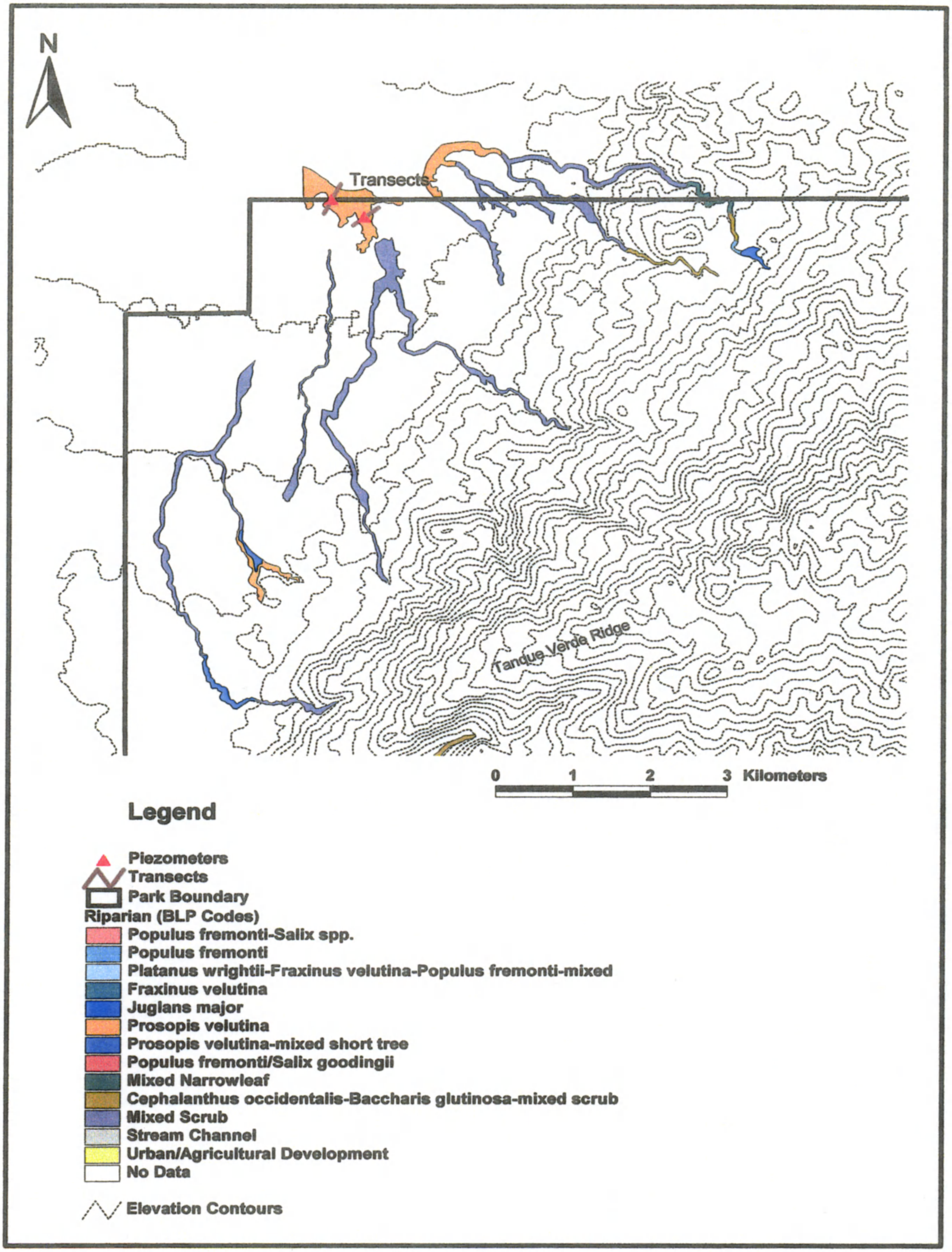


Figure 16. Riparian areas: Tanque Verde Creek tributaries.

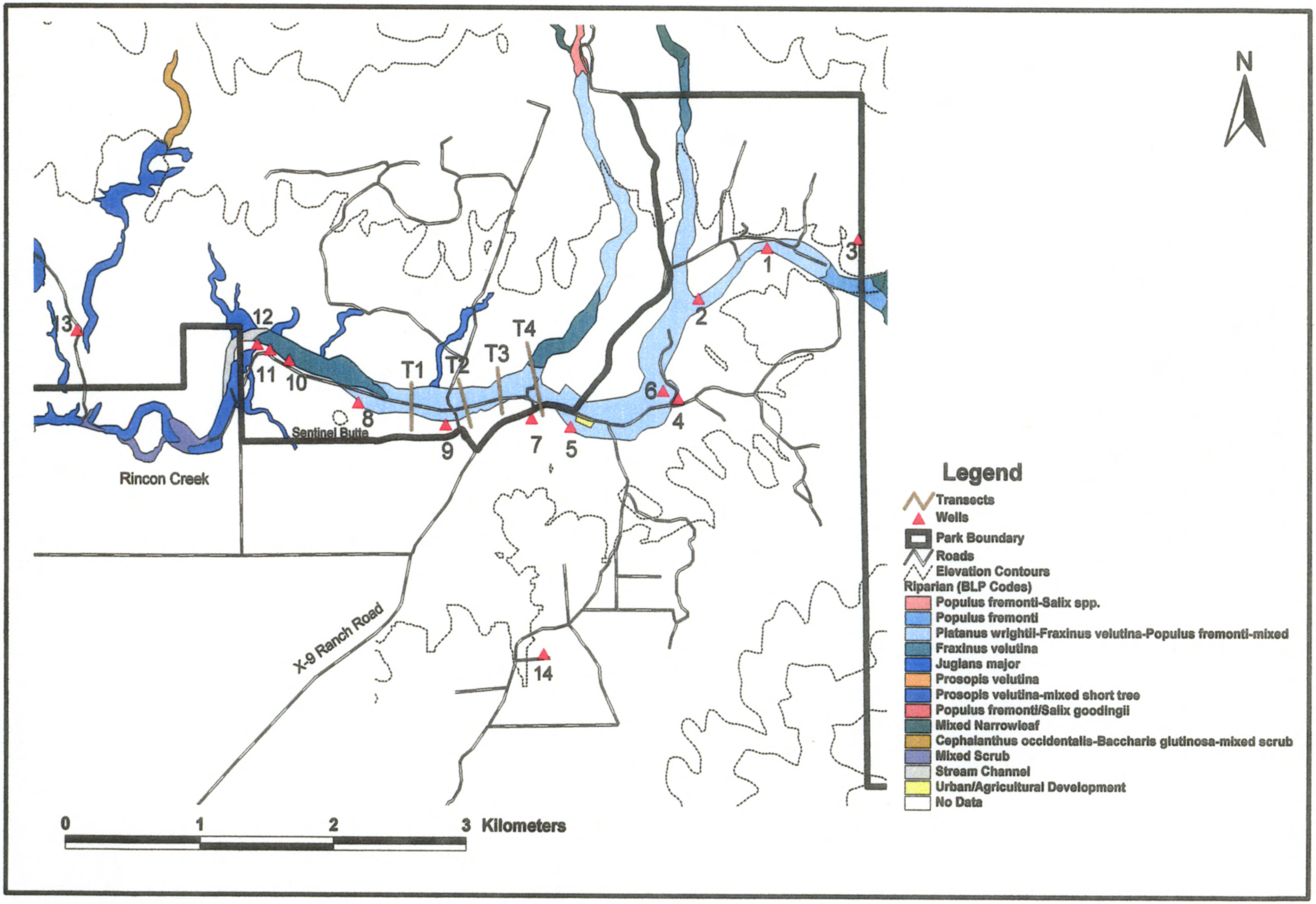


Figure 17. Middle basin riparian areas: Rincon Creek.

RECOMMENDATIONS

Groundwater Monitoring

Monitoring of groundwater in the X9 Ranch area of Rincon Creek and the mesquite bosque in Tanque Verde tributary is strongly recommended. Two shallow piezometers should be installed adjacent to Rincon Creek; one upstream of the existing abandoned well and the other downstream (Figure 17). Two piezometers should be installed along the central axis of the Tanque Verde tributary bosque (Figure 16). See Hydrologic Monitoring Manual (The Nature Conservancy, 1996) for suggested piezometer construction. Monthly groundwater readings from all three Rincon Creek points (two piezometers and abandoned well) and the two Tanque Verde points should give an adequate picture of the groundwater conditions in the areas of concern.

Monitor Streambed Morphology

Changes in sediment movement and storage can have significant effects on the stability and health of the smaller hill slope riparian patches and on the lower unconfined portions of Rincon Creek and Tanque Verde tributary. Conducting annual cross-sectional surveys of the existing morphology of the stream channel and selected upper reach riparian patches is recommended. Repeated inventories will quantify how urbanization and/or increased park usage is altering the system and may allow for early preventative measures.

Four perpendicular transects should be established along Rincon Creek from the X9 Ranch road to Sentinel Butte (Figure 17). Two perpendicular transects should be established in conjunction with the monitoring wells in the Tanque Verde bosque (Figure 16). Transects should extend to the outside edge of the riparian vegetation where feasible. Cross-sectional profiles need to be measured using a transit and leveling rod. Elevation readings should be taken at all significant changes in the bank morphology. Permanent markers should be placed at both ends of each transect and at its intersection with the stream. The placement of markers should be documented with a Global Positioning System (GPS).

In the smaller pools any significant change in depth of fill should be carefully examined and the source of sediment identified. If the sediment is from erosion of the surrounding hillslope remedial action should be taken immediately to halt the erosion. Along Rincon Creek itself, significant bank sloughing or the formation of head cuts may be caused by changes in run off patterns from the surrounding area or the development of nick points within the stream and should be mitigated.

Habitat Monitoring

In conjunction with monitoring groundwater conditions, habitat monitoring is required for effective riparian conservation and management. Biennial riparian vegetation monitoring should be conducted along the same transects established for hydrologic monitoring. Spring and late summer surveys are needed to capture the seasonal change in annual species as well as response of the habitat to late summer water stress. A list of suggested study parameters is given below. Vegetative and/or habitat parameters should then be correlated with the measured hydrologic variables.

Suggested Monitoring Outline

Task 1. Groundwater: Record monthly water level readings from 5 monitoring wells or piezometers described above.

Task 2. Streambed: Annual cross-sectional survey of the four transects on Rincon Creek (locations noted on Figure 17), on selected upper watershed tributaries of Rincon (locations to be field determined) and the two Tanque Verde bosque transects (Figure 16).

Task 3. Vegetation: Biennial vegetation surveys at all locations established for task 2. Suggested habitat parameters are listed below and vary with season.

Early summer survey

Overstory Vegetation

- Percent cover by species
- Species composition
- Diameter Breast Height (DBH)
- Tree height
- Annual branch growth
- Vegetation volume: live and dead (or foliage height diversity)
- Percent native species
- Percent of species in each USFWS wetland plant indicator status
- Percent of canopy dead
- Percent of trees diseased or with visual evidence of pathogens
- Number of young recruits

Understory Vegetation

- Species composition
- Percent cover by species
- Percent of species in each USFWS wetland plant indicator status

Presence/absence of surface water

Late summer survey

<u>Overstory Vegetation</u>

Vegetation volume: live and dead (or foliage height diversity)
Percent of canopy dead
Percent of canopy stressed: yellow and/or wilted leaves
Percent of trees diseased or with visual evidence of pathogens
Number of surviving young recruits

<u>Understory</u>

Species composition
Percent cover by species
Percent of species in each USFWS wetland plant indicator status

Presence/absence of surface water

POTENTIAL REMEDIAL ACTIONS

Groundwater development has and continues to impact the riparian areas within the Park boundary. At greatest risk is the reach of Rincon Creek between the X9 Ranch and the western boundary of the Parks expansion area, and the tributary riparian system of Tanque Verde Creek. The present levels of off-Park pumping stress are having a greater impact on the Tanque Verde tributary than on the Rincon Creek riparian area, but both areas have similar protection/mitigation strategies.

The most important thing that could be done, particularly in Tanque Verde Creek, is to encourage Tucson Water to expand its service area into the wash, and eliminate as many pumping wells as possible. This would have the effect of bringing supplemental water into the area in addition to the amount entering under natural conditions.

The second most important thing (perhaps most important in Rincon Creek) is to take whatever steps are necessary to prevent additional groundwater pumping and the export of water from the vicinity of the Park, particularly if the export is to downstream areas. This includes both pumped groundwater and wastewater. This would have the effect of retaining more water to benefit the Parks' riparian resources, and would be particularly effective if water for areas adjacent to, and upstream from, the Park's riparian areas was from an imported source.

Another mitigating measure would be to discourage the expansion of waste-water collection systems into the area, which would have the effect of increasing the annual water supply if water is delivered to the area from remote sources.

If possible, the importation of treated waste water to the upper ends of the middle reaches of Tanque Verde and Rincon creeks would also be of beneficial effect to the health of the riparian vegetation.

CONCLUSION

The geologic framework of the Tanque Verde Ridge and the Rincon Valley exerts strong control on the hydrology of the riparian systems of the Saguaro National Park. Pantano fault constitutes a line of hydrogeologic separation between the occurrence and utilization of groundwater in the Rincon Valley and the main Tucson basin. Therefore, the groundwater reservoirs supporting the riparian areas within Rincon Mountain District are not directly connected to the Tucson basin aquifer. The upper reaches of Tanque Verde and Rincon Creeks, tributaries and other small washes that lie within the Park can best be described as high-gradient, bedrock-controlled streams or washes. These areas are effectively cut-off from the lower alluvial basin by a series of bedrock dams, but are very susceptible to increased sedimentation or erosion caused by changes in land use.

The riparian habitat adjacent to Rincon Creek through the X9 Ranch area to Sentinel Butte is the best remaining cottonwood-willow riparian habitat within the Park and one of two areas most threatened by increased groundwater development. This short reach of Rincon Creek lies within the Saguaro National Park boundary in an area where the outcrop of the Catalina Fault is in close proximity on both sides of the stream valley. The second threatened habitat is the mesquite bosque growing along the northern boundary of the Park in a tributary of Tanque Verde Creek. These habitats possess high wildlife values and are important to the functioning of Saguaro National Park.

Extensive development of the groundwater resources in and near the alluvium underlying Rincon and Tanque Verde Creeks threaten these valuable resources. Development includes both private wells for homes and resorts, as well as municipal supply wells operated by Tucson Water. Monitoring monthly groundwater levels, conducting annual cross-sectional surveys of existing stream channel morphology and riparian habitat monitoring is strongly recommended.

If groundwater depths fall below 3.5 meters in Rincon Creek or 5 meters in Tanque Verde Creek during a significant portion of the growing season remedial action will be required if the habitat is to survive. If the timing and/or intensity of flood flows in the creek are altered, recruitment events will also be affected. Reductions in either will result in fewer successful recruitment years. If the habitat is to be preserved additional water extraction due to development of new wells, increased pumping from existing wells or transfers of water out of the immediate vicinity must be prevented.

LITERATURE CITED

Arnold, L.W. 1940. An ecological study of the vertebrate animals of the mesquite forest. M.S. thesis, University of Arizona. Tucson, AZ.

Briggs, M., M. Schmid, and B. Halvorson. 1996. Monitoring riparian ecosystems, An inventory of riparian habitat along Rincon Creek near Tucson, Arizona. Arizona Game and Fish Department Heritage Project Number U94018 Final Report.

Bradley, C.E., and D.G. Smith. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, Southern Alberta and Northern Montana. Canadian J. Bot. 64:1433-1442.

Burkham, D.E. 1970. Depletion of streamflow by infiltration in the main channels of the Tucson basin, Southeastern Arizona. U.S. Geological Survey Water Supply Paper 1939-B, U.S. Government Printing Office, Washington D.C.

Davidson, E.S. 1973. Geohydrology and water resources of the Tucson basin, Arizona: Water resources of the Tucson basin. Geological Survey Water Supply Paper 1939-E. U. S. Government Printing Office, Washington D.C.

Halpenny, L.C., and P.C. Halpenny. 1985. Evaluation of adequacy of groundwater supply, Ranchlands Water Company, Rincon Valley, Pima County, Arizona. Water Development Corporation.

Hastings, J.R., and R.M.Turner. 1962. The Changing Mile, An Ecological Assessment of Vegetation Change with Time in the Lower Mile of an Arid and Semi-arid Region. University of Arizona Press. Tucson, AZ.

Johnson, W.C. 1994. Woodland expansion in the Platte River, Nebraska: Patterns and causes. Ecological Monographs 64(1): 45-84.

Judd, B.I., J.M. Laughlin, H.R. Guenther, and R. Handegarde. 1971. The lethal decline of mesquite on the Casa Grande National Monument. Great Basin Naturalist 31: 153-159.

Mahoney, J.M., and S.B. Rood. 1992. Response of a hybrid popular to water table decline in different substrates. Forest Ecology and Management 54: 141-156.

Mac Nish, R. and D.P. Guertin. 1997. Plan of study to characterize the hydrology of riparian areas in SAGUARO NATIONAL PARK and evaluate potential effects of anthropogenic stresses.

Meinzer, O.E. 1927. Plants as indicators of groundwater. U.S. Geologic Survey Water Supply Paper 577:95 pp.

Mott, David N. 1997. Saguaro National Park, Arizona Water Resources Scoping Report. Technical Report NPS/NRWRD/NRTR-97/95. United States Department of the Interior, National Park Service.

The Nature Conservancy. 1996. Hydrologic monitoring manual, Version 4.0. The Biohydrology Program Conservation Science Division. Arlington, Virginia.

Osterkamp, W.R. 1973. Groundwater recharge in the Tucson area, Arizona: U.S. Geol. Survey Misc. Inves. Series Map I-844-E, 1 sheet.

Richter, H.E. 1992. Development of a conceptual model for floodplain restoration in a desert riparian system. Aridlands Newsletter 32:13-17.

Rogers, S. 1987. Hydrologic investigation of the northeast area of the Tucson basin, structure, and stratigraphy. Tucson , AZ: Tucson Water Open File Report WRS-87-1.

Scott, M.L., P.B. Shafroth, and G.T. Auble. 1999. Responses of riparian cottonwoods to alluvial water table declines. Environmental Management 23(3): 347-358.

Smith, G.E.P. 1910. Ground water supply and irrigation in the Rillito Valley. Agricultural Experiment Station, University of Arizona. Tucson, AZ.

Stromberg, J.C. 1994. Arizona Protection Program Legislative Report. Arizona Department of Water Resources, Phoenix, Arizona.

Stromberg, J.C. 1993a. Fremont cottonwood-Goodding willow riparian forests: a review of their ecology, threats and recovery potential. Journal of the Arizona-Nevada Academy of Science 26(3): 97-110.

Stromberg, J.C. 1993b. Instream flow models for mixed deciduous riparian vegetation within a semiarid region. Regulated Rivers: Research & Management 8:225-235.

Stromberg, J.C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona. Ecological Applications 6(1): 113-131.

Stromberg, J.C., S.D. Wilkins, and J.A. Tress. 1993. Vegetation-Hydrology models: implications for management of *Prosopis velutina* (velvet mesquite) riparian ecosystems. Ecological Applications 3(2): 307-314.

Stromberg, J.C., J.A. Tress, S.D. Wilkins, and S.D. Clark. 1992. Response of velvet mesquite to groundwater decline. Journal of Arid Environments 23:45-58.

Swift, B.L. 1984. Status of riparian ecosystems in the United States. Water Resources Bulletin 20:223-228.

Thorman, C.H. and H. Drewes. 1981. Mineral resources of the Rincon Wilderness Study area, Pima Co., Az. Part A. Geology of the Rincon Wilderness Creek area, Pima Co. Az. United States Geological Bulletin 1500.

Urias G., Private inholder. Written communication to F. Walker August 17, 2000.

Urias G., Private inholder. Verbal communication. November 10, 2000.

Appendix A

Riparian Mapping

Saguaro National Park, East

Dr. D. Phillip Guertin

RIPARIAN MAPPING

INTRODUCTION

The riparian mapping project described below satisfies one task of a larger hydrologic study of riparian areas in Saguaro National Park (SNP) East. This study was initiated as a result of a technical report by David Mott entitled *Saguaro National Park, Arizona Water Resources Scoping Report* (Mott, 1997). The report outlines growing concerns to critical and unique desert riparian habitat due to ground water depletion as a result of urban growth in the Tucson basin. This mapping project was undertaken to provide baseline digital data of the vegetation communities associated with riparian areas potentially threatened by the urban development surrounding Saguaro National Park (SNP) East. The geographic information system (GIS) coverage produced will be used in conjunction with hydrologic data and vegetative surveys, to monitor changes in riparian systems located within Saguaro National Park East.

Goals of the mapping effort were:

1) inventory the major riparian communities located in Saguaro National Park East,
2) acquire aerial photography of the riparian areas mapped at a sufficient scale to identify important riparian vegetation features, and
3) provide a digital map (Arc/Info format) of the riparian communities attributed with Brown, Lowe and Pase classifications to the association level (Brown, 1994).

Within Saguaro National Park (SNP) East, the riparian and xeroriparian areas within the tributaries of the Rincon Creek and Tanque Verde Creek below 1219 m (4000 ft) tributary were mapped.

METHODS

The principal goal of this effort was to map riparian vegetation in Saguaro National Park, East to the association level based on the Brown, Lowe and Pace vegetation classification system (Brown, 1994). The process utilized two sets of imagery; U.S. Geological Survey Digital Orthophoto Quarter Quadrangles (DOQQ) and high-resolution videography collected specifically for this project. Other GIS information from previous mapping efforts were also used to assist in the mapping efforts. Table 1 summarizes the information used in this mapping effort.

U.S. Geological Survey Digital Orthophoto Quarter Quadrangles (DOQQ's) were used as the base imagery for the mapping effort. Eight DOQQ's for the U.S. Geological survey 7.5'quadrangles of Tanque Verde Peak and Mica Mountain were obtained and appended together. The advantage of using the DOQQ's is that they are already geo-referenced and differentially rectified. The process of differential rectification, which improves the spatial accuracy of the image, was beyond the scope of this project. Hence the DOQQ's provided a more accurate and stable media for the mapping effort. The

DOQQ's used in this effort were black and white, with a pixel resolution of one meter and a horizontal accuracy of approximately 10 meters.

To assist in the mapping effort the riparian corridors were flown with high-resolution videography by Charles Curtis of Sensair, Tucson, Arizona. Two 8 mm videos were obtained; a 45 degree oblique and vertical. The oblique video was used to locate the riparian within the terrain and approximate its extent and variability. The vertical video was useful for identifying individual shrub and tree species. The minimum spatial resolution of the vertical video was approximately 0.2-0.3 meters depending on the terrain and flight height. An attempt was made to fly all the stream reaches in Saquaro National Park East below 1219 m (4000 ft). However due to difficult terrain, a few reaches were unobtainable.

The videos where time stamped using a global positioning system (GPS time in the audio track). The location of each GPS point was then obtained and entered into the GIS. This allows for the identification of those video segments that could aid in the vegetation classification. The GIS coverage of the video flight lines was superimposed on the DOQQ's. In areas were the interpreter was having difficulty classifying the vegetation from the DOQQ's, the interpreter could locate the closest video image based on the GPS points and then forward the video to that point and use both the oblique and vertical video to assist in the classification.

Table 1: Data used in riparian vegetation mapping.

Information Type	Data Source	Data Format	Metadata
Historical Vegetation Map	Pam Anning Saguaro National Park	Paper Map	vegccc.doc
Vegetation Map of Expansion Area	Meg Weesner Saguaro National Park	Paper Map	See SNP project entitled: A vegetation and plant survey of the newly added lands of Saguaro National Park
Hydrology Coverage	Arizona General Reference Library- Web Site	Digital File in Arc/Info format	www.srnr.arizona.edu/uaaiug/docs/hydro.txt
U.S Geological Survey Digital Orthophoto Quarter Quads (Black and White)	Arizona Regional Image Archive – Web Site	Tiff Image	See Appendix D
U.S Geological Survey Digital Orthophoto Quarter Quads (Color)	Pam Anning Saguaro National Park	Tiff Image	Contact Pam Anning
8 mm Aerial Videography Vertical and Oblique	Charles Curtis	High 8 mm Video Tape	See Appendix D

Previous Saguaro National Park vegetation mapping efforts where reviewed in order to familiarize the researchers with the types of the vegetation that might exist within the park. Most notable was the mapping effort by Patty Guertin of the extension area. With this information, field reconnaissance was undertaken. Most of the riparian areas in the eastern portion of the Park below 1219 m (4000 ft) elevation were subsequently walked.

Releve Procedure

To assist in the classification of vegetation communities the releve procedure developed for the Arizona GAP program was used. The procedure has been well documented in manuals developed for the GAP project (Bennett et al. nd) and will not be reviewed in detail here. It should be pointed out that the purpose of the releve procedure was to determine the potential riparian vegetation communities present in the Park and to assist in training the aerial photographic interpreter. The releve procedure was not used as the basis for mapping.

Based on vegetation characteristics observed in the field or from the imagery, field workers located areas that were representative of creek reaches. Vegetation was sampled in a circle with its center point in the middle of the stream channel and an estimated circumference of 30 meters. The relative dominance of a species was then assessed and assigned a value on a scale of one (lowest) to five (highest). For example, if an area were primarily (90%) cottonwood, cottonwood would be given a value of five (5) on the releve form indicating that it is dominant. If two species were found to have equal representation then they would both be given values of four (4) representing co-dominance. In this manner, the relative abundance of different species were recorded and used later for delineating the riparian vegetation communities.

Global Positioning System (GPS) points were taken at the center point of each releve survey location using the Trimble GeoExplorerII and submitted to park personnel for correction. Supplemental information collected consisted of visual estimation of tree and shrub height, tree and shrub cover, herbaceous cover (forbs and graminoids), and ground cover. Only the maximum height for trees and shrubs within the releve were recorded. (Note: For points 26, 27, & 29, formal releve sheets were not done, these points were used to document the vegetation communities for verification and to locate important hydrological areas).

Based on the dominant or co-dominant species present stream reaches were assigned to a Series or Association level according to the vegetation classification system developed by Brown, Lowe, and Pase (Brown 1994). The classification system distinguishes vegetation by climatic zones based on elevation. Therefore, vegetation found in elevations higher than 1000 m (3281 ft) were placed within the Warm-Temperate climatic zone and those found below 1000 m (3281 ft) were placed within the Tropical-Subtropical climatic zone. When a riparian species (e.g., *Populus fremontii)* was dominant (releve code = 5), the classification was assigned based on that species type (e.g., *Populus fremontii* association*)*. If the riparian species present in an area exhibited co-dominance or associations of three or more different species existed, then a classification found within the Mixed Broadleaf or Narrowleaf Series was used.

Riparian Coverage Creation

The DOQQ's were used as the primary source to digitize riparian vegetation. Riparian areas were initially located based on a digital dataset obtained from Arizona Land Resource Information System (ALRIS). This dataset, an Arc/Info line coverage created in the fall of 1988 from U.S. Geological Survey's 1:100000 scale Digital Line Graphs (DLG), depicts linear hydrologic features (e.g., streams and rivers) in the state of Arizona. The coverage was modified by clipping the features to show the streams below 1219 m (4000 ft) in elevation. The clipped hydrological coverage was superimposed on the DOQQ's, and on-screen digitizing was performed using Arc/Info's© Arcedit module to create polygons of the vegetation along the stream corridors. A fuzzy tolerance of 1 m was used throughout the digitizing process and all polygons were checked for connectivity and continuity. Line coverages were not created for this project.

The minimum mapping resolution used in this project was approximately one hectare. In other words, no attempt was made to map patches less then a hectare, such as individual trees. Nor were within channel string communities mapped since they were difficult to see and delineate on the aerial photography.

RESULTS

A total of 29 field survey points were sampled and an Arc/Info point coverage was created using the GPS points obtained at each survey point. Each survey point has a site ID attribute that is linked to an ArcView data table. This table contains the type(s) of vegetation found at the site along with its associated prominence (reldom.dbf). Summary information collected at each survey point is found in Table 2.

Eleven different Brown, Lowe and Pace vegetation types were identified within Saguaro National Park East: nine vegetation associations and two vegetation series. The two series, Mixed Narrowleaf Series and Mixed Scrub Series represent vegetation types that were difficult to classify to the species level based on interpretation of aerial photography. This was especially true for the mixed scrub series where association is based no only on scrub species, but also forb and grass species. Appendix E lists the Brown Lowe and Pace class types identified for riparian areas located in Saguaro National Park East and describes the vegetation and climatic characteristics for each type.

The riparian dataset is an Arc/Info polygon coverage representing the riparian habitats found below 1219 m (4000 ft) of elevation in Saguaro National Park East. Eighty-four separate riparian vegetation patches (polygons) were identified and mapped using the DOQQs and videography. The map projection is North American Datum (NAD) 1927 with a Universal Transverse Mercator (UTM) coordinate system. Table 3 is a summary of the Brown, Lowe and Pace classes, the number of polygons coded with that class type, and the amount of area associated with each class. Portions of the Arc/Info coverages for the Tanque Verde Creek tributaries and Rincon Creek tributaries are shown in Figures 16 and 15 (main report), respectively.

Table 2: Data from Releve Survey Points

Rel_ID	Location	Elev. (m)	Dominant/Codominant	BLP Class	Video Time	Max Tree Height(m)	Tree Cover (%)	Max Shrub Height(m)	Shrub Cover(%)	Litter Cover(%)	Bare Grd. Cover(%)	Date
1	Box Canyon	963	Carnegiea gigantea, acacia greggi, parkinsonia aculeata	233.211	6:30:50	n/a	n/a	2	30-50	1-5	5-15	07/01/1999
2	Box Canyon	957	Lysiloma watoni, Fraxinus velutina	223.223	6:30:59	5	50-70	2	5-15	5-15		07/01/1999
3	Box Canyon	950	Fraxinus veluntina, Prosopis velutina	224.521	6:30:53	6.5	30-50	2	30-50	5-15		07/01/1999
4	Box Canyon	926	Prosopis velutina	224.521	6:30:51	4	50-70	2	30-50	15-30		07/05/1999
5	Box Canyon	917	Prosopis velutina	224.521	6:30:49	5	50-70	2	50-70	30-50		07/05/1999
6	Box Canyon	914	Prosopis velutina	224.521	6:30:47	9	50-70	2	50-70	15-30		07/05/1999
7	Box Canyon	908	Fraxinus veluntina, Prosopis velutina	224.521	6:30:41	7	80-90	2	50-70	50-70		07/05/1999
8	Box Canyon	899	Prosopis velutina, w/some very large Populus fremontii	224.521	6:30:33	12	50-70	2	30-50	50-70		07/05/1999
9	Tanque Verde Trib., off Douglas Springs trail	1195	Juniperus monosperma, Populus fremontii	223.212	None	6	30-50	2	30-50	1-5	30-50 (Rock)	07/20/1999
10	Tanque Verde Trib., off Douglas Springs trail	1158	Associations of Cephalanthus occidentalis, P. fremontii, A. greggi, B. sarothroides, P. velutina	233.211	None	4	5-15	2.5	30-50	5-15	15-30 (Rock)	07/20/1999
11	Tanque Verde Trib., off Douglas Springs trail	1189	Cephalanthus occidentalis, Salix gooddingii, Populus fremontii, Juglans major	233.21	None	6	30-50	2.5	30-50	5-15	30-50 (Rock)	07/20/1999
12	Tanque Verde Trib., just downstream from Briadal Wreath Falls	1207	Juglans major, Prosopis velutina	223.225	None	6	50-70	2.5	30-50	5-15	50-70 (Rock)	07/20/1999
13	Tanque Verde Trib., Off 3-tanks trail	1204	Prosopis velutina	None	6:12:38	4	5-15	2	50-70	5-15	50-70 (Rock)	07/20/1999
14	Tanque Verde Trib., Off 3-tanks trail	1183	Populus fremontii, Prosopis velutina	234.71	6:12:40	4	15-30	2	30-50	5-15	15-30 (Rock)	07/20/1999
15	Rincon Creek, above private area	1036	Associations of P. fremontii, A. greggi, P. wrightii, C. pallida, B. sarothroides, F. Velutina	223.221	7:24:05	12	30-50	2.5	50-70	5-15	15-30 (Rock)	07/21/1999

Table 2: Data from the Releve Survey Points, continued

Rel_ID	Location	Elev. (m)	Dominant/Codominant	BLP Class	Video Time	Max Tree Height(m)	Tree Cover (%)	Max Shrub Height(m)	Shrub Cover(%)	Litter Cover(%)	Bare Grd. Cover(%)	Date
16	Downstream of Rel. 15	1027	Prosopis velutina, Fraxinus velutina	223.221	7:28:57	14	80-90	2.5	50-70	15-30	5-15 (Rock)	07/21/1999
17	Downstream of Rel. 16	1021	Fraxinus veluntina, Platanus wrightii	223.221	7:32:01	15	50-70	2.5	30-50	5-15	15-30 (Rock)	07/21/1999
18	Chimenea Creek, upstream of ranger station	1055	Quercus oblongifolia, Fraxinus velutina, Salix gooddingii	223.221	7:05:46	13	50-70	2.5	30-50	30-50	30-50 (Rock)	07/23/1999
19	Chimenea Creek, Upstream of Rel. 18	1061	Quercus oblongifolia, Platanus wrightii	223.221	7:27:41	12	50-70	2.5	30-50	15-30	50-70 (Rock)	07/23/1999
20	Chimenea Creek, downstream of Rel. 18	1021	Prosopis velutina, Salix gooddingii	223.211	7:05:38	14	30-50	2.5	50-70	15-30	30-50 (Rock)	07/23/1999
21	Off Cactus Forest Trail	914	Prosopis velutina, Acacia greggi	234.71	5:38:06	5	15-30	2	50-70	5-15	30-50 (Sand)	07/27/1999
22	Off Cactus Forest Trail	860	Prosopis velutina, Acacia greggi	234.71	5:48:07	6	15-30	2.5	50-70	5-15	30-50 (Sand)	07/27/1999
23	Off Loop Rd., near Javalina Picnic area	972	Acacia angustifolia	234.71	5:46:25	n/a	n/a	2.5	50-70	5-15	30-50 (Rock)	07/29/1999
24	Downstream of Rel. 23	963	Prosopis velutina	224.522	6:46:21	6	50-70	2.5	50-70	5-15	15-30 (Rock)	07/29/1999
25	Tanque Verde Trib., off Carillo Trail	960	Prosopis velutina, Carnegia gigantea, Acacia greggii	234.71	6:11:18	5	1-5	2	50-70	1-5	30-50 (Rock)	12/17/1999
26	Rincon Creek Trib.	1000	Celtis reticulata, Prosopis velutina	233.21	7:30:43	n/a	n/a	n/a	n/a	n/a	n/a	12/21/1999
27	Rincon Creek	1000	Celtis reticulata, Baccharis salicifolia	233.21	7:31:49	n/a	n/a	n/a	n/a	n/a	n/a	12/21/1999
28	Medrona Creek	1020	Baccharis salicifolia	233.21	7:13:28	3.5	15-30	2	50-70	1-5	15-30 (Rock)	12/21/1999
29	Chimenea Creek, downstream of Rel. 20	980	P. fremonti, P. wrightii, F. velutina	223.221	6:56:51	n/a	n/a	n/a	n/a	n/a	n/a	12/21/1999

The riparian dataset is an Arc/Info polygon coverage representing the riparian habitats found below 1219 m (4000 ft) of elevation in Saguaro National Park East. Eighty-four separate riparian vegetation patches (polygons) were identified and mapped using the DOQQs and videography. The map projection is North American Datum (NAD) 1927 with a Universal Transverse Mercator (UTM) coordinate system. Table 3 is a summary of the Brown, Lowe and Pace classes, the number of polygons coded with that class type, and the amount of area associated with each class. Portions of the Arc/Info coverages for the Tanque Verde Creek tributaries and Rincon Creek tributaries are shown in Figures 16 and 15 (main report), respectively.

As expected the most common riparian vegetation types where associated with the communities dominated or co-dominated by mesquite. The *Prosopis velutina* Association and *Prosopis velutina*-mixed short tree Association represent 40% of the total riparian area mapped, with mixed scrub series representing another 25% of the area (Table 3). In contrast, vegetation communities dominated or co-dominated by cottonwood represented less then 20% of the mapped riparian areas. Table 4 summarizes the deliverables generated from the riparian mapping effort.

Table 3: Results from Riparian Mapping in Saguaro National Park

Vegetation Type	BLP Code	Number of Polygons	Area in Square Meters	Percent of Total Area
Populus fremonti-Salix spp. Association	223.211	1	33,348	0.39
Populus fremonti Association	223.212	2	70,691	0.83
Platanus wrightii-Fraxinus velutina-Populus fremonti-mixed deciduous Association	223.221	5	1,263,198	14.82
Fraxinus velutina Association	223.223	4	248,867	2.92
Juglans major Association	223.225	1	34,489	0.40
Prosopis velutina Association	224.521	7	1,865,023	21.89
Prosopis velutina-mixed short tree Association	224.522	22	1,572,991	18.46
Populus fremonti-Salix goodingii Association	224.531	2	10,543	0.12
Mixed Narrowleaf Series	233.21	5	592,055	6.95
Cephalanthus occidentalis-Baccharis glutinosa-mixed scrub Association	233.211	6	330,113	3.87
Mixed Scrub Series	234.71	22	2,137,389	25.08
Stream Channel	n/a	3	294,646	3.46
Developed Area	n/a	4	67,696	0.79
Totals		84	8,521,049	100.00

Table 4: Project deliverables.

Name	Format	Description
Riparian	Arc/Info polygon coverage	Riparian vegetation under 4000 feet in elevation
Gpspts	Arc/Info point coverage	GPS points associated with vegetation survey points with releve sampling data
Ripphpts	Arc/Info point coverage	Points of flight lines for aerial video for the entire extent of flight
Ripphpts-clip	Arc/Info point coverage	Points of flight lines for aerial video clipped to a 200 meter buffer of riparian coverage
Aerial Video - oblique	High 8mm video	Oblique view of aerial footage of riparian areas
Aerial Video - vertical	High 8mm video	Vertical view of aerial footage of riparian areas
Reldom.dbf	Dbase database file	Table of the species found at each releve site and the associated dominance code
Vegcode.dbf	Dbase database file	Lookup table containing the BLP classification code and description
Ripmetadata.doc	Microsoft Word	Metadata documentation for riparian coverage
Gpsptsmetadata.doc	Microsoft Word	Metadata documentation for GPS point coverage
Ripphptsmetadata.doc	Microsoft Word	Metadata documentation for flight lines point coverage

DISCUSSION

The lack of information regarding classification of Arizona's riparian vegetation and the appropriate scale needed to realize the goals of this project made classification of riparian vegetation difficult. For example, some areas sampled exhibited co-dominance between riparian and non-riparian species (e.g., *Prosopis velutina* and *Acacia greggii*). The Brown, Lowe and Pace system does not currently have a classification for this type of vegetative community. When this situation occurred, classification was based on the dominant riparian species since the goal was to characterize the riparian vegetation.

An attempt was made to classify all vegetation to the Association level. However, it was difficult to determine dominance in the shrub communities using aerial imagery. As a result those communities were classified only to the Series level with the exception of Brown, Lowe and Pace *Cephalanthus occidentalis-Baccharis glutinosa*-mixed scrub Association that was keyed out from previous mapping work done in the expansion area (see Guertin, 1998). Delineating the shrub communities to the association level requires extensive field work over multiple seasons, and is beyond the scope of this project.

Although it was difficult to classify some vegetation based on available Brown, Lowe and Pace classifications, no attempt was made to create new classifications for this mapping effort. As a result, a classification that differentiates between traditional mesquite bosques and those areas exhibiting dominant mesquite trees, but lacking true bosque characteristics, have the same classification. Brown, Lowe and Pace classification documentation (Brown 1994) discusses the occurrences of mesquite bosques under the Sonoran Riparian Deciduous Forest and Woodlands, tropical-subtropical climatic zone, but an example of this vegetation type is not included in the appendix of examples. Occurrences of mesquite bosques were found in tributaries to Tanque Verde Wash near the confluence with the major wash and along Rincon Creek at its intersection with Old Spanish Trail. Since a "mesquite bosque" vegetation type was not included in the Brown, Lowe and Pace system, these areas were coded with a type found under the Sonoran Oasis Forest and Woodlands, tropical-subtropical climatic zone (224.521). However, most vegetation communities coded with this type are not traditional bosques, i.e., they exhibit smaller trees with a more diverse understory. It is recommended that further analysis of the Brown, Lowe and Pace classification system be conducted to provide a classification for traditional mesquite bosques.

The results from this mapping effort can be used to assess the relative change to the riparian vegetation communities. For example, expansion of the *Prosopis velutina* dominated associations into areas currently supporting *Populus fremontii* dominated associations may indicate the system is becoming more xeric. However, the classification system used in this effort is based on vegetation composition, not vegetation structure and density. Often impacts to riparian systems are first observed through changes in vegetation structure, usually resulting from poor regeneration success. Since the riparian vegetation communities in Saguaro National Park, East are usually found in mixed aged stands it is difficult to determine regeneration success using photographic imagery. Field monitoring will be required to determine changes to vegetation structure and density. However, results from this study could be used to define baseline conditions and assess available wildlife habitat.

LITERATURE CITED

Bennet, P. S., M.R. Kunzmann, and W.L. Halvorson. No Date. Manual for GAP program: Collecting vegetation classification data. National Biological Service Cooperative National Park Resources Studies Unit and University of Arizona Advanced Resources Technology. Tucson, AZ.

Brown, D.E. (Ed.). 1994. Biotic communities Southwestern United States and Northwestern Mexico. Salt Lake City: University of Utah Press.

Guertin, P.P. 1998. A vegetation and plant survey of the newly added lands of Saguaro National Park-Rincon Mountain District. Report submitted to the Saguaro National Park, Tucson, AZ.

Appendix B

Precipitation Data

Tucson Magnetic Observatory

Santa Rita Experimental Range

Tucson Magnetic Observatory
Monthly precipitation (inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1934										0	0.68	2.16	
1935	0.13	2.01	1.37	0	0.13	0	2.17	3.73	1	0	2.13	0.74	14.58
1936	0.115	1	0.74	0.05	0	0.3	1.69	4.59	1.05	0.1	0.86	0.87	12.4
1937	0.151	0.21	0.87	0.03	0.25	0.15	2.49	2.76	0.58	0.24	0.35	0.87	10.31
1938	0.053	0.72	0.77	0.1	0.01	1.38	0.58	1.65	0.43	0.01	0.11	1.08	7.37
1939	0.03	1.45	0.54	0.2	0	0	5.17	1.69	1.27	0.49	0.54	0.2	11.85
1940	0.076	1.78	0.03	0.37	0.31	1.43	0.67	3.64	1.75	0.31	1.69	3.62	16.36
1941	0.18	2.14	1.26	1.02	0.49	0	2.77	0.86	1.64	0.53	0.87	2.53	15.91
1942	0.048	1.82	0.39	1.46	0	0	0.57	1.46	1.72	0.91	0	0.4	9.21
1943	0.049	0.46	1.25	0.04	1.01	0.15	0.42	1.73	1.11	0.33	0	1	7.99
1944	0.038	1.07	0.49	0.63	0.35	0.11	1.69	2.96	1.05	1.25	1.64	1.37	12.99
1945	0.068	0.52	0.64	0.14	0	0	1.23	2.52	0.13	1.26	0	0.18	7.3
1946	0.199	0.13	0.51	0.11	0	0	2.94	3.63	2.4	0.52	0.76	0.6	13.59
1947	0.01	0.04	0.29	0	0	0.25	0.61	2.13	1.68	0.48	0.53	0.39	6.5
1948	0	1.39	0.87	0	0	0.02	1.59	1.17	1.12	0.78	0.02	1.15	8.11
1949	0.174	0.26	0.4	0.39	0	0.01	1.5	0.54	3.96	0.23	0.21	0.86	10.1
1950	0.025	1.25	0.25	0	0.05	1.47	2.17	0.35	0.51	0.05	0	0	6.35
1951	0.152	0.21	0.23	1.64	0.04	0	1.16	2.53	0.36	2.18	1.22	0.91	12
1952	0.033	0.17	2.34	1.19	0.02	0.58	1.9	3.87	0.31	0	2.7	0.63	14.04
1953	0.003	0.97	1.07	0	0	0.4	2.06	0.74	0	0	0.17	0.15	5.59
1954	0.084	0.57	1.93	0	0.53	0.56	3.63	1.17	2.06	0	0	0.07	11.36
1955	0.197	0.28	0.03	0	0.15	0.45	4.77	2.16	0.07	0.28	0.04	0.43	10.63
1956	0.114	0.75	0	0.4	0	0.03	1.09	1.69	0.17	0.43	0	0.21	5.91
1957	0.316	0.81	1.35	0.35	0.26	0.03	0.76	2.88	0.3	2.77	1.04	0.73	14.44
1958	0	1.72	2.62	1.24	0.03	0.53	3.07	1.1	0.33	0.94	1.34	0	12.92
1959	0	0.48	0	0.27	0	0.13	4.42	3.91	0.38	1.3	0.48	1.01	12.38
1960	0.274	0.49	0.33	0	0.05	0.03	0.85		0.83	0.53	0.05	0.63	
1961	0.116	0.04	0.41	0	0	0	2.82	1.92	0.86	0.88	0.56	2.54	11.19
1962	0.151	0.37	0.45	0	0	0	2.52	1.11	2.43	0.2	0.28	0.83	9.7
1963	0.135	2.02	0.8	0.45	0	0	1.88	2.02	1.04	1.06	0.87	0.14	11.63
1964	0.065	0	0.73	0.74	0	0	1.74	4	2.29	1.11	1.05	1.12	13.43
1965	0.069	0.69	0.37	0.47	0.08	0.03	1.15	2.11	0.6	0.08	1.33	6.99	14.59
1966	0.216	2.36	0.19	0.23	0.33	0.11	1.51	3.22	3.8	1.06	0.26	0.17	15.4
1967	0.016	0.07	0.48	0.6	0.41	0.1	2.84	1.37	0.48	0.93	0.5	4.09	12.03
1968	0.053	1.19	1.88	1.13	0.01	0	1.75	3.63	0.08	0.2	1.74	0.87	13.01
1969	0.106	0.54	0.3	0.11	0.26	0	1.68	1.71	0.42	0.01	1.46	0.89	8.44

Tucson Magnetic Observatory
Monthly precipitation (inches)

1970	0	0.03	2.33	0.26	0.17	0.23	1.4	2.38	2.17	1.34	0	0.34	10.65
1971	0.037	0.49	0	0.47	0	0	0.52	5.09	2.17	1.84	0.99	1.96	13.9
1972	0	0	0	0	0.49	1.48	1.86	1.96	1.01	5.15	1.59	0.78	14.32
1973	0.008	2.09	2.86	0.1	0.04	0.55	1.19	0.43	0.06	0	0.73	0	8.13
1974	0.13	0.02	0.88	0	0	0.13	2.18	1.02	1.17	2.32	0.95	0.46	10.43
1975	0.051	0.18	1.77	0.59	0	0	3.01	0.32	1.38	0.27	0.5	0.52	9.05
1976	0.024	1.02	0.5	0.94	0.36	0	1.56	0.54	4.4	0.66	0.48	0.07	10.77
1977	0.322	0	0.76	0.24	0.05	0.25	1.66	1.11	1.05	2.37	0.34	1.61	12.66
1978	0.311	2.69	2.28	0.13	0.77	0.25	1.54	2.4	0.83	2.15	2.67	3.71	22.53
1979	0.38	0.68	1.39	0.12	0.53	0.81	3.09	3.77	0.12	0.18	0.25	0.42	15.16
1980	0.144	3.25	1.87	0.19	0.09	0.06	2.62	3.04	0.9	0.48	0	0.43	14.37
1981	0.085	1.36	2.34	0.27	0.68	0.61	3.12	0.91	0.68	0.16	0.99	0	11.97
1982	0.286	0.38	1.58	0.05	1.42	0.16	0.99	4.92	3.67	0	0.95	2.54	19.52
1983	0.235	1.91	2.95	0.13	0.14	0	2.34	3.17	3.92	6.21	1.7	1.4	26.22
1984	0.057	0	0	0.77	0.25	1.84	4.21	4.68	2.14	1.09	0.84	4.07	20.46
1985	0.175	1.31	0.2	0.56	0	0	1.12	2.07	1.72	1.26	1.52	0.63	12.14
1986	0.001	2.86	1.88	0.07	0.23	0.05	3.13	2.74	1.6	0.56	1.07	1.81	16.01
1987	0.078	2.3	0.95	0.79	0.73	0.07	1.07	1.44	0.71	0.6	0.87	2.01	12.32
1988	0.081	0.37	0.14	1.03	0	0.52	1.33	3.01	0.21	2.08	0.85	0.03	10.38
1989	0.095	0.13	0.98	0	0.07	0.03	1.68	1.74	0.17	2.18	0.14	0.39	8.46
1990	0.079	1.55	1.21	0.39	0	0.21	6.87	2.86	2.38	0.08	0.52	2.6	19.46
1991	0.144	0.87	2.18	0	0	0.29	0.71	1.67	0.22	0.56	0.78	2.4	11.12
1992	0.154	2.01	3.19	0.48	1.73	0	0.82	3.88	0.35	0.05	0	5.17	19.22
1993	0.648	1.82	1.5	0	0.18	0	0.49	3.37	0.47	0.63	1.8	0.31	17.05
1994	0.003	1.52	1.7										

Santa Rita Experimental Range
Monthly precipitation (inches)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1950					0.2	0.62	9.58	1.39	0.48	0	0	0	0.09
1951	3.52	0.38	0.25	3.14	0.08	0	2.81	4.67	1.23	2.57	1.28	2.92	22.85
1952	1.46	0.37	4.32	2.85	0	0.97	1.35	4.7	0.97	0	3.42	1.19	21.6
1953	0	2.1	0.93	0.38	0.18	0.36	5.73	1.82	0	0.18	0.16	0.1	11.94
1954	1.47	0.91	3.91	0	0.86	0.76	5.82	6.39	1.87	0.37	0	0.18	22.54
1955	3.4	0.98	0	0	0	0	4.47	11.43	0.52	0.78	0.01	0.29	21.88
1956	1.69	1.43	0	0.36	0	0.19	3.13	1.63	0.3	0.78	0.05	0.95	10.51
1957	3.7	0.38	1.26	0.48	0.54	1.06	3.83	4.89	0	2.91	0.54	0.78	20.37
1958	0	1.98	4.09	0.9	0.02	2.14	6.48	6.73	2.4	0.61	0.9	0	26.25
1959	0	1.63	0	0.25	0	4.43	6.74	4.66	0.13	2.4	1.1	3.21	24.55
1960	3.82	1.19	0.35	0	0	0.3	2.53	1.77	2.49	2.07	0		0.09
1961	1.08	0.12	0.58	0	0	0.9	2.92	8.07	3.89	3.69	0.9	3.04	25.19
1962	3.27	1.05	1.03	0	0	0.41	3.13	1.19	2.16	0.09	0.57	2.65	15.55
1963	1	1.23	0.85	0.82	0.01	0	4.03	4.64	1.86	0.68	3.89	1.25	20.26
1964	0.07	0.24	1.18	0.54	0	0.19	7.67	4.57	5.89	1.37	1.23	2.18	25.13
1965	1.19	1.98	0.62	0.89	0	0.7	5.12	2.48	1.78	0	1.15	9.13	25.04
1966	2.85	2.86	0.1	0	0.01	0.3	4.63	6.07	4.79	0.43	1.18	0.47	23.69
1967	0.1	0.33	0.88	0.89	0.55	1.68	5.48	4.19	2.49	1.1	1.33	8.49	27.51
1968	0.56	1.81	1.85	0.39	0	0	5.33	3.22	0	0.15	1.33	1.72	16.36
1969	0.35	1.8	0.86	0	0.34	0.05	4.68	4.31	1.83	0.03	1.3	0.78	16.33
1970	0	0.45	2.34	0.28	0	0.65	3.82	4.67	3.76	0.47	10	0.12	0.09
1971	0	1.74	0	0.91	0.04	0.04	2.56	5.65	4.28	2.66	1.68	4.8	24.36
1972	0	0	0.01	0	0.15	1.7	5.04	2.01	1.18	5.64	1.56		0.09
1973	1.7	3	5.21	0	0	1.08	4.22	0.91	0.15	0	1	0	17.27
1974	2.81	0.02	0.88	0	0	0	10.06	3.75	1.2	3.88	0.34	0.35	23.29
1975	1.3	0.12	2.68	1.39	0	0	5.32	2.76	2.67	0	1.59	0.9	18.73
1976	0.43	2.02	0.81	1.52	0.17	0.3	9.21	1.93	3.4	3.08	0.91	0.53	24.31
1977	3.18	0.28	1.08	0.5	0.1	1.08	3.1	3.02	1.92	4.1	0.45	1.55	20.36
1978	10	3.19	2.89	0.15	0.18	0.41	5.09	3.18	2.76	3.36	4.36	4.8	0.09
1979	4.53	0.81	2.51	0	0.65	0.89	2.31	4.87	1.51	0.3	0.62	0.36	19.36
1980	1.74	3.94	2.01	0.11	0.05	0.4	5.93	3.25	4.39		0	0.28	0.09
1981		0.74	3.93	0.5	0.96	1.2	6.68	1.33	2.35	1.82		0	0.09
1982	0.98					0.27	4.1	4.97	3.33	0	2.74		0.09
1983	3.39	2.91	4.21	1.15	0.35	0	3.32	7.47	8.31	5.07	2.61	0.84	39.63
1984	2.51	0	0	1.72	0.36	1.96	7.45	6.8	3.95	1.63	0.83	7.29	34.5
1985	3.84	1.75	0.41	1.5	0.01	0.08	8.11	2.61	3.08	4.57	1.96	0.5	28.42

Santa Rita Experimental Range
Monthly precipitation (inches)

1986	0.77	2.38	1.61	0	0.51	0.85	3.65	5.22	0.98	0.78	0.67	2.21	19.63
1987	1.57	2.68	0.47	1.79	1.4	0.04	4.29	5.39	2.07	0.79	0.83	3.38	24.7
1988	2.19	1.18	0.49	2.87	0	0.35	7.54	8.02	0.3	5.45	0.79	0.74	29.92
1989	2.21	0.56	1.75	0	0.25	0.32	1.43	4.15	0.66	4.16	0.18	0.79	16.46
1990	1.29	2.6	1.06	0.21	0.16	3.3	11.15	3.94	3.85	0.38	0.99	2.41	31.34
1991	1.8	2.36	3.82	0	0	0.97	1.18	4.92	1.24	0.75	1.25	3.95	22.24
1992	2.04	1	4.47	0.36	1.65	0.01	5.29	5.59	1.46	0.07	0.06	5.94	27.94
1993	4.71	2.25	1.9	0	0.66	0	4.18	6.28	0.8	1.26	1.98	0.47	24.49
1994	0.38	1.44	2.71	0.45	0.28	0.53	1.42	4.45	3.62	0.66	3.95	4.93	24.82
1995	1.61	2.21	0.94	0.63	0.15	0	1.76	2.55	1.22	0.65	0.88	0.84	13.44
1996	0.23	1.26	0.39	0	0	0.55	3.88	5.41	1.43	1.88	0.28	0	15.31

Appendix C

Streamflow Data

Rincon Creek Gauging Station

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0.1	1.2	0	0.4	0
2-Oct	0	0	0	0.2	0	0	0	0	0	0	0	0.1	1	0	0.4	0
3-Oct	0	0	0	0.4	0	0	0	0	0	0	0	0	0.9	0	0.4	0
4-Oct	0	0	0	7.5	0	0	0	0	0	0	0	0	0.7	0	0.5	0
5-Oct	0	0	0	0.4	0	0	0	0	0	0	0	0	0.4	0	0.5	0
6-Oct	0	0	0	0.2	0	0	16	0	0	0	0	0	0.4	0	0.4	0
7-Oct	0	0	0	0.2	0	0	7.4	0	0	0	0	0	0.4	0	0.4	0
8-Oct	0	0	3	0.2	0	0	1.6	0	0	0	0	0	0.4	0	0.4	0
9-Oct	0	0	0	0.2	0	0	0.1	0	0	0	0	0	0.3	0	0.4	0
10-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.3	0	0.4	0
11-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.3	0	0.4	0
12-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0	0.3	0
13-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0	0.3	0
14-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0	0.3	0
15-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0	0.3	0
16-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.2	0	0.3	0
17-Oct	0	0	0	0.1	0	0	0	0	0	0	0	0	0.4	0	0.3	0
18-Oct	0	0	0	0.2	0	0	0	0	0	0	0	0	1	0	0.4	0
19-Oct	0	0	0	0.2	0	0	0	0	0	0	0	0	0.6	0	0.4	0
20-Oct	0	0	0	0.2	0	0	0	0	0	0	0	0	0.4	0	0.4	0
21-Oct	0	0	0	0.2	0	0	225	0	0	0	0	0	0.4	0	0.4	0
22-Oct	0	0	0	0.2	0	0	22	0	0	0	0	0	0.4	0	0.3	0
23-Oct	0	0	0	0.2	0	0	6.5	0	0	0	0	0	0.3	0	0.3	0
24-Oct	0	0	0	0.2	0	0	4.2	0	0	0	0	0	0.3	0	0.4	0
25-Oct	0	0	0	0.2	0	0	2.7	0	0	0	0	0	0.3	0	0.4	0
26-Oct	0	0	0	0.2	0	0	2	0	0	0	0	0	0.2	0	0.4	0
27-Oct	0	0	0	0.2	0	0	1.3	0	0	0	0	0	0.2	0	0.3	0
28-Oct	0	0	0	0.2	0	0	0.8	0.3	0	0	0	0	0.2	0	0.3	0
29-Oct	0	0	0	0.2	0	0	0.6	0	0	0	0	0	0.2	0	0.3	0
30-Oct	0	0	0	0.2	0	0	0.4	0	0	0	0	0	0.2	0	0.3	0
31-Oct	0	0	0	0.2	0	0	0.3	0.9	0	0	0	0	0.2	0	0.3	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Oct	0	0	0.03	24	0	0	0	0.14	0	0	0	0	0	0
2-Oct	0	0	0.02	13	0	0	0	0.21	0	0	0	0	0	0
3-Oct	0	0	0.12	8.7	0	0	0	0.15	0	0	0	0	0	0
4-Oct	0	0	0.02	6.3	0.04	0	0	0.11	0	0	0	0	0	0
5-Oct	0	0	0	4.4	0	0	0	0.09	0	0	0	0	0	0
6-Oct	0	0	0	3.2	0	0	0	0.07	0	0	0.04	0	0	0
7-Oct	0	0	0	2.7	0.04	0	0	0.07	0	0	0.04	0	0	0
8-Oct	0	0	0	2.2	0.03	0	0	0.06	0	0	0.03	0	0	0
9-Oct	0	0	0	1.9	0	0	0	0.05	0	0	0.02	0	0	0
10-Oct	0	0	0	1.8	0	0	0	0.06	0	0	0	0	0	0
11-Oct	0	0	0	1.8	0	0	0	0.06	0	0	0	0	0	0
12-Oct	0	0	0	1.7	0	0	0	0.07	0	0	0	0	0	0
13-Oct	0	0	0	1.8	0	0	0	0.07	0	0	0	0	0	0
14-Oct	0	0	0	1.8	0	0	0	0.07	0	0	0	0	0	0
15-Oct	0	0	0	1.9	0	0	0	0.07	0	0	0	0	0	0
16-Oct	0	0	0	2.1	0	0	0	0.06	0	0	0	0	0	0
17-Oct	0	0	0	28	0	0	0	0.06	0	0	0	0	0	0
18-Oct	0	0	0	37	0.09	0	0	0.06	0	0	0	0	0	0
19-Oct	0	0	0	27	396	0	0	0.06	0	0	0	0	0	0
20-Oct	0	0	0	21	252	0	0	0.05	0	0	0	0	0	0
21-Oct	0	0	0	21	30	0	0	0.06	0	0	0	0	0	0
22-Oct	0	0	0	23	12	0	0	0.07	0	0	0	0	0	0
23-Oct	0	0	0	19	7.1	0	0	0.06	0	0	0	0	0	0
24-Oct	0	0	0	19	4.4	0	0	0.05	0	0	0	0	0	0
25-Oct	0	0	0	38	2.9	0	0	0.04	0	0	0	0	0	0
26-Oct	0	0	0	34	5.5	0	0	0.06	0	0	0	0	0	0
27-Oct	0	0	0	16	3.8	0	0	0.04	0	0	0	0	0	0
28-Oct	0	0	0	6	2.8	0	0	0.04	0	0	0	0	0	0
29-Oct	0	0	0	2.1	2.1	0	0	0.05	0	0	0	0	0	0
30-Oct	0	0	0	1.8	1.7	0	0	0.06	0	0	0	0	0	0
31-Oct	0	0	0	1.5	1.5	0	0	0.04	0	0	0	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Nov	0	0	0	0.1	0	0	0.2	0.2	0	0	0	0	0.1	0	0.3	0
2-Nov	0	0	0	0.1	0	0	0.2	26	0	0	0	0	0.1	0	0.3	0
3-Nov	0	0	0	0.1	0	0	0.2	7.7	0	0	0	0	0.1	0	0.3	0
4-Nov	0	0	0	0.1	0	0	0.2	0.1	0	0	0	0	0.1	0	0.3	0
5-Nov	0	0	0	0.1	0	0	0.2	0.1	0	0	0	0	0.1	0	0.3	0
6-Nov	0	0	0	0.1	0	0	0.2	0	0	0	0	0	0.1	0	0.3	0
7-Nov	0	0	0	0.1	0	0	0.2	0	0	0	0	0	0.1	0	0.3	0
8-Nov	0	0	0	0.1	0	0	0.2	0	0	0	0	0	0.1	0	0.3	0
9-Nov	0	0	0	0.1	0	0	0.2	0	0	0	0	0	0.1	0	0.3	0
10-Nov	0	0	0	0.1	0	0	0.2	0	0	0	0	0	0.1	0	0.3	0
11-Nov	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0.1	0	0.3	0
12-Nov	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0.1	0	0.3	0
13-Nov	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0.1	0	0.3	0
14-Nov	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0.1	0	0.2	0
15-Nov	0	0	0	0.1	0	0	0.1	0	0	0	0	0	0.1	0	0.2	0
16-Nov	0	0	0	0.1	0	0	0.2	0	0	0	0	0	0.1	0	0.2	0
17-Nov	0	0	0	0.1	0	4.2	0.1	0	0	0	0	0	0.1	0	0.2	0
18-Nov	0	0	0	0.1	0	4.2	0.1	0	0	0	0	0	0.2	0	0.1	0
19-Nov	0	0	0	0.1	0	3.3	0.4	0	0	0	0	0	0.1	0	0.1	0
20-Nov	0	0	0	0.1	0	2.6	4	0	0	0	0	0	0.1	0	0.1	0
21-Nov	0	0	0	0.1	0	2.1	9.9	0	0	0	0	0.1	0.1	0	0.1	0
22-Nov	0	0	0	0.1	0	1.7	16	0	0	5	0	0	0.1	0	0.1	0
23-Nov	0	0	0	0.1	0	1.5	11	0	0	1	0	0	0.1	0	0.1	0
24-Nov	0	0	0	0.1	0	1.2	10	0	0	0.5	0	0	0.1	0	0	0
25-Nov	0	0	0	0.1	0	1	8.6	0	0	0.5	0	0	0.1	0	0	0
26-Nov	0	0	0	0.1	0	0.8	6.8	0	0	0.5	0	0	0.1	0	0	0
27-Nov	0	0	0	0.1	0	0.6	5.9	0.1	0	0.5	0	0	0.1	0	0	0
28-Nov	0	0	0	0.1	0	0.5	5	0	0	0.5	0	0	0.1	0	0	0
29-Nov	0	0	0	0.1	0	0.4	4.2	0	0	0.5	0	0	0.1	0	0	0
30-Nov	0	0	0	0.1	0	0.3	3.6	0	0	0.5	0	0	0.1	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Nov	0	0	0	1.5	1.4	0	0	0.04	0	0	0	0	0	0
2-Nov	0	0	0	1.5	1.4	0	0	0.09	0	0	0	0	0	0
3-Nov	0	0	0	1.5	1.3	0	0	0.04	0	0	0	0	0	0
4-Nov	0	0	0	1.5	1.2	0	0	0.04	0	0	0	0	0	0
5-Nov	0	0	0	1.5	1.2	0	0	0.04	0	0	0	0	0	0
6-Nov	0	0	0	1.5	1.1	0	0	0.04	0	0	0	0	0	0
7-Nov	0	0	0	1.5	1.1	0	0	0.07	0	0	0	0	0	0
8-Nov	0	0	0	1.2	1	0	0	0.08	0	0	0	0	0	0
9-Nov	0	0	0	1.2	1	0	0	0.08	0	0	0	0	0	0
10-Nov	0	0.41	0	1.2	1	0	0	0.09	0	0	0	0	0	0
11-Nov	0	0	0	1.2	1	0	0	0.07	0	0	0	68	0	0
12-Nov	0	0	0	1.2	1.1	0	0	0.08	0	0	0	354	0	0
13-Nov	0	0	0	1.1	1	0	0	0.07	0	0	0	81	0	0
14-Nov	0	0	0	0.94	1	0	0	0.06	0	0	0	19	0	0
15-Nov	0	0	0	0.99	1	0	0	0.06	0	0	0.05	6.5	0	0
16-Nov	0	0.67	0	13	1.1	0	0	0.07	0	0	1.2	3.1	0	0
17-Nov	0	2.9	0	17	6.2	0	0	0.07	0	0	5	1.6	0	0
18-Nov	0	0.14	0	12	13	0	0	0.09	0	0	3.9	0.97	0	0
19-Nov	0	0	0	7	11	0	0	0.08	0	0	3.4	0.63	0	0
20-Nov	0	0	0	6.5	8.7	0	0	0.09	0	0	3.1	0.51	0	0
21-Nov	0	0	0	8	7.3	0	0	0.11	0	0	2.2	0.45	0	0
22-Nov	0	0	0	8.1	5.9	0	0	0.14	0	0	1.4	0.41	0	0
23-Nov	0	0	0	6.2	5.2	0	0	0.12	0	0	1.9	0.39	0	0
24-Nov	0	0	0	4.7	5.4	0	0	0.18	0	0	2.7	0.36	0	0
25-Nov	0	0	0	3.1	4.8	0	0	0.2	0	0	1.6	0.32	0	0
26-Nov	0	0	0	2.3	4.2	0	0	0.17	0	0	0.99	0.31	0	0
27-Nov	0	0	0	2	3.6	0	0	0.05	0	0	0.72	0.28	0	0
28-Nov	0	0	0	1.7	2.8	0	0	0.04	0	0	0.55	0.29	0	0
29-Nov	0	0	0	1.6	2.3	0	0	0.05	0	0	0.49	0.28	0	0
30-Nov	0	0	0	1.9	1.9	0	0	0.04	0	0	0.43	0.28	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Dec	0	0	0	0.1	0	0.2	3	0	0	0.4	0	0	0.1	0	0	0
2-Dec	0	0	0	0.2	0	0.2	2.5	0	0	0.4	0	0	0.1	0	0	0
3-Dec	0	0	0	0.1	0	0.2	2	0	0	0.4	0	0	0.1	0	0	0
4-Dec	0	0	0	0.1	0	0.2	1.8	0	0	0.4	0	0	0.1	0	0	0
5-Dec	0	0	0	0.1	0	5	1.5	0	0	0.4	0	0	0.1	0	0.1	0
6-Dec	0	0	0	0.1	0	8.1	1.2	0	0	0.2	0	0	0.1	0	0.1	0
7-Dec	0	0	0	0.1	0	3.3	1	0	0	0.4	0	0	0.1	0	0.1	0
8-Dec	0	0	0	0.1	0	2.7	0.9	0	0	0.4	0	0	0.1	0	0.1	0
9-Dec	0	0	0	0.1	0	2.6	0.8	0	0	1.5	0	0	0.1	12	0.1	0
10-Dec	0	0	0	0.1	0	2.5	0.7	0.1	0	2.7	0	0	0.1	405	0.1	0
11-Dec	0	0	0	0.1	0	2.4	0.7	3.3	0	9.6	0	0	0.1	374	0.1	0
12-Dec	0	0	0	0.1	0	2.4	0.7	2.8	0	9.5	0	0	0.1	74	0.1	0
13-Dec	0	0	0	0.1	0	2.2	0.6	2.3	0	9.5	0	0	0.1	46	0.1	0
14-Dec	0	0	0	0.1	0	2.1	0.6	2.3	0	10	0	0	0.1	48	0.1	0
15-Dec	0	0	0	0.1	0	2	0.5	2.2	0	30	0	0	0.1	55	0.1	0.32
16-Dec	0	0	0	0.1	0	1.9	0.5	2.2	0	104	0	0	0.1	51	0.1	0.34
17-Dec	0	0	0	0.1	0	1.8	0.5	2	0	59	0	0	0.1	70	0.1	0.33
18-Dec	0	0	0	0.1	0	1.7	0.4	2	0	39	0	0	0.1	70	0.1	3.8
19-Dec	0	0	0	0	0	1.6	0.4	1.8	0	34	0	0	0.1	58	0.1	33
20-Dec	0	0	0	0	0	1.4	0.4	1.8	0	33	0	0	0.1	58	0.1	415
21-Dec	0	0	0	0	0	1.3	0.4	1.6	0	34	0	0	0.1	55	0.1	90
22-Dec	0	0	0	0	0	1.2	0.4	1.6	0	29	0	0	0.1	977	0.1	40
23-Dec	0	0	0	0.1	0	1.1	0.4	1.6	0	26	0	0	0.1	658	0	33
24-Dec	0	0	0	0.1	0	1	0.4	4.9	0	23	0	0	0.1	136	0	35
25-Dec	0	0	0	0.1	0	0.9	0.3	53	0	21	0	0	0.1	90	0	40
26-Dec	0	0	0	0.1	0	0.8	0.3	44	0	21	0	0	0.1	77	0	35
27-Dec	0	0	0	0.1	0	0.8	0.3	24	0	18	0	0	0.1	72	0.1	28
28-Dec	0	0	0	0.1	0	0.7	0.3	15	0	16	0	0	0.1	68	0	22
29-Dec	0	0	0	0.1	0	0.6	0.2	11	0	14	0	0	0.1	66	0	18
30-Dec	0	0	0	0.1	0	0.5	0.2	9.8	0	13	0	0	0.1	251	0	18
31-Dec	0	0	0	0.1	0	0.4	0.2	11	0	12	0	0	0.2	252	0	15

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Dec	0	0	0	1.8	1.6	0	0	0.04	0	0	0.41	0.28	0	0
2-Dec	0	0	0	1.7	1.5	0	0	0.04	0	0	0.39	0.28	0	0
3-Dec	0	0	0	1.6	1.3	0	0	0.04	0	0	0.34	0.25	0	0
4-Dec	0	0	0	3.6	1.1	0	0	0.06	0	19	0.32	0.25	0	0
5-Dec	0	0.61	0	4.5	1.2	0	0	0.07	0	259	0.32	249	0	0
6-Dec	0	0.17	0	5.6	1.4	0	0	0.05	0	38	0.3	506	0	0
7-Dec	0	0.06	0	5.2	1.1	0	0	0.06	0	13	0.28	119	0	0
8-Dec	0	0	0	11	1	0	0	0.07	0	21	0.28	55	0	0
9-Dec	0	0	0	12	1	0	0	0.09	0	28	0.27	31	0	0
10-Dec	0	0	0	13	0.92	0	0	0.09	0	25	0.26	18	0	0
11-Dec	0	0	0	14	1	0	0	0.09	0	18	0.26	12	0	0
12-Dec	0	0	0	10	1	0	0	0.09	0	17	0.27	8.7	0	0
13-Dec	0	0	0	12	0.9	0	0	0.16	0	12	0.24	6.8	0	0
14-Dec	0	0.02	0	26	0.83	0	0	0.11	0	7	0.24	5	0	0
15-Dec	0	0.05	0	26	0.79	0	0	0.09	0	4.9	0.24	3.9	0	0
16-Dec	0	0.05	0	32	0.71	0	0	0.13	0	3.5	0.24	3.1	0	0
17-Dec	0	0.06	0	19	0.69	0	0	0.06	0	2.6	0.24	2.4	0	0
18-Dec	0	0.06	0	18	0.69	0	0	0.04	20	2	0.24	1.8	0	0
19-Dec	0	0.06	0	29	0.57	0	0	0.04	54	2.7	0.24	1.5	0	0
20-Dec	0	0.09	0	27	0.55	0	0	0.08	80	3.5	0.24	1.3	0	0
21-Dec	0	0.09	0	28	0.55	0	0	0.29	50	2.9	0.25	1.1	0	0
22-Dec	0	0.09	0	43	0.63	0	0	0.21	26	2.7	0.24	0.9	0	0
23-Dec	0	0.09	0	77	0.67	0	0	0.14	20	2.5	0.23	1	0	0
24-Dec	0	0.09	0	59	0.66	0	0	0.13	14	2.4	0.24	1.8	0	0
25-Dec	0	0.09	0	35	0.62	0	0	0.13	12	3	0.24	2.3	0	0
26-Dec	0	0.08	0	37	0.55	0	0	0.12	10	4.2	0.24	32	0	0
27-Dec	0	0.09	0	49	0.58	0	0	0.1	7.6	4.5	0.24	64	0	0
28-Dec	0	0.09	0	25	23	0	0	58	5.7	325	0.24	42	0	0
29-Dec	0	0.08	0	21	23	0	0	77	4.5	296	0.24	33	0	0
30-Dec	0	0.09	0	15	7.6	0	0	55	4.1	91	0.25	31	0	0
31-Dec	0	0.08	0	11	5.4	0	0	32	3.5	47	0.25	31	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Jan	0	0	0	0.1	0	0.4	0.2	18	0	12	0	0	0.2	134	0	15
2-Jan	0	0	0	0.1	0	0.3	0.2	25	0	11	0	0	0.3	80	0	12
3-Jan	0	0	0	0.1	0	0.4	0.2	24	0	10	0	0	0.4	62	0	9.9
4-Jan	0	0	0	0.1	0	0.3	0.2	21	0	12	0	0	0.4	50	0	9
5-Jan	0	0	0	0.1	0	0.3	0.2	21	0	11	0	0	0.4	44	0	7.8
6-Jan	0	0	0	0.1	0	0.3	0.2	18	0	10	0	0	0.4	40	0	7
7-Jan	0	0	0	0.1	0	0.3	0.2	18	0	10	0	0	2.1	36	0	6.8
8-Jan	0	0	0	0.1	50	0.3	0.2	22	0	12	0	0	17	34	0	13
9-Jan	0	0	0	0.1	754	0.3	0.2	24	0	13	0	0	6.3	30	0	15
10-Jan	0	0	0	0.1	168	0.3	0.1	32	0	13	0	0	4.3	27	0	14
11-Jan	0	0	0	0.1	65	0.3	0.1	149	0	7.7	4	0	3.6	27	0	18
12-Jan	0	0	0	0.1	22	0.3	0.1	269	0	9.8	3	0	2.5	25	0	13
13-Jan	0	0	0	0.1	9.8	0.3	0.1	152	0	9.2	0	0	2	22	0	11
14-Jan	0	0	0	0.1	5.8	0.2	0.1	97	0	10	0	0	1.7	20	0	10
15-Jan	0	0	0	0.1	2.9	0.2	0.1	60	0	8.3	0	0	1.7	19	0	10
16-Jan	0	0	0	0.1	1.6	0.2	0.1	83	0	9.2	0	0	1.2	19	0	9.4
17-Jan	0	0	0	0.1	0.7	0.2	0.1	65	0	12	0	0	1	19	0	8.7
18-Jan	0	0	0	0.1	0.2	0.2	0.1	53	0	14	0	0	0.9	27	0	7.6
19-Jan	0	0	0	0.1	0.2	0.2	0.1	51	0	14	0	0	0.9	42	0	6.1
20-Jan	0	0	0	0.1	0.1	0.2	0.1	54	0	14	0	0	1.6	40	0	5
21-Jan	0	0	0	0.1	0.1	0.2	0.1	61	0	13	0	0	4.3	40	0	4.6
22-Jan	0	0	0	0.1	0.1	0.2	0.1	70	0	19	0	0	3.9	34	0	4.3
23-Jan	0	0	0	0.1	0	0.2	0.1	72	0	22	0	0	3.6	30	0	4.9
24-Jan	0	0	0	0	0	0.2	0.1	83	0	44	0	0	3.9	25	0	5.5
25-Jan	0	0	0	0	0	0.2	0.1	88	0	99	0	0	3.6	22	0	6.1
26-Jan	0	0	0	0	0	0.2	0.1	79	0	58	0	0	3.2	21	0	6.4
27-Jan	0	0	0	0	0	0.2	0.1	72	0	48	0	0	2.8	22	0	8
28-Jan	0	0	0	0	3.3	0.1	0.1	60	0	36	0	0	2.5	33	0	14
29-Jan	0	0	0	0.1	4.3	0.1	0.1	39	0	27	0	0	2	33	0	22
30-Jan	0	0	0	0	5.4	0.1	0.1	32	0	22	0	0	1.5	32	0	17
31-Jan	0	0	0	0	6.8	0.1	0.1	31	0	21	1.2	0	1.5	35	0	13

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Jan	0	0.08	0	12	4.3	0	0	20	2.9	28	0.27	31	0	0
2-Jan	0	0.08	0	9.1	3.6	0	0	14	2.3	20	0.27	32	0	0
3-Jan	0	0.08	0	7.4	3.3	0	0	12	1.9	15	0.27	35	0	0.01
4-Jan	0	0.08	0	5.9	2.9	0	0	52	3	13	0.27	156	0	0.01
5-Jan	0	0.08	0	4.7	2.6	0	0	276	24	10	0.28	886	0	0
6-Jan	0	0.08	0	4.6	2.2	0	0	247	77	150	0.25	327	0	0.01
7-Jan	0	0.08	0	4	2	0	0	78	56	1330	0.24	182	0	0.01
8-Jan	0	0.07	0	3.7	1.8	0	0	48	41	1400	0.24	134	0	0
9-Jan	0	0.07	0	3.6	1.7	36	0	32	33	312	0.24	110	0	0
10-Jan	0	0.06	0	3.1	1.7	18	0	23	27	263	0.24	90	0	0
11-Jan	0	0.06	0	2.7	1.6	1.1	0	17	32	413	0.24	77	0	0
12-Jan	0	0.06	0	2.6	1.5	0	0	13	87	162	0.24	77	0	0
13-Jan	0	0.06	0	2.5	1.4	0	0	10	43	430	0.24	78	0	0.02
14-Jan	0	0.08	0	2.2	1.3	0	0	8.7	31	222	0.24	67	0	1.7
15-Jan	76	0.08	0	2	1.3	0	0	7.3	23	141	0.24	59	0	2.2
16-Jan	23	0.08	0	1.8	1.3	0	0	6.3	15	104	0.23	53	0	1.3
17-Jan	8.4	0.08	0	1.7	1.2	0.11	0	33	12	425	0.23	52	0	0.8
18-Jan	3.5	0.08	0	1.7	1.2	1.5	0	22	10	744	0.23	47	0	0.51
19-Jan	2.1	0.08	0	1.6	1.2	1.4	0	18	8.4	588	0.23	44	0	0.54
20-Jan	1.7	0.08	0	1.5	1.5	0.89	0	16	10	235	0.22	39	0	0.85
21-Jan	1.6	0.07	0	1.4	1.3	0.72	0	14	20	153	0.21	35	0	1.1
22-Jan	25	0.06	0	1.4	1.5	0.98	0	12	16	112	0.21	30	0	1.2
23-Jan	16	0.05	0	1.3	1.3	0.72	0	12	13	88	0.21	27	0	0.85
24-Jan	8.4	0.05	0	1.2	1.2	0.41	0	10	10	70	0.21	25	0	0.64
25-Jan	5.3	0.06	0	1.1	1.1	0.31	0	9.4	9.6	55	0.21	26	0	0.51
26-Jan	10	0.08	0	1.1	1.2	0.27	0	8.6	10	43	0.21	88	0	0.56
27-Jan	7.7	0.08	0	1	1.2	0.23	0	8	11	35	0.21	65	0	0.53
28-Jan	5.6	0.08	0	0.95	1.1	0.23	0	7.3	11	31	0.21	52	0	0.47
29-Jan	3.8	0.07	0	0.9	1	0.23	0	6.5	10	26	0.2	43	0	0.43
30-Jan	2.6	0.06	0	0.83	1.1	0.19	0	5.3	9	22	0.2	35	0	0.32
31-Jan	2.1	0.05	0	0.8	2.8	0.16	0	4.7	7.8	19	0.2	29	0	0.26

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Feb	0	0	0	0	6.8	0.1	0.1	28	0	18	3.2	0	1.2	45	0	12
2-Feb	0	0	0	0	8.6	0.1	0.1	26	0	17	7.5	0	1.2	45	0	10
3-Feb	0	0	0	0	10	0.1	0.1	20	0	16	7.7	0	1.2	40	0	8.9
4-Feb	0	0	0	0	15	0.1	0.1	16	0	16	4.6	0	1.2	40	0	8.6
5-Feb	0	0	0	0	57	0.2	0.1	14	0	16	2.5	0	1	40	0	7.7
6-Feb	0	0	0	0	22	0.3	0.1	13	0	15	1.5	0	1.2	40	0	7.3
7-Feb	0	0	0	0	11	0.3	0.1	14	0	15	1.2	0	3.2	50	0	6.8
8-Feb	0	0	0	0	7.4	0.3	0.1	15	0	13	0.9	0	3.2	70	0	7.3
9-Feb	0	0	0	0	6.8	0.3	0.1	17	0	15	0.4	0	3.2	120	0	10
10-Feb	0	0	0	0	5.4	0.3	0.1	17	0	21	5.6	0	3.9	100	0	107
11-Feb	0	0	0	0	4.3	0.3	0.1	27	0	27	114	0	4.3	98	0	66
12-Feb	0	0	0	0	3.5	0.3	0.1	26	0	26	126	0	3.2	99	0	684
13-Feb	0	0	0	0	3	0.3	0.1	24	0	26	52	0	2.5	97	0	208
14-Feb	0	0	0	0	2.7	0.3	0.1	21	0	21	24	0	2.2	86	0	101
15-Feb	0	0	0	0	2.5	0.3	0.1	18	0	20	19	0	2	85	0	41
16-Feb	0	0	0	0	2.1	0.3	0.1	16	0	17	18	0	1.7	80	0	26
17-Feb	0	0	0	0	1.7	0.3	0.1	15	0	14	14	0	2	80	0	20
18-Feb	0	0	0	0	1.4	0.3	0.1	14	0	9.5	13	0	2.5	80	0	16
19-Feb	0	0	0	0	1.2	0.3	0.1	13	0	6.5	15	0	3.6	81	0	14
20-Feb	0	0	0	0	1.2	0.3	0.1	12	0	4.2	18	0	5.6	86	0	13
21-Feb	0	0	0	0	1.1	0.3	0.1	11	0	3.8	21	0	6.6	83	0	12
22-Feb	0	0	0	0	1.8	0.3	0.1	10	0	4.2	25	0	6.6	74	0	11
23-Feb	0	0	0	0	1.5	0.4	0.1	9.2	0	3.8	21	0	6.6	59	0	9
24-Feb	0	0	0	0	1.8	0.5	0.1	8.3	0	3.6	18	0	6.6	50	0	7.8
25-Feb	0	0	0	0	1.4	0.5	0.1	7.4	0	4.8	16	0	5.2	48	0	7.4
26-Feb	0	0	0	0	1.2	0.5	0.1	7.1	0	6.1	15	0	4.7	46	0	6.8
27-Feb	0	0	0	0	1.1	0.5	0.1	6.2	0	5.6	13	0	5.2	42	0	6.7
28-Feb	0	0	0	0	1	0.4	0.1	5.9	0	5.9	11	0	5.2	38	0	7.3
28-Feb	0	0	0	0	0	0	0	6.2				0				6

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Feb	1.8	0.05	0	0.78	3.1	0.16	0	3.9	6.9	17	0.2	27	0	0.2
2-Feb	1.7	0.05	0	0.76	2.9	0.16	0	3.6	7	15	0.18	31	0	0.18
3-Feb	1.6	0.05	0	0.75	2.8	0.16	0	3.6	10	13	0.18	34	0	0.15
4-Feb	1.4	0.05	0	0.91	3.5	0.16	0	3.6	12	11	0.18	30	0	0.15
5-Feb	1.5	0.05	0	0.98	4.2	0.16	0	3.4	10	9.4	0.18	27	0	0.14
6-Feb	1.5	0.05	0	0.63	6.1	0.16	0	3.1	8.5	8.3	0.18	24	0	0.12
7-Feb	1.5	0.05	0	0.62	11	0.16	0	2.8	16	7.7	0.19	21	0	0.08
8-Feb	1.6	0.05	0	0.55	9	0.16	0	2.8	104	7.6	0.44	18	0	0.02
9-Feb	1.6	0.05	0	0.55	6.9	0.23	0	2.7	64	37	0.28	18	0	0
10-Feb	1.6	0.04	0	0.55	5.2	0.23	0	2.2	40	71	0.26	19	0	0
11-Feb	1.6	0.05	0	0.55	4.4	0.23	0	2.1	46	46	0.27	16	0	0
12-Feb	1.6	0.05	0	0.55	4.4	0.27	2.2	54	52	34	0.28	13	0	0
13-Feb	1.6	0.04	0	0.49	6.6	0.19	3.3	50	336	28	0.28	154	0	0
14-Feb	1.6	0.04	0	0.48	9.6	0.16	4.9	27	142	50	0.32	121	0	0
15-Feb	1.6	0.04	0	0.47	11	0.16	4.1	18	73	139	0.32	767	0	0
16-Feb	1.6	0.04	0	0.46	8.5	0.16	3.7	14	50	83	0.33	231	0	0
17-Feb	1.6	0.04	0	0.46	7.5	0.16	4	14	38	68	0.32	123	0	0
18-Feb	1.6	0.03	0	0.46	6.9	0.16	4.9	22	27	71	0.33	84	0	0
19-Feb	1.6	0.03	0	0.42	5.8	0.16	6	24	21	168	0.47	61	0	0
20-Feb	2.1	0.03	0	0.45	12	0.16	5.8	19	16	201	0.63	45	0	0
21-Feb	2.6	0.03	0	0.46	541	0.13	5.4	17	13	110	0.58	36	0	0
22-Feb	2.9	0.03	0	0.46	858	0.1	4.6	15	12	76	0.57	35	0	0
23-Feb	3.8	0.02	0	0.46	250	0.08	4.9	13	11	59	0.52	35	0	0
24-Feb	5	0.02	0	0.46	129	0.07	7.2	11	9	50	0.48	25	0	0
25-Feb	5.6	0.02	0	0.42	74	0.06	8.9	9.4	7.5	43	0.46	21	0	0
26-Feb	6.3	0.02	0	0.42	52	0.05	9.7	8.2	6	36	0.45	16	0	0
27-Feb	7	0.02	0	0.42	40	0.04	10	6.9	4.9	30	0.41	14	0	0
28-Feb	7.3	0.02	0	0.42	31	0.03	7.5	32	4.3	39	0.41	12	0	0.22
28-Feb				0.42					3.9				0	

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Mar	0	0	0	0	0.9	0.4	0.1	7.7	0	11	8.9	0	4.7	39	0	6.2
2-Mar	0	0	0	0	0.8	0.4	0.1	9.8	0	12	7.1	0	4.3	39	0	6.6
3-Mar	0.4	0	0	0	0.8	0.5	0.1	10	0	12	5.6	0	3.2	35	0	5.4
4-Mar	7	0	0	0	0.6	1.3	0.1	12	0	11	5.1	0	2.5	30	0	4.6
5-Mar	12	0	0	0	0.5	1.9	0.1	13	0	13	2.8	0	2.2	28	0	4.3
6-Mar	16	0	0	0	0.5	1.7	0.1	14	0	13	3.2	0	1.7	30	0	4
7-Mar	19	0	0	0	0.5	19	0.1	18	0	14	2.8	0	1.5	43	0	4.2
8-Mar	32	0	0	0	0.5	25	0.1	19	0	14	2.5	0	1.2	53	0	4.1
9-Mar	30	0	0	0	0.5	33	0.1	18	0	18	2.2	0	1	56	0	6.3
10-Mar	20	0	0	0	0.7	26	0.1	15	0	16	1.8	0	1.2	54	0	40
11-Mar	15	0	0	0	0.9	24	0.1	12	0	15	1.8	0	4.8	49	0	39
12-Mar	9.2	0	0	0	0.7	31	0.1	11	0	13	1.6	0	6.6	50	0	41
13-Mar	6	0	0	0	0.8	36	0	9.5	0	15	1.2	0	6.6	51	0	37
14-Mar	6	0	0	0	0.6	42	0	9.2	0	14	1	0	7.1	51	0	31
15-Mar	2.4	0	0	0	0.6	47	0	8	0	13	1	0	6.6	50	0	27
16-Mar	2.2	0	0	0	0.6	50	0	6.2	0	13	1	0	8.4	46	0	24
17-Mar	2	0	0	0	0.5	77	0	4.4	0	11	1.4	0	6.6	42	0	20
18-Mar	1.9	0	0	0	0.5	107	0	3.8	0	12	4.8	0	6.1	35	0	15
19-Mar	1.6	0	0	0	0.9	72	0	3	0	13	4.2	0	6.1	32	0	14
20-Mar	1.4	0	0	0	11	56	0	2.7	0	28	5.3	0	6.1	30	0	12
21-Mar	0.9	0	0	0	17	49	0	2.3	0	32	7.7	0	6	27	0	8.7
22-Mar	0.6	8.8	0	0	16	249	0	2.3	0	32	11	0	6	22	0	7.2
23-Mar	0.6	183	0	0	11	123	0	2.5	0	34	10	0	5	19	0	6.7
24-Mar	0.5	77	0	0	6.5	65	0	4.2	0	26	8.6	0	5	14	0	7.1
25-Mar	0.5	30	0	0	4.5	37	0	3.8	0	26	5.9	0	4	13	0	7.1
26-Mar	0.3	23	0	0	3.6	28	0	3	0	30	4.4	0	4	14	0	6.4
27-Mar	0.4	17	0	0	3.3	25	0	2.5	0	31	4.2	0	3	12	0	6.1
28-Mar	0.4	16	0	0	3.1	27	0	2.2	0	28	3.6	0	3	11	0	6
29-Mar	0.3	12	0	0	2.7	25	0	1.8	0	26	4	0	2	12	0	6.2
30-Mar	0.2	6.8	0	0	2.5	20	0	1.5	0	20	5	0	2	12	0	5.9
31-Mar	0.2	2.8	0	0	2	19	0	1.2	0	16	3.6	0	2	12	0	5.6

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Mar	6.3	0.08	0	0.42	24	0.03	6.2	138	3.7	63	0.4	12	0	3.7
2-Mar	5	2.1	0	0.39	20	0.02	5.2	299	6.4	59	0.39	9.7	0	11
3-Mar	4.1	4.4	0	0.39	19	0.02	4.2	93	37	63	0.36	8.3	0	20
4-Mar	2.9	0.82	0	0.39	18	0.01	3.9	68	39	62	0.38	6.9	0	22
5-Mar	2.3	0.51	0	0.39	17	0.01	4.8	60	60	53	0.4	6.2	0	20
6-Mar	2.3	0.67	0	0.39	17	0.01	4	67	42	45	0.41	327	0	18
7-Mar	2.9	0.93	0	0.39	18	0.01	2.6	47	35	39	0.44	147	0	24
8-Mar	2.3	2.3	0	0.35	20	0	1.8	33	72	34	0.51	70	0	22
9-Mar	2.1	3.8	0	0.34	27	0	1.3	26	104	29	0.56	47	0	20
10-Mar	2.1	4.4	0	0.35	30	0	1.7	21	89	24	0.58	32	0	17
11-Mar	2.1	13	0	0.36	32	0	9.9	21	81	21	0.55	24	0	18
12-Mar	1.9	12	0	0.36	56	0	8.8	17	69	18	0.52	21	0	17
13-Mar	1.9	12	0	0.36	97	0	6	14	64	15	0.48	16	0	13
14-Mar	1.9	14	0	0.33	144	0	4	11	58	13	0.46	13	0	8
15-Mar	2.6	18	0	0.33	132	0	3	8.2	51	11	0.45	9.9	0	5.2
16-Mar	2.6	16	0	0.32	198	0	2.1	9.9	43	11	0.44	7.9	0	3.7
17-Mar	2.9	12	0	0.31	233	0	1.7	11	35	10	0.42	6.6	0	2.7
18-Mar	3.2	8.1	0	0.3	196	0	1.3	10	26	9.3	0.43	5.6	0	2
19-Mar	3.8	4.9	0	0.3	141	0	0.94	10	20	8.8	0.45	4.7	0	1.4
20-Mar	4.7	2.8	0	0.25	122	0	0.94	8.6	17	7.6	84	4.1	0	1.1
21-Mar	4.7	1.6	0	0.24	112	0	1.2	23	14	6.6	28	3.4	0	0.91
22-Mar	5.3	1.1	0	0.22	76	0	1.4	42	12	6.1	12	3	0	0.75
23-Mar	6.3	0.83	0	0.22	66	0	1.3	88	11	5.5	5.8	2.6	0	0.56
24-Mar	10	0.84	0	0.25	61	0	1.1	102	10	5	3.8	2.3	0	0.42
25-Mar	8	0.87	0	0.21	57	0	0.93	92	9.2	4.4	2.6	2.1	0	0.33
26-Mar	6.3	0.95	0	0.18	46	0	0.86	89	8.3	4.3	6	1.9	0	0.25
27-Mar	5.3	0.8	0	0.19	65	0	0.78	72	9.5	12	11	1.8	0	0.2
28-Mar	4.4	0.7	0	0.19	53	0	0.72	70	191	11	9	1.7	0	0.17
29-Mar	3.8	0.6	0	0.2	65	0	0.7	68	146	28	8	1.5	0	0.15
30-Mar	3.5	0.6	0	0.19	72	0	0.66	72	78	32	4.6	1.4	0	0.15
31-Mar	2.6	0.6	0	0.17	72	0	0.65	65	58	29	4.5	1.3	0	0.15

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Apr	0.2	0.9	0	0	1.7	17	0	1	0	15	2.7	0	2	11	0	5.1
2-Apr	0.2	0.3	0	0	1.6	15	0	0.9	0	13	1.8	0	2.2	11	0	5.6
3-Apr	0.2	0.2	0	0	1.3	13	0	0.8	0	13	1.5	0	2	11	0	9
4-Apr	0.2	0.2	0	0	1.2	16	0	0.8	0	12	1	0	13	11	0	7.7
5-Apr	0.2	0.2	0	0	0.9	14	0	0.7	0	11	0.7	0	14	9	0	7.3
6-Apr	0.2	0.2	0	0	0.8	12	0	0.6	0	11	0.5	0	13	8	0	7.2
7-Apr	0.2	0.2	0	0	0.7	11	0	0.6	0	9.5	0.6	0	13	7	0	6.6
8-Apr	0.2	0.2	0	0	0.6	27	0	0.6	0	8.9	0.5	0	14	6	0	5.8
9-Apr	0.2	0.1	0	0	0.5	41	0	0.9	0	8.6	0.5	0	12	5	0	5.3
10-Apr	0.2	0.1	0	0	0.5	42	0	0.8	0	6.8	0.5	0	11	4.5	0	6.8
11-Apr	0.1	0.1	0	0	0.4	35	0	0.7	0	4	0.5	0	9.7	4	0	12
12-Apr	0.1	0.1	0	0	0.4	27	0	0.5	0	1.5	0.5	0	8.4	3.5	0	7.2
13-Apr	0.1	0.1	0	0	0.4	22	0	0.4	0	0.7	0.5	0	7.1	3	0	7.3
14-Apr	0.1	0.1	0	0	0.3	19	0	0.4	0	0.3	0.5	0	5.6	2.5	0	6.3
15-Apr	0.1	0.1	0	0	0.3	16	0	0.3	0	0.3	0.5	0	4.3	2.5	0	5.6
16-Apr	0.1	0.1	0	0	0.4	16	0	0.3	0	0.3	0.5	0	3.6	2	0	5
17-Apr	0.1	0.1	0	0	0.3	15	0	0.2	0	0.3	0.4	0	2.8	2	0	4.5
18-Apr	0.1	0	0	0	0.3	12	0	0.2	0	0.3	0.4	0	2.2	1.5	0	4
19-Apr	0.1	0	0	0	0.2	9.7	0	0.2	0	0.3	0.4	0	2	1.6	0	3.4
20-Apr	0.1	0	0	0	0.2	7.2	0	0.2	0	0.2	0.3	0	1.7	1.6	0	3
21-Apr	0.1	0	0	0	0.2	4.4	0	0.2	0	0.2	0.2	0	1	1.6	0	2.2
22-Apr	0.1	0	0	0	0.2	4.4	0	0.2	0	0.1	0.2	0	0.9	1.8	0	2
23-Apr	0.1	0	0	0	0.1	3.8	0	0.2	0	0.1	0.2	0	0.6	1.8	0	1.9
24-Apr	0.1	0	0	0	0.1	2.7	0	0.2	0	0.1	0.2	0	0.6	1.5	0	1.8
25-Apr	0.1	0	0	0	0.1	2.2	0	0.2	0	0.1	0.2	0	0.4	1.5	0	1.7
26-Apr	0.1	0	0	0	0.1	1.5	0	0.2	0	0.2	0.2	0	0.4	1.4	0	1.5
27-Apr	0	0	0	0	0.1	1	0	0.2	0	0.2	0.1	0	0.4	1.3	0	1.4
28-Apr	0	0	0	0	0.1	0.8	0	0.2	0	0.2	0.1	0	0.3	1.2	0	1.3
29-Apr	0	0	0	0	0.1	0.7	0	0.2	0	0.2	0.1	0	0.2	1.2	0	1.1
30-Apr	0	0	0	0	0.1	0.6	0	0.1	0	0.2	0.1	0	0.2	1.1	0	1.1

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Apr	2.3	0.6	0	0.17	64	0	0.64	71	51	24	3.4	1.2	0	0.13
2-Apr	2.1	0.6	0	0.17	51	0	0.6	70	73	19	2.5	1.1	0	0.12
3-Apr	1.9	0.6	0	0.16	37	0	0.6	57	53	15	1.8	1	0	0.13
4-Apr	1.8	0.6	0	0.16	30	0	0.59	52	44	11	1.4	0.96	0	0.14
5-Apr	1.7	0.6	0	0.13	25	0	0.55	48	37	8.7	1.1	0.88	0	0.14
6-Apr	1.5	0.6	0	0.13	20	0	0.51	42	28	7	0.89	0.82	0	0.13
7-Apr	1.5	0.65	0	0.13	20	0	0.46	36	22	6.1	0.76	0.75	0	0.13
8-Apr	1.3	0.58	0	0.12	15	0	0.44	27	17	5.2	0.67	0.68	0	0.14
9-Apr	1.3	0.58	0	0.11	15	0	0.41	20	14	4.6	0.6	0.66	0	0.16
10-Apr	1.1	0.5	0	0.09	10	0	0.39	15	11	3.9	0.53	0.61	0	0.15
11-Apr	1.1	0.47	0	0.08	10	0	0.39	12	9.2	3.5	0.46	0.58	0	0.14
12-Apr	1	0.46	0	0.07	15	0	0.35	9.3	7.6	3.1	0.45	0.55	0	0.13
13-Apr	0.96	0.42	0	0.06	25	0	0.34	7.6	6.3	2.8	0.44	0.54	0	0.12
14-Apr	0.82	0.4	0	0.04	15	0	0.31	6	5.2	2.7	0.39	0.51	0	0.12
15-Apr	0.78	0.39	0	0.05	15	0	0.28	5	4.2	2.4	0.35	0.51	0	0.11
16-Apr	0.78	0.36	0	0.04	15	0	0.26	4.2	3.6	2.2	0.31	0.5	0	0.11
17-Apr	0.71	0.36	0	0.03	13	0	0.23	3.6	3	2	0.29	0.51	0	0.11
18-Apr	0.7	0.33	0	0.02	16	0	0.21	3.2	2.5	1.8	0.27	0.51	0	0.1
19-Apr	0.63	0.33	0	0.01	13	0	0.2	2.8	1.9	1.7	0.25	0.6	0	0.1
20-Apr	0.62	0.31	0	0.01	12	0	0.17	2.4	1.7	1.5	0.24	2.3	0	0.09
21-Apr	0.53	0.27	0	0	10	0	0.15	2	1.4	1.4	0.22	10	0	0.09
22-Apr	0.52	0.27	0	0	9.4	0	0.13	1.8	1.1	1.3	0.2	11	0	0.08
23-Apr	0.46	0.26	0	0	11	0	0.12	1.6	0.9	1.1	0.19	9.1	0	0.08
24-Apr	0.46	0.26	0	0	12	0	0.13	1.3	0.83	0.99	0.18	7.1	0	0.07
25-Apr	0.42	0.23	0	0	11	0	0.1	1	0.75	0.95	0.18	5	0	0.07
26-Apr	0.41	0.23	0	0	11	0	0.08	0.96	0.67	0.91	0.18	3.3	0	0.07
27-Apr	0.36	0.26	0	0	11	0	0.06	0.91	0.61	0.84	0.18	2.3	0	0.07
28-Apr	0.36	0.24	0	0	10	0	0.05	0.87	0.56	0.8	0.18	1.7	0	0.06
29-Apr	0.36	0.25	0	0	10	0	0.04	0.82	0.51	0.79	0.17	1.3	0	0.06
30-Apr	0.34	0.23	0	0	7.4	0	0.03	0.8	0.47	0.75	0.16	1.1	0	0.06

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-May	0	0	0	0	0	0.5	0	0.1	0	0.2	0.1	0	0.2	1.1	0	1
2-May	0	0	0	0	0	0.5	0	0.1	0	0.2	0.1	0	0.2	1	0	1
3-May	0	0	0	0	0	0.4	0	0.1	0	0.1	0	0	0.1	0.9	0	0.87
4-May	0	0	0	0	0	0.4	0	0.1	0	0.1	0	0	0.1	0.8	0	0.83
5-May	0	0	0	0	0	0.4	0	0.2	0	0.1	0	0	0.1	0.8	0	0.83
6-May	0	0	0	0	0	0.3	0	0.1	0	0.1	0	0	0.1	0.6	0	0.75
7-May	0	0	0	0	0	0.3	0	0.1	0	0.1	0	0	0.1	0.6	0	0.73
8-May	0	0	0	0	0	0.4	0	0.1	0	0.1	0	0	0.1	0.6	0	0.65
9-May	0	0	0	0	0	0.3	0	0.1	0	0.1	0	0	0.1	0.5	0	0.62
10-May	0	0	0	0	0	0.3	0	0.1	0	0.1	0	0	0.1	0.5	0	0.61
11-May	0	0	0	0	0	0.2	0	0.1	0	0.1	0	0	0.1	0.5	0	0.54
12-May	0	0	0	0	0	0.2	0	0	0	0.1	0	0	0.1	0.4	0	0.53
13-May	0	0	0	0	0	0.2	0	0	0	0.1	0	0	0.1	0.4	0	0.48
14-May	0	0	0	0	0	0.2	0	0	0	0	0	0	0.1	0.4	0	0.46
15-May	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0.3	0	0.41
16-May	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0.3	0	0.4
17-May	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0.3	0	0.4
18-May	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0.3	0	0.4
19-May	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.3	0	0.4
20-May	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0.3	0	0.4
21-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.4
22-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.4
23-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0.4
24-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
25-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
26-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
27-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
28-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
29-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
30-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3
31-May	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.3

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-May	0.34	0.22	0	0	5.8	0	0.03	0.77	0.45	0.64	0.14	0.97	0	0.05
2-May	0.27	0.18	0	0	4.5	0	0.04	0.7	0.44	0.6	0.13	0.87	0	0.05
3-May	0.25	0.18	0	0	4	0	0.03	0.68	0.42	0.58	0.12	0.77	0	0.05
4-May	0.21	0.17	0	0	4	0	0.02	0.63	0.39	0.52	0.11	0.7	0	0.04
5-May	0.26	0.14	0	0	4.3	0	0.01	0.62	0.4	0.58	0.09	0.65	0	0.04
6-May	0.24	0.13	0	0	5	0	0.01	0.58	0.31	0.21	0.08	0.64	0	0.04
7-May	0.21	0.11	0	0	3.6	0	0	0.56	0.24	0.38	0.07	0.68	0	0.03
8-May	0.17	0.11	0	0	3	0	0	0.54	0.21	0.44	0.07	0.64	0	0.03
9-May	0.14	0.1	0	0	2.5	0	0	0.52	0.21	0.3	0.06	0.63	0	0.03
10-May	0.07	0.08	0	0	2.1	0	0	0.49	0.2	0.18	0.08	0.57	0	0.03
11-May	0.01	0.07	0	0	1.8	0	0	0.48	0.15	0.2	0.09	0.53	0	0.03
12-May	0	0.03	0	0	1.6	0	0	0.47	0.12	0.18	0.09	0.47	0	0.03
13-May	0	0	0	0	1.6	0	0	0.44	0.09	0.18	0.07	0.45	0	0.02
14-May	0	0	0	0	1.5	0	0	0.42	0.06	0.14	0.04	0.41	0	0.01
15-May	0	0	0	0	1.4	0	0	0.39	0.04	0.05	0.03	0.39	0	0.01
16-May	0	0	0	0	1.3	0	0	0.37	0.03	0.06	0	0.37	0	0
17-May	0	0	0	0	1.3	0	0	0.31	0.03	0.04	0	0.36	0	0
18-May	0	0	0	0	1.2	0	0	0.23	1.9	0.04	0	0.34	0	0.01
19-May	0	0	0	0	1	0	0	0.22	0.25	0.03	0	0.33	0	0
20-May	0	0	0	0	0.93	0	0	0.18	0.14	0.02	0	0.31	0	0
21-May	0	0	0	0	0.9	0	0	0.15	4.1	0.02	0	0.29	0	0
22-May	0	0	0	0	0.87	0	0	0.13	0.37	0.02	0	0.27	0	0
23-May	0	0	0	0	0.81	0	0	0.1	0.28	0.02	0	0.26	0	0
24-May	0	0	0	0	0.78	0	0	0.08	0.25	0.02	0	0.25	0	0
25-May	0	0	0	0	0.79	0	0	0.06	0.21	0.02	0	0.24	0	0
26-May	0	0	0	0	0.71	0	0	0.04	0.14	0.02	0	0.23	0	0
27-May	0	0	0	0	0.73	0	0	0.03	0.25	0.02	0	0.22	0	0
28-May	0	0	0.13	0	0.69	0	0	0.02	0.24	0.02	0	0.2	0	0
29-May	0	0	1.9	0	0.59	0	0	0.01	0.18	0.01	0	0.19	0	0
30-May	0	0	2.6	0	0.57	0	0	0.01	0.12	0.01	0	0.18	0	0
31-May	0	0	2.8	0	0.46	0	0	0.01	0.09	0.01	0	0.17	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2
2-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2
3-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.2
4-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.2
5-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.2
6-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.2
7-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.2
8-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.1
9-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.1
10-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.1
11-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.1
12-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.1
13-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.1
14-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.1
15-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.05
16-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.05
17-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
18-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0
19-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0
20-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0
21-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
22-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
23-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
24-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Jun	0	0	2.9	0	0.43	0	0	0.01	0.05	0.01	0	0.16	0	0
2-Jun	0	0	2.4	0	0.41	0	0	0.01	0.03	0.01	0	0.15	0	0
3-Jun	0	0	2.5	0	0.38	0	0	0.01	0.03	0.01	0	0.14	0	0
4-Jun	0	0	2	0	0.35	0	0	0	0.02	0.01	0	0.13	0	0
5-Jun	0	0	2.2	0	0.31	0	0	0	0.01	0.01	0	0.12	0	0
6-Jun	0	0	2.2	0	0.24	0	0	0	0.01	0.01	0	0.11	0	0
7-Jun	0	0	2.2	0	0.21	0	0	0	0	0.01	0	0.1	0	0
8-Jun	0	0	2.3	0	0.18	0	0	0	0	0.01	0	0.1	0	0
9-Jun	0	0	1.9	0	0.17	0	0	0	0	0.01	0	0.09	0	0
10-Jun	0	0	1.9	0	0.16	0	0	0	0	0.01	0	0.08	0	0
11-Jun	0	0	1.8	0	0.16	0	0	0	0	0.01	0	0.07	0	0
12-Jun	0	0	1.7	0	0.18	0	0	0	0	0.01	0	0.07	0	0
13-Jun	0	0	1.6	0	0.21	0	0	0	0	0.01	0	0.06	0	0
14-Jun	0	0	1.6	0	0.19	0	0	0	0	0.01	0	0.05	0	0
15-Jun	0	0	2.1	0	0.19	0	0	0	0	0.01	0	0.03	0	0
16-Jun	0	0	2.2	0	0.17	0	0	0	0	0.01	0	0.03	0	0
17-Jun	0	0	2	0	0.16	0	0	0	0	0	0	0.03	0	0
18-Jun	0	0	2	0	0.17	0	0	0	0	0	0	0.02	0	0
19-Jun	0	0	2	0	0.16	0	0	0	0	0	0	0.01	0	0
20-Jun	0	0	2	0	0.15	0	0	0	0	0	0	0	0	0
21-Jun	0	0	2	0	0.13	0	0	0	0	0	0	0	0	0
22-Jun	0	0	0.96	0	0.1	0	0	0	0	0	0	0	0	0
23-Jun	0	0	0.04	0	0.1	0	0	0	0	0	0	0	0	0
24-Jun	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0
25-Jun	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0
26-Jun	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0
27-Jun	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
28-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30-Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Jul	0	0	0	0	0	0	2.5	0	1.9	0	0	0	0	0	0	0
4-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-Jul	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-Jul	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0	13	0
18-Jul	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-Jul	2	0	0	0	0	0	0.7	0	0	0	0	0	0	15	0	0
20-Jul	0.1	0.3	0	3	0	0	0	0	0	0	0	0	0	3.8	0	0
21-Jul	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0
22-Jul	0	5.2	179	0	0	0	0	0	0.3	0	0	0	0	0	0	0
23-Jul	0	17	15	0	0	0	0	0	0	0	0	0	0	0	0	0
24-Jul	0	60	6.7	0	0	0	0	0	0.5	0	0	0	0	0	0	0
25-Jul	0	18	1.2	0	0	0	0	0	0.5	0	0	0	0	0	0	0
26-Jul	0	1.3	0	0	0.5	0	0.2	0	0	0	0	0	0	0	0	0
27-Jul	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	0	0
29-Jul	7.5	0	5.6	0.3	0	36	0	0	0	0	0	0.4	0	1.3	0	0
30-Jul	29	0	8.4	0	0	3	2.4	0	2.8	0	0	0.4	0	0	0	0
31-Jul	24	0	154	1.5	0	0	0	0	13	0	0	0	0	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-Jul	0	1.9	0	0.9	0	2.8	0	0	0	0	0	0	0	0
7-Jul	0	0	0	0	0	0	31	0	0	0	0	0	0	0
8-Jul	0	0	0	0	0.02	0	0.61	0	0	0	0	0	0	0
9-Jul	0	0	0	0	0	0	31	0	0	0	0	0	0	0
10-Jul	0	0	0	0	0	0	6	0	0	0	0	0	0	0
11-Jul	0	0	0	0	0	0	32	0	0	0	0	0	0	0
12-Jul	0	0	0	0	3.3	0	19	0	0	0	0	0	0	0
13-Jul	0	0	0	0	9.4	0	0.72	0	0	0	0	0	0.11	0
14-Jul	0	0	0	0	14	0	0.03	0	0	0	0	0	0.14	0
15-Jul	0	0	0	0	7.1	0	84	0	0	0	0	0	0.03	0
16-Jul	0	0	0	13	4.2	0	136	0	0	0	0	0	0	0
17-Jul	0	0	0	5.6	1.5	0	87	0	0	0	0	0	0	0
18-Jul	0	0	0	0	0.46	0	48	0	0	0	0	0	0	0
19-Jul	0	0.18	0	0	0.16	0	52	0	0	0	0	0	0	0
20-Jul	0	0.04	0	0	0.11	0	260	0	0	0	0	0	0	0
21-Jul	0	0	0.23	0	0.06	0	71	0	0	0	0	0	0	0
22-Jul	0	0	0	0	0.03	0	30	0	0	0	0	0	0	0
23-Jul	0	0	0	0	0.01	0	163	0	0	0	0	0	0	0
24-Jul	0	0	0	3.7	0	0		0	0	0	0	0	0	0
25-Jul	0	7.8	0	0	0	0		0	0	0	0	0	0	0
26-Jul	0	0	0	0	0	0		0.04	0	0	0	0	0	0
27-Jul	0	0	0	0	0	0		0	0	0	0	0	0	0
28-Jul	0	0	0	0	0.07	0		0	0	0	0	0	0	0
29-Jul	0	0	0	0	0.03	0		0	0	0	0	0	0	0
30-Jul	0	0	0	0	0.02	0		0	0	0	0	0	0	0
31-Jul	0	0	0	0	0.02	0		0	0	0	0	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Aug	7.2	0	31	0	0	0	0.8	0	1.1	0	49	0	0	0	0	0
2-Aug	0.2	0	22	0	0.5	0	26	0	6.8	0	137	0	0	0	0	2.2
3-Aug	0	2.6	392	0	0	3.4	2.3	0	15	0	21	2.1	0	0	0	0.86
4-Aug	0	17	54	0	1	0	0	0	0.1	0	122	0.2	0	0.4	0	8.6
5-Aug	0	6.8	27	0	150	0	19	0	0	0	53	0	0	0	0	18
6-Aug	0	5.3	64	0	169	48	8.3	0	0.1	0	36	0	0	0	0	3.8
7-Aug	0	14	73	0	20	34	33	0	0	0	19	0	0	0	0	1
8-Aug	0	14	33	0	14	14	0	0	0	0	6.7	0.2	0	0	0	0.71
9-Aug	0	5.7	14	0	7	1.8	0.1	0	0	0	4.2	7.3	0	0	0	3.4
10-Aug	0	3.2	14	0	3.5	0.5	0	0	0	0	2.8	2.5	0	27	0	76
11-Aug	0	2	6.9	0	2	0.1	0	0	0	0	1.7	1.7	0	22	0	9.8
12-Aug	0	16	11	0	24	0	0	0	0	0	4.3	0.7	0	53	0	3.1
13-Aug	0	2.2	317	0	22	0	65	0	8.8	0	2.8	0.5	0	19	4	1.3
14-Aug	0	0.7	151	0	35	0	63	0	0	0	0.7	0	0	7.1	0	0.58
15-Aug	0	1.6	87	0	34	0	114	0	14	0	0.8	0	0	3.1	0	0.33
16-Aug	0	0.5	42	0	29	1	56	0	4.7	0	0.8	0	0	1.3	0	0.2
17-Aug	0	2.5	67	0	40	23	120	0	3.5	0	0.2	0.5	0	2.2	0	0.14
18-Aug	0	1.8	30	0	25	1	55	0	17	0	0.2	0	7.7	4.6	0	0.12
19-Aug	0	395	33	0	17	0	43	0	2.3	0	164	0	0.9	7.8	0	0.1
20-Aug	0	208	135	0	18	0	14	0	0.1	0	27	1.8	0	65	0	0.2
21-Aug	0	101	59	0	7.4	0	8.9	0	0	0	12	4.7	0	28	0	1.1
22-Aug	0	34	48	0	106	19	19	0	138	0	13	1.2	0	9.4	0	0.5
23-Aug	0	39	42	0	69	20	9.8	0	49	0	9.7	0	0	5.6	0	0.26
24-Aug	0	21	110	0	30	38	7.5	0	8.3	0	3.2	0	0	6.8	0	0.18
25-Aug	0	9.2	43	0	8.2	21	12	0	2.8	0	248	0	0	5	0	0.14
26-Aug	0.1	4.1	30	0	3.8	5.8	15	0	0.4	0	106	11	0	4.5	0	1.4
27-Aug	17	1.5	18	0	5.6	0.4	6.2	0	0	0	53	25	0	2.9	0	2.9
28-Aug	12	0.5	11	0	2.1	0.2	3	0	0	0	41	4.1	0	1.9	0	0.61
29-Aug	1.8	0.5	7.5	0	1.2	0.1	1.5	0	5.1	0	18	1.2	0	1	0	2.8
30-Aug	0.1	0.4	5.8	0	1.4	0.1	0.8	0	4.1	0	21	0.2	0	0.9	0	6.9
31-Aug	0	0.4	4.6	0	158	0.1	0.5	0	0.3	0	50	0	0	1.2	0	4.7

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Aug	0	26	0	0	0.02	50		0	0	0	0	0	0	0
2-Aug	0	1.1	0	0	0.01	9.7		0	0	0	0	0	0	0
3-Aug	0	0	0.46	0	0.01	1.1		0	0	0	0	0	0	0
4-Aug	0	0	0.02	0	0	8.7		0	0	0	0	0	0	0
5-Aug	0	0	0	0	0	0.81		0	0	0	0	0	0	0
6-Aug	0	0	0	0	0	0.04		0	0	0	0	0	0	0
7-Aug	0	0	0	0	0	0		0	0	0	0	0	0	0
8-Aug	0	0	0	0	0	0		0	0	0	0	0	0	0
9-Aug	0	0	0	0	0	0		0	0	0	0	0	0	0
10-Aug	0	0	2.1	0	0	0		0	0	0	0	0	0	0
11-Aug	0	0	0	0	0	0		0	0	0	0	0	0	0
12-Aug	21	0	0	6.4	0	0		0	0	0	0	0	0	0
13-Aug	18	0	0	1.1	0	0		0	0	0	0	0	0	0
14-Aug	11	0	0	0	0	0		0	0	0	0	0.04	0	0.01
15-Aug	2.2	0	0	0	0	0	110	0	0	0	0	0	0	3.8
16-Aug	0.61	0	0	0	0	0	65	0	0	0	0	0	0	0.32
17-Aug	0.04	0	0	0	0	0	35	0	0	0	0	0	0	0.02
18-Aug	0	5	16	0	0	0	18	0	0	0	0	0	0	0
19-Aug	0	0	634	0	0	0	9.6	0	0	0	17	0.07	0	0
20-Aug	0	0	138	0	0	0	6	0	0	0	3.4	0	0	0
21-Aug	0	0	199	0	0	0	3.7	0	0	0.02	1.2	0	0.21	0
22-Aug	0	0	106	0	0	0	2.3	0	0	0	5.1	0	0	0
23-Aug	0	0	26	0	0	0	1.4	0	0	0	0.2	0	0	0
24-Aug	0	25	6.7	0	0	0	0.9	0	200	0	0	0	0	0
25-Aug	0	1	3.7	0	0	0	0.73	0	50	0	0	0	0	0
26-Aug	1	0	1.9	0.43	0	0	0.59	0	20	0	0	0	0	0
27-Aug	0	0	1.4	0	0	0	0.47	0	10	3.1	0	0	0	0
28-Aug	0	0	1.3	0	0	0	0.4	0	4.3	32	0	0	0	0
29-Aug	0	0	3.2	0	0	0	0.29	0	1.7	23	0	0	0.14	0
30-Aug	0	0	7	0	0	0	0.19	0	1	474	0	0	0	0
31-Aug	0	0	2.8	0	0	0	9.6	0	0.8	202	0	0	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1-Sep	0	0.3	2.8	0	262	0.1	0.4	0	0	0	27	0	0	1.1	0	2.6
2-Sep	0	0.3	1.9	0	35	0.1	0.4	0	0	0	16	0	0	1	0	1.2
3-Sep	0	0.2	1.6	0	8.2	0.1	0.3	0	0	0	50	0	0	0.8	0	0.68
4-Sep	0	0.2	1.4	0	4.5	0.1	0.2	0	0	0	75	0	0	0.6	0	0.41
5-Sep	0	0.1	1.2	0	3.4	0.1	0.1	0	0	0	23	0	0	0.6	0	0.33
6-Sep	0	0.1	1.2	0	2.7	0	0.1	0	0	0	12	0	0	0.4	0	0.28
7-Sep	0	0	1.1	0	2.1	0	0	0	0	0	8.4	0	0	0.4	0	0.25
8-Sep	0	0	1.1	0	1.9	0	0	0	48	0	5	0	0	0	0	0.22
9-Sep	0	0	1.1	0	1.5	0	0	0	14	0	3.2	0.6	0	0	1.1	0.18
10-Sep	0	0	0.9	0	1.1	0	0	0	4	0	2	89	0	0	0	0.12
11-Sep	0	0	0.8	0	0.9	0	0.6	0	1.7	0	1	29	0	2.2	0	0.06
12-Sep	0	0	0.6	0	0.8	0	0	0	5.2	0	0.7	37	0	62	0	0.02
13-Sep	0	0	0.5	0	0.7	0	0	0	4.3	0	0.6	23	0	47	0	0
14-Sep	0	0	0.5	0	0.6	0	0	0	2.1	0	0.6	34	0	30	0	0
15-Sep	0	0	0.4	0	0.5	0	0	0	1.3	0	0.4	80	0	82	0	0
16-Sep	0	0	0.4	0	0.4	0	0	0	1	0	0.4	21	0	48	0	0
17-Sep	0	0	0.4	0	0.3	0	0	0	0.7	0	0.3	10	0	21	0	0
18-Sep	0	0	0.3	0	0.2	0	0	0	0.5	0	0.2	4.3	0	17	0	0
19-Sep	0	0	0.2	0	0.1	0	0	0	0.3	0	0.2	16	0	10	0	0
20-Sep	0	0	0.2	0	0	0	0	0	0.2	0	0.2	11	0	7.9	0	0
21-Sep	0	0	0.2	0	0	0	0	0	0.2	0	0.2	5.2	0	7.5	0	0
22-Sep	0	0	0.2	0	0	0	0	0	0.2	0	0.2	4.9	0	5.8	0	0
23-Sep	0	0	0.2	0	0	0	0	0	0.2	0	0.2	102	0	5	0	0
24-Sep	0	0.3	0.2	0	0	0	0	0	0.2	0	0.1	52	0	3.5	0	0
25-Sep	0	0	0.2	0	0	0	0	0	0.1	0	0.1	16	0	2.9	0	0
26-Sep	0	0	0.3	0	0	0	0	0	0.1	0.1	0.1	9.7	0	2.1	0	0
27-Sep	0	0	0.4	0	0	0	0	0	0.1	0	0.1	5.2	0	1.6	0	0
28-Sep	0	0	0.3	0	0	0	0	0	0.1	0	0	3.9	0	1.4	0	0
29-Sep	0	0	0.4	0	0	0	0	0	0.1	0	0	2.8	0	1.2	0	0
30-Sep	0	0	0.4	0	0	0	0	0	0.1	0	0	2	0	1	0	0

Daily Streamflow (cfs), Rincon Creek Gaging Station, Tucson Az.

	1968	1969	1970	1971	1972	1973	1989	1990	1991	1992	1993	1994	1995	1996
1-Sep	0	0	7.8	0.71	0	0	27	0	0.5	72	0	0	0.15	0
2-Sep	0	0	15	0	0	0	20	0	0.01	28	0	0	0.03	0
3-Sep	0	0	6.3	0	0	0	8.9	0	0.01	12	92	0	0	0
4-Sep	1.6	276	3.1	0	0	0	4	0	0	5.8	20	0	13	0
5-Sep	0	134	1.9	0	0	0	3	0	0	3.1	4.3	0	9.6	0
6-Sep	16	67	1.2	0	0	0	2	0	0	1.8	1.5	0	1.3	0
7-Sep	0.05	35	0.85	0	0	0	1.3	0	0	0.97	0.52	0	0.09	0
8-Sep	0	21	6	0	0	0	0.94	0	0	0.58	0.19	0	0	0
9-Sep	0	18	7	0	0	0	0.87	0	0	0.18	0.11	0	0	0
10-Sep	0	8	1.6	0	0	0	0.67	0	0	0.03	0.08	0	2.2	0
11-Sep	0	4.4	1.1	0	0	0	0.55	0	0	0.02	31	0	5.6	0.08
12-Sep	0	3.2	0.73	0	0	0	0.42	0	0	0.02	29	0	1.5	0
13-Sep	0	2.6	0.69	0	0	0	0.3	0	0	0.02	5.4	0	0.3	0.35
14-Sep	0	1.9	0.62	0	0	0	0.24	0	0	0.01	2.3	0	0.05	0
15-Sep	0	1.4	0.53	0	0	0	0.24	0	0	0.01	1.1	0	0	0
16-Sep	0	0.72	0.5	0	0	0	0.2	0	0	0.01	0.47	0	0	0
17-Sep	0	0.37	124	0	0	0	0.18	0	0	0.01	0.22	0	0	0
18-Sep	0	0.2	34	0	0	0	0.17	0	0	0.01	0.15	0	0	0
19-Sep	0	0.1	24	0	0	0	0.15	0	0	0.01	0.11	0	0	0
20-Sep	0	0.1	9.4	0	0	0	0.13	0	0	0.01	0.09	0	0	0
21-Sep	0	0.05	3.3	0	0	0	0.12	0	0	0.01	0.08	0	0	0
22-Sep	0	0.05	1.4	0	0	0	0.13	0	0	0.01	0.07	0	0	0
23-Sep	0	0.05	0.84	0	0	0	0.12	0	0	0.01	0.04	0	0	0
24-Sep	0	0.05	0.61	0	0	0	0.1	0	0	0.01	0.02	0	0	0
25-Sep	0	0.05	0.44	0	0	0	0.11	0	0	0.01	0	0	0.27	0
26-Sep	0	0.04	0.29	0	0	0	0.09	0	0	0	0	0	0.01	0
27-Sep	0	0.04	0.21	0	0	0	0.07	0	0	0	0	0	0	0
28-Sep	0	0.04	0.16	0	0	0	0.06	0	0	0	0	25	0	0
29-Sep	0	0.04	15	0	0	0	0.07	0	0	0	0	0.1	0	0
30-Sep	0	0.03	30	0	0	0	0.15	0	0	0	0	0	0	0

Appendix D

Metadata

Metadata for Digital Orthophoto Quarter Quads

Greyscale DOQQ Metadata

Quarter Quad	URL
Tanque Verde Peak, (nw)	http://aria.arizona.edu/servlet/MetadataServlet?ID=368
Tanque Verde Peak, (ne)	http://aria.arizona.edu/servlet/MetadataServlet?ID=369
Tanque Verde Peak, (sw)	http://aria.arizona.edu/servlet/MetadataServlet?ID=371
Tanque Verde Peak, (se)	http://aria.arizona.edu/servlet/MetadataServlet?ID=370
Mica Mountain, (nw)	http://aria.arizona.edu/servlet/MetadataServlet?ID=352
Mica Mountain, (ne)	http://aria.arizona.edu/servlet/MetadataServlet?ID=353
Mica Mountain, (sw)	http://aria.arizona.edu/servlet/MetadataServlet?ID=355
Mica Mountain, (se)	http://aria.arizona.edu/servlet/MetadataServlet?ID=354

Metadata for GPS Points - Arc/Info Coverage

Report Date: 01-Jan-2000

Metadata Data Set Name: gpspts

1 Identification Information
1.1 Citation Information:
- 8.1 Originator: Felicia M. Sirchia
- 8.2 Publication Date: 20000101
- 8.4 Title: GPS points of releve sample plots in Saguaro National Park
- 8.6 Data Presentation Form: Digital (Arc/Info Format)
- 8.8.1 Publication Place: Tucson, Arizona
- 8.8.2 Publisher: University of Arizona

1.2 Description
- 1.2.1 Abstract:
  Points were generated from a Trimble GeoExplorerII and are associated with releve sample plots. The releve's were conducted to collect data for riparian vegetation classification purposes.
- 1.2.2 Purpose:
  To provide a digital and georeferenced record of sample points within the park.

1.3 Time Period Of Content
- 9.1 Single Date/Time:
- 9.1.1 Calendar Date: 1999
- 1.3.1 Currentness Reference:
  Year data was collected.

1.4 Status
- 1.4.1 Progress: Completed
- 1.4.2 Maintenance and Update Frequency: Not Applicable

1.5 Geographic Extent
- 1.5.1 Description of Geographic Extent:
  Saguaro National Park East Rincon Mountain District

1.6 Keywords
- 1.6.1.1 Theme Keyword Thesaurus: None
  - 1.6.1.2 Theme Keyword: Point
  - 1.6.1.2 Theme Keyword: Releve Points
- 1.6.2.1 Place Keyword Thesaurus: None
  - 1.6.2.2 Place Keyword: Arizona
  - 1.6.2.2 Place Keyword: Saguaro National Park
  - 1.6.2.2 Place Keyword: Tucson

1.8 Access Constraints:
  None

1.9 Use Constraints:
  None

1.10 Point of Contact

10.2 Contact Organization Primary	
10.1.2 Contact Organization:	University of Arizona
10.1.1 Contact Person:	Dr. Phil Guertin
10.3 Contact Position:	Associate Professor
10.4 Contact Address	
10.4.1 Address Type	Mailing and Physical Address
10.4.2 Address:	325 Biosciences East
10.4.3 City:	Tucson
10.4.4 State or Province:	Arizona
10.4.5 Postal Code:	85721
10.4.6 Country:	USA
10.5 Contact Voice Telephone:	520-621-3045
10.7 Contact Facsimile Telephone:	520-621-8801
10.8 Contact Electronic Mail Address:	phil@nexus.srnr.arizona.edu
10.9 Hours of Service:	8:00am to 5:00pm Monday thru Friday

1.14 Native Data Set Environment: UNIX-ARC/INFO

2 Data Quality Information

2.1 Attribute Accuracy
2.1.1 Attribute Accuracy Report:

2.2 Logical Consistency Report:
Coverage was built for point topology
2.3 Completeness Report:

2.4 Positional Accuracy
2.4.1 Horizontal Positional Accuracy
2.4.1.1 Horizontal Positional Accuracy Report:

2.5 Lineage
2.5.1 Methodology
2.5.1.1 Methodology Type:
2.5.1.4 Methodology Citation:

8.1 Originator:	
8.2 Publication Date	
8.4 Title:	Aerial Video of Riparian Corridors in Saguaro National Park
8.6 Data Presentation Form:	High 8mm Video
8.8.1 Publication Place:	Tucson, Arizona
8.8.2 Publisher:	
8.9 Other Citation Details:	

3 Spatial Data Organization Information

4 Spatial Reference Information
4.1 Horizontal Coordinate System Definition
4.1.2 Planar
4.1.2.2.1 Grid Coordinate System Name: Universal Transverse Mercator (UTM)
4.1.4.1 Horizontal Datum Name: North American Datum of 1927
4.1.4.2 Ellipsoid Name: Clarke 1866

5 Entity and Attribute Information
5.1 Detailed Description
5.1.2 Attribute
5.1.2.1 Attribute Label: Comment
5.1.2.2 Attribute Definition:
Comment item used to document unique features found at the site (i.e., pools, wildlife).
5.1.2 Attribute
5.1.2.1 Attribute Label: GPS_Date
5.1.2.2 Attribute Definition:
Date site was sampled.
5.1.2 Attribute
5.1.2.1 Attribute Label: GPS_Time
5.1.2.2 Attribute Definition:
Time of day site was sampled, .
5.1.2 Attribute
5.1.2.1 Attribute Label: Datafile
5.1.2.2 Attribute Definition:
Name of rover file.
5.1.2 Attribute
5.1.2.1 Attribute Label: Rel_ID
5.1.2.2 Attribute Definition:
Primary key relating the point attribute table (PAT) to a data table that summarizes information collected at the site.
5.1.2 Attribute
5.1.2.1 Attribute Label: BLP_ID
5.1.2.2 Attribute Definition:
Key field relating to a data table describing vegetation classifications based on the Brown, Lowe, and Pase System.
5.1.2.3 Attribute Definition Source:
See ripmetadata.doc
6 Distribution Information
6.1 Distributor
10.2 Contact Organization Primary
10.1.2 Contact Organization: Saguaro National Park
10.1.1 Contact Person: Pam Anning
10.3 Contact Position: Biological Science Technician

10.4 Contact Address	
10.4.1 Address Type:	Mailing and Physical Address
10.4.2 Address:	2700 N. Kinney Rd
10.4.3 City:	Tucson
10.4.4 State or Province:	Arizona
10.4.5 Postal Code:	85743
10.4.6 Country:	USA
10.5 Contact Voice Telephone:	520-733-5174
10.7 Contact Facsimile Telephone:	520-733-5184
10.8 Contact Electronic Mail Address:	pam_anning@nps.gov
10.9 Hours of Service:	7:30am to 5:30pm Monday thru Thursday

7 Metadata Reference Information	
7.1 Metadata Date:	19991231
7.2 Metadata Review Date:	
7.4 Metadata Contact:	
10.2 Contact Organization Primary	
10.1.2 Contact Organization:	Saguaro National Park
10.1.1 Contact Person:	Pam Anning
10.3 Contact Position:	Biological Science Technician
10.4 Contact Address	
10.4.1 Address Type:	Mailing and Physical Address
10.4.2 Address:	2700 N. Kinney Rd
10.4.3 City:	Tucson
10.4.4 State or Province:	Arizona
10.4.5 Postal Code:	85743
10.4.6 Country:	USA
10.5 Contact Voice Telephone:	520-733-5174
10.7 Contact Facsimile Telephone:	520-733-5184
10.8 Contact Electronic Mail Address:	pam_anning@nps.gov
10.9 Hours of Service:	7:30am to 5:30pm Monday thru Thursday

Metadata for Riparian Vegetation - Arc/Info Coverage

Report Date: 01-Jan-2000

Metadata Data Set Name: Riparian

1 Identification Information
1.1 Citation Information:
- 8.1 Originator: Felicia M. Sirchia
- 8.2 Publication Date: 20000101
- 8.4 Title: Lower Elevation Riparian Vegetation of Saguaro National Park
- 8.6 Data Presentation Form: Digital (Arc/Info Format)
- 8.8.1 Publication Place: Tucson, Arizona
- 8.8.2 Publisher: University of Arizona

1.2 Description
- 1.2.1 Abstract:
  The riparian areas mapped consisted of major streams, Rincon Creek and Tanque Verde Wash, and the lower reaches (< 4000') tributary to the major streams.
- 1.2.2 Purpose:
  The purpose of this coverage is to provide a baseline inventory of the lower reaches (< 4000') of riparian vegetation communities in Saguaro National Park East.

1.3 Time Period Of Content
- 9.1 Single Date/Time:
- 9.1.1 Calendar Date: 1999
- 1.3.1 Currentness Reference:
  The year field work was conducted to produce the vegetation map.

1.4 Status
- 1.4.1 Progress: Completed
- 1.4.2 Maintenance and Update Frequency: As Needed

1.5 Geographic Extent
- 1.5.1 Description of Geographic Extent:
  Saguaro National Park East Rincon Mountain District

1.6 Keywords
- 1.6.1.1 Theme Keyword Thesaurus: None
  - 1.6.1.2 Theme Keyword: Vegetation
  - 1.6.1.2 Theme Keyword: Land cover
- 1.6.2.1 Place Keyword Thesaurus: None
  - 1.6.2.2 Place Keyword: Arizona
  - 1.6.2.2 Place Keyword: Saguaro National Park
  - 1.6.2.2 Place Keyword: Tucson

1.7 Taxonomy
- 1.7.1 Taxonomic Keywords: Plants

1.7 Taxonomy
- 1.7.2 Taxonomic Coverage

1.7.2.1 Specific Taxonomic Information
1.7.2.1.1 Kingdom: Plant
1.7.2.1.2 Division-Phylum: Interagency Taxonomic Information System (ITIS)

1.8 Access Constraints:
None
1.9 Use Constraints:
None
1.10 Point of Contact
10.2 Contact Organization Primary
10.1.2 Contact Organization: University of Arizona
10.1.1 Contact Person: Dr. Phil Guertin
10.3 Contact Position: Associate Professor
10.4 Contact Address
10.4.1 Address Type Mailing and Physical Address
10.4.2 Address: 325 Biosciences East
10.4.3 City: Tucson
10.4.4 State or Province: Arizona
10.4.5 Postal Code: 85721
10.4.6 Country: USA
10.5 Contact Voice Telephone: 520-621-3045
10.7 Contact Facsimile Telephone: 520-621-8801
10.8 Contact Electronic Mail Address: phil@nexus.srnr.arizona.edu
10.9 Hours of Service: 8:00am to 5:00pm Monday thru Friday

1.14 Native Data Set Environment: UNIX-ARC/INFO

2 Data Quality Information

2.1 Attribute Accuracy
2.1.1 Attribute Accuracy Report:
Vegetation types have been attributed and checked.
2.2 Logical Consistency Report:
All polygons have been checked for topology.
2.3 Completeness Report:
Each polygon has been attributed with a BLP Classification.
2.4 Positional Accuracy
2.4.1 Horizontal Positional Accuracy
2.4.1.1 Horizontal Positional Accuracy Report:

2.5 Lineage
2.5.1 Methodology
2.5.1.1 Methodology Type: Field work, on screen digitizing
2.5.1.4 Methodology Citation:
8.1 Originator: Felicia M. Sirchia

8.2 Publication Date 20000101
8.4 Title: Lower Elevation Riparian Vegetation of Saguaro National Park
8.6 Data Presentation Form: Map/Digital
8.8.1 Publication Place: Tucson, Arizona
8.8.2 Publisher: University of Arizona
8.9 Other Citation Details:
2.5.2 Source Information
2.5.2.1 Source Citation:
8.1 Originator: Pamela J. Anning
8.2 Publication Date: 19970901
8.4 Title:
Historic Vegetation of Saguaro National Park
8.6 Data Presentation Form: Map
8.8.1 Publication Place:
Tucson, Arizona
8.8.2 Publisher:
Saguaro National Park
8.9 Other Citation Details:
2.5.2.3 Type Of Source Media: Paper
2.5.2.4 Source Time Period Of Content:
9.1 Single Date/Time
9.1.1 Calendar Date: 1937
2.5.2.4.1 Source Currentness Reference: Ground Condition

3 Spatial Data Organization Information

4 Spatial Reference Information
4.1 Horizontal Coordinate System Definition
4.1.2 Planar
4.1.2.2.1 Grid Coordinate System Name: Universal Transverse Mercator(UTM)
4.1.4.1 Horizontal Datum Name: North American Datum of 1927
4.1.4.2 Ellipsoid Name: Clarke 1866

5 Entity and Attribute Information
5.1 Detailed Description
5.1.2 Attribute
5.1.2.1 Attribute Label: BLP_ID
5.1.2.2 Attribute Definition:
Key field relating to a data table describing vegetation classifications based on the Brown, Lowe, and Pase System.
5.1.2.3 Attribute Definition Source:
The vegetation classification was devised by Brown, Lowe, and Pase as described in Biotic Communities Southwestern United States and Northwestern Mexico, 1994. University of Utah Press, Brown, D.E. (ed).
5.1.2.4.1 Enumerated Domain

5.1.2.4.1.1 Enumerated Domain Value: 1
5.1.2.4.1.2 Enumerated Domain Value Definition: channel
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Stream channel
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 2
5.1.2.4.1.2 Enumerated Domain Value Definition: developed
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas disturbed by urban or agricultural development.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 3
5.1.2.4.1.2 Enumerated Domain Value Definition: Populus fremonti – Salix spp.
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by Populus fremonti, Salix spp. or both and characterized by warm-temperate climatic conditions.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 4
5.1.2.4.1.2 Enumerated Domain Value Definition: Populus fremonti
5.1.2.4.1.3 Enumerated Domain Value Definition Source: areas that are dominated by Populus fremonti and characterized by warm-temperate climatic conditions.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 5
5.1.2.4.1.2 Enumerated Domain Value Definition: Platanus wrightii-Fraxinus velutina-Populus fremonti-mixed deciduous
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas co-dominated by warm-temperate mixed deciduous trees.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 6
5.1.2.4.1.2 Enumerated Domain Value Definition: Fraxinus velutina
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by Fraxinus velutina and characterized by warm-temperate climatic conditions.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 7
5.1.2.4.1.2 Enumerated Domain Value Definition: Juglans major
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by Juglans major and characterized by warm-temperate climatic conditions.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 8
5.1.2.4.1.2 Enumerated Domain Value Definition: Mixed Narrowleaf
5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by mixed narrowleaf species characterized by warm-temperate climatic conditions and shrub cover exceeds tree cover.
5.1.2.4.1 Enumerated Domain
5.1.2.4.1.1 Enumerated Domain Value: 9
5.1.2.4.1.2 Enumerated Domain Value Definition: Cephalanthus occidentalis-Baccharis glutinosa-mixed scrub

5.1.2.4.1.3 Enumerated Domain Value Definition Source: areas that are dominated by Cephalanthus occidentalis or Baccharis spp. characterized by warm-temperate climatic conditions and shrub cover exceeds tree cover.

5.1.2.4.1 Enumerated Domain

5.1.2.4.1.1 Enumerated Domain Value: 10

5.1.2.4.1.2 Enumerated Domain Value Definition: Prosopis velutina

5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by Prosopis velutina and characterized by tropical-subtropical climatic conditions.

5.1.2.4.1 Enumerated Domain

5.1.2.4.1.1 Enumerated Domain Value: 11

5.1.2.4.1.2 Enumerated Domain Value Definition: Prosopis velutina-mixed short tree

5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by Prosopis velutina, Celtis reticulata, and Acacia spp. exhibiting shorter statures and characterized by tropical-subtropical climatic conditions

5.1.2.4.1 Enumerated Domain

5.1.2.4.1.1 Enumerated Domain Value: 12

5.1.2.4.1.2 Enumerated Domain Value Definition: Populus fremonti/Salix Spp.

5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by Populus fremonti, Salix spp. or both and characterized by tropical-subtropical climatic conditions.

5.1.2.4.1 Enumerated Domain

5.1.2.4.1.1 Enumerated Domain Value 13

5.1.2.4.1.2 Enumerated Domain Value Definition Mixed Scrub

5.1.2.4.1.3 Enumerated Domain Value Definition Source: Areas that are dominated by mixed scrub species characterized by tropical-subtropical climatic conditions and shrub cover exceeds tree cover.

6 Distribution Information

6.1 Distributor

10.2 Contact Organization Primary

10.1.2 Contact Organization: Saguaro National Park

10.1.1 Contact Person: Pam Anning

10.3 Contact Position: Biological Science Technician

10.4 Contact Address

10.4.1 Address Type: Mailing and Physical Address

10.4.2 Address: 2700 N. Kinney Rd

10.4.3 City: Tucson

10.4.4 State or Province: Arizona

10.4.5 Postal Code: 85743

10.4.6 Country: USA

10.5 Contact Voice Telephone: 520-733-5174

10.7 Contact Facsimile Telephone: 520-733-5184

10.8 Contact Electronic Mail Address: pam_anning@nps.gov

10.9 Hours of Service: 7:30am to 5:30pm Monday thru Thursday

7 Metadata Reference Information	
7.1 Metadata Date:	19991231
7.2 Metadata Review Date:	
7.4 Metadata Contact:	
10.2 Contact Organization Primary	
10.1.2 Contact Organization:	Saguaro National Park
10.1.1 Contact Person:	Pam Anning
10.3 Contact Position:	Biological Science Technician
10.4 Contact Address	
10.4.1 Address Type:	Mailing and Physical Address
10.4.2 Address:	2700 N. Kinney Rd
10.4.3 City:	Tucson
10.4.4 State or Province:	Arizona
10.4.5 Postal Code:	85743
10.4.6 Country:	USA
10.5 Contact Voice Telephone:	520-733-5174
10.7 Contact Facsimile Telephone:	520-733-5184
10.8 Contact Electronic Mail Address:	pam_anning@nps.gov
10.9 Hours of Service:	7:30am to 5:30pm Monday thru Thursday

Metadata for Aerial Photo Points - Arc/Info Coverage

Report Date: 01-Jan-2000

Metadata Data Set Name: Ripphpts

1 Identification Information
1.1 Citation Information:
- 8.1 Originator: Felicia M. Sirchia
- 8.2 Publication Date: 20000101
- 8.4 Title: Aerial photo points of riparian corridors in Saguaro National Park
- 8.6 Data Presentation Form: Digital (Arc/Info Format)
- 8.8.1 Publication Place: Tucson, Arizona
- 8.8.2 Publisher: University of Arizona

1.2 Description
- 1.2.1 Abstract:
  Flight lines of aerial video taken at Saguaro National Park East. Points were generated from X,Y coordinates located in an ASCII text file obtained from…
- 1.2.2 Purpose:
  To provide flight lines of the aerial video coverage of riparian areas of Saguaro National Park. Also used to link video footage to georeferenced points.

1.3 Time Period Of Content
- 9.1 Single Date/Time: September, 1999
- 9.1.1 Calendar Date: 1999
- 1.3.1 Currentness Reference:
  The month and year of the flight.

1.4 Status
- 1.4.1 Progress: Completed
- 1.4.2 Maintenance and Update Frequency: Not Applicable

1.5 Geographic Extent
- 1.5.1 Description of Geographic Extent:
  Saguaro National Park East Rincon Mountain District

1.6 Keywords
- 1.6.1.1 Theme Keyword Thesaurus: None
  - 1.6.1.2 Theme Keyword: Aerial Video
  - 1.6.1.2 Theme Keyword: Riparian Areas
- 1.6.2.1 Place Keyword Thesaurus: None
  - 1.6.2.2 Place Keyword: Arizona
  - 1.6.2.2 Place Keyword: Saguaro National Park
  - 1.6.2.2 Place Keyword: Tucson

1.8 Access Constraints:
None

1.9 Use Constraints:
None

1.10 Point of Contact

10.2 Contact Organization Primary	
10.1.2 Contact Organization:	University of Arizona
10.1.1 Contact Person:	Dr. Phil Guertin
10.3 Contact Position:	Associate Professor
10.4 Contact Address	
10.4.1 Address Type	Mailing and Physical Address
10.4.2 Address:	325 Biosciences East
10.4.3 City:	Tucson
10.4.4 State or Province:	Arizona
10.4.5 Postal Code:	85721
10.4.6 Country:	USA
10.5 Contact Voice Telephone:	520-621-3045
10.7 Contact Facsimile Telephone:	520-621-8801
10.8 Contact Electronic Mail Address:	phil@nexus.srnr.arizona.edu
10.9 Hours of Service:	8:00am to 5:00pm Monday thru Friday

1.14 Native Data Set Environment: UNIX-ARC/INFO

2 Data Quality Information

2.1 Attribute Accuracy
2.1.1 Attribute Accuracy Report:
Checked against text file for accuracy
2.2 Logical Consistency Report:
Coverage built for point topology
2.3 Completeness Report:
Checked against text file for completeness
2.4 Positional Accuracy
2.4.1 Horizontal Positional Accuracy
2.4.1.1 Horizontal Positional Accuracy Report:

2.5 Lineage
2.5.1 Methodology
2.5.1.1 Methodology Type:
2.5.1.4 Methodology Citation:

8.1 Originator:	
8.2 Publication Date	
8.4 Title:	Aerial Video of Riparian Corridors in Saguaro National Park
8.6 Data Presentation Form:	High 8mm Video
8.8.1 Publication Place:	Tucson, Arizona
8.8.2 Publisher:	
8.9 Other Citation Details:	

3 Spatial Data Organization Information

4 Spatial Reference Information
4.1 Horizontal Coordinate System Definition
4.1.2 Planar
4.1.2.2.1 Grid Coordinate System Name: Universal Transverse Mercator (UTM)
4.1.4.1 Horizontal Datum Name: North American Datum of 1927
4.1.4.2 Ellipsoid Name: Clarke 1866

5 Entity and Attribute Information
5.1 Detailed Description
5.1.2 Attribute
5.1.2.1 Attribute Label: Time1
5.1.2.2 Attribute Definition:
Item indicating the time of day associated with the point, corresponds to time stamp on video.
5.1.2 Attribute
5.1.2.1 Attribute Label: Elev_of_plane
5.1.2.2 Attribute Definition:
Altitude of plane.
6 Distribution Information
6.1 Distributor
10.2 Contact Organization Primary
10.1.2 Contact Organization: Saguaro National Park
10.1.1 Contact Person: Pam Anning
10.3 Contact Position: Biological Science Technician
10.4 Contact Address
10.4.1 Address Type: Mailing and Physical Address
10.4.2 Address: 2700 N. Kinney Rd
10.4.3 City: Tucson
10.4.4 State or Province: Arizona
10.4.5 Postal Code: 85743
10.4.6 Country: USA
10.5 Contact Voice Telephone: 520-733-5174
10.7 Contact Facsimile Telephone: 520-733-5184
10.8 Contact Electronic Mail Address: pam_anning@nps.gov
10.9 Hours of Service: 7:30am to 5:30pm Monday thru Thursday

7 Metadata Reference Information
7.1 Metadata Date: 19991231
7.2 Metadata Review Date:
7.4 Metadata Contact:
10.2 Contact Organization Primary
10.1.2 Contact Organization: Saguaro National Park
10.1.1 Contact Person: Pam Anning

10.3 Contact Position:	Biological Science Technician
10.4 Contact Address	
10.4.1 Address Type:	Mailing and Physical Address
10.4.2 Address:	2700 N. Kinney Rd
10.4.3 City:	Tucson
10.4.4 State or Province:	Arizona
10.4.5 Postal Code:	85743
10.4.6 Country:	USA
10.5 Contact Voice Telephone:	520-733-5174
10.7 Contact Facsimile Telephone:	520-733-5184
10.8 Contact Electronic Mail Address:	pam_anning@nps.gov
10.9 Hours of Service:	7:30am to 5:30pm Monday thru Thursday

Appendix E

Riparian Vegetation Types

in

Saguaro National Park East

Nomenclature of biotic communities of Nearctic and adjacent Neotropical North America with community (Series) and association examples for the North American Southwest that are known or expected to exist in Saguaro National Park East, Arizona, according to the system of biotic community classification developed by Brown, Lowe, and Pase (1994).

WARM TEMPARATE WETLANDS

Cottonwood-Willow Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampforest; Riparian Forest
CLIMATIC ZONE:	Warm Temperate Swamp & Riparian Forests
REGIONAL FORMATION:	Interior Southwestern Riparian Deciduous Forest & Woodland
SERIES:	Cottonwood-Willow
CLASSIFICATION CODE:	223.21

DESCRIPTION:
This series is a characteristic of stream features throughout the southwest's warm-temperate zones at elevation ranges of 1000-1750 meters. Typically found in alluvial sands, clays, and gravels on flood plains periodically subjected to spring floods. Characteristic species include *Populus fremonti* and *Salix gooddingii*. Understory species include *Baccharis* spp., *Acacia greggi, Celtis* spp., and *Vitis arizonica.*

ASSOCIATIONS:

223.211	*Populus fremonti – Salix* spp.
223.212	*Populus fremonti*

Mixed Broadleaf Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampforest; Riparian Forest
CLIMATIC ZONE:	Warm Temperate Swamp & Riparian Forests
REGIONAL FORMATION:	Interior Southwestern Riparian Deciduous Forest & Woodland
SERIES:	Mixed Broadleaf
CLASSIFICATION CODE:	223.22

DESCRIPTION:
This series is found at elevation ranges of 1000-1750 meters along rubble-bottomed perennial and near-perennial streams. Characteristic species *include Populus fremonti, Salix gooddingii, Fraxinus velutina, Platanus wrightii, Juglans major*, and *Celtis reticulata* with understory species of *Rhus* spp. and *Vitis arizonica.*

ASSOCIATIONS:

223.221	*Platanus wrightii-Fraxinus velutina-Populus fremonti*-mixed deciduous
223.223	*Fraxinus velutina*
223.225	*Juglans major*

Mixed Narrowleaf Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampscrub; Riparian Scrub
CLIMATIC ZONE:	Warm Temperate Swamp & Riparian Scrubs
REGIONAL FORMATION:	Interior Southwestern Swamps and Riparian Scrub
SERIES:	Mixed Narrowleaf
CLASSIFICATION CODE:	233.21

DESCRIPTION:
This series is found in elevation ranges of approximately 1000-1750 meters and may constitute a riparian understory or prelude for the riparian forests. Typical species found in this series include *Prosopis velutina, Acacia greggii, Parkinsonia* spp., *Chilopsis linearis, Celtis reiticulata, Celtis pallida, Baccharis salicifolia, and Cephalanthus occidentalis.* Also, based on previous mapping of the expansion area, it was found that *Gossypium thurberi, Jatropha cardiophylla, Muhlenbergia* spp., *Celtis pallida*, and *Lysiloma microphylla* are contributors to this vegetation type.

ASSOCIATION:

233.211	*Cephalanthus occidentalis-Baccharis glutinosa*-mixed scrub

TROPICAL-SUBTROPICAL WETLANDS

Mesquite Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampforest; Riparian Forest
CLIMATIC ZONE:	Tropical-Subtropical Swamp, Riparian & Oasis Forests
REGIONAL FORMATION:	Sonoran Riparian Deciduous Forests & Woodlands
SERIES:	Mesquite
CLASSIFICATION CODE:	Not defined at this time

DESCRIPTION:
Typically found below 1000 meters, this vegetation type is often referred to as a mesquite bosque. Characterized by large, numerous mesquites over 6 meters typically located on alluvial sands and old floodplains.

ASSOCIATION: None defined

Mesquite Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampforest; Riparian Forest
CLIMATIC ZONE:	Tropical-Subtropical Swamp, Riparian & Oasis Forests
REGIONAL FORMATION:	Sonoran Riparian & Oasis Forests
SERIES:	Mesquite

CLASSIFICATION CODE: 224.52

DESCRIPTION:

This series is found in streams and springs below 1000 meters in elevation. Typical species include *Prosopis velutina, Celtis reticulata, Baccharis salicifolia, Baccharis sarothroides*, and *Acacia greggii*. With understories containing Ziziphus obtusifolia, Lycium spp,. and Atriplex spp. These plant associations are more mesic in nature with small statures.

ASSOCIATIONS:

224.521	*Prosopis velutina*
224.522	*Prosopis velutina*-mixed short tree

Cottonwood-Willow Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampforest; Riparian Forest
CLIMATIC ZONE:	Tropical-Subtropical Swamp, Riparian & Oasis Forests
REGIONAL FORMATION:	Sonoran Riparian & Oasis Forests
SERIES:	Cottonwood-Willow
CLASSIFICATION CODE:	224.53

DESCRIPTION:

This series is found in perennial and intermittent streams and springs below 1000 meters in elevation. Typical species include *Populus fremontii, Salix gooddingii, and Acacia greggii.* Understory species may include *Baccaris* spp. and *Vitis arizonica.*

ASSOCIATION:

224.531	*Populus fremonti/Salix goodingii*

Mixed Scrub Series

BIOGEOGRAPHIC REALM:	Nearctic
VEGETATION:	Nearctic Wetland Vegetation
FORMATION-TYPE:	Swampscrub; Riparian Scrub
CLIMATIC ZONE:	Tropical-Subtropical Swamp & Riparian Scrubs
REGIONAL FORMATION:	Sonoran Riparian Scrubland
SERIES:	Mixed Scrub
CLASSIFICATION CODE:	234.71

DESCRIPTION:

This series is found in and along drainages less than 1000 meters in elevation. Scrublands are of low to medium height (1.5-3.0 meters) and dense. Typical species include *Acacia greggii, Baccharis salicifolia, Celtis pallida, Chilopsis linearis, Hymenoclea monogyra*, and *Prosopis velutina* with *Baccharis salicifolia* found within the stream channel.

ASSOCIATION: Classified only to series level

NON-VEGETATION

CLASSIFICATION CODE: Channel

DESCRIPTION:
This code was given to those areas lacking vegetation and falling within the stream corridor.

CLASSIFICATION CODE: Developed

DESCRIPTION:
This code was used to describe areas that were contiguous with the riparian vegetation mapped but were clearly disturbed by urban or agricultural development.

Your order details

Our Order Ref: 01515847-001
Your Ref: 167357991
Despatched on: 17/6/2016

Your shipping address:

INTERLIBRARY LOAN
UNIVERSITY ARIZONA LIBRARIES
1510 E UNIVERSITY BLVD
TUCSON
US-AZ
85721-0055
US

Your item details

UIN:	BLL01016867682
Author:	American Institute of Aeronautics and Astro
Title:	AIAA guidance, navigation and control conference 2014 : held at the AIAA SciTech forum, National Harbor, Maryland, USA, 13-17 January 2014.
Publisher:	Reston : AIAA, [2014]
ISBN:	9781632669322
Edition:	
Year:	2014
Pages:	-
Author name(s):	Park, Sangyoung
Chapter title words:	Orbit design and control of technology validation mission for refractive space telescope in formation flying

Comments

INTERLIBRARY LOAN
UNIVERSITY ARIZONA LIBRARIES
1510 E UNIVERSITY BLVD
TUCSON
US-AZ
85721-0055
US

AIAA SciTech
13-17 January 2014, National Harbor, Maryland
AIAA Guidance, Navigation, and Control Conference

AIAA 2014-0451

CrossMark

Orbit Design and Control of Technology Validation Mission for Refractive Space Telescope in Formation Flying

Sang-Young Park[1]
Yonsei University, Seoul, 120-749, Republic of Korea

Philip C. Calhoun[2], Neerav Shah[3] and Trevor W. Williams[4]
NASA Goddard Space Flight Center, Greenbelt, MD, 20771

Many proposed formation flying missions seek to advance the state of the art in spacecraft science imaging by utilizing precision dual spacecraft formation flying to enable a "virtual" telescope (VT). Using precision alignment of two spacecraft very long focal lengths can be achieved by locating the optics on one spacecraft and the detector on the other. Furthermore, orders of magnitude improvement in science imaging over conventional single spacecraft instruments is possible with advances in precision formation flying. Precise astrometric alignment control is required for accurate inertial pointing of the VT. This work presents orbit design and control approaches for VT formation flying, with specific application to the recently proposed Virtual Telescope Demonstration Mission (VTDM) using cubesats. The characteristics of the mission orbit are derived from solutions to Hill's equations for the relevant mission orbit. A relative orbit control technique pertaining to the astrometric alignment problem is developed by utilizing the Constrained Model Predictive Control (CMPC) approach. This method enables design of formation flying control laws for a thruster assembly with limited magnitude. Precision formation flying is achieved by use of separate control laws for formation maintenance and precision astrometric alignment. The proposed control scheme compensates for inertial astrometric alignment errors as well as differences in orbital perturbations between the VTDM satellites. Numerical simulations are shown to validate the performance of the proposed relative orbit and alignment control laws for the VTDM. The results satisfy mission requirements and indicate the general applicability of the control algorithm to the VT formation flying architecture. Consequently, the proposed methods of orbit design and control can be applied to inertial astrometric alignment and formation keeping for the many proposed dual spacecraft precision formation flying missions.

I. Introduction

THERE are many space telescopes that utilize the principle of a reflective telescope, such as Hubble Space Telescope, Spitzer Space Telescope, Planck Observatory, and James Webb Space Telescope. These space telescopes obtain images by reflective light with a single or combination of mirrors. Telescopes using reflective optics have the advantage of minimal chromatic aberration and require optical manufacturing precision for only a single reflective surface of each element. On the other hand, refractive telescopes bend light through an objective

[1] Professor, Astrodynamics and Control Lab., Department of Astronomy, AIAA Senior Member, International Academy of Astronautics (IAA) Member.
[2] Senior Aerospace Engineer, Attitude Control System Engineering Branch, MS 591, 8800 Greenbelt Rd., Greenbelt, MD 20771, AIAA member.
[3] Aerospace Engineer, Attitude Control System Engineering Branch, MS 591, 8800 Greenbelt Rd., Greenbelt, MD 20771, AIAA Senior member.
[4] Senior Aerospace Engineer, Navigation and Mission Design Branch, MS 595, 8800 Greenbelt Rd., Greenbelt, MD 20771.

lens to converge at a focal point to make an image. This enables a much longer focal length telescope for higher resolution imaging, with particular use in high energy applications, such X-ray imaging. A longer focal length allows higher magnification of an image in a narrower field of view, which also minimizes chromatic aberration resulting in a sharper image. Telescopes using single spacecraft designs have strict mechanical alignment and stability requirements for large metering structures, making a longer focal length telescope a significant challenge. A potential solution uses two satellites instead, one with the refractive lens and the other with the detector. The separation between the two spacecraft can be used for an increased focal length telescope. The metering structure is replaced by precision formation flying using astrometric alignment control, thus enabling very long focal length telescopes. This architecture is known as a "virtual" telescope (VT).[5,17] Astrometric alignment refers to using dual-spacecraft precision formation flying to align the optics and detector on separated spacecraft along the line-of-sight from detector to a celestial target.

Many proposed missions use the VT astrometric alignment architecture. The Milli-Arc-Second Structure Imager (MASSIM) introduces a set of diffractive-refractive lenses on an optics satellite to focus X-rays onto detectors on a second satellite[1]. The proposed MASSIM requires two satellites in formation flying at a baseline separation of 1000 km in order to achieve X-ray imaging with milli-arc-second resolution. System requirements of two satellites in formation flying at 100 m baseline separation are also given for an application of X-ray solar flare imaging with 0.1 arcsec angular resolution[2]. Similarly to the MASSIM, the concept of the New Worlds Observer (NWO) requires two satellites in formation flying consisting of a telescope and an external starshade for measurement of extra-solar planets[3]. To enable a solar coronagraph, the PROBA-3 mission also provides space system consisting of two satellites separated by about 150 m[4]. In these applications, one satellite provides an external occulter to block the light from a primary source, providing a method to image exo-solar planets or solar corona, respectively using an optical instrument on the other satellite.

Precise satellite formation flying is necessary for required inertial alignment of an optics (or occulter) satellite with respect to a detector satellite for long baseline refracting space telescope [1,2], shadowing[3], or occulting missions[4], . The most challenging aspects of these missions are the relative navigation and control of satellites in formation flying. The inertial pointing requires very precise astrometric alignment control and estimation to make it possible for the "virtual" telescope to enable science imaging[5]. A study on covariance analysis of astrometric alignment estimation is performed for a space refracting telescope in formation flying[5]. Relative control for the astrometric inertial pointing also plays a key role in enabling the "virtual" telescope. Precise control and estimation requirements for relative spacecraft dynamics in a complex space environment provide a challenging system design. Initial flight applications will likely focus of shorter baselines, such as for heliophyiscs applications[2]. Thus, demonstration of a scalable formation flying architecture would facilitate extension of VT operation to larger baselines.

NASA Goddard Space Flight Center (GSFC) has proposed the Virtual Telescope Demonstration Mission (VTDM)[17] to develop and demonstrate new technologies required for a "virtual" telescope in a formation flying architecture that is scalable over a wide range of spacecraft separations. The VTDM offers a low-cost, small-scale route to demonstrate virtual telescope (e.g., a refractive space telescope) using two 6U cubesats, providing a necessary first step in the development of virtual telescope technology. The VTDM is composed of an Optics cubesat with a simple lens and a Detector cubesat with array of linear CCDs for demonstration of solar disk imaging[17]. A 3U version of this design has been proposed by a team at Yonsei University in consultation with the VTDM team at NASA GSFC. This VT design, as shown in Fig. 1, is called the Cubesat Astronomy by NASA and Yonsei using Virtual Telescope Alignment (CANYVAL). The VTDM tests five core technologies including, Guidance, Navigation and Control (GNC) system, astrometric alignment system, optics system, micro-propulsion system, and inter-satellite cross link system[17]. The GNC system for the VTDM requires control algorithm development for inertial astrometric alignment between two cubesats. Hence, the main objective of the current study is to investigate orbit design and control algorithm for this crucial technology. This algorithm is required to function with constrained control inputs since the orbit control will be accomplished using a thruster system with limited thrust magnitude. The Constrained Model Predictive Control (CMPC) approach is a well-known method to solve constrained quadratic regulation problems[6]. Hence, in the current study, the CMPC approach proposed in Bemporad et al.[7] is utilized to build an orbit controller for the CANYVAL detector satellite.

The current study has addressed multiple challenges, which are described herein. First, a proper orbit design to meet the mission objectives is introduced by using the Hill's dynamics and solutions. Second, a relative orbit control algorithm for the astrometric alignment phase is developed via the CMPC technique. Third, separate orbit maneuver strategy is proposed for regulating and formation keeping controls. Fourth, numerical simulations are performed to give insights into the developed algorithm and to evaluate the compatibility of the controller with severe orbital perturbations. This paper is organized as follows. Section 2 outlines representative relative orbit and attitude