# EVIDENCE

# ARIZONA
# NAVIGABLE STREAM
# ADJUDICATION COMMISSION

# EVIDENCE ON HAND PRIOR TO
# AUGUST 9, 2002
# FOR
# SANTA CRUZ RIVER

**SANTA CRUZ, PIMA & PINAL COUNTIES**

**VOLUME I OF I**

**006**

# Tab 1

# Exhibit Tab Replacement Page for Scanning

# TESTIMONY RELEVANT TO ALL WATERCOURSES

Presented by Arizona Center for Law in the Public Interest

to the

Arizona Navigable Stream Adjudication Commission

February 18, 1997



The Arizona Center for Law in the Public Interest offers the following testimony relevant to all findings and recommendations of the Commission on whether watercourses were navigable as of statehood. We made many of these points in preliminary testimony to the Commission on February 6, 1996.

As amended, the state statute governing Commission proceedings contains grossly illegal and inaccurate standards for the determination of navigability and non-navigability. Federal law, as developed by the federal courts, sets the test for determining title to the beds of watercourses. Arizona Center for Law v. Hassell, 837 P.2d 158, 164-65 (Ariz. App. 1991). That test is a liberal one: Whether the waterway was at statehood susceptible for use as a highway for transporting people or goods. Utah v. United States, 403 U.S. 9, 11 (1971). A river may be found navigable for title purposes despite occasional impediments such as sand or gravel bars, and despite the fact that it is only navigable a few months out of the year. State of Oregon v. Riverfront Protective Association, 672 F.2d 792, 795 (9th Cir. 1982). Actual use for boating, whether commercial or sporting, can demonstrate susceptibility as a highway for public passage. Utah v. United States, 403 U.S. at 11. Although state ownership turns on navigability at the time of statehood, evidence of current recreational use by small craft such as canoes is probative of navigability at statehood. North Dakota v. Andrus, 671 F.2d 271, 277-78 (8th Cir. 1982).

The remoteness of a river and lack of actual use at statehood does not defeat a finding of navigability: The question is whether the river was susceptible of transporting people or goods. United States v. Utah, 283 U.S. 64, 83 (1931). A river is deemed navigable if it could transport people or goods by any conveyance - not merely those in use at the time of statehood. State of Alaska v. Ahtna, Inc. 891 F.2d 1401, 1405 (9th Cir. 1989). In fact, present-day use of a river for guided recreational trips can provide conclusive evidence of navigability at statehood. Id. at 1405. Conversely, the fact that dams or diversions render a waterway non-navigable today does not matter, as long as it was passable in its original condition. See Frank, Forever Free, 16 U.C. Davis L. Rev. 579, 586 (1983).

Under the standards set forth above, the Arizona Court of Appeals concluded in 1991 that there was substantial evidence from which a factfinder might conclude that portions of rivers and streams other than the Colorado met the applicable standard of navigability at the time Arizona became a state. Hassell, 837 P.2d at 165. In reaching that conclusion, the Court had before it much of the same evidence that is now before this Commission. If anything, the Commission has before it even more substantial evidence of navigability than was before the Court, due to extensive studies conducted by the State Land Department since the Court's decision, and other evidence offered by various parties.

Unfortunately, the Legislature has tried to restrict this Commission's ability to find watercourses navigable by imposing a number of tests and presumptions that are flatly contrary to the federal test of navigability. These include the following:

1. A presumption that the entire watercourse was nonnavigable if any determination of nonnavigability in a public proceeding exists for the watercourse or a portion thereof. ARS §37-1128.B. The presumption can be overcome only by "clear and convincing evidence." There is absolutely no such presumption under the Federal test, and the presumption is absurd on its face. The mere fact that a "public proceeding" took place does not mean that the state's title claims were properly adjudicated (or even represented). Moreover, the state does not have the authority to relinquish its public trust ownership where the watercourse was in fact navigable at statehood. Illinois Central RR v. Illinois, 146 U.S. 387 (1892). Further, the mere fact that a small reach of a river was found nonnavigable hardly means that another reach (which could be hundreds of miles away) is presumptively non-navigable. It is also violative of the public trust doctrine for the state to place a higher burden of proof on itself to show navigability than applies in an order civil case.

2. A requirement that the Commission must find and recommend a watercourse was nonnavigable, if as of statehood it either was not used or susceptible of being used for both commercial trade and travel; or flowed only in direct response to precipitation and was dry at all other times. ARS 37-1128.C. There are absolutely no such restrictions on finding navigability under the federal test. As noted above, the federal test merely requires susceptibility for use as a highway for the transportation of people or goods. There is no requirement that such transportation be "commercial." Nor does the federal test in any way prohibit a finding of navigability where a watercourse flows "only in direct response to precipitation." The issue under the federal test is susceptibility for use for transportation -- if that susceptibility is due to rain events, then the test is met.

3. A presumption of non-navigability, defeatable only by clear and convincing evidence, if any of the following applied: i)

no sustained trade and travel occurred both upstream and downstream in the watercourse; ii) no profitable commercial enterprise was conducted; iii) vessels customarily used for commerce in 1912, such as keelboats, steamboats or powered barges, were not used on the watercourse; iv) diversions were made from the watercourse for various purposes that would have been inconsistent with or impediments to navigation; v) any boating or fishing was for recreational and not commercial purposes; vi) any flotation of logs or other material that occurred or was possible on the watercourse was not for commercial purposes; vii) there were structures constructed in or across the watercourse that would have inconsistent with or impediments to navigation; viii) transportation in proximity to the watercourse was customarily accomplished by methods other than by boat; ix) the United States did not regulate the watercourse under the rivers and harbors act of 1899. ARS §37-1128.D.

None of the above create any sort of presumption of non-navigability under the federal test, let alone the kind of presumption against navigability imposed by ARS 37-1128.D. As the above discussion of the federal test shows, the federal test does not require evidence of actual use for travel at all, let alone commercial use by large vessels of the period. Moreover, the federal test looks to the watercourse's **ordinary and natural** condition - not its condition when altered by human activity. The fact that floating of logs, boating, and fishing occurred is probative of **navigability** under the federal test: it does not become evidence of **non-navigability** merely because it was not commercial. Nor does the federal test create any presumption of non-navigability merely because a rivers was not regulated under the rivers and harbors act, or because travel near the watercourse was customarily done other than by boat. The test is susceptibility for use in travel, not whether the watercourse was regulated under other laws or whether boats were the preferred mode of travel.

4. A bar on consideration of: a) previously appropriated water as being within the ordinary and natural condition; b) use of ferries; c) fishing from the banks; d) use under flood conditions. ARS §37-1128.E. There is absolutely nothing in the federal test that allows these types of exclusions. Federal law looks to whether the watercourse was navigable in fact - it does not impose artificial restrictions on what can be considered in making that determination. For example, federal courts have explicitly relied on ferry travel as evidence of navigability. City of Centralia v. FERC, 851 F.2d 278 (9th Cir. 1988). They also routinely consider evidence of actual boating and fishing use, and do not bar such evidence based on the conditions or location of use.

5. A requirement to considers dams and diversions and other human uses as part of the ordinary and natural condition of the watercourse. Such a requirements is not a part of the federal test, and conflicts with the plain meaning of the word "natural."

For all the foregoing reasons, any determination of non-navigability by this Commission under the tests set out in ARS §37-1128 will have no legal validity or persuasive value in establishing ownership of streambeds. Accordingly, we urge the Commission to: a) suspend further proceedings to determine navigability or non-navigability of watercourse; b) refrain from making any findings or recommendations on navigability or non-navigability; and c) advise the legislature that there is no point in conducting further proceedings or making findings and recommendations unless and until the standards for determining navigability in ARS 37-1128 are changed to accurately reflect federal law.

DATED this 18th day of February, 1997.

David S. Baron
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in the Public Interest
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# Tab 2

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ARIZONA AUDUBON COUNCIL
Huachuca Audubon Society, Maricopa Audubon Society
Northern Arizona Audubon Society, Prescott Audubon Society
Tucson Audubon Society, Yuma Audubon Society
White Mountain Audubon Society

RECEIVED 1-27-98

ORIGINAL

96-004-009
San Pedro River

97-004-004
Santa Cruz River

December 26, 1997

Navigable Stream Adjudication Commission
1700 West Washington Street, Rm. 404
Phoenix, Arizona 85007

Dear Sirs,

The Arizona Audubon Council has researched the navigability conditions of the Santa Cruz and San Pedro Rivers. We have determined that both of these rivers were navigable during the period when Arizona joined the United States of America.

The Arizona Audubon Council requests to be on the mailing list to receive information and updates pertaining to this adjudication process.

Sincerely,

Al Anderson

Al Anderson
Secretary, AAC

3305 Eagle Ridge Drive, Sierra Vista, Arizona, 85635 (520) 378-2460 fax (520) 378-2107

# Tab 3

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RECEIVED 2-13-98

?7-004-005
?ta Cruz
?iver

Mark Larkin
H.C. 65 Box 363
Tumacacori, AZ
85640

ORIGINAL

9 Feb. 1998

Navigable Streams Adjudication
Commission
1700 W. Washington
Rm. 404
Phoenix, Arizona
85007

Dear Sirs,

I am writing to comment on the Navigable Streams Adjudication, particularly as it concerns the Santa Cruz River.

The issue of navigability certainly does not pertain to the Santa Cruz River now, nor did it in 1912. The studies done by Julie Stromberg from ASU, indicate that stream flow was intermittent from Tubac downstream. Springs existed at Canoa, San Xavier and Tucson, but did not contribute enough water for perennial flow through the entire reach. Downstream from Marana, the stream channel loses its integrity in a braided, ephemeral channel known as the Vekol Wash.

In the perennial reach upstream from Tubac, flows alternated between periods of high, fast water, and dry season flows of less than 3 cfs. Around the turn of the century, certain land developers made fraudulent claims of navigability in their attempts to sell land in the region. In the one thousand years of human settlement in the area, there is no evidence of river transportation. Goods and people moved by foot, pack animal, wagon and rail.

The Santa Cruz River is not, and never was, navigable.

Sincerely,
Mark Larkin
Mark Larkin

# Tab 4

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RECEIVED 2-19-1998

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ORIGINAL

97 - 004 - 006
Santa Cruz
River

BEFORE THE ARIZONA NAVIGABLE STREAM ADJUDICATION COMMISSION

IN THE MATTER OF NAVIGABILITY OF THE SANTA CRUZ RIVER: Gila River Confluence to the Headwaters

NO.__________________

MEMORANDUM CONCERNING NAVIGABILITY, ARIZONA PUBLIC TRUST INTEREST AND MOTION FOR DETERMINATION OF LACK OF JURISDICTION, AND IN THE ALTERNATIVE, NON-NAVIGABILITY

Rio Rico Properties Inc. (hereinafter "Rio Rico") submits the memorandum attached hereto and incorporated herein by reference for consideration by the Commission in determining the navigability of the Santa Cruz River from the Gila Confluence to the Headwaters, and moves that the Commission determine as a matter of law that it has no jurisdiction to adjudicate over that portion of the Santa Cruz River encompassed within the historical boundaries of Baca Float No. 3, or in the alternative, that the Santa Cruz River was not a navigable watercourse on February 14, 1912.

RESPECTFULLY SUBMITTED this 19th day of February, 1998.

MEYER, HENDRICKS, BIVENS & MOYES, P.A.

By ____________________________
Lee A. Storey
Randall Lindsey
3003 North Central Avenue
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Phoenix, Arizona 85012-2915

Attorneys for Rio Rico Properties Inc.

## MEMORANDUM

INTRODUCTION

The Arizona Stream Adjudication Commission, for two reasons, must rule that the State has no public trust interest in that portion of the Santa Cruz River passing through the Rio Rico Project, known formerly as Baca Float No. 3. First, the State has no public trust interest because that section of the River was not in the public domain at the time of the Treaty of Guadalupe Hidalgo ending the Mexican-American War. In 1821, the Mexican government had granted Baca Float No. 3 as private property to Luis María Cabeza de Baca. As private domain, the property rights to the River passing through the Float were protected under the treaties of Guadalupe Hidalgo and the Gadsden Purchase, and at the time of statehood could not have passed in trust from the United States Government to the State. Further, in 1860, the United States Congress, by act of law, acknowledged the validity of the Mexican grant. In 1898, the Supreme Court defined Congress' acknowledgment as an unconditional relinquishment of all United States Government rights to the premises.[1] The State, therefore, has no public interest right over that section of the Santa Cruz River encompassed in Baca Float No. 3, because by 1912 the federal government had already declared that portion of the riverbed as private property, thus preventing the U.S. from passing to the State any public trust right it might once have held.

Secondly, the State has no trust interest in the Santa Cruz River because the River was not navigable at the time of statehood. All reliable evidence points to the fact that the Upper Santa Cruz, throughout its history, was used almost exclusively for irrigation during periods of flow. No significant evidence exists to suggest otherwise. The history of the Santa Cruz is one of irrigation, not navigation.

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[1] *See* Shaw v. Kellogg 170 U.S. 312, 18 S.Ct. 632 (1898).

## I. THE COMMISSION HAS NO JURISDICTION TO ADJUDICATE THE NAVIGABILITY OF THAT PORTION OF THE SANTA CRUZ RIVER PASSING THROUGH THE RIO RICO PROJECT (FORMERLY KNOWN AS BACA FLOAT NO. 3) BECAUSE THE STATE'S PUBLIC TRUST INTEREST DOES NOT EXTEND TO LANDS WHOSE TITLE DESCENDS FROM MEXICAN AND SPANISH LAND GRANTS MADE PRIOR TO THE MEXICAN-AMERICAN WAR.

### A. The United States Recognizes the Validity of Private Property Rights Descendant From Mexican and Spanish Land Grants Pre-Dating the Treaties of Guadalupe Hidalgo and the Gadsden Purchase.

In 1848, the United States and Mexico formally ended the Mexican-American War by signing the Treaty of Guadalupe Hidalgo. Under the terms of the Treaty, Mexico ceded to the United States large portions of what is presently the American Southwest. In accepting title to the ceded territory, the United States pledged to recognize and respect the property rights of Mexican landowners whose property fell within the transferred territory. Article VIII of the Treaty provides:

> "... property of every kind, now belonging to Mexicans ... shall be inviolably respected ... [and the] present owners ... shall enjoy with respect to it, guarantees equally ample as if the same belonged to citizens of the United States."

Five years later, in the treaty formalizing the Gadsden Purchase, a land transaction in which Mexico sold to the United States a large tract of territory, much of which has become present-day Southern Arizona, the United States Government again pledged its recognition and respect for the property rights of those Mexicans with existing claims in the transferred territories. Article V of the Gadsden Treaty states:

> "All of the provisions of the eighth [article] ... of the treaty of Guadalupe Hidalgo, shall apply to the territory ceded ... in ... the present treaty, and to all the rights of persons and property ... within the same, as fully and as effectually as if the [eighth article] were herein again recited and set forth."

By pledging its protection of Mexican property rights as they existed at the time of acquisition, the United States obligated itself to define and respect those rights as recognized under the Mexican system. That is, the United States obligated itself to the Mexican legal definition of the pre-existing rights.[2]

In the treaties of Guadalupe Hidalgo and the Gadsden Purchase, the United States pledged to inviolably honor the property rights of Mexicans in the ceded territories. In subsequent decisions interpreting the treaty language, the Supreme Court has concluded that the promised protection implies the recognition of Mexican property rights as they existed at the time of annexation. That is, the successors in title to lands originally belonging to Mexican landowners enjoy the full rights and benefits which their predecessors were granted under Mexican law.

B. State Public Trust Interests Do Not Run to Property Rights Descendant from Mexican and Spanish Land Grants Pre-Dating the Treaties of Guadalupe Hidalgo and the Gadsden Purchase.

In addition to recognizing the validity of rights established by Mexican grants pre-dating the treaties of Guadalupe Hidalgo and the Gadsden Purchase, the Supreme Court has more specifically stated that the public trust interest of States where such land grants exist does not encompass those waters within the boundaries of valid prior Mexican land grants. In its decision in Shively v. Bowlby, the Court recognized that absolute property and dominion over the soils under tide waters and navigable rivers was normally held in trust by the United States for the future States.[3] It concluded, however, that this trust doctrine did not apply to private lands which had previously been granted by Mexico.[4] The Court stated that when the United States acquired the territory from Mexico, it was bound by the principles of international law to protect all rights of property transferred previously under

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[2] *See e.g.* Knight v. United Land Assn., 142 U.S. 161, 12 S.Ct. 258 (1891).

[3] *See* 152 U.S. 1, 14 S.Ct. 548 (1894).

[4] *Ibid.*

lawful grants from the Mexican government.[5] It then cited approvingly to its own decision in City and County of San Francisco v. Le Roy, in which, by adhering to the original Mexican pueblo boundary, it affirmed title to tidelands below the high water mark as validly vested in the Mexican grantee.[6]

In Le Roy, the Court adhered to the boundaries of the original Mexican pueblo grant as defined in the patent issued by the California Land Commission. In United States v. Coronado Beach Co., the Court did the same.[7] It stated that, although California acquired title to submerged tidelands from the United States when it became a State in 1850, it did so subject to prior Mexican grants.[8] The Court then went on to conclude that the language of the patent was clear as to the extent of the grant and that the grant did indeed include submerged tidelands, lands normally reserved in trust for the States.

While title to the Baca grant was never patented, subsequent case law has acknowledged its validity as equal to any deriving from a patent. In Shaw v. Kellogg, the Court commented upon this lack of formality stating, "there is no magic in the word 'patent,' or in the instrument which the word defines," and that title to the Baca lands was "complete without one."[9] In addition to dismissing the need for a formal patent, the Court defined the nature of the title confirmed by Congress describing it as "full, absolute, and

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[5] *Ibid.*

[6] *Ibid; see also* City and County of San Francisco v. Le Roy, 138 U.S. 656, 11 S.Ct. 364 (1891).

[7] *See* 255 U.S. 472, 41 S.Ct. 378 (1921).

[8] *Ibid.*

[9] *See* 170 U.S. 312, 18 S.Ct. 632 (1898).

unconditional," encompassing a "relinquishment . . . of all rights of the United States to the premises."[10]

Most recently in its Summa Corp. v. California ex rel. Lands Comm'n, decision, the Supreme Court again confirmed the priority of Mexican land grants over the public trust interests of a State.[11] In Summa Corp., the State of California and City of Los Angeles alleged that under their public trust interest they were not required to exercise powers of eminent domain nor to pay compensation in order to construct improvements in a lagoon which, by all accounts, was part of the tidelands normally reserved in trust by the State.[12] The Court ruled against the City and State concluding that California could not "at this late date assert its public trust easement over petitioner's property, when petitioner's predecessor-in-interest had their interest confirmed without any mention of such an easement. . . ." It stated further that the "interest claimed by California . . . must have been presented in the patent proceeding or be barred."[13]

In adjudicating the priority of Mexican grant rights with respect to States' public trust interest, the Supreme Court has consistently protected the superiority of Mexican grants. Whether basing its reasoning upon the strict language of patent documents or the failure of States to make timely claims during the adjudicatory process, the Court has vigilantly guarded the private property rights of Mexican grantees against encroachment of the public domain.

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[10] *Ibid.*

[11] *See* 466 U.S. 198, 104 S.Ct. 1751 (1984).

[12] *Ibid.*

[13] *Ibid.*

C. The Rights Adherent to that Section of the Upper Santa Cruz Originally Encompassed in Baca Float No. 3 Derive from a Mexican Land Grant Pre-Dating the Treaties of Guadalupe Hidalgo and the Gadsden Purchase.

Between 1851 and 1891 the United States Government established various mechanisms for the adjudication of prior Mexican land claims in the newly acquired territories of the American Southwest.[14] In 1858, one of these, the Surveyor General, declared valid an 1821 Mexican land grant to Luis María Cabeza de Baca of Approximately 500,000 acres.[15] In 1860, by act of law, Congress acknowledged the validity of Baca's title to the grant.[16] Given, however, that the Baca grant conflicted with another grant also validated by the Surveyor General, Congress ruled that the heirs of Baca could, in lieu of the original grant land, select "an equal quantity of vacant land, not mineral, in the territory of New Mexico,[17] to be located by them in square bodies, not exceeding five in number."[18] On June 17, 1863, John Watts, acting as attorney for the Baca heirs, located the third of these square bodies, or "floats," on the Santa Cruz River in what was then the Arizona Territory, and which now encompasses that portion of the Upper Santa Cruz north of present day Nogales, Arizona passing through and owned by Rio Rico Properties Inc.[19]

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[14] In 1851, Congress established the Board of Land Commissioners, in 1854, the office of the Surveyor General, and in 1891, the Court of Private Land Claims.

[15] *See* H.R. EXEC. DOC. NO. 36-14, at 3.

[16] *See* Law of June 21, 1860, 12 Stat. 71, Chap. 167.

[17] At the time of the Act, the New Mexico Territory included what would later become the Arizona Territory.

[18] *See* Law of June 21, 1860.

[19] *See* Wise v. Watts, 239 F. 207 (9th Cir. 1917).

In 1914, the U.S. Supreme Court confirmed the validity of the grant and location of the float.[20] In its opinion, the Court stated that the "Land Department has always treated the lands selected as segregated from the public domain," and "title having passed by the location of the grant and the approval of it, the title could not be subsequently devested (sic). . . ."[21] Though long established by Congress as descendant from a valid Mexican land grant pre-dating the treaties of Guadalupe Hidalgo and the Gadsden Purchase, in 1914, the title to Baca Float No. 3 was finally confirmed by the Supreme Court as fully vested in the Baca heirs and successors in interest.

In 1914, the Supreme Court confirmed that from the date of the original Mexican land grant in 1821, the property encompassed by the Baca Float No. 3 had ceased to be part of the public domain. At the time of Arizona statehood, therefore, the property had been privately held for nearly a hundred years. Title to the property held by Rio Rico Properties Inc. descends from the valid 1821 Mexican land grant and continues to be privately held.

D. Arizona's Public Interest in Navigable Waterways Does Not Extend to that Section of the Santa Cruz River Originally Encompassed in Baca Float No. 3 Because Title to the Property Derives from a Valid Mexican Land Grant Pre-Dating the Treaties of Guadalupe Hidalgo and the Gadsden Purchase.

Given that the property rights to Baca Float No. 3 are descendant from a Mexican land grant, and that such rights are given full effect under the treaties of Guadalupe Hidalgo and the Gadsden Purchase, and further given that the United States Supreme Court has determined that State public trust interests over tide waters and navigable rivers do not extend across the boundaries of prior Mexican land grants, the State of Arizona has no public trust interest in that portion of the Santa Cruz River encompassed within the historical boundaries of Baca Float No. 3, i.e., the Rio Rico Project. At the time of Arizona statehood, the property rights in the Santa Cruz River had been removed from the public

[20] *See* Lane v. Watts, 34 S.Ct. 965, 234 U.S. 525 (1914).

[21] *Ibid.*

domain and could not pass in trust under the equal footing doctrine from the United States to the State of Arizona.

While it could be argued that the State of Arizona might have retained its trust interest had a patent been issued more narrowly defining the Baca grant, or the State timely asserted its claim to the Surveyor General, neither in fact occurred. No patent was ever issued for the Baca grant, and when the Supreme Court, in Shaw v. Kellogg, finally had cause to define the extent of the grant, it did so describing the title as "full, absolute, and unconditional" leaving no right over the premises to the United States.[22] The United States, therefore, had no public interest in the Baca grant which it could pass to Arizona at statehood. The title to Baca Float No. 3, long before statehood, had ceased to be a part of the public domain.

In 1864, the Territorial Legislature of Arizona declared all bodies of water "capable of being used for the purposes of navigation or irrigation . . . to be public property . . . ."[23] Though apparently purporting to exercise some form of public trust, the Territorial Legislature's declaration did not take place within the proper adjudicatory mechanism of the Surveyor General and occurred subsequent to the Baca land grant (1821), to the grant's implicit recognition under the Gadsden Purchase Treaty (1853), and to Congress' explicit recognition of the grant in its Act of 1860. Again, by 1864, Baca Float No. 3 had long been in private hands. The Territorial Legislature's declaration could, therefore, have had no effect sans a declaration of eminent domain and payment of just compensation. No record exists of such declaration or payment.

Whether, as successor to the United States' interest, the State of Arizona enjoys no public interest right given the "full, absolute, and unconditional" relinquishment by the

[22] *See* 170 U.S. 312, 18 S.Ct. 632 (1898).

[23] *See* Art. 22, Howell Code, Ariz. Terr. Legis., 1864.

United States of all property claims, or because, like the State of California, it failed to assert its claim during the appropriate adjudicatory process, the State of Arizona lacks a public trust interest in Baca Float No. 3. The Supreme Court has clearly and consistently supported the absolute validity of prior Mexican land grants and their superiority to subsequent State claims of a public trust interest over the lands.

## II. THE STATE'S PUBLIC TRUST INTEREST DOES NOT EXTEND TO THE UPPER SANTA CRUZ RIVER BECAUSE THE RIVER WAS NOT NAVIGABLE AT THE TIME OF ARIZONA STATEHOOD.

### A. Consistent Evidence Supports the Conclusion that at the Time of Arizona Statehood the Santa Cruz River was a Significant Source of Irrigation and Not That it was Navigable.

The history of the Upper Santa Cruz is one of agriculture and irrigation, not of commerce and commercial navigation. Beginning with the earliest Native American inhabitants, the central activity in the Santa Cruz River Basin has been agricultural, and the agriculture has been driven by irrigation. From the basic flood plain techniques of the indigenous inhabitants, to the *acequias* of the Spanish and Mexican *colonistas*, to the modern pumps of the Anglo settlers, the Santa Cruz has been the central source of irrigation for the Santa Cruz Basin.

Since the period of earliest recording, the use of the Santa Cruz River for irrigation has been significant and well documented. With annual rainfall less than 15 inches, cultivation of most crops in the Santa Cruz River Basin requires extensive irrigation.[24] As early as the 1750's disputes over the limited supply required water sharing arrangements.[25] As near to statehood as 1903, a territorial governor reported that during the dry season the

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[24] *See* MICHAEL C. MEYER, AGRICULTURAL HISTORY OF THE BACA FLOAT NUMBER THREE (July 1985) (unpublished manuscript).

[25] *See* MEYER *citing* JOHN L. KESSELL, FRIARS, SOLDIERS AND REFORMERS: HISPANIC ARIZONA AND THE SONORA MISSION FRONTIER (1976).

supply of water for irrigation was quite inadequate.[26] In Pima and Santa Cruz Counties, the United States census reported an over four-fold increase in the number of acres under irrigation from 1889 to 1909, an increase which prompted the same territorial governor to advocate the pumping of ground water in order to expand agricultural production.[27] Agriculture has dominated the history of the Santa Cruz River Basin and irrigation, during periods of flow, complemented in the twentieth century by groundwater pumping, has been its source.

Compared to the extensive literature detailing the agricultural activities along the Santa Cruz, virtually no evidence exists to suggest the river was at any time navigable. Indeed the extensive use made of the river for irrigation and the great demands placed upon the documented limits of the surface water supply would suggest navigational use as highly unlikely. The waters of the Santa Cruz River have traditionally been a cornerstone of the Basin's economy, not, however, because of their navigability and transportation value, but because the River's intermittent supply and, more recently, significant groundwater pumping have supported the agriculture which dominates the region's history.

## CONCLUSION

The Arizona Stream Adjudication Commission has no jurisdiction to rule on the navigability of that portion of the Upper Santa Cruz River passing through former Baca Float No. 3. It has no jurisdiction because the State of Arizona's public trust interest does not extend to lands whose title descends from Mexican land grants made prior to the Mexican-American War and which were subsequently recognized as valid by the United

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[26] *See* C.A. Anderson, Potential Development of Water Resources of the Upper Santa Cruz River Basin in Santa Cruz County, Arizona, and in Sonora, Mexico (1955) Arizona State Land Department *citing* A.C. Brodie, Report of the Governor of Arizona to the Secretary of the Interior for the Year Ended June 30, 1903 (1903).

[27] *See* Anderson, *citing* A.O. Brodie, Report of the Governor of Arizona to the Secretary of the Interior for the Year Ended June 30, 1904 (1904).

States government. Even if the Commission were to exercise jurisdiction over that portion of the Santa Cruz River passing through the former Baca Float No. 3, the State of Arizona would have no public trust ownership interest in the stream bed of the River. It would have no ownership interest because no reliable evidence exists to suggest that the Santa Cruz was navigable at the time of Arizona statehood.

Therefore, the undersigned urge the Commission to rule that, 1) it has no jurisdiction over the water rights at the Rio Rico project because it is a valid Mexican land grant, and/or 2) that the Upper Santa Cruz River was not navigable at the time of Statehood for all the reasons set forth herein.

RESPECTFULLY SUBMITTED this 19th day of February, 1998.

MEYER, HENDRICKS, BIVENS & MOYES, P.A.

By ______________________
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# Tab 5

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ORIGINAL

96 - 004 - 011
San Pedro
River

97 - 004 - 007
Santa Cruz
River

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BEFORE THE
ARIZONA NAVIGABLE STREAMBED ADJUDICATION COMMISSION

IN THE MANNER OF THE NAVIGABILITY OF THE SAN PEDRO, AND SANTA CRUZ RIVERS ETAL.

Admin. Docket No. ____

COMMENTS AND EXHIBITS

The National Encyclopedia, Collier & Son, 1950, Page 370, Vol. 1.

Arizona. The lower reaches of the Colorado River, the western boundary of the state, are its only navigable waters.

Howell v. Johnson et al. 89 Fed. Rep. 556, (1898) Knowles, District Judge:

In the case of Basey v. Gallagher, 20 Wall. 670, The supreme court said in regard to this act: "The act of congress of 1866 recognized the right to water by prior appropriation for agricultural and manufacturing purposes as well as mining;" and also decided that if the right to appropriate water for any of the purposes named was recognized by either local customs, or by the legislation of any state or territory, or by the decisions of the court, it would be sufficient.

...A state, upon its admission into the Union, acquires, by virtue of its sovereign powers, the title to the beds of all navigable rivers, lakes, and tide waters within its boundaries,...This title gives it, to some extent, a control over the waters of such rivers and lakes, and the power to establish and determine what shall be riparian rights...

The idea that there can arise any international water right question in the case of the appropriation of the waters...cannot be maintained. The right to such waters...must always be a question pertaining to private persons.

Arizona Territorial Statutes 1863, Bill of Rights Art. 22; All streams, lakes, and ponds of water capable of being used for the purpose of navigation OR irrigation, ar hereby declared to be public property;...

Revised Statutes 1901 Sect.4174(civil Code): " All rivers, creeks, and streams of running water in the Territory of Arizona are hereby declared to public, and applicable to the purposes of irrigation and mining as hereafter provided."

TITLE XXI Eminent Domain Sect. 2445 ( 2 );...The right of eminent domain may be exercised in behalf of the following uses: 4. Wharves, docks, ferries, for public transportation, and for floating logs and lumber on streams not navigable.

Hill v. Lenormand 2 Ariz 354 (1888) Wright, C.J.-...The...plaintiffs... appropriated the waters of the San Pedro river,...As is very generally the case in the Pacific states and territories, the conditions are so changed that riparian rights do not attach. In the case at bar, riparian rights do not apply.

Boquillas v. Curtis 213 U.S. 339 (1908) Mr. Justice Holmes; This is a bill in equity brought by the appellant to prevent the defendants from withdrawing water from the San Pedro River...

It is not denied that what is called the common law doctrine of riparian water rights does not obtain in Arizona...

...In this Territory irrigation was practiced in the Santa Cruz Valley prior to the cession and it is well known the right of appropriation without regard to the riparian character of the lands was there in force probably from the time when the Spaniards first settled in the valley. Our statutes, as well as those of New Mexico, seem to have had their origin in the Mexican law as modified by custom.

I will present something at this time that may not seem relevent, except for GAT, and NAFTA, in which the Federal Government gave away water rights to Mexico it may not have held title to. Water Rights of the Western States, Bancroft-Whitney Company (1911) Vol.I, Page 221: The case (Boquillas V. Curtis) is an unequivocal decision in support of the Colorado doctrine so far as it affects the rights of riparian proprietors:...if riparian rights do not exist, the United States has no more right to waters on its lands than other land owners.

Blackstone, Modern american Law, Vol.VI, (1917) Page 47,49: Property is the right of a person to a thing and consists in the right of use or enjoyment of the thing and the disposal and transfer of the same right to others. Rights to the use of water acquired by appropriation come within this definition. Indeed, the term "right" itself, when used in this connection,imports a property right, and carries with it all the elements of property. 16 Colo. 61

The property right acquired by the appropriation is not in the corpus of the water, but in the incorporeal right of diversion and use, and the right itself is an incorporeal hereditament. 18 Colo. 298

The right is usufructuary: it is a right to divert and use water belonging to the stream and does not attach primarily to the body of the water in the stream. 3 Cal. 249

In December,1846, at the Gila, Lt. George Stoneman decided to perform a naval experiment on that shallow stream. Lashing together some cottonwood logs, he set sail with about twenty-five hundred pounds of food and supplies. He hadn't traveled far when the craft sank. Stoneman went down with his ship then walked ashore declaring the river unsuitable for navigation. In 1862 Stoneman was made Major General, and was governor of California 1883-87. Diamond in the Rough, Marshall Trimble,1988.

Collier's Encyclopedia, Vol. 11, 1986, Page 99: In the San Carlos Reservation the Gila was dammed (Coolidge Dam) to provide water for irrigation, and there are several other irrigation projects along its lower course. The dam was complete in 1928.

The rest of the streams, washes, lakes, rivers, etc., of this State, are to numerous for me to cite individual case law, at this time. I shall include all of them, and the before mentioned, now.

U.S. v. Rio Grande Irrigation Co. 174 U.S. 690,705,706, (1989): March 3, 1877, an Act, c. 107, was passed for the sale of desert lands, which contained in its first section this proviso, 19 Stat. 377:

...water of all lakes, rivers, and other sources of water supply upon the public lands and not navigable, shall remain and be held free for the appropriation and use of the public for irrigation, mining, and manufacturing purposes subject to existing rights.

...To infer therfrom that Congress intended to release its control over the navigable streams of this country and to grant in aid of mining industries and the reclamation of arid lands the right to appropriate the waters on the sources of navigable streams..., is to carry those statutes beyond what their fair import permits.

Fletcher v. Peck, 10 U.S. (6 Cranch.)87, (1810)...If an act be done under a law, a succeeding legislature cannot undo it. The past cannot be recalled by the most absolute power.

Supra. 4174; All rivers, etc, in the Territory of Arizona are...applicable to the purpose of irrigation and mining...

ARIZ. CONST. ART.XXII Sect. §1. No rights,...claims,... existing at the time of the admission of this state into the union, shall be affected by a change in the form of government, from territory to state, but all shall continue as if no change had taken place;...

ART. XVII §1. The common law doctrine of riparian water rights shall not obtain or be of any effect in the state.

THE RECORDS OF THE ARIZONA CONSTITUTIONAL CONVENTION OF 1910, November 29, afternoon; Mr Kingan: I would like to ask the gentleman from Maricopa a question. What is the reason for inserting that (ART XVII, §1) in the constitution? It is the law of this territory and has been for forty or fifty years, and it seems to me it is a matter purely segislative.

Mr. Baker: The answer is that it is purely fundamental. If a future legislature should undertake to establish a common law doctrine of water rights in this territory, they could do so. I want it fixed so that no legislature can ever do that thing.

There may be riparian rights,even if there are no navigable streams in a state, in order to claim a stream bed; but, there can be no claim to navigabilty if riparian rights do not exist. The state may only derive its rights and powers from those that exist in the people.

22FEB98

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Last paragraph my thoughts. RLD

# Tab 6

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97-004-008
Santa Cruz
River
001

September 19, 1997

**VIA HAND-DELIVERY**

Christina Waddell, Executive Director
State of Arizona Navigable Stream
Adjudication Commission
1700 W. Washington, Room 404
Phoenix, AZ 85007

Re: **Historic Evidence Regarding Statewide Water Course Non-Navigability**

Dear Christina:

On behalf of our clients, various insureds of Chicago Title Insurance Company, we are submitting the following evidence for use and consideration by the Arizona Navigable Stream Adjudication Commission ("ANSAC") in connection with its determinations/recommendations with respect to navigability on the various watercourses which the Commission is addressing pursuant to its authority under A.R.S. § 38-431.01, et. seq.:

1. Seven (7) copies of the relevant portions of a document entitled "Map of the Navigable Waterways of the United States." This map, dated December 14, 1914, was prepared by the Chief of Engineers, USA. We have enclosed copies of both the legend to the map and that portion relating to the State of Arizona. As is readily apparent from examination of the legend and the portion with regard to the State of Arizona, by failing to identify any watercourse in the Arizona with any of the colors indicated in the legend, the Chief of Engineers has indicated his determination that none of Arizona's

waterways were deemed to be "navigable" in accordance with the definition utilized by the Chief of Engineers for purposes of preparing the map.

2. Seven (7) copies of a map entitled "Official Map of the Territory of Arizona" compiled by Richard Gird, C.E. Commissioner, dated October 23, 1864. This map is of significance in that it depicts the alignment of various watercourses at or about the date on which the Territory of Arizona was created. In addition, the members of ANSAC should note that the map contains a specific reference to the "present head of navigation" and "supposed head of navigation" at two locations on the Colorado River in the northwest corner of the then-Territory. Those two notations with regard to navigability are in stark contrast to the absence of any other indications of navigability with respect to the balance of the waterways in the Territory.[1]

We appreciate your assistance in making copies of both of these maps available to the members of ANSAC.

Very truly yours,

MARISCAL, WEEKS, McINTYRE
& FRIEDLANDER, P.A.

By [signature]
James T. Braselton

JTB/tg
Enclosures
cc: Richard Marsh (w/out enc.)
Burt Levinson (w/out enc.)
F:\USERS\JTB\-L3864.WAD

[1] For ease of reference, we have highlighted the two notations with regard to navigation in yellow.

ORIGINAL

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Santa Cruz
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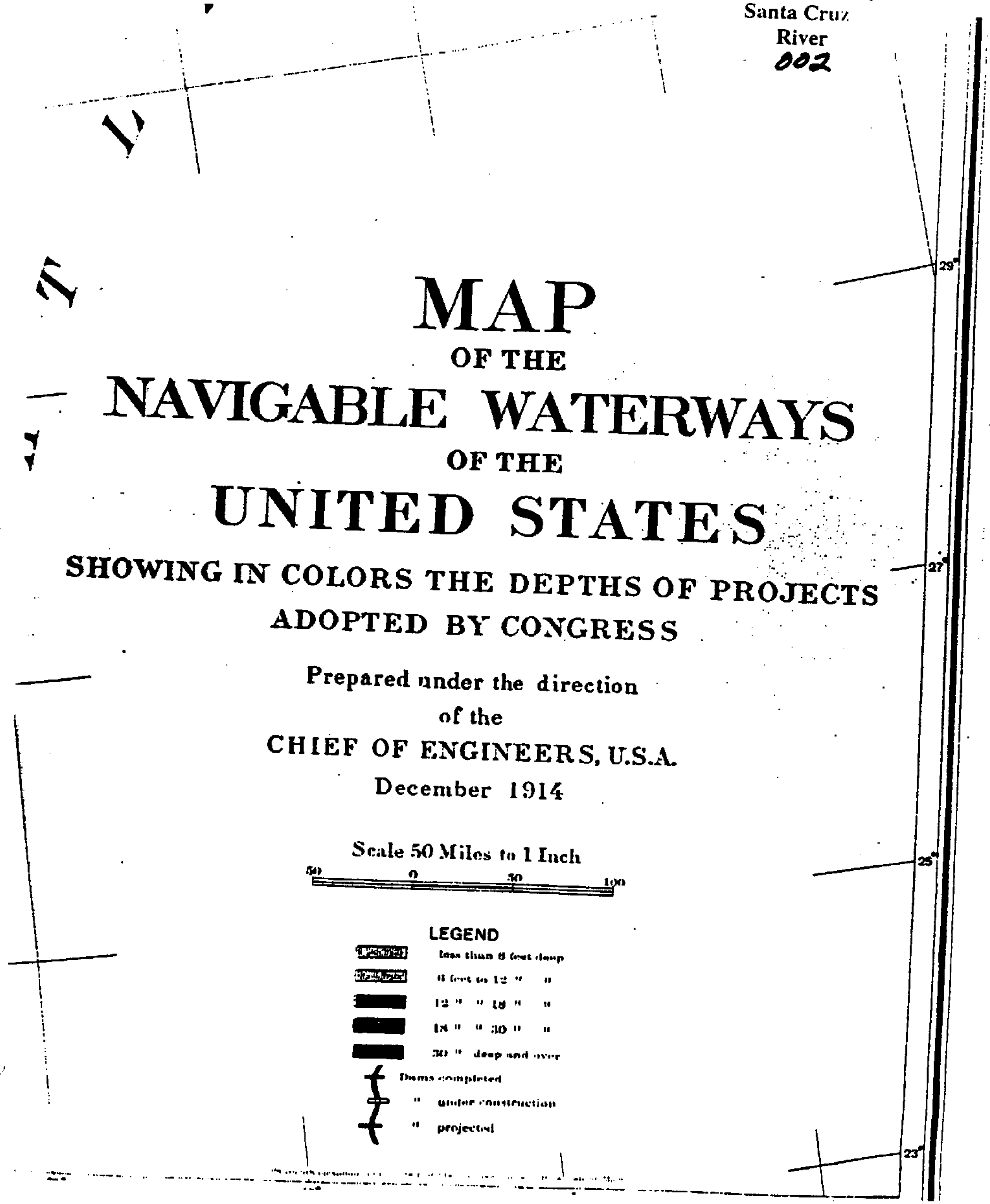
002



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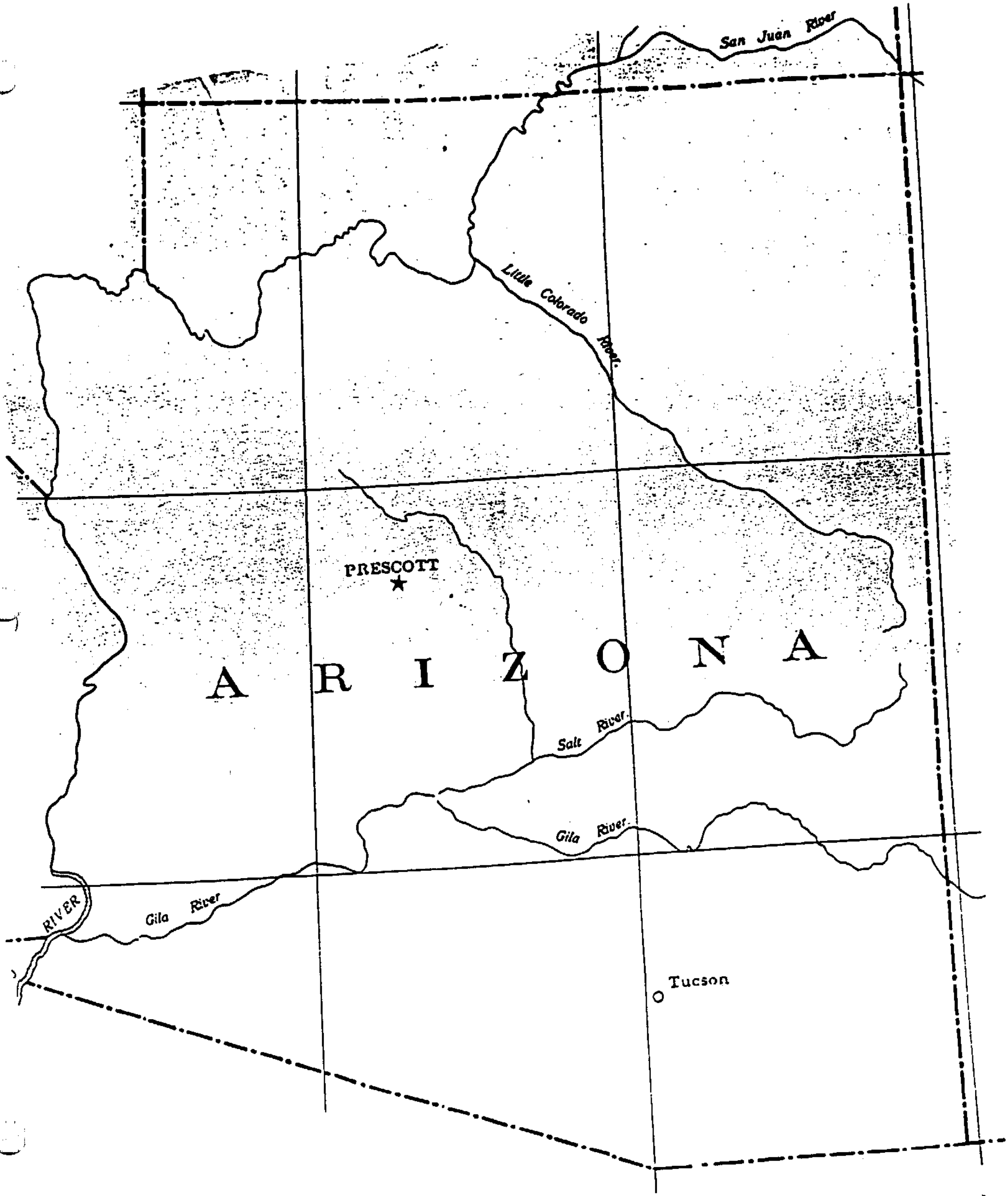

San Juan River
Little Colorado River.
PRESCOTT
ARIZONA
Salt River.
Gila River.
Gila River
RIVER
Tucson

# Tab 7

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# REVIEW OF THE HYDROGEOLOGY OF THE SANTA CRUZ BASIN IN THE VICINITY OF THE SANTA CRUZ-PIMA COUNTY LINE

By


Leonard C. Halpenny
and
Philip C. Halpenny



WATER DEVELOPMENT CORPORATION
*Consultants in Water Resources*

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With my compliments 12-10-97

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**ACKNOWLEDGEMENTS**

The authors are very grateful for permission to utilize the historical quotations in Chapter 3, which are from Tucson's Santa Cruz River: Chronicle of a Desert Stream, by J.L. Betancourt and R.M. Turner, which has been submitted to the University of Arizona Press for publication.

# REVIEW OF THE HYDROGEOLOGY OF THE SANTA CRUZ BASIN IN THE VICINITY OF THE SANTA CRUZ-PIMA COUNTY LINE

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Leonard C. Halpenny
and
Philip C. Halpenny

---

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

The hydrogeologic review discussed in this report has led to development of the following conclusions:

1. The aquifer systems of Pima and Santa Cruz County are connected hydrologically, but differ in fundamental hydrogeologic aspects, with the transition zone at and slightly north of the Pima-Santa Cruz County Line. The differences include differences in the aquifer materials, their distribution and extent in both width and depth, and their hydraulic properties.

2. The valley of the Santa Cruz River in Pima County has been severely overdeveloped. The valley of the Santa Cruz River in Santa Cruz County is in a "safe yield" category and has not been overdeveloped. It is not likely to be overdeveloped in the future. The reasons are geologic and hydraulic. The valley in Pima County is wide and deep, which constitutes a reservoir of groundwater that can be mined. The valley in Santa Cruz County is narrow and shallow, so that available reserves are relatively limited, but the aquifer is easily recharged.

3. For most of more than 200 years (1775 to 1988) the Santa Cruz River has flowed in Santa Cruz County but has been dry in Pima County as far north as San Xavier Mission, an indication that the aquifer system in Santa Cruz County remains full. Water levels in Santa Cruz County have remained constant on a long-term basis but have declined in Pima County.

4. It is considered likely that the Arizona State Legislature erred when the Santa Cruz County portion of the Upper Santa Cruz Basin was included within the Tucson Active Management Area, because the groundwater supply in Santa Cruz County was not overdeveloped in 1980 and cannot be more than locally and temporarily overdeveloped in the future. Accordingly, application in Santa Cruz County of the conservation measures mandated in the First and Second and subsequent Management Plans of the Tucson AMA cannot alleviate the overdevelopment of the groundwater supply in Pima County.

5. The final chapter (Chapter 8) of this report reviews the efforts in the late 1940s and early 1950s to control ground water mining in Arizona. At Hearings held in 1952 and 1954 on the possible need to control groundwater withdrawal in Santa Cruz County, the conclusion, for some of the same geologic and hydraulic reasons given in this report, was that control was not warranted and a "Critical Area" designation was not made (equivalent, in that time and context, to an AMA).

6. New or increased development of groundwater along the Santa Cruz River north of the Santa Cruz-Pima County Line is not considered likely to drain much water northward across the County Line, because of substantial differences in transmissivity of the aquifer system and of volume stored in it.

## <u>Recommendations</u>

1. It is recommended, because of the differences in the hydrogeology of the two counties, that the water conservation measures required in the TAMA First Management Plan (1980), the Second Management Plan (effective in 1990) and subsequent Management Plans, be not required in Santa Cruz County.

2. In the event that the groundwater development situation in Santa Cruz County changes between say, 1988 and 2025, it is recommended that the State Legislature review the situation and request the Department of Water Resources for advice.

## INTRODUCTION

### Reason For This Report

In February 1988 the Santa Cruz County Board of Supervisors requested the author to review the hydrogeology of the Santa Cruz Valley and offer an opinion as to the effects of pumping in the Tucson Basin upon the groundwater supply lying within the boundaries of Santa Cruz County.

The author has had extensive experience in the area dating from 1939, and had collected a large amount of data on the southern Pima County part of the valley as consultant to ASARCO, Incorporated. Water Development Corporation has recently been involved in more than a dozen hydrogeological investigations in the Santa Cruz County part of the valley, several in the northern area of the County. The invitation to review the hydrogeology of the area offered an opportunity to interpret the data which had been collected in the separate investigations and offer a regional interpretation.

The necessity for an interpretation of the geohydrology of the area had also become apparent in discussion of a separate and important issue in the hydrology of Arizona. In October of 1987 hearings were held in Maricopa County Superior Court on the hydrologic relations between underground water and surface water in the major alluvial valleys of Arizona, as a necessary preliminary to the adjudication of the surface waters of the Gila River Basin. The problem facing the Court was to rule upon the interface and distinction between groundwater, administered under the Groundwater Act of 1980, and surface water, administered under separate legislation and precedent. The author was invited by the Court to testify on this question, and as part of the testimony the issue became whether, prior to irrigation pumping, the large rivers of the Gila River Basin were through-flowing, perennial streams (and had therefore subsequently become intermittent because of irrigation pumping). The author testified that, along with stretches of other streams, the Santa Cruz River had in fact not flowed continuously from its source even in the pre-Anglo settlement period. This fact obviously complicated the discussion of the distinction between groundwater and surface water, but the Court was not prepared at that time to discuss the various geohydrologic reasons that caused the rivers of the Gila River Basin to be ephemeral, perennial and intermittent in various reaches of the same river.

As part of his testimony, the author talked about early-day surface flows of the Santa Cruz River from the International Boundary to San Xavier Mission near Tucson. His testimony was that, prior to heavy pumping of groundwater from the Tucson Basin (Santa Cruz-Pima County Line to Rillito Narrows north of Tucson), the early-day surface flow of the Santa Cruz River was generally as follows:

| Reach of the River | Type of Surface Flow |
|---|---|
| International Boundary to Pima-Santa Cruz County Line | Perennial (continuous flow) |
| Pima-Santa Cruz County Line to within one or two miles south of San Xavier Mission | Ephemeral (flowed only following storm runoff events) |
| One or two miles south of San Xavier Mission to Rillito Narrows | Intermittent (places where the stream flowed part of each year, separated by places where flow occurred only after rainstorms) |

The opinion was based on personal observations made by the author during the period 1939-1987 inclusive, supplemented by historical readings over the years that relate to early-day irrigation by diversion from the river in the vicinity of Tumacacori, existence of springs and a cienega south of Martinez Butte near San Xavier Mission, existence of Silver Lake Spring, and existence of a water-wheel flour mill near the base of A-Mountain in the late nineteenth century.

## Objective of This Report

The objective of this report is to review and discuss every aspect of the differences in the hydrologic regime of the Santa Cruz River basin from the International Boundary northward nearly to Tucson, with special attention to the situation in the vicinity of the Santa Cruz-Pima County Line. The topics reviewed include historic accounts, climate, possibility of climatic changes, physiology and geomorphology, geology and geologic structure, possible differences in occurrence of groundwater, and possible differences in chemical quality of groundwater.

## Geographic Areas Discussed

### Santa Cruz County

The area within Santa Cruz County that is discussed in this report is the drainage basin of the Santa Cruz River from the International Boundary at the south end to the Santa Cruz-Pima County Line on the north end. Omitted are the headwater drainage basin of the Santa Cruz River in San Rafael Valley, and the portion of the drainage area in Mexico.

### Pima County

The area within Pima County that is discussed in this report is that portion of the Tucson Basin that lies between the Pima-Santa Cruz County Line at the south end and the U.S. Geological Survey Gaging Station at Congress Street Bridge on the Santa Cruz River at the north end. The Tucson Basin has been defined by Davidson (1973) as the drainage area of the Santa Cruz River from Latitude 31° 45' on the south end (about 1.6 miles north of the Pima-Santa Cruz County Line), to the Rillito Narrows near the Rillito Cement Plant at Rillito, on the north end. Omitted in this report, therefore, is the portion of the Tucson Basin drained by Rillito Creek and its tributaries and the downstream portion between Congress Street in Tucson and the Rillito Narrows.

It is not fully possible to adhere to this division, however, because in order to establish understanding of the physical setting and the geologic setting it is deemed necessary to include the relations of the Catalina Mountains and the Tanque Verde Mountains north of Congress Street (extended eastward) in the background discussions.

### Location Map

Plate 1 is a copy of the official map of the Tucson Active Management Area (TAMA) as administered by the Arizona Department of Water Resources (DWR) under the Groundwater Management Act of 1980. The Management Area includes the drainage basin of the Santa Cruz River between the International Boundary and latitude 31° 45' (southern limit of Tucson Basin as defined) and the Tucson Basin as defined.

# SURFACE FLOW IN SANTA CRUZ RIVER

## Historical and Contemporary Accounts

Accounts of the pre-Anglo, pre-irrigated pumping period of the history of the valley tend to agree, over a range of many decades, as to the reaches in which the river did not flow perennially. The historical accounts of flow in the river have been collated and compiled by J.L. Betancourt and R.M. Turner in their book, tentatively titled Tucson's Santa Cruz River: Chronicle of a Desert Stream (submitted for publication by Univ. of Ariz. Press). A draft version has been provided, with provisional page numbers, of the relevant sections of the book. The sources utilized by Betancourt and Turner are also listed for each observation.

## Historical Observations

The following observations are arranged in chronological order. The relevant observations are underlined. Page numbers in brackets refer to the draft version of the Betancourt-Turner book. Statements by the authors of the book are enclosed in brackets to separate them from the original observations.

1775 Pedro Font (in Bolton, 1931)[27]

> We set out from La Canoa at two in the afternoon, and at five halted at Punta de los Llanos, having traveled 3 leagues (7.8 mi.) to the north-northwest. At the campsite and in the plains which follow there is grass, but no water... [Punta de los Llanos, or Point of the Plains, refers to the opening up of the valley north of Continental.]

1804 Manuel de Leon, at Tubac (in McCarty 1976)[28]

> Our river is the Santa Cruz, which takes its name from the Santa Cruz presidio at its headwaters, forty miles to the southeast of us. Only in the rainy season does it enjoy a steady flow. During the rest of the year it sinks into the sand in many places.

1804 Jose de Zuniga, at Tucson (in McCarty 1976)[28-29]

> Our major river, however, is the Santa Maria Suamca (Santa Cruz River), which arises 95 miles to the southeast from a spring near the presidio of Santa Cruz. From its origin it flows past Santa Barbara, San Luis, and Buena Vista, as well as the abandoned missions of Guevavi and Calabazas, the Pima mission at Tumacacori, and the Tubac presidio. When rainfall is only average or below, it flows above ground to a point some five miles north of Tubac and goes underground all the way to San Xavier del Bac. Only during years of exceptionally heavy rainfall does it water the flat land between Tubac and San Xavier.

1821 Ignacio Elias Gonzales, on La Canoa Land Grant (in Report of Surveyor General 1880)[29-30]

> ...it is a place that contains ample level land through which runs the River of this military post, although without water due to the many sandy places that impede its current half a league to the north (of Tubac). Only during the rainy seasons, when it receives water from its tributaries does the river flow.

1848 Cave Couts, traveling (in Couts 1961)[31-32]

> The river, or more properly, branch or creek, disappears in its sandy bottom a little below Ft. Tubac and probably does not rise again...The whole country between the mountains, and from Tubac to Tucson, is remarkably sandy and requires very strong streams to run any distance. Cannot find the Santa Cruz River in any map, reason for thinking it does not rise again. [Each page of Couts' diary is accompanied by a hand-drawn sketch showing the day's route. The river's flow is shown to disappear just below the ford near La Canoa. Approaching San Xavier, he notes an increase in the size and density of mesquite and is forced to amend his earlier conclusions about the river's flow:] Rio is called San Xavier, though the same as Santa Cruz, which disappears near Ft. Tubac and rises in a spring above Xavier del Bac from whence it is called San Xavier...

1848 John E. Durivage, traveling (in Durivage 1937)[32]

> We camped eight miles from the last rancho (Tubac) having traveled twenty-five miles during the day. Just below this point the river sinks into the sand and appears again only at intervals for many miles.

1849 H.M.T. Powell, traveling (in Powell 1931)[33]

> (Nine miles north of Tubac)...we crossed the river to left bank...three or four hundred yards below where we crossed the river sinks into the sand, and where it rises again we do not know. It sinks into the bend northeast of the point of the double peak mountains...

1852 J.R. Bartlett, traveling (in Bartlett 1854)[35]

> The rain having continued the whole night, we were much delayed in getting off this morning. The whole country was drenched with water and the road almost impassable for heavily-loaded wagons. After a hard journey of eighteen miles, we stopped at the banks of the river (nine miles north of Tubac) and strange as it may appear, notwithstanding all the rain that had fallen, the river, such is the uncertainty of the streams in this country, was quite dry.

1856-57 W.H. Emory, traveling (in Emory 1857)[37]

> After leaving Tubac, which is situated about midway between Santa Cruz and Tucson, the valley expands into a wide open basin, the mountains receding on either hand, and the dry valley now almost exclusively occupied by mesquite, is bordered by a wide stretch of gravelly table land...Approaching the town of San Xavier, noted for its superb church, contrasting strangely with the mud hovels surrounding it, we again come upon running water, with its constantly associated fertility and verdure...

<u>1867 W.A. Bell, traveling</u> (in Bell 1869)[42]

> One word about the Rio Santa Cruz, the eccentric course of which can be traced at a glance on the map. For the first 150 miles from its source it is a perennial stream; but four miles south of Roade's Ranch, at a spot called Canoa, <u>it usually sinks below the surface; it then flows underground almost to San Xavier, and again appears at a spot called Punta de Agua</u>. The Papagos are thus supplied with water, and are enabled to raise what crops they require around their huts by means of irrigation.

<u>1872 T. White</u>[44]

> [All accounts agree that the flow of the Santa Cruz first disappeared not far north of Tubac, near the ford at La Canoa. In December 1872 Theodore White noted that "about a mile south of where this line (southern boundary of T18S, R13E) crosses, the Santa Cruz is a large, ever running stream of water, <u>but sinks into the sand in a short distance."</u> [Directly west of this point are the present headquarters of the Canoa Ranch.]

## Contemporary Observations

### 1939-1982 Leonard C. Halpenny personal observations

#### Upper Santa Cruz River Area

During this period the author of this report has noted perennial flow in the Santa Cruz River from the International Boundary most of the time as far north as the mouth of Sonoita Creek at Rio Rico. In the spring of 1963 the river dried up at the Nogales pumping station on the Santa Cruz River at State Highway 82, but rains in July 1963 restored the perennial flow. Santa Fe Ranch and Guevavi Ranch between State Highway 82 and the mouth of Sonoita Creek at Rio Rico, have traditionally diverted water from the Santa Cruz River for irrigation, under claimed water rights dating into the 18th century. The major flood in October 1983 changed the course of the river so much that the diversion structures have not been feasible since then.

#### County Line to Near Martinez Butte

In the period 1939-1982, the author did not observe perennial flow in this reach of the Santa Cruz River. The only flows were the result of storm runoff.

#### From South of Martinez Butte and San Xavier Mission

Martinez Butte (also known sometimes as Sahuarita Butte) lies on the east side of the Santa Cruz River a short distance east of San Xavier Mission. For perhaps two miles south of Martinez Butte the historic records indicate there was a cienega along the Santa Cruz River in this vicinity. When first visited in in late 1939, there was perennial flow from this area downstream for a distance of about two miles. This perennial flow ceased shortly thereafter.

### 1983-1987 Leonard C. Halpenny personal observation

The flood event of October 1983 and preceding floods recharged the aquifer systems along the Santa Cruz River and its major tributaries in Santa Cruz County, following decline of groundwater levels during the drought period that extended from the late 1940s through the early 1960s. The major tributaries in Santa Cruz County were perennial for about 18 months after October 1983, an event which had certainly not occurred since 1939.

## Summary of Historical Record

The record from 1775 through the nineteenth century clearly indicates that the Santa Cruz River was perennial from what is now the International Boundary to as far north as a zone ranging between a few miles north of Tubac and the vicinity of the headquarters of the Canoa Ranch.

The differences in the period 1775-1872 between the termination of perennial flow a short distance north of Tubac to the Canoa Ranch headquarters could be attributed to differences between wet and dry years, or to the phenomenon of seasonal differences in transpiration by phreatophytes. The fact that, since about 1983, the river is again perennial within the same zone as in 1775-1872 indicates the interaction of other factors which affect surface flow in the stream. These other factors will be addressed in subsequent chapters of this document.

## Other Streams in Santa Cruz County

### Nogales Wash

Nogales Wash rises in Mexico, passes through Nogales, and is tributary to Potrero Creek near the north end of Nogales. This stream has normally been dry except following rainstorms. In the last few years, however, wastewater occurring in Nogales, Sonora has caused the wash to flow a few gallons per minute on a perennial basis.

### Potrero Creek

Potrero Creek rises on U.S. National Forest land a few miles northeast of downtown Nogales. It flows northeastward through the Meadow Hills subdivision, where it joins Nogales Wash a short distance east of Highway I-19. From there it flows northward and joins the Santa Cruz River near Rio Rico.

From the headwaters to a short distance west of I-19, Potrero Creek is ephemeral. Relatively impermeable Nogales Formation is at or near the land surface along a subsurface ridge that crosses Potrero Creek near I-19. The underflow in the Older Alluvium, moving slowly northeastward, is brought to the surface at this ridge and the stream is perennial from there to the confluence with the Santa Cruz River.

### Sonoita Creek

The headwaters of Sonoita Creek are near the town of Sonoita. The creek flows southwest, through Patagonia, and joins the Santa Cruz River near Rio Rico, a short distance downstream from the confluence of Potrero Creek.

From the headwaters to Monkey Springs (between Sonoita and Patagonia) Sonoita Creek is ephemeral. Flow of Monkey Springs causes the wash to be perennial for about one mile. The stream is ephemeral again to the southeast edge of Patagonia, where a fault cuts across the creek. From that point the stream is perennial for several miles through the Nature Conservancy Preserve, where it again becomes ephemeral, which de Leon recognized in 1804:

1804 Manuel de Leon, at Tubac (McCarty 1976)[28]

> ...which we call the Sonoita River, takes its name from the abandoned Pima mission of the same name. It flows steadily for the first fifteen miles of its westward course, but sinks beneath the sand seven to eight miles before joining the Santa Cruz.

## Sopori Wash

Sopori Wash rises on the west side of the Tumacacori Mountains and flows north, northeastward, and eastward. It joins the Santa Cruz River about one mile south of the Santa Cruz-Pima County Line. The stream is ephemeral for most of its course, except for a short distance immediately upstream from the Sopori Ranch headquarters. In this area two, or possibly three, faults cross the wash in a northeastward direction. These faults bring Older Alluvium underflow to the surface. They are downthrown on the northwest side. This faulting of Older Alluvium is discussed in Chapter 5. From Sopori Ranch headquarters to the confluence with the Santa Cruz the wash is ephemeral.

# PHYSICAL SETTING

## Topography

### Santa Cruz County Portion

The Santa Cruz River valley from the International Boundary to the Santa Cruz-Pima County Line is fairly narrow. It is limited on the east by the Patagonia, San Cayetano and Santa Rita Mountains and, on the west, by the Pajarito, Atascosa, and Tumacacori Mountains. Along both sides, the distance from the bases of the mountains to the stream ranges from about 3 to about 6 miles. The mountain peaks along the east side of the valley are in the range of 6,000 to 8,600 feet above sea level. Along the west side the peaks are lower, in the range of 4,900 to 5,300 feet above sea level.

The drainage area upstream from the gaging station at the International Boundary is 542 square miles and, at the former gaging station at Continental, 1,640 square miles. Thus, the drainage area between the two points is 1,098 square miles, of which about three-quarters (about 825 square miles) is in Santa Cruz County.

The elevation of the river bed at the Boundary is 3,702 feet and, at Continental, 2,836 feet. The distance between the stations is about 45 miles. The gradient of the stream is therefore about 19.2 feet per mile.

The principal tributary streams along the east side of the valley are Sonoita Creek (the largest), Josephine Canyon, Montosa Canyon, Cottonwood Wash, and Agua Caliente Wash. Along the west side the principal tributary streams are Nogales Wash, Potrero Creek, Calabasas Canyon, Agua Fria Canyon, Peck Canyon, and Sopori Wash (the largest).

The Santa Cruz River has cut an Inner Valley along its course which was subsequently refilled with stream-transported alluvial material. This Inner Valley ranges in width from about one-half mile to one mile and it is relatively flat. The edges of this Inner Valley are terrace slopes which rise generally about 10 to 15 feet above the valley floor. However, near the Palo Parado Interchange on Highway I-19, the top of the terrace is more than 100 feet above the valley floor.

#### Summary

The river valley in Santa Cruz County is relatively narrow with steep side slopes and with a relatively steep downstream gradient. The tributary streams are relatively deeply incised. The Inner Valley along the stream is relatively narrow.

## Pima County Portion

The Santa Cruz River valley in Pima County south of Tucson is a broad flat plain, wider on the east side than on the west. The mountains along the east side are the Santa Rita, Empire, Rincon, Tanque Verde and Catalina ranges. Along the west side are the Sierrita Mountains and the southern portion of the Tucson Mountains. The mountain peaks along the east side are in the range of 8,400 to 8,600 feet above sea level. Along the west side the mountain peaks are in the range of 4,700 to 6,000 feet. From mountain range to mountain range, the width of the valley is about 12 to 25 miles.

The drainage area of the stream at the gaging station in Tucson is 2,190 square miles, greater by 550 square miles than at the former Continental gaging station. The drainage area between the south line of Pima County and Continental is approximately 275 square miles.

The elevation of the river bed at Tucson is 2,327 feet above sea level, 509 feet lower than at Continental. The distance between the two points is 27 miles. The gradient of the stream is therefore 18.9 feet per mile, slightly less than in Santa Cruz County.

The principal tributary stream entering the Santa Cruz River from the east is Rillito Creek, which collects runoff from the surrounding mountains via its tributaries-- Cienega Creek, Pantano Wash, Tanque Verde Wash, and Sabino Canyon. There are no principal tributaries entering the river from the west side of the valley.

The inner valley of the river in the southern part of Pima County is about one mile wide and bordered by terraces about 10 feet high from the Santa Cruz-Pima County Line northward along the west side for about 8½ miles and, along the east side, not at all. From those points, northward to Tucson there are no terraces, and the desert floor is indistinguishable from the inner valley.

### Summary

The river valley in Pima County becomes substantially wider than in Santa Cruz County, to a maximum of about 25 miles, beginning a short distance north of the Pima-Santa Cruz County line. The inner valley along the river blends with the desert floor beginning at the points where the main valley becomes wider. The gradient along the river channel is slightly lower than in Santa Cruz County.

## Terraces Along the Inner Valley

From the International Boundary to approximately the Santa Cruz-Pima County Line, the edges of the Inner Valley of the Santa Cruz River are marked by steep terrace slopes. The material underlying the terraces is Older Alluvium, mainly of Pliocene (late Tertiary) age. The upper surface of these terraces is gently sloping fanglomerate that extends from the mountains to the edge of the trough cut by the river before it was partially backfilled with Younger Alluvium, probably less than 11,000 years ago (Davidson, 1973, p.E-27). Helmick (1986) made a detailed study of the relative ages of the terrace slopes along three side washes tributary to the river along the east side, between Tumacacori and Amado. He deduced that development of the terraces began in Pleistocene (early Quarternary) time and backfilling of the Inner Valley occurred in Recent (late Quaternary time), long after the basin had been almost filled with Pliocene alluvial material eroded from the mountains.

As one enters Pima County from the south along I-19, the terraces along the east side of the river disappear almost at the County line. Along the west side, however, the terraces continue for a distance of 8½ miles northeast of the County line, but at a gradually diminishing height above the floor of the Inner Valley. From these two points, there are no terraces as far north as Martinez Butte near San Xavier Mission. Instead, the desert plain merges into the floor of the Inner Valley without a discernible edge.

## Climate

For this report, the primary climatic factor of relevance is precipitation. Data for five stations along the Santa Cruz Valley are given in the following tabulation:

| Name of Station | Elevation at Station (ft/msl) | Precipitation 1985 (in) | 30-year average |
|---|---|---|---|
| Nogales 6N. | 3,560 | 21.35 | 21.35 |
| Tumacacori Nat. Mon. | 3,267 | 17.60 | 14.73 |
| Santa Rita Exp. Sta. | 4,300 | 28.42 | 21.02 |
| Sahuarita 8W. | 3,560 | 15.72 | 13.72 |
| Tucson WBO Airport | 2,584 | 12.88 | 11.14 |

The Nogales, Tumacacori, and Tucson stations are along the axis of the valley. The data from them can be considered representative of the progressive upstream increase in elevation along the valley axis. The Sahuarita and Santa Rita Experiment Station sites are on the side slopes of the valley about midway between Tucson and Nogales. Data from these two stations represent the situation nearer to the margins of the valley.

# GEOLOGIC SETTING

## Introduction

There are three broad units of geologic formations that relate to the occurrence of groundwater in Southern Arizona, including the portion of the Santa Cruz River valley that is the subject of this report. The oldest of these units is hydrologic bedrock, which is exposed in the mountains that border the valley and which underlies the valley floor. This category includes a wide variety of igneous and metamorphic rocks. Where exposed in the mountains the rocks are partially fractured, and rain or snowmelt penetrates into these fractures. This water slowly moves downward and valleyward through the fracture systems and eventually seeps into the alluvial materials underlying the desert floor. This source of groundwater replenishment is termed "mountain front recharge".

Little or no water can be anticipated by drilling a well in the hydrologic bedrock, either where exposed in the mountains or beneath the valley floor.

The next oldest formational unit is generally of late Tertiary age or younger. This unit is termed "Older Alluvium" by some and "Basin fill" by others. It is comprised of alluvial materials eroded from the nearby mountains, transported down-gradient toward the axis of the valley, and deposited within the valley. The materials range from clay or silt through progressively larger particle sizes (sand and gravel) up to the size of cobblestones and boulders. The farther the process of transportation proceeds, the smaller and more rounded the particles become. Gravels and boulders deposited near the base of a mountain are much more angular than those found nearer the axis of a basin. The finest particles, clay and silt, generally are deposited closest to the axis of the basin, mixed or interlayered with sand and gravel. If the basin does not have through drainage (closed basin) a playa will develop in the center and most of the clay and silt is deposited there. The thick lakebeds of the Middle San Pedro Valley and in Safford Valley along the Gila River were deposited in ancient closed basins.

The thickness of the Older Alluvium ranges from a few inches at the bases of the mountains to as much as 6,000 feet or more along the axes of the valleys. Groundwater accumulates in the material and the total volume stored is extremely large.

The third geologic unit of importance is termed the "Younger Alluvium". This material also is of alluvial origin but is generally coarser than the material of the Older Alluvium. The manner in which the Younger Alluvium was deposited differs from deposition of Older Alluvium, for the source is sediment transport along a through-flowing stream. During a much wetter climatic cycle many thousands of years ago, the desert streams in the southwest carried more runoff and eroded deeply. During this cycle of high runoff the streams removed Older Alluvium to a depth of 100 to 150 feet and to a width of one-half mile to perhaps 3 miles. The eroded material was transported downstream, out of the basin. When the wet cycle began to wane, the desert streams began to redeposit the sediments they were transporting, and the trough that had been cut began to refill. This process is continuing today along parts of many desert streams in the southwest. Along the Santa Cruz River the redeposition has reached a thickness of 100 to 125 feet, generally 10 to 25 feet lower than the floor of the adjacent Older Alluvium. At the interface between Older and Younger Alluvium there remains a terrace in many valleys.

The following discussions relating to hydrologic bedrock are highly generalized. A great amount of detailed geologic mapping has been done by various geologists, but the present discussion is directed only to the rocks of the mountains as a source of weathered and eroded material redeposited in the valleys.

Reports reviewed in preparing this subchapter are as follows: Andreasen and Pitkin (1963), Cooper (1960 and 1973), Davidson (1973), Drewes (1968, 1971-1, 1971-2,1972-1, 1972-2, 1973, 1980), and Oppenheimer and Sumner (1980).

# Geologic Features in Santa Cruz County

## Sources of Alluvial Material Along East Side of Valley

The Patagonia Mountains along the east side are comprised mainly of granite assigned an age of Precambrian or younger. Material eroded from these rocks constitutes a source of Older Alluvium for the east flank of the Santa Cruz River in that vicinity. The hills that separate Nogales Wash from the upper portion of the Santa Cruz River are comprised of a dense conglomerate (Nogales Formation) of early Tertiary age in the southern part and of granite in the northern part.

The eastern flank of the Patagonia Mountains is a mixture of volcanic rocks, is highly fractured and faulted, and is mineralized in places. These rocks are a source of Older Alluvium in the headwaters of the Santa Cruz River in the San Rafael Valley.

The south flank of the San Cayetano Mountains is a source of eroded material along Sonoita Creek, derived from andesitic rock and early Tertiary conglomerate. The west flank is a mixture of rhyolitic and andesitic rocks.

The west flank of the Santa Rita Mountains contains rocks of many different types and ages, including granite, cavernous limestone of Paleozoic age, and rhyolitic and andesitic volcanic rocks, all highly faulted. The limestone is the source of water for Agua Caliente Spring on Agua Caliente Wash.

## Older Alluvium Along East Side of Valley

The composition of the Older Alluvium along the east side of the valley reflects the character of the source material. The volcanic source material produces clay, small and coarse gravels, but little sand. Many of the small rocks can be broken easily with a hammer in contrast to granitic rocks which are much harder and more resistant to erosion. Color changes in the alluvium partially reflect the color of the source rocks but can also result from oxidation after they have been deposited.

The Older Alluvium in front of the Santa Rita mountains is partially conglomeratized. This conglomerate is exposed in steep slopes along the side washes and along the east side of the river valley.

## Sources of Alluvial Material Along West Side of Valley

The mountains along the west side of the valley are predominantly comprised of rhyolitic and andesitic volcanic rock. There are some volcanic dikes and one or two small outcrops of granite. At the north end of the Tumacacori Mountains there is an outcrop of cemented gravelly sand of Paleozoic age. This formation is exposed in the bed of Sopori Creek about a mile upstream from the Sopori Ranch headquarters.

## Older Alluvium Along West Side of Valley

Beginning at the confluence of Potrero Creek and Nogales Wash, the Older Alluvium is buff colored and is comprised of weakly cemented sand and gravel with some clay. As one progresses northward, the amount of cementation seems to increase, at least as far as Rock Corral Canyon near Tumacacori. From Tumacacori northward to the mouth of Sopori Creek at the County Line, the Older Alluvium is a dark purplish red and is comprised of rhyolitic boulders, clay, and some sand and gravel beds. This material is partially cemented and is exposed along side washes as steep slopes and cliffs.

## Younger Alluvium of Inner Valley of Santa Cruz River

The Younger Alluvium is comprised mainly of fine to coarse sand and small to medium gravel with occasional lenses of silt. The thickness of the material is in the range of about 90 to 120 feet. The width at the land surface is in the range of one-half to one mile.

Younger Alluvium also has been deposited along the major washes for a short distance upstream from the edge of the main deposit.

## Geologic Features in Pima County

### Sources of Alluvial Material Along East Side of Valley

The rocks of the mountains along the east side of the Tucson Basin include granite, gneiss, Paleozoic sediments, Cretaceous sediments and volcanic rocks, and early Tertiary sediments. The rocks of the Empire Mountains are more disturbed by faulting than in the mountains farther north and northwest. All have contributed detrital material for redeposit as Older Alluvium.

### Older Alluvium Along East Side of Valley

The thickness of material overlying hydrologic bedrock in the eastern part of the Tucson Basin is as much as 12,500 feet and exceeds 1,600 feet in most of the basin (Oppenheimer and Sumner, 1980). Davidson (1973) compiled an excellent analysis of the upper part of the Older Alluvium, based on drill-hole data. His work included mapping of faults in the Older Alluvium. The materials are mostly sand and gravel with lenses of silt and clay. The alluvium was deposited as a series of coalescing fans in front of the mountain masses. Silty, clayey gypsiferous beds occur in the southeastern portion of the basin east of the Santa Cruz Fault.

### Sources of Alluvial Material Along West Side of Valley

The core of the Sierrita Mountains is granite. There is an overthrust faulted zone along the northeast side of the mountain mass. Paleozoic sediments and Cretaceous sediments and volcanic rocks are exposed. The eroded and weathered fragments range from clay through sand and gravel.

The southern part of the Tucson Mountains is comprised mainly of andesite and rhyolite of Cretaceous and early Tertiary age. There are basaltic rocks in the Black Hills, Martinez Butte, and Tumamoc Hill. Detritus from the Tucson Mountains is finer-grained than on the eastern side of the Tucson Basin.

### Older Alluvium Along West Side of Valley

The alluvium derived from the Sierrita Mountains has been deposited in a graceful fan that extends nearly all the way around the mountain mass. There are few wells near the mountain, for there is a fairly shallow rock pediment around the base. Basinward from this pediment the alluvial material is predominantly sand and gravel with some silt and clay.

The course of the Santa Cruz River closely follows the east flank of the Tucson Mountains as far as downtown Tucson, and there is little Older Alluvium between the river and the mountains.

## Differences in Age of Alluvium at the Land Surface

The Davidson map (1973-Plate 1) shows the desert plain of the entire Tucson Basin to be underlain by alluvium of Quaternary age--Younger Alluvium, ranging in thickness from a few feet at the edges of the valley to more than 100 feet along the axis (ibid., Plate 2, Section H-H').

In contrast, in Santa Cruz County the desert plain is mapped as Older Alluvium of Quaternary-Tertiary age (Pliocene-Pleistocene). The only Younger Alluvium shown on the maps is along the Santa Cruz River and along the lower ends of major side washes.

This difference in age of the uppermost materials underlying the desert plain is a strong indication that the basin was lowered northward of a line across the valley at about the County Line or a short distance farther north. This interpretation is confirmed by the northward disappearance of the terraces along the edges of the Inner Valley, as discussed in Chapter 4. Such lowering could have occurred as a result of faulting in the Older Alluvium or of compaction of fine-grained materials of Pliocene age. These topics are discussed on the following pages.

## Faulting in the Older Alluvium

There are two geologic maps that relate to faulting in the Older Alluvium in the Santa Cruz River Valley. One (Drewes 1980) depicts the tectonic features of southeastern Arizona. The other (Davidson 1973) depicts faulting within the Tucson Basin.

The Drewes map indicates a fault, downthrown on the valleyward side, that extends northward on the western side of the valley, more or less along the line between Rs. 12 and 13E. It is shown to cross Sopori Wash about one mile west of I-19. The length of this portion of the fault is about 30 miles and it is shown to extend northward almost from the line between Ts. 23 and 24S. to the line between Ts. 18 and 19S. (see Figure 5-1). At this point the fault is shown to turn directly east for about 4 miles and thence northeast for about 2 miles. This is termed the "West Side Fault".

A second fault is shown on the Drewes map on the west side of the valley on the Sopori Ranch, in T.20S., R.12E. In the northern part of the township the fault trends east-northeastward. It crosses Sopori Wash at the Sopori Ranch headquarters and is shown to be downthrown on the northwest side. It is mapped only for a distance of about a quarter of a mile northeastward into Pima County. For convenience, this fault is termed the "Sopori Ranch Fault" in this report.

The Drewes map also shows a major fault in the alluvium along the east side of the valley in Pima County. This fault is shown to begin near Elephant Head in front of the Santa Rita Mountains and to extend northeastward for about 20 miles, where it is shown to cross Pantano Wash near the southern end of Rincon Valley. This fault is shown to be downthrown on the northwest (basinward) side. We have termed this the "Elephant Head-Pantano Wash Fault".

One of the major faults mapped by Davidson in the alluvium is the Santa Cruz Fault (1973, Plate 1). This fault follows the western limit of the graben in the Tucson Basin and extends south-southeastward along the west side of the basin. It is downfaulted on th eastern side. The southern end of the Santa Cruz Fault is indicated to die out or become unidentifiable, for it is shown to terminate with a "(?)" at the south line of Sec. 8, T.18S., R.14E.

The Sopori Ranch Fault and the Elephant Head-Pantano Wash Fault of Drewes are both downthrown on the northwestern side. If projected across the middle of the valley they are in alignment, crossing the valley in an east-northeastward direction. Figure 5-1 shows the two faults and a heavy dashed line connecting them. The position of the south end of the Santa Cruz Fault is also shown as well as the places of termination of the west-side and east-side terraces that mark the edges of the Inner Valley of the river.

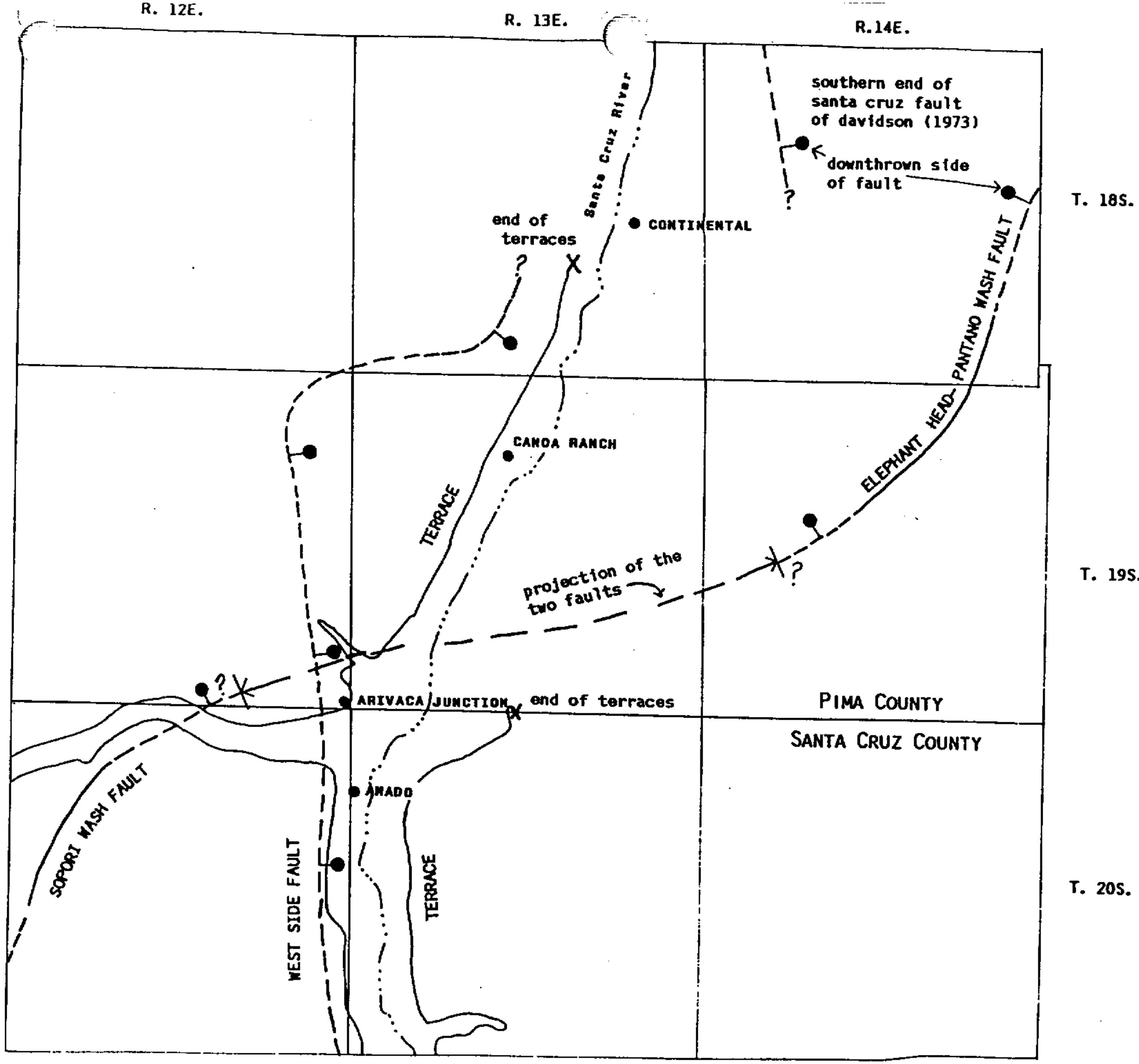


Figure 5-1.- Faulting in the alluvium of the Santa Cruz Valley near the Santa Cruz-Pima County Line.

## Depth to Bedrock

The Oppenheimer-Sumner map (1980) shows depths to bedrock in the alluvial basins of southern and central Arizona, including the Santa Cruz River Valley. This map was prepared from drill-hole data and geophysical data, and shows connected lines of depth to bedrock. The data indicate that the greatest depth in the Tucson basin to be southeast of Tucson at the site of an oil test drilled several years ago. The depth at that point is 12,571 feet. Around the point is an obloid line representing a depth of 11,200 feet, then 9,600 feet, etc. The axis of these obloid lines extends south-southwestward to about the Pima-Santa Cruz County Line, where the depth to bedrock is shown to be 4,800 feet. At this point the 4,800-foot line turns westward. Near the axis of the Santa Cruz River the 4,800 foot line turns southward along the east side of the river. Northward along the river the depth to bedrock is shown to be less than 1,600 feet opposite Twin Buttes and less than 800 feet along the Tucson Mountains.

The Drewes map terms this deep trough along the river in Santa Cruz County the "Santa Cruz Graben". The graben extends south, up Nogales Wash rather than southeastward along the Santa Cruz River. The depth lines are obloid and are along each side of the river. At Nogales the depth to bedrock is shown to be greater than 800 feet. Opposite about Tumacacori the depth is shown to be greater than 1,600 feet and, opposite Carmen, greater than 3,200 feet. Opposite the Tubac Valley Country Club the depth is shown to be greater than 4,800 feet. From there the trough of the graben (4,800 plus feet) shifts slightly northeastward. At the mouth of Sopori Creek the depth to bedrock is shown to be about 3,200 feet.

## Lowering of the Land Surface in the Tucson Basin

Lowering of the land surface has occurred and is continuing to occur in the Tucson Basin. It occurs as a result of two processes--compaction of fine-grained sediments caused by the weight of accumulating overburden, and subsidence as a result of dewatering fine-grained sediments by large withdrawals of groundwater. Both of these processes are irreversible. Faulting has occurred in the alluvium as a result of compaction and possibly as a result of continued sinking of the floor of the Santa Cruz graben.

The Tinaja Formation of Davidson (1973), of Pliocene (Tertiary) age, contains fine-grained materials described as follows (ibid., pp. E-20 and E-21):

> Tinaja Beds
>
> The Tinaja beds are a major part of the aquifer in the Tucson basin. They crop out only along the margins of the basin, where they are exposed because of erosion or nondeposition of overlying sedimentary units. The most continuous outcrops are in the foothills of the Santa Catalina and Rincon Mountains and in the Santa Rita Mountains and south of Tinaja Wash in the Sierrita Mountains. In the basin the beds are concealed by several hundred feet of overlying detritus but are partly or completely penetrated by many wells. The beds are 0 to more than 2,000 and perhaps as much as 5,000 feet thick; sandy gravel is the dominant lithology at the basin margins, but it grades to gypsiferous clayey silt and mudstone along the central axis of the basin.
>
> .......................
>
> The Tinaja beds are interpreted as a sedimentary detrital filling of a subsiding basin. The central part of the basin is a triangular downfaulted block bounded by the Santa Cruz fault, the fault parallel to Rillito and Tanque Verde Creeks, and a probable major fault that trends northeast through the basin. In much of the downfaulted block, the Tinaja beds are a clayey silt to mudstone in the lower part and a clayey gravel to clayey silt in the upper part, and outside of the downfaulted block the beds generally are a gravel or pebbly sand. The best evidence of

> the faulted nature of the block is in the southwestern part of the basin, where at least 2,000 feet of clayey silt and mudstone assigned to the Tinaja abuts hard, cemented gravel and conglomerate of the Pantano (pls. 1 and 2, Santa Cruz fault, particularly sections C-C', H-H', and I-I'). A similar lithologic change, vertical offsets of rock units near well (D-13-14)27acb (pls. 1 and 2, section B-B'), and the linearity of Rillito and Tanque Verde Creeks indicate a probable fault contact between the lower Tinaja beds and the Pantano. Silty gravel to mudstone of the Tinaja beds is proximate to well-cemented gravel of the Pantano along the eastern side of the triangular block. The lateral lithologic change, which probably is due to a fault offset, is best illustrated on the eastern part of section E-E' (pl. 2).

Tinaja Formation has not been identified in Santa Cruz County.

## Compaction

Compaction of the fine-grained Tinaja sediments would occur as a result of the weight of accumulating overburden. According to Davidson (ibid., p. E-27), about 2 to 3 million years have elapsed since the youngest Tinaja beds were deposited. If compaction amounted to an average of only one foot in 20,000 years, the total compaction would have been 100 feet in two million years.

## Subsidence

The sinking of the basin caused by compaction is a geologic process. The dewatering of the aquifer caused by irrigation pumping obviously has occurred in a distinct time scale compared to the time frame of deposition of the Tinaja to the present. However, the occurrence of subsidence caused by dewatering is an indication of the existence of the fine-grained materials which are the most easily compacted. Therefore a sketch of the possible areas of greatest subsidence is an indication of the areas of possible concentration of compaction.

The first published record of the occurrence of subsidence in the vicinity of Sahuarita is contained in the 1965 report by Matlock, Schwalen and Shaw (p. 17). They describe subsidence around several wells in the Sahuarita area. A photograph on page 18 (ibid.) shows a well casing protruding a height of 6 inches above the concrete pump base, indicating that subsidence of 6 inches had occurred since the well was drilled.

A thorough and detailed report on subsidence and potential subsidence in the Tucson Basin indicates that the zone of greatest potential subsidence in the Tucson Basin follows the trough of greatest depth to bedrock (Anderson, 1987, Sheet 3). This map indicates a zone of potential subsidence extending northward from the Santa Cruz-Pima County Line. The width of this zone is shown to be 2 to 3 miles and the length about 35 miles. The projected accumulated amount of subsidence anticipated to occur increases from 1-3 feet in T.19S.-T.18S., to 3-6 feet in the southern part of 17S., 6-10 in the middle part, and more than 10 in the northern part. It remains more than 10 feet in 16S. (Sahuarita) and then begins to rise again in 15S., where in the northern part it is 1-3 feet. These figures of course indicate the center of groundwater withdrawal.

## Relation of Terraces to Lowering of the Land Surface

The fact that the terraces that mark the Inner Valley of the river in Santa Cruz County disappear at the County Line on the east side and a few miles farther north on the west side is not a coincidence. North of these two points of disappearance the alluvial outwash slopes blend into the river flood plain, and the Inner Valley cannot be identified. It has been shown that the fine-grained facies of the Tinaja Formation are along the deepest part of the graben in Pima County, but have not been identified in Santa Cruz County. It has also been shown that these fine-grained facies have been undergoing compaction since deposition ceased and that, as a result, faulting has occurred within the alluvium. Faults in alluvium are difficult to detect, and the amount of movement across them cannot be measured. With compaction being very slow but a continuing process, movement across the alluvial faults can be expected also to be slow and continuing.

The time when faulting began in the alluvium can be estimated. Deposition of the Middle and Upper units of the Tinaja Formation began about 12 million years ago and ended about 2 to 3 million years ago (Davidson, 1973, p. E-27), at the beginning of the Quaternary system. The faulting could have been initiated, therefore, about 2 to 3 million years ago and probably has continued little by little up to the initiation of the Holocene period about 11,000 years ago, when the present-day drainage of the Santa Cruz began.

Calvo and Pearthree (1982) have made an intensive study of the fault scarps along the northwest flank of the Santa Rita Mountains, at the interface of the Tucson Basin with the mountain mass. Their estimate of the age of faulting northwest of Elephant Head (Table 2, p. 11) was based on the age of soil profiles at the fault scarps. Of seven soil profiles, the age of the oldest was indicated to be 1 to 2 million years, and the youngest, less than 4,000 years. This would indicate periodic resumption of faulting in small increments over a long period. Offset at one fault was shown to be of the order of about 10 feet (ibid., Fig. 7, p. 26). Two major surface rupture events were dated to 200,000 years and 100,000 years, with estimated earthquake magnitudes of 6.9 (ibid., p. 42).

The disappearance of the terraces can be attributed either to slow but steady compaction or to resultant faulting in the alluvium. The subsiding portion of the basin begins close to the Santa Cruz-Pima County Line. Figure 5-2 is a diagrammatic sketch illustrating the relation between the disappearance of the terraces and the sinking of the basin northward.

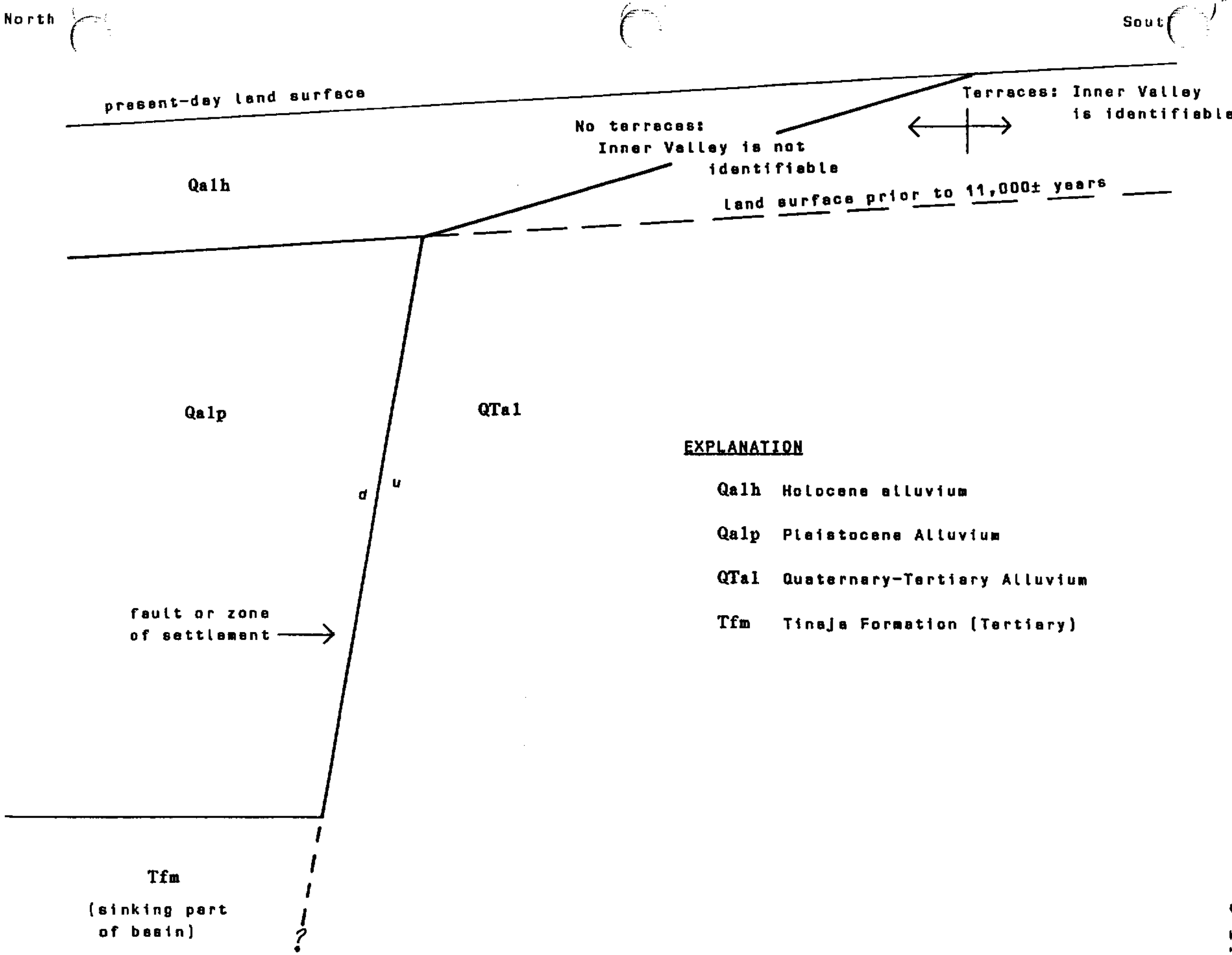


Figure 5-2.- Diagrammatic sketch along edge of Inner Valley near the County Line, illustrating relation of terraces to present-day topography (not to scale).

## Summary

This chapter focuses on the geology of the Santa Cruz valley northward from the International Boundary through Santa Cruz County into the Tucson Basin. In the entire study area most of the basin fill is shown to be Older Alluvium. However, an important change is shown to have occurred in the approximate vicinity of the Santa Cruz-Pima County Line. Southward the alluvial outwash has been mapped as being of Quarternary-Tertiary age (Older Alluvium), which has only a very thin mantle of Younger Alluvium on top of it. In contrast, the surface of the alluvial fill of practically all of the Tucson Basin is mapped as Quarternary Alluvium and the thickness on top of Older Alluvium is shown by geologic cross-sections (Davidson, 1973, Plate 2) to be as much as 100 feet or more. Upon entering the Tucson Basin, the Inner Valley of the Santa Cruz River disappears, and the Younger Alluvium along the stream merges with Quaternary Alluvium eroded from the nearby mountains. The terraces no longer exist.

A logical explanation of this geologic difference between the two areas is that the Tucson Basin portion of the valley was lowered in some manner and that the Santa Cruz County portion was not. Two methods by which such lowering could occur are discussed--one being downfaulting of the Older Alluvium surface at some time after much of it had been deposited (early Pleistocene time), with subsequent additional movement triggered by continued compaction of the fine-grained facies of the Tinaja Formation northward. The other plausible method is by slumping, without concommitant faulting. Of the two hypotheses, concommitant faulting triggered by compaction is considered more likely. In describing the Tinaja Formation, Davidson stated (1973, p. E-21) that "The Tinaja beds are interpreted as a sedimentary detrital filling <u>of a subsiding basin</u>" (emphasis added).

## OCCURRENCE OF GROUNDWATER

### Santa Cruz County

### Older Alluvium

#### Data from Well Tests

Until about 1980 the only wells known to have been drilled in Older Alluvium in Santa Cruz County were as supplies for domestic and livestock use. These wells generally were drilled to a shallow depth below the water table because the required well yield was low. Beginning in 1982 it became possible for the author of this report to participate in efforts to explore the Older Alluvium to greater depths, to learn if greater yields could be obtained from wells drilled in the Older Alluvium.

#### Wells with Test Data

In 1982-1983, three wells were drilled on the Sonoita Creek Ranch on upper Guevavi Wash in T.23S., R.14E. The pertinent data for these three wells are as follows:

| Item | Well No. 1 | Well No. 2 | Well No. 3 |
|---|---|---|---|
| Depth, feet | 387 | 285 | 385 |
| Depth to static water level, feet | 174 | 162 | 229 |
| Diameter, inches | 6 | 6 | 6 |
| Gravel packed | No | No | No |
| Constant discharge for 72 hours, gpm | 74 | 89 | 40 |
| Specific capacity gpm per foot of drawdown | 2.7 | 1.6 | 1.9 |

These wells produced water from the Salero Formation, a gravelly sand unit of Cretaceous age. The Older Alluvium was thin and occurred only above the water table.

In 1983 a municipal supply well was drilled for Tubac Valley Water Company at Tubac in the Older Alluvium on the west side of the Inner Valley of the Santa Cruz River. The well was drilled to a planned depth of 650 feet. Examination of the drill cuttings indicated that the material below a depth of 390 feet was predominantly hard conglomerate with clay. The hole was backfilled with pea gravel between the zone 390 and 650 feet and then cased with 16-inch casing. The well was gravel-packed. The depth to static water level was 74 feet. During development the well discharge reached 1,750 gpm. The 72-hour test was conducted at a constant discharge of 1,500 gpm. The specific capacity was 9.6 gpm per foot of drawdown.

In 1984 a 6-inch diameter gravel-packed test production well was drilled in Older Alluvium in Sec. 24, T.21S., R.12E., about 2 miles south and one mile west of the new Tubac area municipal well. The depth was 500 feet. The depth to static water level was 156 feet. The well was tested for 72 hours at an average of 92 gpm. The specific capacity was 1.4 gpm per foot of drawdown.

In 1984 one existing well was tested and a second well was drilled and tested at Palo Parado Hills Subdivision in T.22S., R.13E. The area is situated on a mesa of Older Alluvium west and slightly north of the Palo Parado Interchange on I-19. The data for the two tests are as follows:

| Item | Existing Well | New Well |
|---|---|---|
| Depth, feet | 450 | 520 |
| Depth to static water level, feet | 292 | 412 |
| Diameter, inches | 8 | 8 |
| Gravel packed | No | No |
| Length of test, hours | 4 | 11½ |
| Discharge during test, gpm | 24 | 47 |
| Specific capacity, gpm per foot of drawdown | 22.1 | 5.2 |

In 1984 two wells were drilled for the City of Nogales in Meadow Hills Subdivision along Potrero Creek. The aquifer is Older Alluvium. The pertinent data for these wells are as follows:

| Item | Well No. | Well No. |
|---|---|---|
| Depth, feet | 310 | 450 |
| Depth to static water level, feet | 126 | 126 |
| Diameter, inches | 16 | 16 |
| Gravel packed | No | No |
| Length of test, hours | 20½ | 24 |
| Discharge during test, gpm | 100-220 | 425-475 |
| Specific capacity, gpm per foot of drawdown | 1.3 | 2.3 |

In 1984-1986 three water wells were drilled in Sec. 4, T.21S., R.13E., for the Wingfield Cattle Company on the east side of the Santa Cruz River opposite the golf course at Tubac Valley Country Club. The pertinent data for these wells are as follows:

| Item | Well No. 1 | Well No. 2 | Well No. 3 |
|---|---|---|---|
| Depth, feet | 550 | 560 | 500 |
| Depth to static water level, feet | 153 | 145 | 146 |
| Diameter, inches | 12 | 12 | 12 |
| Gravel packed | No | No | No |
| Constant discharge for 72 hours, gpm | 325 | 500-525 | 250-275 |
| Specific capacity gpm per foot of drawdown | 1.2 | 1.9 | 1.3 |

The wells produced water from a conglomerate unit in the Older Alluvium. The water temperature in two of the wells exceeded 120°F.

In 1985 a test-production well was tested in Older Alluvium at Kino Springs Subdivision, about 2 miles south of the golf course complex. The hole had been drilled to a depth of about 1,000 feet in 1983, but had not been cased. The hole was reamed to a depth of 500 feet and cased with 8-inch casing. The log of the well indicated Older Alluvium to a depth of 180 feet, under which the formation was fractured granodiorite. The well was not gravel packed. At the start of the 72-hour test the depth to static water level was 78 feet. The average discharge during the test was 175 gpm. The specific capacity was 0.6 gpm per foot of drawdown.

## Other Wells

Wells have been drilled in Older Alluvium for municipal water supply in the Rio Rico subdivision near the confluences of Potrero Creek and Sonoita Creek with the Santa Cruz River. The author does not have data relating to the depth or productivity of these wells.

The irrigation wells along Sopori Wash between the Sopori Ranch headquarters and I-19 produce water from Older Alluvium, not from Younger Alluvium.

## Hydraulic Character of the Aquifer System

The computed coefficients of transmissivity of the aquifers tested as discussed in this chapter ranged from 10,000 to 22,000 gpd/ft (gallons per day per foot), much lower than in the Tucson Basin in Pima County.

The highest well yield known is 1,750 gpm on a short-term basis. Few well yields exceed 500 gpm.

The specific capacity of a well is the number of gallons per minute produced from each foot of drawdown of water level during the period the well is being operated. For the well tests described in this subchapter, the specific capacities ranged from 0.6 to 22.1 gpm per foot of drawdown.

## Sources of Recharge and Changes in Water Levels

The main source of recharge to the aquifer system of the Older Alluvium is "mountain-front recharge", which occurs along the bases of the mountains on both sides of the valley. The source of mountain-front recharge is percolation of rainwater and snowmelt into fractures in the hard rocks of the mountains. The amount of this percolation is not great on an annual basis. It slowly follows fractures deeper into the mountain rocks, and moves into the Older Alluvium at the interface between hydrologic bedrock and the alluvium.

This water slowly moves down-gradient toward the axis of the valley along the Inner Valley of the river. At this point it moves into and becomes recharge of the Younger Alluvium. If the stream is perennial, this mountain-front recharge enters the river and contributes to base flow of the river.

The annual volume of mountain-front recharge along each side of the river in Santa Cruz County ranges from less than 50 up to 300 acre-feet per year per mile of mountain front (Osterkamp, 1973-1).

During a period of about 20 years beginning after World War II and ending in about the mid-1960s, water levels in wells in the Younger Alluvium declined, as discussed in the following subchapter. As a result, some water was drained out of Older Alluvium at the edges of the Inner Valley, and water levels in wells within about 1½ to 2 miles of the Inner Valley also declined. When water levels in wells in the Inner Valley began to recover from their decline, water levels also rose to their original levels in the nearby wells in the Older Alluvium.

There has not been a regional, continual decline of water levels in wells in the Older Alluvium in Santa Cruz County similar to what has occurred in Pima, Pinal, and Maricopa County.

## Younger Alluvium

As discussed previously, the Younger Alluvium along the Santa Cruz River and along the lower reaches of th larger tributary side washes is no more than 125 feet thick and no wider than about one mile. In Santa Cruz County this has been the major source of water supply for all of this century. Until the 1980s no efforts had been made to develop or explore the potential groundwater resources of the Older Alluvium other than for stock watering or minor domestic uses.

Many wells have been drilled over the years, mostly for domestic use but some for irrigation supply.

## Sources of Recharge and Changes in Water Levels

The underground water stored in the Younger Alluvium receives groundwater recharge from two sources, one substantial but traditionally infrequent, and the other comparatively small but constant. This minor source of recharge has been discussed in the Older Alluvium subchapter of this report under the term "mountain-front recharge".

The substantial source of recharge is perennial flow in the Santa Cruz River. As long as the river remained perennial, water levels in the Younger Alluvium remained constant. When droughts occurred or the withdrawals from wells exceeded the surface flow in the river, water levels subsided. Pumping from wells in the Younger Alluvium began to increase in the late 1930s and continued to increase through about 1960 to 1970. By that time, pumping for irrigation began to decrease, partly because the land became more valuable for other uses. In the 1970s some of the copper mining companies began to purchase irrigated land along the Inner Valley for the purpose of transferring water rights from agriculture to mining use. Some of the purchases were in Santa Cruz County.

During the drought years of the mid-1940s to the mid-1960s, water levels in the wells in the Younger Alluvium began to decline, and replenishing flows in the river were rare. By the mid-1960s a wetter cycle began and it lasted at least through 1983. The water-level decline in the wells had been as much as 20 feet at some points and was of the order of 10 to 15 feet in most parts of the Inner Valley. The rise in water levels that began intermittently in about 1965 continued until the aquifer was fully replenished.

In addition to the effects of the wetter climatic cycle of about 1965 to 1983, the twin-city Nogales Wastewater Treatment Plant at Rio Rico was constructed and began operation in the late 1960s. The treated water is discharged into the Santa Cruz River. The volume of treated water has increased progressively. As of 1985-1986 the Santa Cruz is perennial as far downstream as Tubac, and perennial in the winter at the southern end of the Canoa Land Grant in Pima County.

The difference between the point where river flow sinks into the ground in the summer and in the winter is attributed to water consumption by phreatophytes (mainly cottonwood and mesquite) growing along the sides of the river. These trees are dormant in the winter but consume substantial amounts of water in the summer. Thus, they do not deplete stream flow in the winter season, and the flowing stream can travel farther north before it sinks into the underlying aquifer system.

The situation of a perennial stream flowing as far north as approximately the County Line, as described by the early historical accounts, has been re-established in the 1980s.

Historically, short-term declines of water-levels in wells in the Younger Alluvium were rectified whenever the river was flowing. The almost 20-year gradual decline after World War II was rectified when river flows became more frequent. For the long term, withdrawal of water from wells in the Younger Alluvium is in balance with recharge, and there cannot be a continual decline similar to the situations that have occurred in Pima, Pinal, and Maricopa Counties.

## Records of Water Level Changes

Beginning about 1915, the University of Arizona, under the direction of Dr. G.E.P. Smith, began a program of monitoring annual changes in water levels in wells in the Santa Cruz Valley. This work continued without interruption until about 1979. The program increased in scope owing to gradual increases in the number of wells and, after World War II, there were substantial increases in withdrawals of groundwater. Many of the data have been published (Schwalen and Shaw, 1957, Schwalen and Shaw, 1961; Matlock, Schwalen and Shaw, 1965).

The U.S. Geological Survey started a less ambitious water-level monitoring program in 1939 (Turner and others, 1943, 1947), Johnson (1952), Coates and Halpenny (1954), Feth (1954), which was substantially reduced in scope in about 1958.

Beginning in 1980, the Basic Data Section of DWR assumed responsibility for the program, which still continues. All of the basic water-level records and well records were transferred to DWR from the University of Arizona and the Geological Survey. These data were entered into a computer database and are available to the public upon request.

Table 6-1 shows, for the period 1953-1982, changes in water levels in wells near the Santa Cruz River from the southern end near Nogales to about Green Valley in Pima County. The data show that within Santa Cruz County there has been no overall decline of the water table during this period but, instead, a zone of rises in water levels. However, from the County Line northward to Green Valley, the data show an increasing decline ranging from 20 feet a short distance north of the County Line to 120 feet in the vicinity of Green Valley.

Between 1982 and 1988, water levels north of the County Line have risen, partly as a result of reduced pumping for mining and irrigation, and partly from recharge from seasonal wastewater flows in the Santa Cruz River north of the County Line.

## Recoverable Groundwater

Osterkamp (1973-2) prepared a map of recoverable groundwater in the Tucson Area, which included the Santa Cruz Valley and all tributaries from about 12 miles north of the Pinal-Pima County Line southward to the International Boundary. One part of the map is a tabulation of recoverable groundwater by subareas and by categories of depth. Table 6-2 is a compilation of the figures along the Santa Cruz Valley in Santa Cruz County, with a sub-tabulation for Upper Sopori Wash.

The amount of recoverable groundwater along the valley is shown to be 5.72 million acre-feet above a depth of 1,200 feet within an area of 177.1 square miles. The volume recoverable per square mile is therefore about 32,300 acre-feet and, per acre, about 50 acre-feet.

TABLE 6-1

**CHANGES IN DEPTH TO THE WATER TABLE ALONG THE SANTA CRUZ RIVER, 1953-1982**

[From Sheet 2 in: Murphey, B.A., and Hadley, J.D., 1984, Maps showing groundwater conditions in the Upper Santa Cruz Basin Area, Pima, Santa Cruz, Pinal, and Cochise Counties, Arizona-1982: Ariz. Dept. of Water Resources Hydrologic Map Series No. 11.]

| Approximate Location | Change in Water Level 1953-1982 (ft) |
|---|---|
| <u>Santa Cruz County</u> | |
| State Highway 82 | 0 |
| Rio Rico-Calabasas | +20 |
| Tumacacori | +20 |
| Amado | 0 |
| <u>Pima County</u> | |
| Distance downstream from Santa Cruz-Pima County Line | |
| 1 1/4 miles | -20 |
| 2 1/4 miles | -40 |
| 6 1/2 miles | -60 |
| 8 1/2 miles | -80 |
| 10 1/2 miles | -100 |
| 11 1/2 miles | -120 |

TABLE 6-2

**ESTIMATED RECOVERABLE GROUNDWATER IN STORAGE**
**SANTA CRUZ VALLEY IN SANTA CRUZ COUNTY**
(From Osterkamp, 1973-2. In million acre-feet.)

| Sub-Area No. | Area (sq. mi.) | Less Than 300 Feet | Between 300 and 700 Feet | Between 700 and 1,200 Feet | Between Land Surface and 1,200 Feet |
|---|---|---|---|---|---|
| 71 | 30.9 | .39 | .83 | .70 | 1.91 |
| 72 | 29.2 | .40 | .71 | .66 | 1.77 |
| 73 | 29.9 | .15 | .47 | .17 | .79 |
| 74 | 30.3 | .11 | .29 | .13 | .53 |
| 75 | 25.4 | .30 | 0.0 | 0.0 | .31[1] |
| 76 | 31.4 | .13 | .23 | .05 | .41 |
| Sub-Total | 177.1 | 1.47 | 2.53 | 1.71 | 5.72[1] |
| Upper Sopori Wash | | | | | |
| 67 | 39.1 | .55 | .49 | 0.0 | 1.04 |
| 68 | 15.1 | .12 | .21 | .04 | .37 |
| Sub-Total | 54.2 | .67 | .70 | .04 | 1.41 |
| TOTAL | 231.3 | 2.14 | 3.23 | 1.75 | 7.13[1] |

[1] Total across differs because of rounding.

## Underflow Beneath Santa Cruz River at County Line

Underground water is constantly moving through the aquifer system of the Santa Cruz basin. Computations have been made by three different authors of the annual volume of water that crosses the Santa Cruz-Pima County Line along the course of the Santa Cruz River, with the following figures being developed:

| Author | Average Annual Volume of Underflow (ac-ft per year) |
|---|---|
| Brown (1976) | 10,000 |
| Davidson (1973, p. E-60) | 9,200 |
| Travers and Mock (1984, Fig. 8) | 8,000 |
| Average of the figures, rounded | 9,100 |

This is equivalent to a constant discharge of about 5,400 gpm.

Unlike surface runoff, underflow is almost constant, and changes little between wet and dry cycles.

## Pima County

### Older Alluvium

Much has been written about the groundwater resources of the Tucson Basin, the overdraft with accompanying declines of water levels in wells, the need for importation of water via the Central Arizona Project (CAP), and the need for imposition of rigid controls under the Groundwater Management Act of 1980 with establishment of the Tucson Active Management Area. The data are readily available and it is considered unnecessary to restate them in this report.

As of 1988 the controls are in effect, the works required for importation of CAP water are nearing completion, and the goal of eventually reducing the overdraft to zero by the year 2025 is underway.

All of the groundwater produced from wells in the part of the Tucson Basin that is discussed in this report is withdrawn from Older Alluvium, because the Younger Alluvium along the river from Martinez Butte to downtown Tucson has been drained.

## Hydraulic Character of the Aquifer System

One of the Davidson maps (1973, Plate 1) contains lines of equal transmissivity of the aquifer system of the Tucson Basin. The following is quoted from the Davidson report (ibid., pp. E44-E45):

### TRANSMISSIVITY

The capacity of the aquifer to transmit water to wells or to sustain downgradient water movement is expressed as transmissivity. The transmissivity is the rate of flow in gallons per day, at the temperature of water in the aquifer, through a 1-foot-wide vertical section of the entire aquifer under a hydraulic gradient of 1 foot of head per foot of flow distance. The transmissivity is the product of the average coefficient of permeability and the thickness of the aquifer. In the Tucson basin the transmissivity was determined mainly from aquifer tests. In general, the greatest transmissivity and the largest yielding wells are along the Santa Cruz River and Rillito Creek.

The transmissivity values were computed by Anderson (1972), who used data from 240 short-term aquifer tests; the tests were supervised and conducted mainly by the staffs of the University of Arizona Agricultural Engineering Department and the Bureau of Reclamation. The general pattern of transmissivity (pl. 1) was established chiefly from the aquifer-test-derived values; supplementary values were computed from specific-capacity data and estimated from well logs.

The transmissivity values computed from aquifer tests range from about 1,000 to almost 500,000 gpd per ft (Anderson 1972), but the transmissivity of most of the aquifer is less than 50,000 gpd per foot (pl. 1). Transmissivities of the next largest part of the aquifer range from 50,000 to 180,000 gpd per ft, and the transmissivities of small parts along the Santa Cruz River and Rillito Creek are from 180,000 to 300,000 gpd per ft or more.

Specific capacities of wells commonly range from about 5 to 100 gpm per foot of drawdown. Most wells along the flood plain of the Santa Cruz River, where the transmissivity is greatest, have specific capacities of 20 to 50 gpm per foot of drawdown, and most wells in the central part of the basin have specific capacities of 10 to 40 gpm per foot of drawdown (Anderson, 1972).

Yields of larger capacity wells (municipal, industrial, and agricultural) commonly range between about 1,000 and about 3,000 gpm, with rare yields up to nearly 5,000 gpm.

Specific capacities of wells in the Tucson Basin range from more than 10 up to 120 gpm per foot of drawdown (Anderson, 1972, Plate 3).

### Younger Alluvium

The only places in the Tucson Basin where water is produced from wells in the Younger Alluvium is along Rincon Creek, lower Pantano Creek, Tanque Verde Wash, lower Ventana Canyon, lower Sabino Creek, lower Bear Canyon, Rillito Creek, and the Santa Cruz River downstream from the Congress Street gaging station.

### Recoverable Groundwater

Table 6-3 is a compilation of the Osterkamp 1973-2 figures for recoverable groundwater in the part of the Tucson Basin between the Santa Cruz-Pima County Line and the gaging station on the river at Congress Street in Tucson.

The amount of recoverable groundwater is shown to be 29.81 million acre-feet above a depth of 1,200 feet within an area of 549.5 square miles. The volume recoverable is therefore about 54,200 acre-feet per square mile and about 85 acre-feet per acre.

TABLE 6-3

**ESTIMATED RECOVERABLE GROUNDWATER IN STORAGE IN TUCSON BASIN BETWEEN THE SANTA CRUZ-PIMA COUNTY LINE AND DOWNTOWN TUCSON**

(From Osterkamp, 1973. In million acre-feet.)

| Sub-Area No. | Area (sq. mi.) | Less Than 300 Feet | Between 300 and 700 Feet | Between 700 and 1,200 Feet | Between Land Surface and 1,200 Feet |
|---|---|---|---|---|---|
| 52 | 28.0 | .39 | .56 | .43 | 1.38 |
| 53 | 30.0 | .17 | .69 | .68 | 1.54 |
| 54 | 29.4 | .14 | .53 | .33 | 1.00 |
| 55 | 34.4 | .67 | .55 | .18 | 1.40 |
| 56 | 42.0 | .33 | 1.40 | 1.30 | 3.03 |
| 57 | 31.2 | .08 | .78 | .81 | 1.67 |
| 58 | 31.4 | .33 | .49 | .20 | 1.02 |
| 59 | 36.6 | .43 | 1.10 | 1.20 | 2.73 |
| 60 | 35.4 | .02 | .75 | 1.10 | 1.87 |
| 61 | 18.1 | 0.0 | .23 | .54 | .77 |
| 62 | 27.4 | .17 | .60 | .35 | 1.12 |
| 63 | 42.8 | .28 | 1.30 | 1.40 | 2.98 |
| 64 | 23.3 | 0.0 | .39 | .68 | 1.07 |
| 65 | 35.3 | .27 | .98 | .69 | 1.94 |
| 66 | 36.3 | .10 | .88 | 1.10 | 2.08 |
| 69 | 40.9 | .39 | 1.20 | 1.10 | 2.69 |
| 70 | 27.0 | .22 | .64 | .66 | 1.52 |
| TOTAL | 549.5 | 3.99 | 13.07 | 12.75 | 29.81 |

## Comparison of Groundwater Conditions in the Two Areas

### Hydraulic Character of the Aquifer System

In Santa Cruz County the highest coefficient of transmissivity is 22,000 gpd/ft; in Pima County, nearly 500,000 gpd/ft. The aquifer system in Santa Cruz County is not nearly as productive as in Pima County.

The highest known yield of an Older Alluvium well in Santa Cruz County is 1,750 gpm. Maximum well yields in Pima County are 3,000 gpm or more.

The highest specific capacity of wells in Older Alluvium in Santa Cruz County is 22 gpm per foot of drawdown. In Pima County the range is far greater and is 10 to 120 gpm per foot of drawdown (Anderson, 1972, Plate 2).

### Changes in Water Level

In Santa Cruz County, the aquifer system is in balance and water levels in wells have not declined on a long-term basis. Withdrawals do not exceed safe yield. In the future, overdevelopment on a severe scale is not likely owing to the lower productivity of the aquifer system.

In contrast, in Pima County mining of groundwater has occurred on an extensive scale at least since World war II and, as a consequence, water levels in wells have declined substantially.

### Volume of Recoverable Groundwater

In Santa Cruz County, the volume of recoverable groundwater per square mile of aquifer above a depth of 1,200 feet was estimated by the U.S. Geological Survey as of 1973 to be about 32,300 acre-feet, about 50 acre-feet per acre.

In Pima County, the volume of recoverable groundwater above a depth of 1,200 feet in the Tucson Basin south of Congress Street in Tucson was estimated to be about 54,200 acre-feet per square mile and about 85 acre-feet per acre.

## Summary

### Santa Cruz County

The underground supply in Santa Cruz County is in equilibrium with recharge and discharge in balance. "Safe yield" has not been exceeded on a long-term basis. The water contained in the Younger Alluvium underlying the Santa Cruz River within the Inner Valley is considered to be surface water and therefore appropriable. Control of these waters is presently under the ongoing process of adjudication of the surface waters of the Gila River Basin. After the adjudication is completed, the allowable withdrawals from the system will be fixed.

The zones of Older Alluvium that lie between the mountains and the axis of the valley contain groundwater as defined in the Groundwater Management Act of 1980. Within this aquifer system the coefficient of transmissivity is comparatively low and well yields are comparatively low. The recharge to this part of the system results from mountain-front recharge and infiltration along the courses of ephemeral washes when runoff occurs. Because of low transmissivity values, each well cannot have a large areal impact on lowering water levels, and only affects the local area.

Owing to the constraints of low transmissivities and mountain front recharge as a source, it is considered to be physically difficult and very likely economically infeasible to develop a large well field of many small wells sited over a large area. Local development of this groundwater is controlled under the provisions of the requirement for proof of a 100-year supply before a Certificate of Assured Supply can be issued.

In the opinion of the author of this report, the groundwater supply within the Older Alluvium can be controlled under the requirements for demonstration of a 100-year supply, and the underground supply of the Younger Alluvium is already under control. It is apparent, therefore, that there is little likelihood of future overdevelopment of the system.

## Pima County

As stated elsewhere in this report, the Younger Alluvium in Pima County is no longer an effective aquifer, and the groundwater supply in the Older Alluvium is overdeveloped.

The much higher transmissivity values which exist in the Older Alluvium, and the wide and deep character of the aquifer permit the development and operation of high-capacity wells and well fields, with consequent areal and basin-wide depletion and lowering of water levels. Instead of mountain front recharge stored in a relatively narrow band of Older Alluvium (as in Santa Cruz County) as the source of water supply, the source of supply in Pima County is the vast amount of water stored in the Older Alluvium, which contitutes a source which can be "mined" by high-capacity wells and well-fields.

## QUALITY OF GROUNDWATER

The chemical quality of groundwater in the Upper Santa Cruz Basin is shown graphically on Sheet 3 of the report by Murphey and Hadley (idem., 1984). A much more detailed study of the area between the County Line and Martinez Butte was made in the late 1970s by the Upper Santa Cruz Basin Task Force (1979).

The data indicate that, along the Santa Cruz River from the International Boundary to Martinez Butte, the chemical quality of groundwater in the Younger Alluvium generally meets prevailing Drinking Water Standards. In the Older Alluvium, the chemical quality of the groundwater in Santa Cruz County is generally lower in total dissolved solids content than in Pima County and, in general, the water quality in both counties is acceptable under prevailing Drinking Water Standards.

It is considered that the chemical quality of the groundwater has little or no bearing on the hydrogeologic differences between the aquifer systems in Santa Cruz and Pima Counties.

## PREVIOUS LEGISLATIVE ACTION

Immediately following the end of World War II there was a great increase in development of irrigated agriculture in central and southern Arizona. By 1948 some forward-looking legislators, among them Dr. R.H. Forbes (see Colley, 1975), began serious efforts to control the increase in the rate of groundwater withdrawal. There was strong opposition, but the Groundwater Act of 1948 was finally passed. This legislation provided only for registration with the State Land Department of all wells producing more than 100 gpm and of filing Notice of Intention to Drill for all planned new wells.

In 1950 the Legislature passed a law that established a framework for designating "Critical Areas" within which no new land could be developed by utilization of groundwater.

In 1951 the Legislature authorized the Governor to appoint a 12-member Groundwater Committee to advise on implementing the "Critical Area" framework. The Committee held meetings throughout central and southern Arizona at which local opinions were heard. By the end of 1951 it was apparent that the strong resistance of 1948 had diminished and that there was a greater awareness of the problem. The State Land Commissioner, W.W. Lane held formal public hearings as a requirement for establishing Critical Areas, and as a result, the major areas of heavy groundwater development were declared critical areas.

In January 1952 the Legislature passed Senate Bill 56, which called for establishment of a 24-member Underground Water Commission, an office, utilization of outside consultants, and preparation by the U.S. Geological Survey of a comprehensive report on the groundwater resources within the Gila River Basin (Halpenny and others, 1952). More Hearings were held throughout the State, and a final report by the Underground Water Commission was prepared and submitted to the Legislature (Underground Water Commission, 1952).

That report contained a map of the State that delineated the areas "recommended to closing for new development". The map is reproduced here as Figure 8-1. The map includes only the portion of Santa Cruz County that lies between the Tubac Country Club (Otero Land Grant) and the County Line.

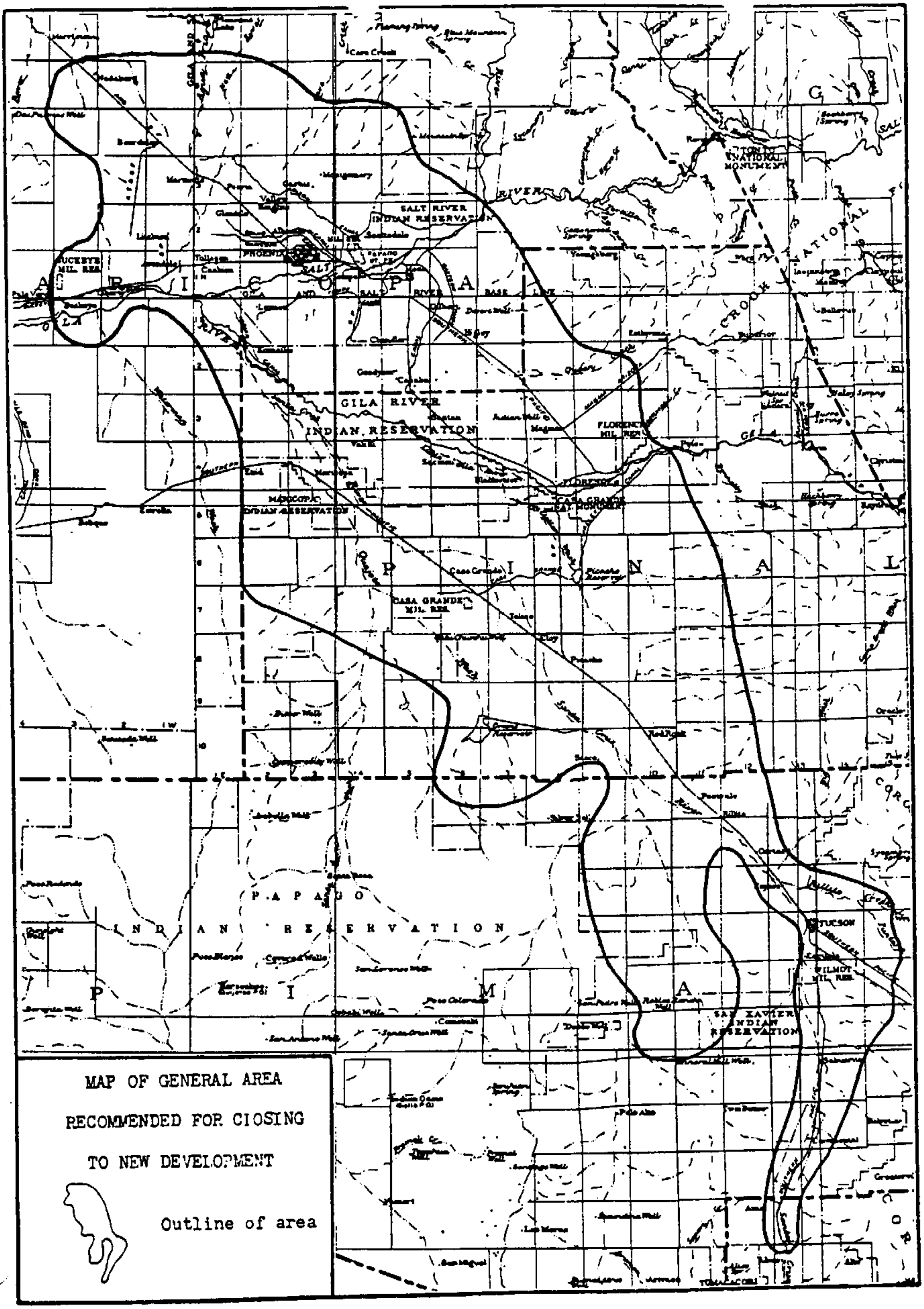


**Figure 8-1.**- Map from Underground Water Commission Report, 1952, p. 4.

With respect to the part of the Upper Santa Cruz Valley that lies in Santa Cruz County, the Commission report stated the following (ibid., p. 12):

> **Upper Santa Cruz Valley**
>
> The Upper Santa Cruz Valley is that part of the valley extending from the Rillito Narrows south to the Mexican border. It is hydrologically connected with the Lower Santa Cruz Valley at the Rillito Narrows.
>
> The southern section of the valley lying in Santa Cruz County is almost totally developed. The irrigable land lies within the inner valley of the Santa Cruz River and the recharge from the river and side washes is such that this area has not shown any persistent decline.
>
> The northern part of the valley widens out at the southern border of Pima County and in this section the requirements exceed the recharge to the aquifers.
>
> The present rate of decline is somewhat less than that in the Salt River and the Lower Santa Cruz Valleys but there has been a general lowering of the water table of from 20 to 50 feet since pumping was commenced. The declines to date have not seriously affected the economic operation of the wells for irrigation or other use but have accelerated during recent years.
>
> If the declines continue, the highly productive shallow water-bearing formations will be largely unwatered, resulting in substantial decreases in the yield of wells. The water-bearing strata of the older fill are not as productive of those of the recent fill, but additional drilling may encounter more productive aquifers than heretofore encountered in the deeper alluvium.

In 1954 State Land Commissioner Roger Ernst held formal Hearings for receiving testimony relative to enlarging existing Critical Areas and establishing additional areas.

In his capacity as District Engineer, Groundwater Branch, U.S. Geological Survey, Halpenny attended and testified at all the Hearings as to the factual situation relating to the groundwater supply of each area. The Hearings at Marana, Tucson, Sahuarita, and Nogales also were attended by Professor H.C. Schwalen of the College of Agriculture, University of Arizona. Professor Schwalen testified about the local groundwater studies done by his office beginning in 1915.

At all the Hearings except Nogales, the factual situation that emerged, and the testimony elicited from attendees, indicated a strong need for groundwater control. The results of the Nogales Hearing led the Land Commissioner to conclude there was no need to declare the Santa Cruz River basin within Santa Cruz County a Critical Area.

## ARTICLE 3. MANAGEMENT OF PUBLIC TRUST LANDS

### § 37-1151. Petition to release public trust status

A. In responding to a petition filed by a record title owner or lessee the department shall consider the extent to which the property that has been confirmed to the state's ownership in a quiet title action, either because of its nature or because of changes, is no longer of material use for protecting public trust values. If the department concludes that the property is not of material use for protecting public trust values, the department shall consider the extent to which a release of the trust is appropriate in light of the public benefit to be derived from alternate uses, and the equitable interests or hardships of the record title holder or lessee, including each of the following:

1. The year in which the property was acquired by the record owner or lessee.

2. The entity or person from whom the property was acquired by the record owner or lessee.

3. The manner in which the record owner or lessee acquired the property.

4. The purchase price or lease terms paid by the record owner or lessee.

5. The amount of property taxes paid each year since the record owner or lessee acquired the property.

6. The profit or benefit derived from the property by the record owner.

7. The extent to which the record owner on the date of acquisition knew or should have known that the property was potentially trust land.

8. All improvements made to the property since the record owner or lessee acquired the property.

9. The public trust values identified by the commission.

10. Whether any improvements on the property impair, obstruct, promote or destroy the value of the watercourse for public trust values.

11. The existing uses of the property, its reasonable highest and best use and whether such uses impair, obstruct, promote or destroy the value of the watercourse for public trust values.

12. Whether the physical condition of the watercourse has materially changed since February 14, 1912 adversely affecting the watercourse's capability of being navigated, including changes due to construction of dams, reservoirs, dikes, levees, canals and ditches that were constructed for water conservation or flood control purposes by public entities, municipal corporations or the United States.

13. Any diminution in value to the record owner's or lessee's contiguous property caused by this state's ownership.

14. The degree of effect of continuation of the current use or any proposed change in use of the property on public trust values.

15. The impact of continuation of the current use or any proposed change in use of the property on the public trust values.

16. The impact of continuation of the current use or any proposed change in use of the property when examined cumulatively in conjunction with existing authorized impediments to full use of the public trust values.

17. The impact of continuation of the current use or any proposed change in use of the property on the public trust values if those values are considered with respect to the primary purpose to which the property is now suited.

18. The degree to which continuation of the current use or any proposed change in use requires that broad public uses be set aside in favor of more limited and private uses.

B. At least thirty days before issuing a decision that land may be released from the public trust under this section the department shall provide written notice of the proposed action and an opportunity to comment to any person who has previously requested written notice of actions under this section. The department shall provide contemporaneous written notice of the final decision to any person who filed a comment.

Amended by Laws 1994, Ch. 277, § 14, eff. April 25, 1994.

## Historical and Statutory Notes

The 1994 amendment in subsec. A rewrote the introductory paragraph, substituted "values" for "or navigation purposes" in par. 10, substituted "values" for "purposes" in par. 11, substituted "values" for "uses of navigation, fishing and recreation" in par. 14, substituted "values" for "resource" in par. 15, substituted "values" for "resource" in par. 16, and rewrote par. 17.

For severability provisions of Laws 1994, Ch. 277, see Historical and Statutory Notes under § 37-1101.

## Administrative Code References

Release of lands from public trust status for sale, see A.A.C. R12-5-2404.

## § 37-1154. Public improvements in beds of navigable watercourses; definition

A. A determination that a watercourse or a portion or reach of a watercourse is navigable does not affect the right of a public entity to own, operate, maintain or repair a public improvement reasonably constructed in the bed of the watercourse under the public entity's powers if the improvement was constructed before the determination that the watercourse, portion or reach is navigable and does not materially impair the public trust. The public entity is considered to have obtained this state's consent to construct the public improvement and is not liable to pay compensation to this state for the land on which the public improvement is constructed if the improvement does not materially impair, obstruct or destroy the function of the watercourse for public trust purposes.

B. If the commissioner determines that the public improvement described in subsection A of this section does not, or will not if appropriate conditions are followed, materially impair the public trust uses, the department may require the public entity to obtain a permit for the improvement pursuant to § 37-1153 but shall not assess any fee for issuing the permit.

C. At least thirty days before issuing a decision under subsection D or E of this section the department shall provide written notice of the proposed action and an opportunity to comment to any person who has previously requested notice of actions under this section. The department shall provide contemporaneous written notice of the final decision to any person who filed a comment.

D. If the commissioner determines that the public improvement described in subsection A of this section destroys the function of the watercourse for public trust purposes and is not in furtherance of the public trust status of the land, the public entity may petition the department for release of public trust status pursuant to § 37-1151. In evaluating the petition, the department shall consider, in addition to the factors prescribed by § 37-1151, whether constructing the public improvement was undertaken pursuant to the public entity's authority and whether the public improvement continues to serve a public purpose.

E. If the commissioner determines that a release is appropriate under subsection D of this section, the public entity may purchase this state's interest in the land without a public auction by paying an amount to be determined by the department pursuant to § 37-1152 directly to this state pursuant to § 9-401, subsection A, § 11-251, paragraph 45 or § 48-3603, subsection C, paragraph 2, as applicable. No cause of action or claim for reimbursement accrues for the benefit of any public entity that exercises its right to purchase this state's interest pursuant to this subsection.

F. For purposes of this section, "public improvement" includes any facility established, constructed or maintained by a public entity pursuant to law and those works described in § 37-1101, paragraph 5.

Amended by Laws 1994, Ch. 277, § 15, eff. April 25, 1994.

Historical and Statutory Notes

The 1994 amendment, in the first sentence of subsec. A, deleted "by the commission" following "A determination", and deleted "commission's" preceding "determination that the watercourse,".

For severability provisions of Laws 1994, Ch. 277, see Historical and Statutory Notes under § 37-1101.

## § 37-1156. Riparian trust fund; acquisition and management of riparian lands

A. The riparian trust fund is established in the state treasury consisting of monies received from the sale or use of sovereign streambed lands and resources under this chapter, damages collected from the United States pursuant to § 37-1131 and any other appropriations, gifts, grants or donations designated by the donor for that purpose. The state treasurer shall maintain the fund separate and apart from all other funds. On notice from the commissioner the state treasurer shall invest and divest monies in the riparian trust fund as provided by § 35-313, and monies earned shall be credited to the riparian trust fund. The state treasurer shall report and maintain a separate accounting of income and other proceeds from investing trust fund monies.

B. The state land commissioner shall use the income, other proceeds and not more than seventy-five per cent of any added principal of the fund in a fiscal year pursuant to this section:

1. To acquire, from willing sellers, land or interests in land located in riparian areas in this state for public purposes consistent with conservation of wildlife and recreation.

2. For such other expenditures as promote the purposes of the public trust.

C. The state land commissioner shall consult with and receive advice from the Arizona state parks board and the Arizona game and fish department regarding the acquisition and management of land and interests in land under this section.

Amended by Laws 1994, Ch. 277, § 16, eff. April 25, 1994.

Historical and Statutory Notes

The 1994 amendment inserted ", damages collected from the United States pursuant to § 37-1131" in subsec. A; and in subsec. B, deleted par. 1, and renumbered pars. 2 and 3 as pars. 1 and 2.

For severability provisions of Laws 1994, Ch. 277, see Historical and Statutory Notes under § 37-1101.

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Arizona State Land Department

# ARIZONA STREAM NAVIGABILITY STUDY

*for the*

# SANTA CRUZ RIVER

## Gila River Confluence to the Headwaters

■ Final Report ■


*Prepared by*

**SFC Engineering Company**

*In Association With*

*George V. Sabol Consulting Engineers, Inc.,*

JE Fuller/Hydrology & Geomorphology, Inc.,

SWCA, Inc. Environmental Consultants,

University of Arizona Water Resources Research Center,

*and the*

Arizona Geological Survey


■ November 1996 ■

SECTION 2

# ARCHAEOLOGICAL OVERVIEW OF THE SANTA CRUZ RIVER VALLEY

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# ARCHAEOLOGICAL OVERVIEW OF THE SANTA CRUZ RIVER VALLEY

*Dawn M. Greenwald*
*Dennis Gilpin*

Archaeology along most of the Santa Cruz River, particularly the middle Santa Cruz in the Tucson Basin, has received much attention, especially since the 1970s (Table 1). However, the upper Santa Cruz, designated here as the portion that originates in the Canelo Hills and continues through the San Rafael Valley to Nogales, Arizona, is an exception. This area is not well known archaeologically, and what little is known indicates that it was occupied prehistorically by people who were part of a different cultural system than the inhabitants of the lower and middle Santa Cruz River valleys.

## ARCHAEOLOGICAL PROJECTS

### Early Investigations

A large portion of the lower Santa Cruz River valley (from north of the Tucson Mountains to the confluence with the Gila River) was surveyed in the 1920s by Gila Pueblo (Gladwin and Gladwin 1929a, 1929b, 1930). The surveys covered an area east-west from Florence to the Sierra Estrella Mountains and north-south from the Phoenix Mountains to Chuichu. These reconnaissance surveys were conducted to determine the boundaries of the culture (later designated Hohokam) associated with red-on-buff pottery. In 1925 Dr. Byron Cummings directed another reconnaissance along the southwestern slopes of Tanque Verde ridge in the eastern Tucson Basin. This survey led to the excavation of about half of the Tanque Verde Ruin in 1927 by E. J. Hands. Haury (1927, 1928a, 1928b) discussed the findings on house types, and Fraps (1935) summarized the investigations.

A number of large, important sites were excavated in the 1930s. In the Tucson Basin, Cummings examined the Martinez Hill site, which was partially excavated by Gabel (1931) and partially restored. The site was located at the foot of Martinez Hill and about one-half mile east of the Santa Cruz River. It contained contiguous-room surface structures with thick adobe walls. Three of seven room blocks were excavated. University Indian Ruin, on the upper eastern terrace of Pantano Wash, was excavated first under the direction of Cummings (Kelly 1936), then during the late 1930s by Haury. Hayden investigated the site more

Table 1. Major Archaeological Projects along the Santa Cruz River

| Sponsor | Type of Project | Areal Extent | No. of Sites | References |
|---|---|---|---|---|
| Gila Pueblo | reconnaissance | E-W from Florence to the Estrella Mtns., N-S from the Phoenix Mtns. to Chuichu | >200 | Gladwin and Gladwin 1929a, 1929b, 1930 |
| Gila Pueblo | excavation | Snaketown | 1 | Gladwin et al. 1937 |
| Gila Pueblo | excavation | Hodges Ruin | 1 | Kelly 1978 |
| ? | survey | 70 miles along the Upper Santa Cruz River | ca. 140 | Danson 1946 |
| ? | survey | Pantano and Rillito drainages | ? | Rogers 1958 |
| NPS and U. of Arizona | excavation | University Indian Ruin | 1 | Hayden 1957 |
| | survey | From Tubac to Sahuarita along the Santa Cruz River | | Frick 1954 |
| ? | excavation | Black Mountain | 1 | Fontana, Greenleaf, and Cassidy 1959 |
| AZ State Highway Dept. | excavation | Punta de Agua | 10 | Greenleaf 1975 |
| Amerind Foundation | excavation | Palo Parado | 1 | Di Peso 1956 |
| City of Tucson | inventory and survey | Survey: Santa Cruz Riverpark, Tucson (ca. 22 km linear distance); Inventory: Tucson Basin | 63<br>487 | Betancourt 1978a, 1978b |
| AZ SHPO, NSF, ASM, BOR, AZ State Lands Dept. | survey - northern Tucson Basin | 707,200 acres, N-S from northern Tucson Mtns. to north of the Picacho Mtns., E-W from the Tortolita Mtns. to approximately Casa Grande | ca. 50 | Fish, Fish, and Madsen 1992 |
| | survey - southern Tucson Basin | | | Doelle, Dart, and Wallace 1985 |
| BOR | survey - Tucson Aqueduct, Central Arizona Project | Phase A: ca. 14,540 acres, Picacho Reservoir to Rillito<br>Phase B: 11,898.8 acres, Rillito to SW corner of San Xavier Indian Reservation | 89<br>57 | Czaplicki 1984; Herron and Ciolek-Torrello 1988<br>Downum, Rankin, and Czaplicki 1986; Seymour 1989 |
| BOR | excavation - Picacho Reservoir | Between the Picacho Mtns. and Picacho Reservoir | 21 | Bayham, Morris, and Shackley 1986 |
| BOR | excavation - Tucson Aqueduct, Phase A | Around the Picacho Mtns. | ca. 35 | Ciolek-Torrello 1988; Ciolek-Torrello, Callahan, and Greenwald 1988; Ciolek-Torrello and Wilcox 1988 |
| BOR | excavation - Tucson Aqueduct, Phase B | N-S from Rillito to south of Martinez Hill and west of the Tucson Mtns. | 13 | Czaplicki and Ravesloot 1989a, 1989b, 1989c |
| ANAMAX Mining Co. | survey - ANAMAX-Rosemont | 16,000 acres, around the Santa Rita Mtns. | 89 | Debowski 1980 |

Table 1. Major Archaeological Projects along the Santa Cruz River, continued

| Sponsor | Type of Project | Areal Extent | No. of Sites | References |
|---|---|---|---|---|
| ANAMAX Mining Co. | excavation - ANAMAX-Rosemont | | 32 | Ferg et al. 1984; Huckell 1984a |
| BOR | survey - Santa Cruz Flats | 951.2 acres, Santa Cruz Flats | 15 | Halbirt and Henderson 1993; Henderson 1988a, 1988b |
| BOR | excavation - Santa Cruz Flats | Santa Cruz Flats | 16 | Halbirt and Henderson 1993; Henderson and Martynec 1993 |
| BOR | survey - Santa Rosa Canal | 2689 acres, S of Maricopa through Santa Cruz Flats to S of Picacho Reservoir | 85 | Marmaduke 1993 |
| BOR | excavation - Santa Rosa Canal | | 60 | Marmaduke 1993; Marmaduke and Martynec 1993 |
| BOR | survey - Chuichu | 3408 acres, Chuichu District of the Papago Indian Reservation | 50 | Marmaduke and Robinson 1983 |
| BOR | sample survey - Gila River Indian Reservation | ca. 1400 acres | ? | Marmaduke and Conway 1984 |
| Pepper Tree Ranch and U. of Arizona Foundation | excavation | Los Morteros | 1 | Lange and Deaver 1989 |
| American Continental Corp. | excavation | Los Morteros | 1 | Bernard-Shaw 1989a |
| Pima Co. Dept. of Trans. | excavation | West Branch | 1 | Huntington 1986 |
| City of Tucson | excavation | Valencia | 1 | Doelle 1985a |
| | excavation | Lonetree | 1 | Bernard-Shaw 1989b |
| NSF | excavation | Dairy Site | 1 | Fish et al. 1992 |
| AZ Dept. of Transportation | excavation | San Xavier Bridge | 1 | Ravesloot 1987 |
| Pima Co. Dept. of Trans. and Flood Control District | excavation | Houghton Road | 1 | Ciolek-Torrello 1995 |
| American Continental Corp. | excavation | Redtail | 1 | Bernard-Shaw 1990 |

? = report does not specify
NPS = National Park Service; SHPO = State Historic Preservation Office; NSF = National Science Foundation; ASM = Arizona State Museum; BOR = Bureau of Reclamation

intensively in 1940 (Hayden 1957), excavating two groups of contiguous rooms with thick adobe walls. Excavations at Hodges Ruin commenced in 1936 under the direction of Carl Miller and were continued by Isabel Kelly in 1937. However, Kelly's employment with Gila Pueblo ended in 1938, and her work at the site was not reported (Betancourt 1978a:7). James Officer, a graduate student at the University of Arizona, worked on a report but never finished it, and a compilation of the data was finally completed in the 1970s by Kelly and Gayle Hartmann (Kelly 1978).

Between 1934 and 1935, Gila Pueblo excavated the large Hohokam village site of Snaketown (Gladwin et al. 1937), located on the north side of the Gila River about three miles west of Gila Butte. This work was a milestone in Hohokam archaeology, providing expanded and systematized knowledge on Hohokam material culture. Architecture, ballcourts, and canals were investigated, and the chronological sequence that the Gladwins developed is the basis for the chronology used today (Figure 1).

In 1941 Danson (1946) surveyed the Santa Cruz River from its headwaters in the San Rafael Valley to Tubac, and from 1937 to 1939 Mitalsky conducted an informal reconnaissance in the Tucson area. Another survey, by Frick (1954), completed in the early 1950s, covered the Santa Cruz Valley from Tubac to Sahuarita. In 1958 Malcolm J. Rogers surveyed the Pantano and Rillito drainages for pre-Hohokam occupation of the Tucson Basin (Rogers 1958).

The first work on the San Xavier Indian Reservation was undertaken in the late 1950s and 1960s. Investigations at San Xavier del Bac Mission started in 1958 (Robinson 1963), and Fontana, Greenleaf, and Cassidy (1959) documented features on Black Mountain, including rock walls, terraces (trincheras), petroglyphs, and circular stone enclosures, similar to feature assemblages found on top of Martinez Hill and Tumamoc Hill (Betancourt 1978a:10). In 1965-1966 excavations were carried out on four prehistoric sites on the Punta de Agua Ranch, funded by the state for the Highway Salvage Program of the Arizona State Museum (Greenleaf 1975). Important data gathered during this project led to the seriation of Rincon phase pottery into early, middle, and late variants (Huntington 1986:6).

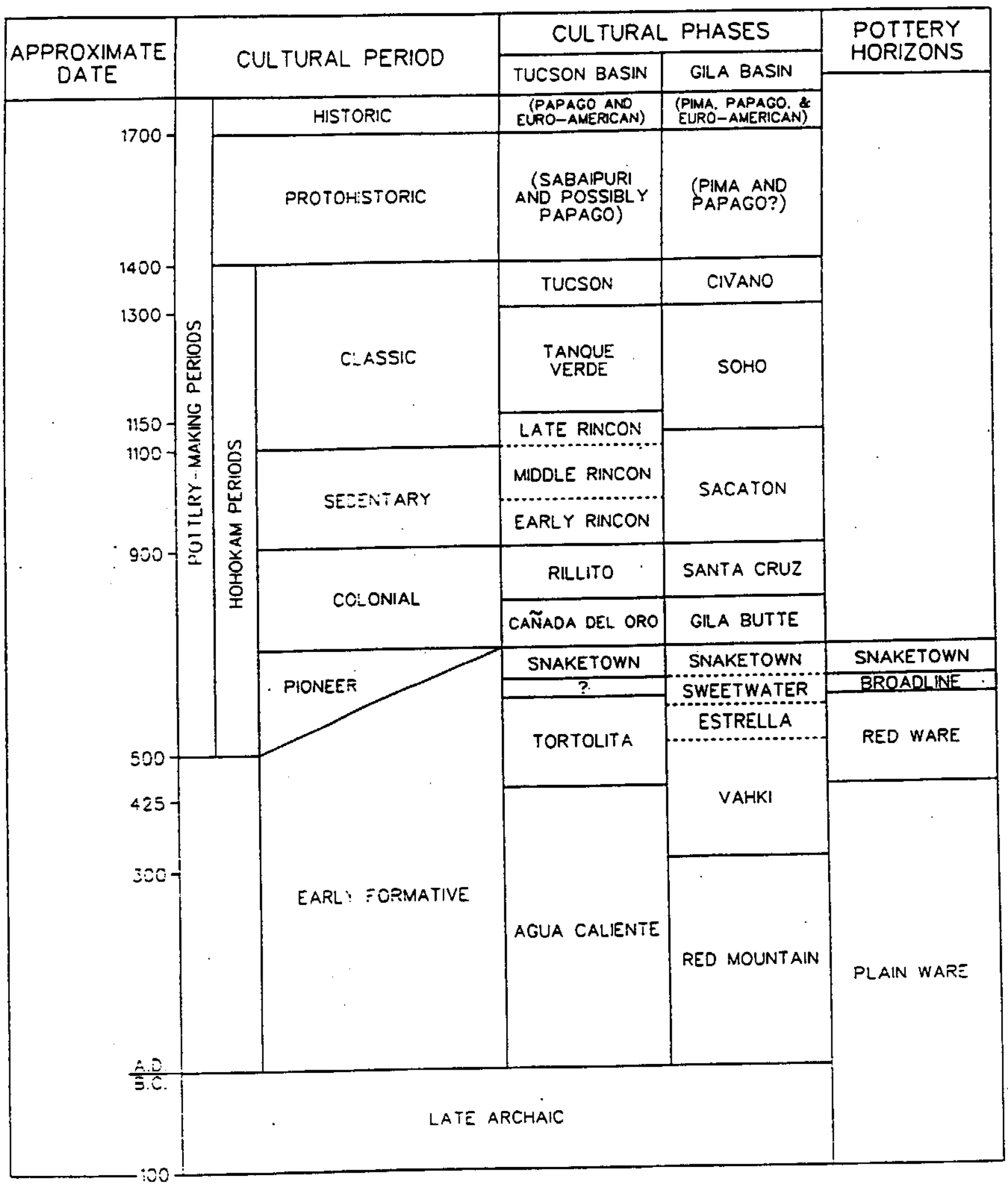


Figure 1. Cultural periods and phase sequences for sites along the Santa Cruz River (adapted from Deaver and Ciolek-Torrello 1995 and Wallace, Heidke, and Doelle 1995).

Other significant excavations took place prior to the 1970s. Di Peso (1956) reported on extensive excavations he conducted at the Paloparado (Palo Parado) site, a major southern outpost of the Hohokam. The Rabid Ruin, located on a terrace about 3 km upstream from the confluence of the Rillito with the Santa Cruz River, was excavated as a salvage operation by Laurens Hammack. Two Tanque Verde phase pit houses were excavated, and a cremation area was documented. Excavations on the Whiptail site began in 1966 and extended to 1971. The 20-60 acre site was located on a bajada at the foot of the Agua Caliente Hills. Fifty of the 100 houses identified were excavated, revealing a settlement pattern of dispersed house clusters and isolated houses. No report of this work has ever been published.

## Investigations since 1970

Since 1970 the amount of work conducted along the Santa Cruz River, particularly in the Tucson Basin, has substantially increased. One important project was the Santa Cruz Riverpark survey and management study by Julio Betancourt (1978a, 1978b). Betancourt documented and re-evaluated previous research in the Tucson Basin and established the existence of some important sites within highly developed areas in the City of Tucson. Other large surveys have included the Northern Tucson Basin (Fish, Fish, and Madsen 1984, 1992; Skibo 1988), the Southern Tucson Basin (Doelle, Dart, and Wallace 1985), the San Xavier Project (Doelle and Wallace 1986), Saguaro National Monument (Simpson and Wells 1983, 1984), the ANAMAX-Rosemont Project (Debowski 1980), the Tucson Aqueduct Project (Czaplicki 1984; Czaplicki and Mayberry 1983; Czaplicki and Rankin 1985; Downum, Rankin, and Czaplicki 1986; McCarthy 1982), the Santa Cruz Flats (Halbirt and Henderson 1993; Henderson and Martynec 1993), the Santa Rosa Canal Alignment (Marmaduke 1993; Marmaduke and Martynec 1993), the Chuichu District of the Papago Indian Reservation (Marmaduke and Robinson 1983), the Papago Water Supply Project (Dart 1987), and the Gila River Indian Reservation Sample Survey (Marmaduke and Conway 1984) (Figure 2). Most of these large surveys were the result of an increase in contract work due to the implementation of federal legislation to mitigate the effects of development.

In addition to the surveys, there has also been an increase in the number of sites that have been excavated, often due to their identification during survey and documentation as significant sources of archaeological data (i.e., eligibility to the National Register of Historic Places). Some major excavated sites include Los Morteros (Bernard-Shaw 1989a; Lange and Deaver 1989), West Branch (Huntington 1986), Valencia (Doelle 1985a), Lonetree (Bernard-Shaw 1989b), Redtail (Bernard-Shaw 1990), the Dairy Site (Fish et al. 1992), Tator Hills (Halbirt and Henderson 1993), Picacho Pass (Greenwald and Ciolek-Torrello 1988), McClellan Wash (Herron and Ciolek-Torrello 1988), the San Xavier Bridge Site (Ravesloot 1987), ANAMAX-Rosemont (Ferg et al. 1984), and Shelltown and the Hind Site (Marmaduke and Martynec 1993) (Figure 3). In many cases, these and similar sites filled in gaps in the culture history of the Santa Cruz River valley and contributed data that illuminated settlement structure, intra- and interregional interactions, the subsistence base, and changes in social and economic structures through time.

## CULTURE HISTORY

### The Paleoindian and Archaic Traditions

The Paleoindian tradition and the early stages of the subsequent cultural tradition, the Archaic period, are not well represented along the Santa Cruz River or in the Southwest in general. Chronologically sensitive diagnostic artifacts or features are often lacking for these time periods. Dart (1987:21) has postulated that there are two reasons for this: (1) surfaces containing evidence of early prehistoric activity are very eroded, and (2) if surfaces have remained intact, they probably are deeply buried. In fact, none of the Paleoindian artifacts known so far along the Santa Cruz were found in a context that is unarguably Paleoindian (i.e., they are all surface finds, with the exception of the Clovis point recovered from a Hohokam pit house at the Valencia Road site). The situation along the Santa Cruz therefore contrasts sharply with that in the San Pedro River valley, where buried Clovis kill sites have yielded evidence that continues to be remarkable in the context of New World prehistory. Paleoindian period occupations were adaptations to climatic conditions of the last Ice Age, which contributed to the availability of water sources and overall moist conditions. Between the Paleoindian and Archaic periods, there was a reduction in the available moisture, resulting in variations in water sources and a drier climate. After approximately 2050 B.C., available moisture increased. These climatic patterns contributed to fluctuating patterns in faunal and vegetal resources and thus to changes in human adaptations during these early periods.

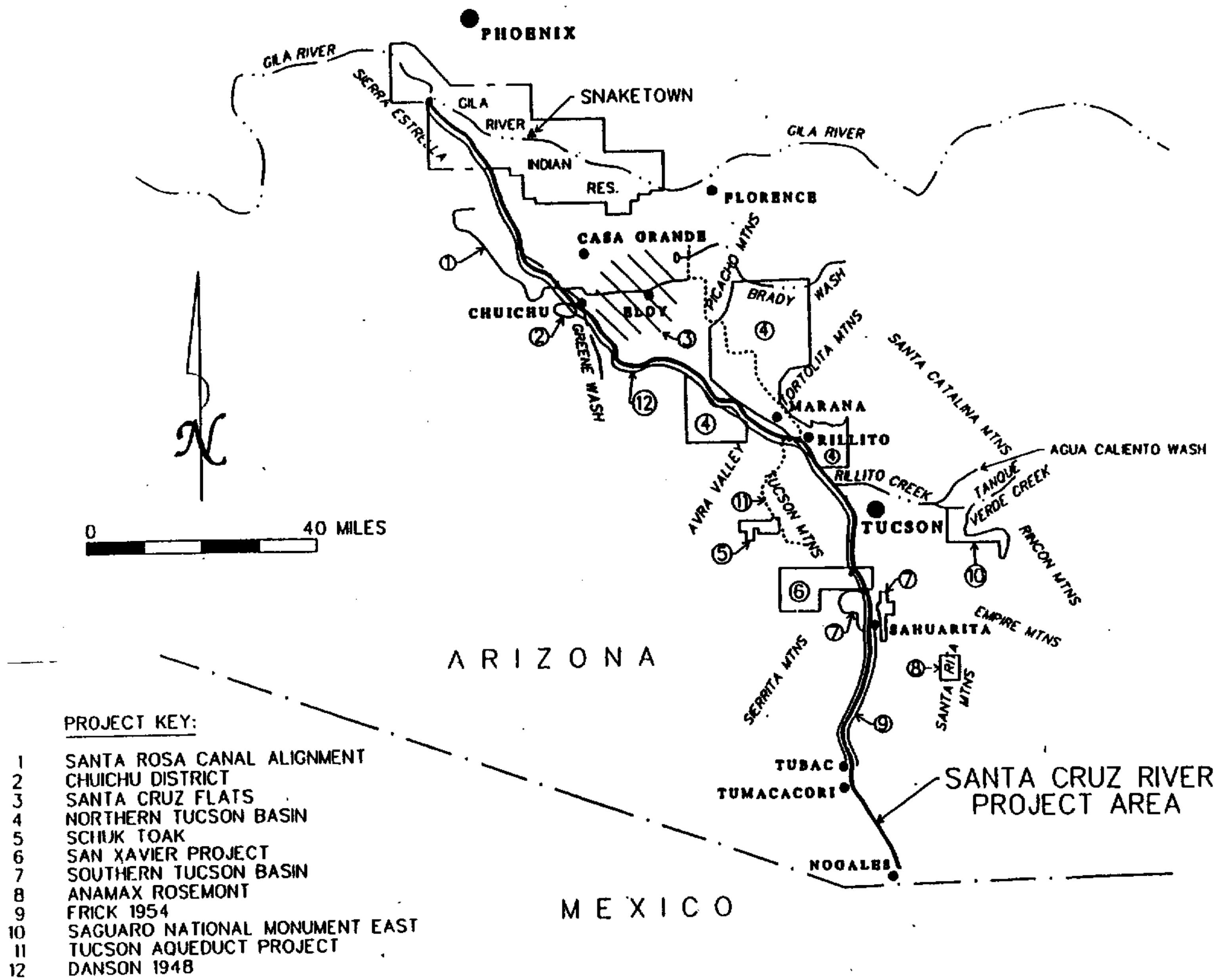


Figure 2. Recent archaeological investigations along the Santa Cruz River.

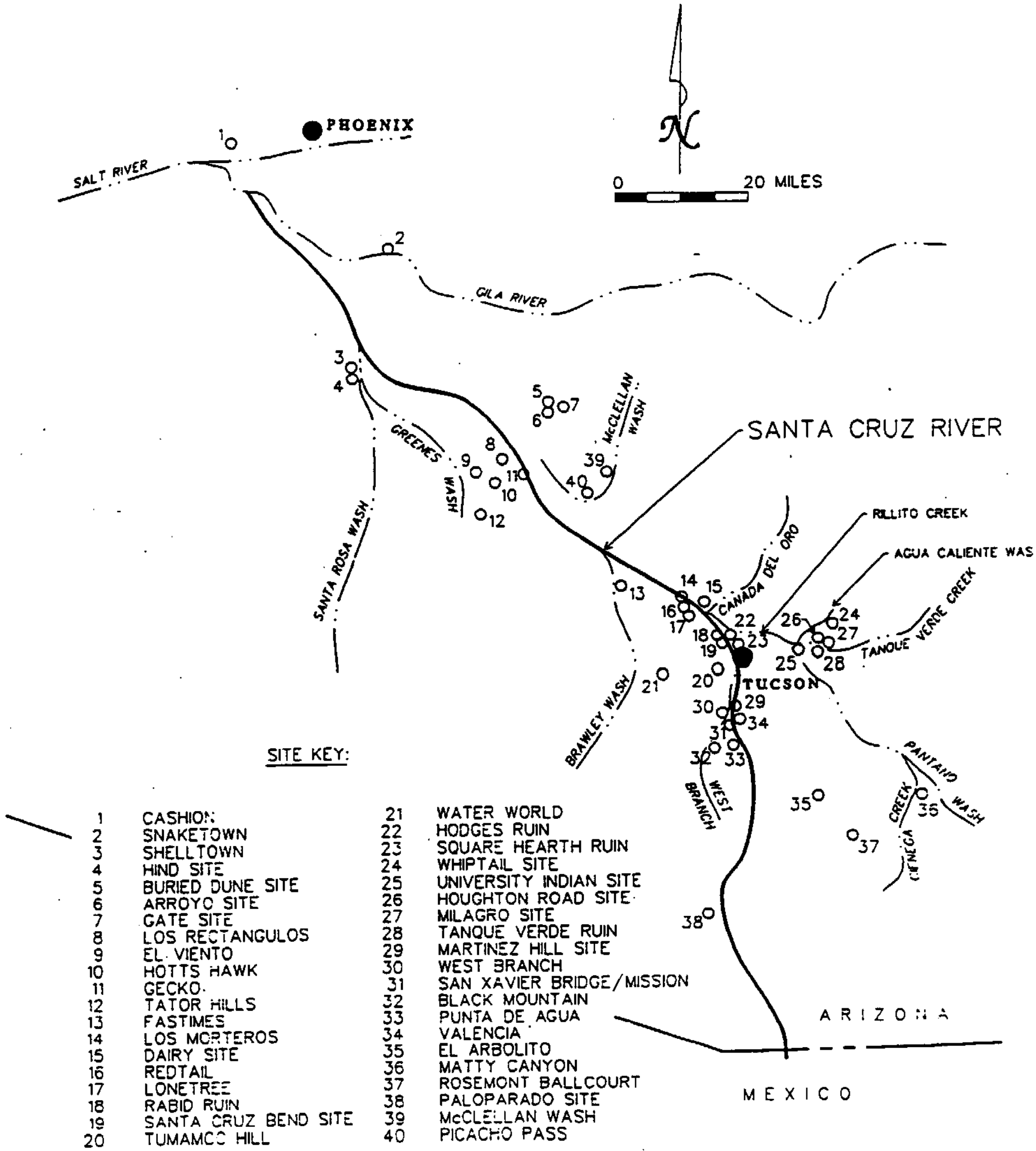


Figure 3. Excavated sites along the Santa Cruz River.

The Paleoindian tradition in North America is characterized by large spear points, flake blades and scrapers, and other flaked stone tools, and sometimes the associated remains of large late-Pleistocene mammals, such as bison and mammoth. Because well-produced, specialized spear points dominate Paleoindian assemblages, and known sites consist of camps and kill/butcher sites, archaeologists believe that Paleoindian subsistence was based primarily on hunting now-extinct megafauna. The earliest evidence of the Paleoindian tradition along the Santa Cruz River is termed the Llano Culture and is characterized by fluted Clovis points. It may date as early as 9500 B.C., and points diagnostic of this culture have been documented from the Rattlesnake Pass area of the Tucson Mountains (Agenbroad 1967:118), from the Avra Valley (Huckell 1982:15-19), near the southwest corner of San Xavier Indian Reservation (Betancourt 1978a:35), in the Santa Catalina Mountains (Huckell 1984b:134), and in the Tucson Basin (Doelle 1985a:181). Later Paleoindian occupations, the Plano Culture, are represented by lanceolate, unfluted knives and spear points and are associated with either modern species of fauna or an overlap of modern and extinct species (Jennings 1968:111-112). The Plainview projectile point is from the Plano complex and dates sometime between 8350 and 7850 B.C. (Huckell 1984b:135). Examples of this point type have been found in the Tortolita and Santa Catalina mountains (Dart 1987:19) and on the west edge of the Picacho Mountains (Wallace and Holmlund 1986:14).

The Archaic period, representing the Cochise culture, has been divided into three stages: Sulphur Spring (7500-3500 B.C.), Chiricahua (3500-1500 B.C.), and San Pedro (1500-ca. 100 B.C.). Tool assemblages from the Early and Middle Archaic, or Sulphur Spring and Chiricahua stages, exhibit a predominance of ground stone associated with plant food gathering and processing rather than the emphasis on hunting technology seen earlier. The Early Archaic is poorly documented (Huckell 1984a), but there is evidence for Middle Archaic sites along the Santa Cruz River. Near the Picacho Mountains, three sites have been dated to the Middle Archaic period. Two of these sites, the Buried Dune Site, a short-term field camp, and the Arroyo Site, a long-term base camp, were located in old dune deposits (Bayham, Morris, and Shackley 1986:368-369). The third site, the Gate Site, a hunting and gathering base camp, was in the lower bajada of the Picacho Mountains (Bayham, Morris, and Shackley 1986:98). In the Santa Cruz Flats project area, 17 sites contained Middle Archaic remains. Most of these sites were thermal features, such as roasting pits and fire-cracked rock concentrations, indicating that the primary activity at the sites was to gather and prepare food (Henderson 1993:382-383). Three sites contained structures, which appeared to be no more than temporary brush shelters. Henderson (1993:384) interprets the Middle Archaic occupation as comprising small, mobile groups moving seasonally in response to resource availability over extensive distances. Middle Archaic sites in the Tucson Basin included large base camps, small specialized activity areas, quarry sites, and possibly burials (Huckell 1984a:139). Sites in the Avra Valley represented short-term occupations for food gathering and processing activities.

Mobility patterns and subsistence practices changed dramatically, particularly in the Tucson Basin, between the Middle and Late Archaic. Late Archaic sites investigated in and around the Tucson Basin and Santa Cruz Flats, such as the Milagro Site (Huckell, Tagg, and Huckell 1987), Matty Canyon (Eddy and Cooley 1983), and the Tator Hills Site (Halbirt and Henderson 1993), were located in floodplains, areas adjacent to floodplains, or alluvial fans. Similarities among these sites are a relatively permanent water supply, an abundance of maize, small, informal pit houses, large intramural and extramural storage pits, many roasting pits and fire-cracked rock concentrations, middens, and overlapping inhumation and cremation areas (Ciolek-Torrello 1995:535). Houses averaged only 6 $m^2$ in area; they were built into shallow, basin-shaped pits with a pole framework covered with brush, hides, or grass (Halbirt and Copus 1993:44). Pit houses lacked hearths or entryways, but large storage pits were common internal features. Because much of the small space inside of pit houses was used for storage, it has been postulated that they were used primarily for storage and only secondarily as shelters (Ciolek-Torrello 1995:535). Recent excavations at the Santa Cruz Bend site have documented almost 200 houses dating between 400 and 200 B.C., with features and house types following this general pattern, although houses were larger and more variable in size (3-5 m in diameter) (Ciolek-Torrello 1995:537). Although this large settlement suggests that Late Archaic populations were aggregating during the maize-growing and harvesting seasons, there is evidence that such occupation was relatively short-term (Ciolek-Torrello 1995:537). Base camps located in bajada environments indicate that seasonal exploitation of resources still took place during the Late Archaic, so that full-time sedentism did not occur until the early Formative period. Food-processing equipment, such as milling stones, hand grinding tools, and projectile points, remained the same throughout the Archaic, suggesting both a continued reliance on wild seed plants and hunting practices and that maize cultivation, although important in the new diet, had not changed the Archaic subsistence pattern significantly enough to affect the technological system.

### The Archaic-Hohokam Transition

Recent investigations in the Tucson Basin have lent support to the theory that the Hohokam culture developed out of the Archaic tradition in Southern Arizona. The Late Archaic period showed the beginnings of sedentism while retaining the technological characteristics related to seasonal mobility. The Agua Caliente phase (ca. 50 B.C. - A.D. 425), represents a transitional stage between the Archaic and Hohokam traditions that saw the development of maize dependence, sedentism, a new ceramic and lithic technology, and large, permanent houses. Sites dating to this transitional period occur in a variety of environments, including the river floodplain and terraces, and are represented by the Houghton Road site (Ciolek-Torrello 1995), El Arbolito (Huckell 1987), and the Square Hearth site (Mabry and Clark 1994). Settlement patterns consisting of agricultural hamlets in floodplain settings and camps in bajada areas reflected a subsistence strategy based on floodwater farming of maize, garden hunting, and foraging in the bajada and upland zones (Ciolek-Torrello 1995:561). Late Archaic projectile point styles, bifacial reduction technology, and food-processing technology (milling stones and cobble handstones) remained the same; however, a new expedient flaked stone technology developed as well as a ceramic technology producing plainwares, smudged brownwares, and incipient redwares (Ciolek-Torrello 1995:561). Burials were a mixture of inhumations and cremations, and houses were circular, oval, or rectangular pits, averaging 8.9 $m^2$ in area, with well-defined entryways. Small, informal Archaic style houses with interior storage pits continued, and new bean-shaped communal houses appeared.

### The Prehistoric Ceramic Periods

The prehistoric ceramic periods are usually interpreted within the context of the Hohokam cultural sequence, which is divided into four periods: Pioneer (A.D. 425-750), Colonial (A.D. 750-950), Sedentary (A.D. 950-1150), and Classic (A.D. 1150-1400). Distinctions between the periods are based on diagnostic ceramic types and variations in architecture and other material culture.

### *Pioneer Period/Early Formative Period*

Along the lower Santa Cruz River, Pioneer period occupation resembles Hohokam cultural patterns. In the middle Santa Cruz River valley, the Pioneer period occupation has been argued to be more reflective of the Mogollon culture (Deaver and Ciolek-Torrello 1995:483) and has been termed the Early Formative. Little is known of the Pioneer period in the upper Santa Cruz River valley.

**Lower Santa Cruz**

During the Pioneer period, the first pottery vessels appear. The Hohokam lived in pit houses of various shapes and sizes, with clay-lined hearths, entryways, and a roof-support configuration of 2-4 posts, arranged in small clusters. A biseasonal settlement pattern is postulated, based on excavations along the Salt River valley, in which permanent winter villages and temporary summer hamlets co-occurred. The winter villages had formalized pit house architecture, and the summer hamlets contained ephemeral, informal structures (Cable and Doyel 1984:266-269). Interregional exchange is evident by the presence of Mogollon ceramics from the mountainous regions to the east and shell from the Sea of Cortez.

Early Pioneer period sites are lacking along the lower reach of the Santa Cruz River (Marmaduke and Conway 1984; Wilcox 1979); however, seven late Pioneer period sites are known along the Gila River where its course brings it close to the Santa Cruz River (Wilcox 1979:Figure 25). Sites were an average of 4.9 km apart (including the sites north of the Gila along the same river stretch) and fell into three size classes: one site was 0.025-35 acres in size; three sites were 50-165 acres in size; and three sites were 180-550 acres in size (Wilcox 1979:99, Figure 25). No Pioneer period sites have been identified in the Santa Cruz Flats (Halbirt and Henderson 1993; Henderson and Martynec 1993; Marmaduke 1993).

**Middle Santa Cruz**

The Early Formative period in the middle Santa Cruz Valley includes three ceramic horizons, two of which are correlated with phase names (Figure 1). The earliest is the Red Ware horizon, also known as the Tortolita phase, and it is represented by the Lonetree (Bernard-Shaw 1989b), Rabid Ruin (Slawson 1990), and Valencia (Huckell 1993) sites. This phase is marked by the addition of a slipped and polished redware, a greater variety of vessel forms, larger houses (ca.

16.2 $m^2$), a preference for semiflexed inhumations, and the emergence of a permanent and cohesive settlement structure (Bernard-Shaw 1990; Ciolek-Torrello 1995:543; Whittlesey 1995:471). Following the Tortolita phase is the Early Broadline horizon, identified by the appearance of red-on-brown pottery with broadline geometric patterns. Isolated sherds of this type have been found at the Dairy site (Fish et al. 1992), the Hodges Ruin (Kelly 1978), Paloparado (Di Peso 1956), and Valencia Road (Heidke 1993). One structure at Redtail Village has been assigned to this Early Broadline horizon (Deaver and Ciolek-Torrello 1995:486). It was a rectangular structure, 11.2 $m^2$ in area, with an entryway and thinly plastered walls and floor. Corn and agave remains were found on the floor (Bernard-Shaw 1989c:26-28). The late Early Formative period is the Snaketown phase and is concurrent with the Snaketown horizon. It is characterized by red-on-brown pottery with a hachure decorative style and some incising or scoring on the exterior of vessels. Ceramic technology reflected increasing influence from the Gila Basin, and some pottery may have been imported from the Gila Basin during this time (Deaver 1989:53). The lithic assemblages reflect typical ceramic period technologies, including corn-grinding equipment and expedient flaked stone tools. Structures of the Snaketown phase come from the Hodges Ruin, Redtail Village, and Hawk's Nest (Gardiner 1989:17-19) sites. Structures in the Tucson Basin were square to rectangular with long vestibule entryways. The structures at Hawk's Nest, in the Santa Rita Mountains to the southeast, were small and less formal; they were circular or oblong with vestibule entries. During the Snaketown phase,

> the Tucson Basin pottery tradition adopted many aspects of the Gila Basin Hohokam tradition that became even more strongly expressed in the Colonial period. It was probably at this time that the Hohokam emerged as a regional culture (Wilcox 1988:251; Cable and Doyel 1987; Doyel 1991; Fish 1989:28) with the Tucson Basin becoming a local node in the Hohokam regional system [Deaver and Ciolek-Torrello 1995:487-488].

### *Colonial Period*

The Colonial period is separated into two phases in the Tucson Basin: Cañada del Oro (A.D. 750-850), and Rillito (A.D. 850-950). During the Colonial period there is evidence for continuing village development, and the ballcourt system was in place. The ballcourt at Los Morteros probably dates to the Rillito phase. Ballcourt villages appear to be evenly spaced along the southern drainage (Doelle 1985a, 1985b; Doelle and Wallace 1986). By the end of the Colonial period, an expanding population saw most villages along secondary rather than primary drainages of the Santa Cruz in the Tucson Basin (Betancourt 1978a:18). Sites with components dating to the Colonial period included Redtail Village, Hodges Ruin, the Dairy Site, Rosemont Ballcourt, Fastimes, and Water World (Deaver and Ciolek-Torrello 1995).

Evidence from Water World and Fastimes indicated that houses were clustered into groups sharing common areas or courtyards (Czaplicki and Ravesloot 1989a:13-14) and that cremation areas were separated from the habitation areas. At Fastimes, five separate house groups or farmsteads were identified; seven house groups were documented at Water World. One of the latter house groups represented a permanent occupation, and the other six appeared to represent winter occupation (Czaplicki and Ravesloot 1989c:13). Occupants of these sites, which were located along the bajada on the western slopes of the Tucson Mountains, practiced seasonal floodwater farming using the natural runoff from gullies or arroyos that spread out over gully-mouth fan surfaces. It is postulated that these sites were eventually abandoned when headcutting of the fan surfaces limited or destroyed ideal farming conditions (Czaplicki and Ravesloot 1989a:16-17).

### *Sedentary Period*

The Sedentary period is represented by the Sacaton phase in the lower Santa Cruz River/Gila Basin area and by the Rincon phase in the Tucson Basin, although some archaeologists perceive the late Rincon phase as part of the Classic period (Bernard-Shaw 1989c). This was a period of population growth and expansion. Villages were located along primary and secondary drainages, with large villages associated with smaller hamlets and farmsteads. Most known sites in the lower Santa Cruz Valley have only been surveyed; sites in the Tucson Basin are better known because many have undergone excavation. Sites dating to this period include Valencia, West Branch, Hodges Ruin, Tanque Verde Wash, and Punta de Agua. During the Sedentary period, there was a reduction in Phoenix-Tucson Basin contact, an expansion of local ceramic traditions (Bernard-Shaw 1989c:7), and a preference for inhumations. Greenleaf (1975) believes that the Santa Cruz River was the line of communication for the dissemination of a new type of pottery, Rincon Polychrome. Vessels of this type "were found at the north and south extremities--one near Cashion where the Santa Cruz joins the Gila, and the other at Paloparado" (Greenleaf 1975:109).

Houses at the Punta de Agua site changed from a variety of shapes (oval, square, or subrectangular) in the Rillito phase to oval or subrectangular in the early Rincon phase, to usually subrectangular during the middle and late Rincon phases (Greenleaf 1975:36). The shape of the entry also changed from short and straight sided during the early Rincon to large and bulbous during the late Rincon. At the West Branch site, Rincon habitation structures were quite variable in size. In the Wyoming Street precinct, domestic structures were divided into four size classes: less than 10 $m^2$; 10-15 $m^2$; 15.5-20 $m^2$; and more than 20 $m^2$.

Doelle, Huntington, and Wallace (1987) have found similarities in community organization during early and middle phases of the Sedentary period and a reorganization or shift in settlement pattern by the late Rincon phase. Part of this shift in settlement location (away from the floodplain) was due to floodplain entrenchment and cienega formation (Waters 1987a:60). Nonriverine agricultural features, such as rock piles, check dams, terraces, and large roasting pits, began to appear on terraces and bajadas. Settlement-pattern shifts have been documented in the San Xavier Project area, at Ventana Wash, and in the ANAMAX Project area (Doelle, Huntington, and Wallace 1987:81).

### *Classic Period*

The Classic period is represented in the Tucson Basin by the Tanque Verde phase (A.D. 1150-1300) and the Tucson phase (A.D. 1300-1400). During the Tanque Verde phase, the size of sites along primary drainages increased, but the number of sites declined. House styles changed to rectangular structures with free-standing adobe walls. There was continued use of nonriverine agricultural systems as well as floodwater farming. Large Classic period sites were documented in the Santa Cruz Flats, where the occupational focus extended from the alluvial plain near Greene Wash to the Santa Cruz River (Henderson and Martynec 1993:591). At Santa Cruz Flats the primary habitation zones—represented by large villages such as El Viento (256 hectares), Gecko (16 hectares), and Los Rectángulos (60 hectares)—appeared to be associated with a zone of secondary habitation sites, such as the Hotts Hawk farmstead (Henderson and Martynec 1993:583).

During the Tucson phase, contiguous pueblo structures appeared that were surrounded by compound walls. Other traits included platform mounds, inhumations, and intrusive polychrome ceramic types from the Tonto Basin area. The number of sites continued to decrease as their size continued to grow. Sites representing this time period include Martinez Hill, Tumamoc Hill, and Black Mountain (Betancourt 1978a:20). At the culmination of the Tucson phase, these sites appear to have been abandoned.

## The Protohistoric Period

The protohistoric period is the transition between the prehistoric and historic periods, from approximately A.D. 1400 to 1700. The Paloparado Ruin was identified by Di Peso (1956) as a site containing a short Hohokam occupation followed by an "Upper Pima" occupation from around A.D. 1250 through 1751. Di Peso's interpretation has been the subject of considerable debate, with most archaeologists arguing that there was no protohistoric component at all.

Doyel (1977) has attributed the England Ranch Ruin, near Calabasas, to an Upper Pima phase (A.D. 1500-1700) based on similarities with excavated sites in the San Pedro Valley (Betancourt 1978a), although no evidence for Spanish contact was found (Ravesloot and Whittlesey 1987:90). Isolated artifacts and a burial have been identified as "Sobaipuri" (Ravesloot and Whittlesey 1987:90-91), a general term used for the protohistoric culture(s) of southern Arizona.

## The Historic Period

A considerable amount of historical archaeology has been done along the Santa Cruz River, most of it focusing on Spanish missions and presidios and historic Tucson. A few homesteads, rancherías, and mining sites have also been investigated. Barnes (1984) and Whittlesey, Ciolek-Torrello, and Sterner (1994) provide good overviews of the historical archaeology in the region. In addition, Ayres (1981, 1983, 1987, 1988a, 1988b, 1988c, 1989, 1990a, 1991, 1992a, 1992b, 1992c, 1993a, 1993b, 1993c, 1995) has summarized ongoing research in the Santa Cruz River valley and has presented some information on a number of projects that have not been published. A common approach of historical archaeologists working in the Santa Cruz River valley has been to use archival data to identify the ethnicity, occupation, social class, and gender of particular sites, then to see how these various social statuses and roles are reflected in artifact assemblages. Ultimately, the objective is to reconstruct the daily lives of different groups of people during this period.

### *Spanish Colonial Archaeology*

Spanish colonial archaeology has focused on the Spanish missions at Guevavi, Tumacacori, San Xavier del Bac, and San Agustín (at Tucson) and the presidios at Tubac and Tucson. Between 1964 and 1966, William J. Robinson conducted excavations in the convento at Guevavi, a Spanish mission on the Santa Cruz just north of the international border (Robinson 1976). The mission was established in 1701 by Father Kino at a Sobaipuri community he had observed in 1691, but the structures excavated by Robinson dated to the mid to late eighteenth century. After Guevavi was acquired by the Archaeological Conservancy, National Park Service archaeologists mapped and this site and nearby Calabazas (Burton 1992a) and conducted excavations at Guevavi. The site was then made an outlying component of Tumacacori National Monument (Burton 1992b). From September 8 to October 24, 1980, Lee Fratt and Maurice Montgomery of the National Park Service Western Archeological and Conservation Center conducted excavations at the convento at Tumacacori National Monument (Ayres 1981:37-38; Fratt 1981, 1986; Shenk 1976), a Spanish mission established in 1691 and abandoned in 1844.

In 1963 archaeology students from the University of Arizona and avocational archaeologists from the Arizona Archaeological and Historical Society conducted excavations at Mission San Xavier del Bac, established in 1691 and still in use (Robinson 1963). Although the purpose of the excavations was to try to find evidence of occupation of the Santa Cruz River valley between about 1450 and 1540, nothing was found that could be dated prior to the eighteenth century. Cheek's (1974) dissertation is on the historical archaeology of Mission San Xavier del Bac. The Arizona State Museum conducted additional work at the site in conjunction with the U.S. Bicentennial in 1976 (Ciolek-Torrello and Brew 1976). More recently, Jack S. Williams excavated inside a room adjacent to the nave of the mission church and identified a series of floors and related artifacts dating between about 1700 and 1900 (Ayres 1988a:35).

Excavations at the Presidio of San Ignacio de Tubac by the Arizona State Museum are described by Shenk and Teague (1975). Excavations at Tubac by Williams and Ivonne De La Cruz of the Center for Spanish Colonial Archaeology have not yet been published, but Ayres (1988b, 1988c, 1989, 1992a, 1993b) has summarized these studies. According to Ayres (1988b:39), "Tubac was the location of a mission visita/farm (1732-1751), and later of Spanish

(1752-1776; 1787-1821) and Mexican (1821-1849) presidios (military bases) as well as two Apache Peace settlements (1790-1848; 1851-1854), a major mining camp (1855-1860), and a Mexican military colony (1851-1854)." Ayres (1992a:31) also states, "Between 1856 and 1861, the settlement was the largest mining and commercial center in what would become Arizona Territory. During the later nineteenth century, Tubac continued as a relatively small agricultural and ranching village. Ethnic groups present at Tubac prior to 1900 include Pimans, Opatas, Yaquis, Apaches, Piros, Chinese, Mexicanos, Africans, other Hispanos, Germans and Anglo-Americans." Ayres (1989:38) mentions that by 1989, research was focusing on identifying specific buildings shown on a 1766 map by Josef de Urrutia. Fifteen to 25 mounds had been recognized in the southern half of the site, and the total number of buildings was estimated at between 100 and 150. Ayres (1992a:31) reported on the continuation of this project, stating that by 1991, 150 to 200 structures had been identified in this area, and excavations had been conducted in the south end of the Captain's house and in the Otero residence, two adobe structures that were occupied in the second half of the eighteenth century. In 1991 Williams and De La Cruz excavated a group of adobe houses around a small plaza. In 1993 excavations in a segment of an eighteenth century acequia (aqueduct) exposed a structure of upright poles that dated to the initial period of occupation (1732-1751)(Ayres 1993b:27). Excavations have also been conducted in the east midden and at the site of the Luis Lim Mercantile (ca. 1900-1920), where evidence of earlier structures was found, "including a Spanish period house not shown on the 1766 Urrutia plan" (Ayres 1993b:27).

Mission San Agustín, on the west side of the Santa Cruz River south of Congress Street in Tucson, is designated Site AZ BB:13:6(ASM). Established in 1757 as a visita (a mission where church services were provided by a visiting priest who resided at another mission) on the site of an earlier village and consisting at one time of "a Pima village, a chapel, a large two-storied structure (the convento), a granary, and an orchard" (Betancourt 1978:68), Mission San Agustín was studied in 1949-1950 and 1956, before its destruction by development (Betancourt 1978b:68-70). The first excavations were conducted in 1949-1950, when three areas, including two cemeteries, were excavated prior to expansion of a brickyard. In 1956 excavations were conducted in the mission buildings and the compound wall before the area was turned into a landfill. More recently, excavations at the site have identified some outlying features and recovered additional artifacts (Ayres 1988b; Ciolek-Torrello and Whittlesey 1991;

Deaver and Albright 1992; Elson and Doelle 1987; Williams 1986). Williams (1986) identified a stone-lined acequia that possibly dated to the colonial period, although it was probably later reused by Solomon Warner as a millrace in the 1870s (Ciolek-Torrello and Whittlesey 1991). In the summer of 1988, and De La Cruz conducted excavations at the Mission Gardens/Castañeda site at the base of Sentinel Peak ("A" Mountain) and identified orchards and related outbuildings and granaries of the Mission Visita de San Agustín (Ayres 1988b:39-40). A portion of the San Agustín Mission complex south-southeast of the two-story convento and east of the Carillo house was tested by Statistical Research, and few intact deposits were found (Ayres 1992b:21-22; Ciolek-Torrello and Whittlesey 1991).

The Presidio of San Agustín del Tucson was first archaeologically investigated by Emil Haury and Edward Danson (Haury and Fathauer 1974; Olson 1985). In 1987 Williams conducted excavations at the Tucson Metropolitan Library site, located outside the boundaries of the Spanish presidio, and recovered artifacts dating between 1775 and 1900 (Ayres 1987:41; Williams 1988). Portions of the Presidio wall were identified during 1992 excavations conducted by Homer Thiel in the courtyard of the 1919 Pima County Courthouse (Ayres 1993a:22; Thiel, Faught, and Bayman 1993). The original wall of the Tucson Presidio was built between 1776 and 1783, but extensions and repairs may have been made later. The wall fell into disrepair in the 1850s. At the Spanish Presidio Cemetery, which dated from the 1770s to the 1860s, 19 complete burials of Caucasians and Native Americans were relocated to make way for a gas line, and dozens of other graves were identified (Faught 1992; Thiel, Faught, and Bayman 1993).

### *The Santa Cruz River at Tucson*

Studies of the San Agustín Mission have already been described, but other archaeological studies along the Santa Cruz River at Tucson have identified more recent historic sites. The survey of the proposed Santa Cruz Riverpark Archaeological District in Tucson (Betancourt 1978b), from Camino del Cerro to Los Reales Road, resulted in the identification of 19 historic sites, including four Sobaipuri or Piman burials, San Agustín Mission, Warner's Mill, the Pioneer Mill, two homesteads, a foundation and brick cistern, two irrigation systems (the Crosscut water recovery and distribution system and Farmer's Ditch), a lime kiln, a dump, and five artifact scatters. Two of the burials were thought to be associated with San Agustín del Oiur (or Oyaut), a Sobaipuri village shown on Kino's 1695-1696 map (Bolton 1936:272). One of the artifact scatters may be associated with the Silver Lake Hotel.

Ayres (1981:38) reported that the 1980 Pima College survey of Midvale Farms, on the West Branch of the Santa Cruz River at the southwestern edge of Tucson, recorded two late-nineteenth century rancherías that were scheduled to be excavated in 1981. In 1979, Bruce Huckell excavated a three-room structure at the late-nineteenth century community of Los Reales on the east side of the Santa Cruz (Ayres 1984:228). David Stephen, J. R. Billings, and Douglas Craig of Pima College excavated three houses at Los Reales (Ayres 1983:41).

### *Downtown Tucson*

In addition to archaeological research on the Presidio of Tucson, a number of archaeological projects have been conducted in downtown Tucson that have investigated numerous sites dating to the territorial period and modern development of the city. Motsinger, Bierer, and Stein (1993) summarize historic sites within the City of Tucson Downtown Heritage Incentive District and provide a bibliography of previous work conducted within the district.

The Tucson Urban Renewal Project ran from 1967 to 1972 and investigated sites dating from 1776 to 1920. Although a number of specialized studies (Anderson 1968, 1970; Ayres 1978, 1990b; Barnes 1983, 1984; Clonts 1983; Lister and Lister 1989; Olsen 1978; Renk 1969; Roubicek 1969) came out of this research, the project is largely unreported.

Excavations just outside the walls of the Tucson Presidio identified over 90 historic and prehistoric features, most of which dated between about 1870 and 1920. These included 31 foundations, 1 well, 4 privies, 3 refuse deposits, and a grave (Ayres 1990b:44). The work was conducted by Richard Ciolek-Torrello of Statistical Research, Inc. (SRI).

Ciolek-Torrello and Mark Swanson of SRI conducted excavations in an area of downtown Tucson adjacent to the location of previous excavations that had exposed portions of the presidio of San Agustín del Tucson (AZ BB:13:9[ASM]). Ciolek-Torrello and Swanson found over 100 prehistoric and historic features, most dating from 1880 to 1912. Included were "three large trash-filled borrow pits, seven privies, and two wells" (Ayres 1991:33). Ciolek-

Torrello and Swanson identified 116 features, including "numerous adobe and masonry house foundations, privies, wells, septic tanks, and small trash deposits dating to the late nineteenth and early twentieth centuries" (Ayres 1993a:21).

In 1990, Jonathan Mabry of Desert Archaeology, Inc., excavated a city block (Block 83) in downtown Tucson, identifying 32 features, primarily "foundations, trash piles, latrines, and well shafts" (Ayres 1993a:21; Mabry 1991). Desert Archaeology also conducted excavations at the Hotel Catalina Site (AZ BB:13:405[ASM]), the DeLong House, the Presidio Wall, and the Presidio Cemetery (AZ BB:13:13[ASM]). Excavations by Mabry and Lisa Eppley at the Hotel Catalina Site, first occupied between 1889 and 1896, identified mostly foundation remains, although a privy and trash pit were also found and excavated (Ayres 1993a:21). The DeLong House site (excavated by Jim Bayman) consisted of the adobe foundations of two structures: a house built between 1862 and 1886, and a house built over the earlier foundations sometime prior to 1886, when the DeLongs purchased it. The DeLong House was demolished in 1929 to make way for the third Pima County Courthouse (Ayres 1993a:21-22). Excavations conducted by Homer Thiel in 1992 in the courtyard of the 1919 Pima County Courthouse resulted in the identification of the Presidio wall and "portions of the 1881 County Jail, the 1883 Pioneer Hose firehouse, the 1883 City Jail, a shortlived fountain dating to 1929, and an early twentieth century privy" (Ayres 1993a:22; Thiel, Faught, and Bayman 1993). In 1992 Danielle Desruisseaux conducted excavations in Tucson Block 138 in the Barrio Libre, the historic Mexican neighborhood of Tucson, and found 50 features dating from the 1880s to 1990, including foundations for houses and outbuildings, as well as wells, privies, and bottle dumps. These features were associated with "the Soto (Yaqui Indian), Torres (Mexican), and Ransom (Afro-American/Mexican) families" (Ayres 1993a:22). Research on these sites focused on the study of ethnicity, gender, and social class and how they are reflected in artifact assemblages and faunal remains.

### *Mining*

In 1982 the Arizona State Museum and Archaeological Research Services conducted excavations at 30 historic sites in the Helvetia-Rosemont Mining District in the Santa Rita Mountains east of the Santa Cruz River (Ayres 1984). The sites included the town of old Rosemont (1894-1910), new Rosemont (1915-1921), the Rosemont school, 12 mining-related sites, five ranches, a Forest Service facility (1904-1937) comprising two sites, and seven sites of indeterminate or miscellaneous function.

In 1992 Laurie V. Slawson and Ronald P. Maldonado of Cultural and Environmental Systems, Inc., (CES) conducted excavations at a historic mining camp near the San Xavier Mine southwest of Tucson. The site (AZ DD:4:202[ASM]) consisted of a possible habitation area and associated artifacts dating between about 1900 and 1930 (Ayres 1992c:36). Slawson and Ayres (Ayres 1993c) also conducted research on the Vulcan Mine and an associated mining camp in the Pima Mining District south of Tucson. The Vulcan Mine was in operation from 1896 to 1923 (Ayres 1993c:33). Whittlesey, Ciolek-Torrello, and Sterner (1994:333) summarize excavations conducted by CES at four sites in the Silver Bell Mining District southwest of the Santa Cruz River and northwest of Tucson. The Tin House Well site (AZ AA:10:5[ASM]) was a large mine and associated camp, the Happy Hour site (AZ AA:10:3[ASM]) was a small mining camp, and sites AZ AA:10:12(ASM) and AZ AA:10:26(ASM) were two cemeteries associated with the town of Silver Bell.

### *Farming and Ranching*

McGuire (1979) reports on excavations at the Punta de Agua ranch on the Santa Cruz River south of San Xavier. The site was established by Fritz Contzen in 1855 and occupied by him until 1867, when it passed into the hands of Juan Elias, who lived there until it was included in the San Xavier Indian Reservation in 1877. McGuire studied the relationship between economic and social status of the occupants of the site and the ways ethnicity is reflected in the archaeological record.

In an archaeological survey along the Santa Cruz River northeast of Tucson, Stein (1993) recorded a number of homesteads dating from the 1880s to the 1900s and twentieth-century farms operated by the Pima Farm Company and Cortaro Farms. In 1978 archaeologists from the National Park Service excavated the Lewis-Weber site, a homestead dating from 1882 to 1910 that is now within the City of Tucson (Curriden 1981).

### *Other Studies*

Whittlesey, Ciolek-Torrello, and Sterner (1994:339) summarize unsuccessful attempts to archaeologically identify several historically documented stage stations that have been archaeologically documented along the Santa Cruz River northwest of Tucson. Stein (1990) hypothesized that the oldest of these, the Point of the Mountain Butterfield Stage Station (1858), which later became the Ruelas Ranch (1876-1898), had been destroyed by a trailer court.

## The Upper Santa Cruz River

So little of the culture history of this portion of the Santa Cruz River is known that it is appropriate to describe the scant evidence separately. The occupation of this portion of the river valley has been described only in old survey or reconnaissance data (Danson 1946; Frick 1954; Sauer and Brand 1931). Most of this information indicates that cultural affiliations and settlement patterns were quite different in the upper Santa Cruz valley than in the middle and lower portions (Wilcox 1987:241).

The earliest dated sites are from the Colonial period (Danson 1946:39), although there were many campsites and other temporary sites that (1) did not contain ceramics and could represent either preceramic cultures or short-term ceramic period occupations, or (2) contained mostly plainwares, which are not generally temporally diagnostic. Campsites were found along the entire length of the upper Santa Cruz, with the majority occurring in the San Rafael Valley near the headwaters of the river. Most were located on the bluffs overlooking the river, and some of these sites, according to Danson (1946:10), represent Papago occupation. Large campsites with numerous sherds, mostly plainware, and some ground stone were found throughout the upper Santa Cruz on the edge of low bluffs and terraces above the valley floor. These were early ceramic period sites, although they could not be assigned dates. "Late Sherd Areas" were all found north of the international border. These sites contained more pottery, including decorated wares, and the ground stone assemblage was dominated by trough metates, indicating a corn-based diet. Many of these sites were associated with permanent village sites, suggesting that they represented hamlets or farmsteads of the Colonial or Sedentary periods.

Classic period sites are identified as "Compound Sites" (Danson 1946:18) and terraced hill, or trincheras, sites. After re-analyzing the data from Di Peso's excavations at the Paloparado site, Wilcox (1987:239) determined that the Classic component of the site was strikingly different from the Colonial-Sedentary period Hohokam occupation. The Classic period occupation consisted of a closely aggregated series of more than 15 domestic compounds, each composed of 3-8 houses with entryways facing a common courtyard that contained work and burial areas (Wilcox 1987:246). According to Wilcox,

> Other sites similar to the Classic component at Palo Parado exist in the Rio Rico area, and sites as far up the Santa Cruz as the San Rafael Valley exhibit analogously aggregated compound site structure (Sauer and Brand 1931; Danson 1946; personal observation). The structure of these sites contrasts with that in the Tucson Basin (Wallace and Holmlund 1984), and the local ceramics are different. Palo Parado Ruin thus appears to lie near the northern end of a settlement system different from the one in the Tucson Basin [Wilcox 1987:241].

Danson (1946:18) found two of six compound sites north of the international border; four were found in Sonora.

Another site type was the "house ring," circular or oval rings of rock with cleared areas in the center. Danson (1946:12) attributes this type of site to the protohistoric period.

## ENVIRONMENTAL RECONSTRUCTIONS

Interpretations of Holocene vegetation and climate have engendered much debate, but the generally accepted view is the sequence developed by Antevs (1955, 1962) and Sayles and Antevs (1941) with three basic periods: the Anathermal, the Altithermal, and the Medithermal. The subhumid Anathermal occurred circa 9000-5500 B.C.. The arid, hot Altithermal (ca. 5500-2000 B.C.) followed, to be succeeded by a semi-arid Medithermal with a moist initial phase and drought oscillations (Gish 1993:204). This scenario represents a general regional trend, with more variable local depositional histories dependent on the nature of a particular fluvial system, such as the size and character of the watershed and local floodplain dynamics. In fact, Waters (1989:Figure 3.7) shows that periods of channel downcutting and filling were specific to different water systems (e.g., the San Pedro River, Cienega Creek, Whitewater Draw, the Santa Cruz River).

Generally, data indicate that, prior to 1890, large segments of the Santa Cruz floodplain were not entrenched:

> The Santa Cruz River flowed intermittently through a broad, flat, grassy valley within a narrow, shallow channel. The river was surrounded by numerous mesquite thickets and occasional cottonwood groves, and was supported by a shallow water table. Discharge was normally confined to the small channel, and only during infrequent storms did water overtop the banks and spread over the floodplain. These stretches of the river were punctuated by wet marshlands or cienegas at a few locations where groundwater was forced upward to the surface [Waters 1987a:42].

Prehistoric environmental conditions along the Santa Cruz River have been reconstructed from archaeological studies using paleobotanical, paleofaunal, and geomorphological investigations. Perhaps the most intriguing studies have been the reconstructions of the depositional environments and hydrologic conditions in the middle Santa Cruz Valley (Haynes and Huckell 1986; Waters 1987a, 1987b, 1989). Haynes and Huckell (1986) developed a general stratigraphic sequence for the Santa Cruz River based on exposures 5-12 km south of the San Xavier Bridge site. The sequence suggested that the alluvial history of the river was relatively stable until approximately 550 B.C., when floodplain aggradation occurred. Haynes and Huckell defined five major episodes of alluvial downcutting and filling.

Other stratigraphic investigations were conducted at the San Xavier Bridge site (Waters 1987b), with correlations made to natural exposures upstream and downstream of the site. Seven major geologic units were defined, and dates were derived from radiocarbon and archaeomagnetic samples. Waters determined that the alluvial environment along the Santa Cruz was used by Late Archaic, Hohokam, and Postclassic populations. Channel erosion and widening occurred during Paleoindian through Middle Archaic times (Figure 4), followed generally by channel filling during the Late Archaic. During the Pioneer and early Colonial periods, the floodplain was entrenched, which "would have made farming impossible on the upper floodplain or in the river bottom; only after filling would farming be possible" (Waters 1987b:57). Waters believes that the floodplain would have been suitable for farming during the Rillito and early Rincon phases, with additional floodwater farming possible on the discontinuous channel fans that composed the lower bajada (ak chin farming) (Waters 1987b:59). This period corresponded to intensive occupation on the floodplain. During the

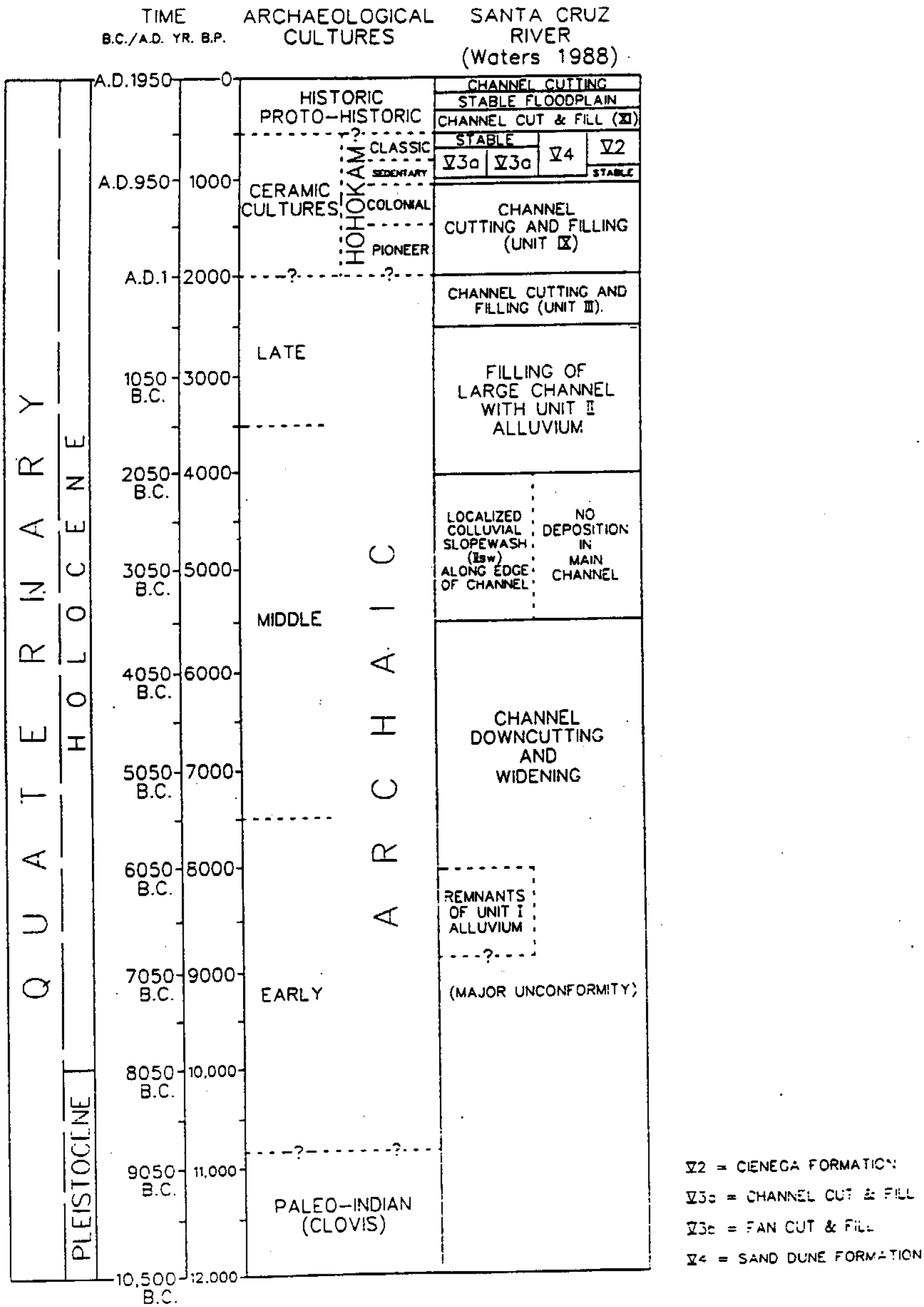


Figure 4. Alluvial sequence for the Santa Cruz River along the San Xavier reach (from Waters 1989:Figure 3.7).

middle Rincon phase, prehistoric settlement shifted to the north. Waters believes that the shift may have been related to the development of dunes and the entrenchment of the southern floodplain, as well as the cutting of a discontinuous gully in the southern portion of the reservation (Waters 1987b:59). Another shift in settlement, from the west to the east side of the river during the late Rincon phase, corresponded to continued headcutting of the discontinuous gully, which probably destroyed arable land, and to the emergence of a cienega environment to the north. The cienega near Martinez Hill apparently attracted settlement during the Tanque Verde phase, as the number of sites continued to increase on the east side of the river, particularly around Martinez Hill. The river channel in the southern portion of the reservation stabilized and began to fill at this time. These conditions continued through the Tucson phase, after which sites were abandoned, at about the same time that major entrenchment of the Santa Cruz floodplain was taking place (Waters 1987b:59). The channel filled again during protohistoric occupation of the San Xavier Bridge site.

In the Avra Valley, Waters (1987a) found that late Holocene deposition primarily occurred in arroyo fan deltas and discontinuous gully fan environments. These areas had floodwater agriculture potential, and Hohokam settlers appeared to locate there for the purpose of optimizing farming conditions. Field (1992) found that floodwater farming on alluvial fans in the northern Tucson Basin promoted settlement primarily on the bajadas below the Tortolita Mountains and the Tucson Mountains. Prehistoric populations took advantage of these potential agricultural areas as conditions allowed, perhaps partly because the floodplain environment of the river was highly variable (Waters 1987b:59). Although Waters suggests that the floodplain environment and surface hydrology of the river were not conducive to canal irrigation, he believes that limited canal or ditch irrigation would have been suitable near cienega environments. Others believe that canals may have been present on a small scale, possibly in association with primary ballcourt villages (Doelle 1985b; Doyel 1984). In fact, a few canals have been documented during archaeological excavations. About 1 mile from the Hodges Ruin, on the east side of the river, 1 or 2 canal segments were found (Kinkade and Fritz 1975), and canals associated with the Sedentary period have been found at Los Morteros on the first terrace and on the floodplain on the west side of the river (Bernard-Shaw 1988).

## CONCLUSIONS

Archaeological studies along the Santa Cruz River are of interest for three reasons: (1) they document the natural conditions of the river prior to the advent of groundwater pumping; (2) they indicate what changes occurred in the river in its natural condition; and (3) they show how the river has been used throughout human history.

Environmental reconstructions, particularly that of Waters (1989), suggest that prior to 1890, the Santa Cruz River was an intermittent stream with occasional marshlands or cienegas. Large segments of the floodplain were unentrenched and supported mesquite and cottonwood bosques. Although sequences of stream aggradation and erosion varied according to specific geographical location, the only areas that were consistently conducive to irrigation agriculture were around the cienegas.

Archaeological studies have demonstrated long-term (11,500 years) occupation of the Santa Cruz River valley generally, but there have been clear differences in the cultural history of the upper, middle, and lower stretches of the valley. Some of this variability has resulted from changes in the condition of the river, which in turn resulted in changing farming practices.

The archaeology of the upper Santa Cruz River valley is not well known, but it appears to contrast with the archaeology of the middle and lower valleys. The most distinctive sites date to the Classic Period (A.D. 1150-1400) and consist of compounds of 3-8 houses constructed around courtyards. This type of site seems to be the northernmost manifestation of a settlement pattern that is centered in northern Mexico. By about A.D. 1450, however, settlement had shifted to the ranchería pattern (dispersed hamlets and farmsteads) that characterized the area when the Spaniards arrived in the 1690s.

The middle Santa Cruz River valley has been occupied almost continuously since the Archaic period, and early farming communities appeared along this reach of the river as early as 400 B.C. Some of these communities appear to have been repeatedly occupied on a seasonal basis for at least 200 years. By the Pioneer Period (A.D. 1-750), some communities along the middle Santa Cruz River were occupied year-round. Colonial Period (A.D. 750-950) farmers practiced floodwater farming on bajadas and alluvial fans until headcutting of arroyos occurred.

Sedentary period (A.D. 950-1150) entrenchment and cienega formation led to movement away from the floodplains. In the Classic period, populations aggregated into fewer larger sites and farmed both floodplains and uplands. After about A.D. 1400, settlement shifted to the ranchería pattern described above. Throughout the prehistoric agricultural periods, irrigation from the Santa Cruz River was limited.

The lower Santa Cruz River valley was apparently never occupied as intensively as the middle portion of the valley, and most sites that have been recorded in this area are associated with the Gila River rather than the Santa Cruz.

Historical archaeology in the Santa Cruz River valley has been as extensive as in any other area of Arizona and has confirmed locations of historic sites and identified colonial, United States territorial, and twentieth century farms and irrigation systems. It is noteworthy that water wells were commonly found in archaeological excavations in historic Tucson, a testament to high groundwater levels during the colonial and territorial periods.

Thus, the archaeological record suggests that the Santa Cruz River was marginal for irrigation agriculture using prehistoric agricultural technologies and that the most extensive use of the river for irrigation occurred in historic times. The prehistoric peoples of the Santa Cruz River valley traded in shell, ceramics, and presumably other items. The well-documented use of the river as a transportation and settlement corridor in historic times is materially manifest in the chain of missions, presidios, and other communities along the river that have been investigated by historical archaeologists. Despite all of this archaeological work, however, no archaeological evidence of navigation along the Santa Cruz River has been found.

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Arizona State Land Department

# ARIZONA STREAM NAVIGABILITY STUDY

*for the*

# SANTA CRUZ RIVER

**Gila River Confluence to the Headwaters**

**Final Report**

*Prepared by*

**SFC Engineering Company**

*In Association With*

*George V. Sabol Consulting Engineers, Inc.,*
**JE Fuller/Hydrology & Geomorphology, Inc.,**
**SWCA, Inc. Environmental Consultants,**
**University of Arizona Water Resources Research Center,**
*and the*
**Arizona Geological Survey**

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SECTION 3

# A Historical Study of the Santa Cruz River

**Background Information for Determination of Navigability of the River at the Time of Arizona Statehood, 1912**

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November 1996

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# EXECUTIVE SUMMARY

The purpose of this document is to provide relevant historic information that will help to answer the question: was any portion of the Santa Cruz River navigable at the time of statehood in 1912? In order to ensure a reasonably comprehensive analysis, many factors must be considered. The determination of where and how much perennial water there was in the river at any given time probably cannot be accurately determined; however, it is certainly not the only consideration. The Santa Cruz River Valley has been a center of travel, commerce, settlement, and agricultural activities for thousands of years.

To describe these impacts more clearly, the information is presented by sections: the upper Santa Cruz River (Santa Cruz County); the middle Santa Cruz River (Pima County); and, the lower Santa Cruz River (Pinal County).

The Santa Cruz River supported communities long before Anglo settlement. According to recent archaeological findings, people in farming villages near Tucson were using surface water to irrigate crops as long as 2000 to 3000 years ago. These same people supplemented their diet with fish caught from the river. More recently, 300 to 400 years ago, Indians were still irrigating crops with surface water near Tucson, San Xavier, and Tubac. This practice continued throughout the Spanish missionization of the southern Arizona and well into the period of Anglo settlement. No evidence was found to suggest that the early inhabitants of the valley used boats on the river. However, according to the journals of an early Anglo traveler, the place called "La Canoa" (just south of Green Valley) is named after an early Mexican settler who used a canoe to cross the river during times of high water. Other sources, however, explain the origin of the name differently.

During Anglo settlement of the Tucson valley, perennial water was used for irrigation. Two dams were constructed near Tucson to provide water for grain and ore mills. The lakes behind the dams also provided the community with recreation for swimming, boating, and fishing. Around this time, a land speculator reported that the river near Calabasas (Rio Rico) was large enough for steamboats, but this was found to be only false advertising to promote the sale of land. A group of men left from Nogales to try to bring a boat all the way to Tucson on a good-will trip around the time of statehood. The launch was successful for some miles, but never made it beyond Tubac because of low water. No other known instances of boating on the Santa Cruz River during this time period were discovered.

Some portions of the river remain perennial to this day. Other parts of the river north of Nogales and Tucson have more water now than they did at the time of statehood due to wastewater effluent flow. Many perennial sections of the river have been lost: The perennial waters near San Xavier persisted until 1949, and supported native fish until at least 1937; and, the perennial section of the river near Tucson probably had some perennial flow in 1912, but by that time the river was deeply entrenched. Therefore, the water table was already lower than it was before entrenchment began after the floods of 1890. The United States Geological Survey kept data on streamflow at certain measuring points on the Santa Cruz River, and by 1910, it was reported that the entire base flow of the river, at both the Mexican border and near the Congress St. Bridge in Tucson, was diverted for agriculture.

The upper Santa Cruz River in Santa Cruz County, including the headwaters in the San Rafael Valley, is relatively stable. Perennial flow exists in many places here, as well as some cienegas. The geology changes north of Tubac, and the river frequently went subsurface here throughout history, as it does today. However, the perennial reaches at San Xavier and Tucson are gone. The lower Santa Cruz River in Pinal County never supported perennial flow. In fact, it was only during rare flood events that water from the Santa Cruz River reached the Gila confluence. Early explorers said that the river through Pinal County had a nearly indistinguishable channel, and maps showed a discontinuous channel there. This section of the river remains relatively unchanged.

The biggest changes in the valley have been along the middle Santa Cruz River, especially from Tucson to Tubac, because of population growth, mining and agriculture. This combination of events has led to loss of perennial water, an increase in groundwater withdrawal, and an extensive change in the vegetative structure there.

In more recent times, some people have attempted to navigate the river. These canoers report that boating is feasible, especially in the effluent-dominated areas. The *Tucson Citizen*, a local newspaper, reported on canoers who boated on both the effluent-dominated section in the upper portion of the river, on the Rillito River, and on other portions of the Santa Cruz during floods in 1990.

Boating, then, has occurred on rare occasions on portions of the Santa Cruz River. The river has also provided other benefits, including fish for human consumption, water for crop irrigation, recreation and necessary relief for early travelers. At least one major travel route followed the course of the river, and communities have existed along the river for thousands of years.

# SANTA CRUZ RIVER HISTORY

## I. THE HISTORIC SETTING

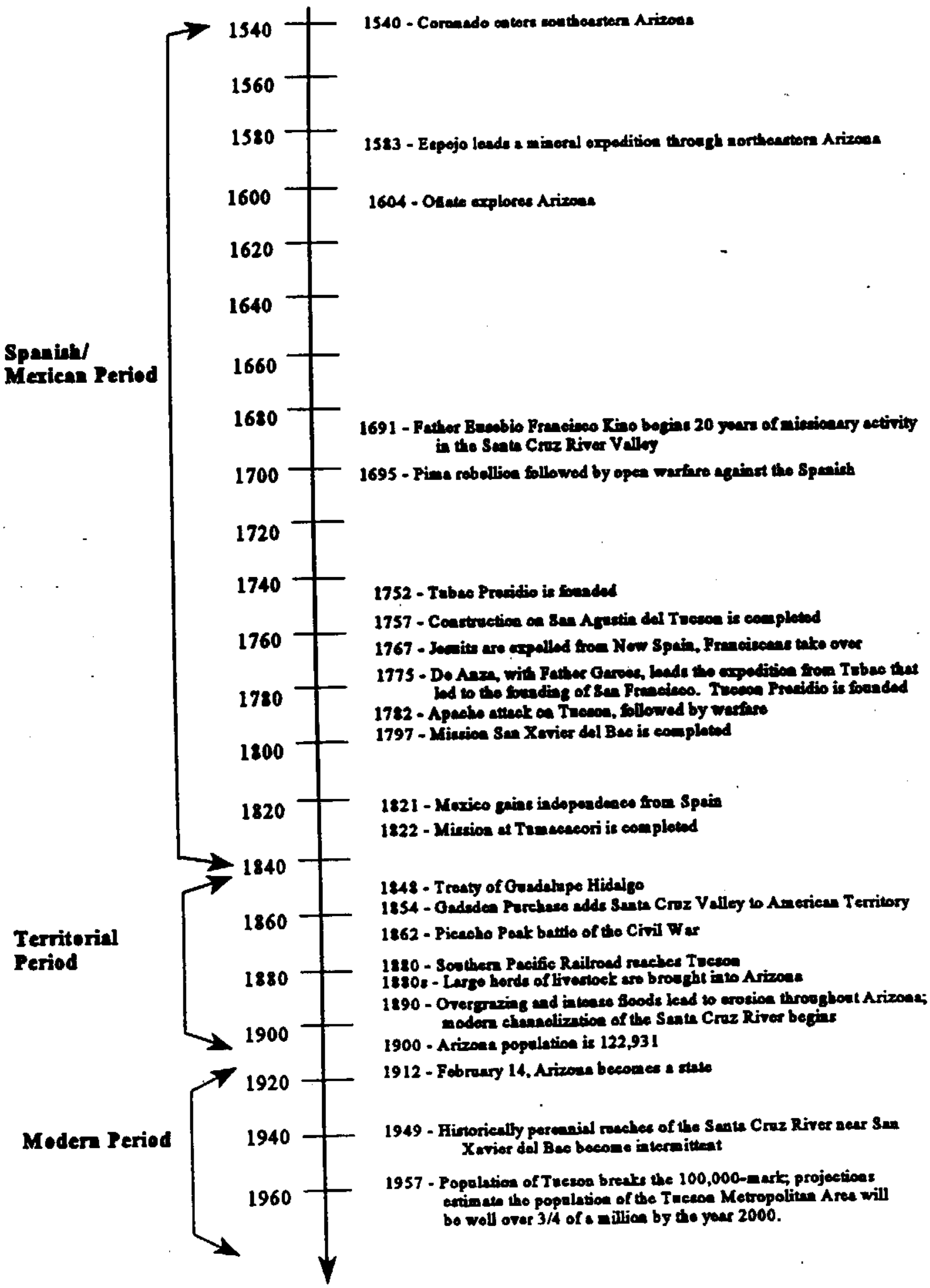
The Santa Cruz River Basin encompasses about 8,200 square miles. All of the streams in the watershed have a collective length of approximately 9,720 miles. Of those 9,720 miles of streams in the Arizona portion of the Santa Cruz River Basin, only 73 miles are perennial (Arizona Department of Environmental Quality 1994). The river crosses the international boundary twice, with a generally northward course after the loop it makes in Mexico. It is convenient for organizational purposes to study three sections: The river in Santa Cruz County; in Pima County; and in Pinal County. It is also useful to study three periods of history: the Spanish/Mexican Period through the 1840s; the Territorial Period, from the 1840s until statehood in 1912; and, the Modern Period, from statehood to the present (Figure 1).

### Upper Santa Cruz River - Santa Cruz County

The Santa Cruz River originates in numerous springs and creeks in the upper San Rafael Valley in extreme south-central Arizona, between the Huachuca Mountains, the Canelo Hills, and the Patagonia Mountains. The river flows south from this valley for about 8 miles, where it enters Sonora, Mexico. After a 32-mile loop into Mexico, it curves northward and re-enters Arizona five miles east of Nogales. The river then runs north past Rio Rico, which was once known as Calabasas, then winds toward Tumacacori National Historic Park and Tubac Presidio State Park.

According to most historical accounts, the Santa Cruz was largely perennial, from its headwaters south into Mexico, and then back into Arizona just north of Tubac. The headwaters area had numerous marshy areas, especially a large one north of the town of Santa Cruz. Near the Santa Cruz/Pima County line, the geology changes from a high bedrock situation to a deep alluvial system, and the river usually sinks below the surface. This part of the Santa Cruz River Valley is broad and flat, and bounded on both sides by mountains. Historically this entire stretch of the river was lined with riparian vegetation.

**Figure 1. Chronology of Important Events in the Santa Cruz River Valley, 1540 - Present**



The river may also have gone underground at at least one other location near Tubac during low-water periods. (Halpenny, personal communication, 1996).

## Middle Santa Cruz River - Pima County

The river, running north into Pima County, passes Green Valley, enters the San Xavier Indian Reservation, and comes within sight of the Mission San Xavier del Bac. Historically the river went underground just north of Tubac, and did not have perennial surface flow again until it reached the San Xavier Mission. It was no coincidence that the Mission was located near the river. Until the 20th century, this portion was perennial, and in fact supported early Indian agriculture for hundreds of years.

The river then went underground just north of the Mission, and again came to the surface near Sentinel Hill, or "A" Mountain, in Tucson. Numerous springs contributed to the surface flow that existed both at San Xavier and near Sentinel Hill. Other springs present in the area were often used by early travelers as stopping points to replenish water supplies and water livestock (see Betancourt and Turner 1990: p. 50; Page 1954: pp. 63, 69). Nine-mile waterhole, shortly before the confluence with the Rillito, was traditionally the last dependable watering place on the trail to the Gila River. Just north of Tucson, south of the Pinal County line, the waters disappeared again.

## Lower Santa Cruz River - Pinal County

From Tucson the river turns to a north-northwest course, and at the Pinal County line it generally disappears. Since the river is cryptic in this region, very little has been written about it, except as a route of travel that was known to be lacking in water. The river runs through the desert in Pinal County until it meets the Gila River near Phoenix, 222 channel miles from its origin (Holub and Bufkin 1987). Some maps show the river as discontinuous, with the main stem emptying into playa. Waters from Santa Rosa Wash form a new channel to the Gila. Only during flood times was the river continuous to the Gila.

## Tributaries

The major tributaries of the Santa Cruz River from south to north are Nogales Wash, Sonoita Creek, Rillito Creek, Cañada del Oro and the Altar-Brawley Wash.

Nogales Wash flows from Mexico, through Nogales and northward to the Santa Cruz River. This wash, together with a number of swampy areas around Nogales, made the area, according to an 1883 article in the *Phoenix Herald*, "a swamp dangerous for both man and beasts to cross." Malaria was rampant, so to deal with this problem, and reclaim land for human use, some of the swamps were drained.

Sonoita Creek flows perennially from its origin on the east side of the Santa Rita Mountains, through a Nature Conservancy Preserve to Patagonia Lake (a manmade lake and State Park), and from there, ephemerally, through lush riparian vegetation to the Santa Cruz River at Rio Rico.

The Rillito River is the largest tributary of the Santa Cruz River. One of its branches, Cienega Creek, starts high in the Santa Rita mountains, and much of it is perennial today. It becomes Pantano Wash until the confluence with Tanque Verde Wash at Craycroft Road in Tucson, after which the river is called "Rillito Creek." Pantano Wash tends to be a summer stream with little underflow beyond the Cienega Creek stretch. The other branch, Tanque Verde Wash, is primarily a winter-flowing stream, carrying water from Sabino Creek which starts at the top of Mt. Lemmon at about 10,000' elevation. Bear Canyon and Agua Caliente are two other mountain streams tributary to the Tanque Verde Wash, which has a strong underflow to the confluence, and even today has perennial flow for most of its length.

The Cañada del Oro Wash flows from the northwest side of the Santa Catalina Mountains through the town of Oro Valley to its confluence with the Santa Cruz River north of Tucson. One of its tributaries in Oro Valley, Honeybee Canyon, flows most of the time.

The Altar-Brawley Wash, west of the Tucson Mountains, also collects waters which flow into the Santa Cruz River north of Marana. A marsh at Arivaca has water perennially, but the remainder of the area is ephemeral today. This Wash is deeply incised south of Ajo Way.

Santa Rosa Wash is an ephemeral stream which contributes to the flow of the Santa Cruz River near the Gila confluence. Many small ephemeral washes in the surrounding mountains contribute to the Santa Cruz River's flow at certain times of year.

# II. HISTORIC VEGETATION, WILDLIFE AND CLIMATE

## Vegetation

In the early days of exploration and settlement, the upper and middle Santa Cruz River valleys were consistently described as lush or fertile valleys with excellent grazing grounds, abundant grass, occasional forests of huge mesquite trees, and a river lined with giant cottonwoods, walnuts, willows and other riparian species. The lower Santa Cruz was considered dry with undependable water and grass. Kino (Bolton 1919) praised the richness of the valley and its potential, and he believed it had sufficient water, grass and wood to support a community of several thousand people and cattle. Many nineteenth century travelers described the river including: Bartlett (1965) in the early 1850s, Durivage (1937) in 1849, Parke (1857) in 1857, Aldrich (1950) in 1849, Reid (1858) in 1858, Froebel (1859) in 1859, Browne (1974) in 1864, Spring (in Gustafson 1966) in 1881, Couts (1961) in 1848 and '49, Cooke (1854) in 1854, Powell (1931) in 1849-52, Way (in Duffen 1960) in 1858, Clarke (1988) in 1851, Zuniga (in Hammond 1931) in 1795, and Bell (1854). Cadastral surveys conducted in the late 1800s are summarized in Betancourt and Turner (1990) and provide useful information. Some sample quotes follow.

### Upper Santa Cruz

Travelers were welcomed upon reaching the town of Santa Cruz, which had orchards and farms providing fresh food. However, some found the town unappealing and the inhabitants sickly (apparently from malaria). Those who came through after Apache depredations found little to praise except the river. For many years it was the largest town between El Paso and California.

> *"The right, or West bank of the stream, on which we now are, is highly picturesque, not being as usual, a long unsightly bluff, but rises to the Mountains in a thousand little swells and undulations...The soil of the valley is rich and the grasses (grama and others) grow here luxuriantly.... Between 3 and 4 miles brought us to Santa Cruz. The corn fields come so close to the West side of the valley at places*

*that it threw our waggons on the side hill; one large one canted and turned over the water which flooded it....*" Powell (1931) in 1852.

"*Our journey down the valley of the Santa Cruz was one of the most agreeable in our entire tour. We were accompanied by Señor Commodoran, an intelligent Mexican, whose friendship toward Americans traveling through the country has long been proverbial. . . . After passing through the canyon of the San-Lazaro we entered a valley which opens out onto a magnificent grazing range, extending nearly 20 miles to the foot-hills of the Pinitos Mountains. Groves of cotton-wood of gigantic size fringe the stream at intervals of every few miles; the grass is wonderfully luxuriant, covering the valley and hill-sides as far as the eye can reach with a rich gold-colored carpeting . . . Our camp for the night was under a fine grove of cotton-wood, where the grass, shaded from the crisping rays of the sun, grew up in luxuriant masses high over our heads. Here we cut and slashed at the tufts, and burned out broad spaces for our fires, of which there was constant danger, till our camp was secure from conflagration; and then the venison and wild-ducks were quickly placed in the frying-pans, and their savory odors mingled with the pleasant fumes of the coffee-pot, and the creature-comforts of earth were ours in perfection.*" Browne, J. Ross (1974) [first published in 1864](pages 212-213).

"*The soil in the valley of the river is exceedingly rich, the best I have seen in Mexico. ... On the river's banks are cotton and musketi* [mesquite] *trees...At sunset we halted for the night, with excellent wood and water at hand....*[Tubac area] *...we encamped for the night by the side of a running stream, about one mile from the town of Tucson.*" Aldrich, Lorenzo (1950) in October, 1849.

"*...at Santa Cruz, and further down, the banks of the river, and the valley itself, are covered with poplars and willows, ash-trees and plantains, oaks and walnut trees... Some portions of the valley are of such grand, rich, and simple beauty, as for instance Tumacacori and San Xavier del Bac, that they would be remarkable in any part of the world...*" Froebel, Julius (1859).

"*If you will portray in your imagination a bottom covered with tall, golden colored grass, hedged by mountains whose sands glitter like metal, divided by a meandering stream a dozen yards wide and as many inches deep, this shaded by cotton-woods, willows, and musquites, then a few hundred yards higher up another stream, a creek with less volume pouring in from the right, and in the fork an elevated rolling surface, you will have a view of Calabasas (Pumpkin, so called from an old yellow adobe house, named from its color, which stands on the right bank of the river near the above noticed junction.) Then picture to your mind's-eye this bottom dotted with shanties of straw and cloth, and the fork covered with military tents, and you have the tenements belonging to Calabasas, which were occupied by several hundred citizens, and four companies of the 1st Dragoons at the time or our arrival.*" page 187-188. February 8, 1857. Reid, John C. (1858).

"*The valley continued about half a mile wide, thickly covered with mesquit trees of a large size. The bottom-lands resembled meadows, being covered with luxuriant* *grass, and but few trees. The immediate banks of the river, which is here [near the mouth of Sonoita creek] as diminutive as near Tucson, are lined with cotton-wood trees of a gigantic size. ... In some places there are large groves of these trees, rendering this part of the valley the most picturesque and beautiful we had seen."* Bartlett, J.R. (1965), in July, 1852 [first published in 1854] (Vol. 2, page 307).

**Middle Santa Cruz**

*"Leaving San Xavier, we followed the course of the Santa Cruz Valley for two days, making only one camp at Rhodes's ranch* [near Tucson]. *I had supposed, previous to our entrance into this region, that Arizona was nearly a continuous desert, as indeed it is from Fort Yuma to Tucson; but nothing can be a greater mistake than to form a general opinion of the country from a journey up the Gila. The valley of the Santa Cruz is one of the richest and most beautiful grazing and agricultural regions I have ever seen. Occasionally the river sinks, but even at these points the grass is abundant and luxuriant. We traveled, league after league, through waving fields of grass, from two to four feet high, and this at a season when cattle were dying of starvation all over the middle and southern parts of California. Mesquite and cotton-wood are abundant, and there is no lack of water most of the way to Santa Cruz."* (pages 143-144) Browne, J. Ross (1974), in late January, 1864 [first published in 1864].

"[From San Xavier to Tubac] *The bottoms in places, are several miles wide and highly fertile. Cotton-wood and musquite, of good size, are abundant in them. The river runs in the middle of a valley that varies in width, from a few to several miles, of surpassing beauty. The valley, table-land and mountain sides here, as elsewhere in the Purchase, are covered with a luxuriant coating of gramma grass which is the staff of life for every four-footed animal throughout the country. The mountain tops are white, till late in the spring, with snow."* page 185. February, 1857. Reid, John C. (1858).

*"...It passes through one of the most beautiful and fertile valleys in the world, once inhabited by Mexicans, but now presenting a melancholy spectacle of deserted ranchos and fields running to waste. We procured water, in places from zeqjias [acequias] which were used to irrigate the land...*[Tubac area] Clarke, A.B. (1988), on May 27, 1849 [first published in 1849].

[several miles south of Tucson] *"A rapid brook, clear as crystal, and full of aquatic plants, fish and tortoises of various kinds, flowed through a small meadow covered with shrubs... We had hitherto been following the course of the river of Santa Cruz, which although its channel was found dry in several places, constantly re-appeared. But below Tucson it loses itself in the desert..."* Froebel, Julius (1859), in July, 1855.

*"Starting early from Tucson, the first day's noon will generally find a traveler at one of the sinks of the Santa Cruz, where the water disappears in a shallow bed of gravel and quicksand. The stream has here a fall of 75 feet to the mile, and there is*

*an abundance of grass for feed.... The great peaks of the Sierra Santa Rita now loom grandly before one through the trees."* Hinton (1970), in 1878.

**Lower Santa Cruz**

This stretch of the Gila Trail has been known as the "Ninety Mile Desert" and was feared for its lack of water during most times of year.

*"...we came in sight of the Presidio of Teuson* [Tucson] *and finding good water and grass we camped. Learning that there is no water beyond two miles from Teuson, to the river Gila, about one hundred miles..."* Clarke, A.B. (1988), in 1849.

*"Hence to the Gila River was a desert plain without water"* (Harris 1960), in the mid-1800s.

*"We left our Camp between the Mountains after breakfast. It is just at the top of a divide; the water, when there is any, runs all ways from here. The ground is perfectly bare and the larrea, mesquite, or some scattering weeds spring up solitary. Once in a way at long intervals there is a bunch or two of grass. .... There was neither water nor grass for the cattle... The road was very dusty..."* Powell (1931), in 1852.

*"During some seasons it flows further than others, so that the length of the stream above ground is subject to considerable variation; but it never succeeds in reaching the Rio Gila on the surface, although I believe it flows over the bedrock and under the drift which covers it for the remaining one hundred miles from Tucson to Maricopa Wells, where a large spring, the waters of the Rio Santa Cruz, it is believed - comes to the surface and flows to the Gila. ..."* Bell (1869).

*"Today we passed through Tucson. ... Here we heard some awful tales of the route ahead of us* [from Tucson to the Gila], *dead animals strewing the road, wagons forsaken, human skeletons, who had famished for want of water etc."* (Hunter no date) in 1849.

*"...the Sierra Tucson, near the town of that name, and along beyond the base of which it flows northward for miles, when it sinks and is lost sight of permanently. It is supposed to enter the Gila by some subterranean channel near Florence... ."* Hinton (1970), in 1878.

**The Tributaries**

Early travelers found a series of cienegas along many parts of the Cienega Creek, Pantano Wash (both of which mean "swampy area") and Rillito River watershed. A long stretch of the river, probably all the way to the confluence with the Santa Cruz, was called "Cienegas Las Pimas." The entire lower valley was described as:

> "*...an unbroken forest, principally of mesquite, with a good growth of gramma and other grasses between the trees. The river course was indefinite - a continuous grove of tall cottonwood, ash, willow and walnut trees with underbrush and sacaton and galleta grass, and it was further obstructed by beaver dams...Such portion of rainfall as found its way to the river channel was retarded and controlled in its flow, and perhaps not oftener than once in a century did a master flood erode and sweep the river channel... .*" Smith (1910).

> "*The water was in marshes, coming from springs and a little brackish... The grass, or rather cane, was some 6 feet high... .*" Eccleston (*In* Hammond and Howes 1950), in November, 1849.

Similar marshy areas were described in the headwaters area, in Nogales, in nearby locations as far north as Tubac, Patagonia, Arivaca (in the Altar-Avra Valley basin), and at the Gila River/Santa Rosa Wash confluence. Irwin, a medical officer at Fort Buchanan in 1859, believed the marshy areas around the Fort, near present-day Patagonia, were responsible for the persistent malaria infecting the troops. His description follows:

> "*This cienega consists of alluvial deposits and extensive beds of decaying organic matter, the result of the rank, forced vegetation of the hot season. Here several warm and cold springs pour forth their contents, which run over the surrounding level surface, forming a peat marsh of considerable extent, wherein there are several stagnant filthy pools, in which vast herds of swine may be seen constantly basking in the mud or rooting up the foetid and miasmatic soil of the adjacent quagmires... .*" Irwin (in Betancourt and Turner 1990) in 1859.

## Historic Changes in Vegetation

Very few of the historic vegetation features described by early travelers are recognizable in the valley today: the water table has dropped significantly; the loss of surface water and water table decline resulted in loss of vegetation and increased erosion; and the lush native grasses that early explorers described are virtually nonexistent. Cottonwoods exist only in isolated remnant forests, most notably where effluent flows, and a few scattered individual trees exist in other areas. Only a few remnant cienegas remain. Groundwater pumping led to the loss of a very large and old mesquite bosque and cottonwood forest in the San Xavier District in the 1960s. (Halpenny 1962). Some cienegas were drained to control malaria. Arroyo formation discussed below radically changed the nature of much of the area. Sabino Creek, Sonoita Creek, Arivaca Cienega, Honeybee Canyon and Cienega Creek are remnants of these former riparian areas and cienegas.

## Wildlife

Early travelers described wildlife not found or rare in the area today and other wildlife still common in specific areas. Julius Froebel described the river near Tucson in 1855 as: *"A rapid brook, clear as crystal, and full of aquatic plants, fish, and tortoises of various kinds... ."* (Froebel 1859: p. 503). It is not clear what kind of fish or tortoises he spoke of, but it is clear that the dry bed of the Santa Cruz River near Tucson has no such wildlife today, except some aquatic species that survive in wastewater effluent flows. Beaver were described on the Rillito, at Ft. Buchanan, and possibly near Tucson. Muskrat were described near Tucson and elsewhere by early settlers. Some samples of descriptions follow:

### Upper and Middle Santa Cruz

> *"Near Santa Cruz in Sonora, we found this animal* [wolf] *more common than we had observed it elsewhere on our route. It, as well as the coyote, were often destructive to the flocks... .*
>
> *"These animals* [grizzlies] *were observed by us in greater or less numbers in the San Luis mountains, the Sierra Madre, and at Los Nogales; being particularly numerous at the first and last named localities.*

*"During our stay at Los Nogales in the month of June, particularly the latter part, the heat during the day was quite oppressive; and the valleys of the streams, with their thick undergrowth affording a good protection from the rays of the sun, were the favorite places of resort for these animals... ."* Kennerly, C.B.R. (1856) in 1855.

*"Like the flora, the fauna of this vicinity is of a highly diversified and interesting description. The following have been noticed: the panther, leopard* [jaguar?], *wild cat, lynx, grey wolf, coyote, red fox, grey fox, grizzly bear, brown or cinnamon bear, badger, pole cat, weasel, raccoon, beaver, rat, mouse, prairie dog, gopher, grey squirrel, brown squirrel, ground squirrel, antelope, white-tailed deer, black-tailed deer, peccary or Mexican hog, and the mustang or wild horse which roams over the plain in vast herds."*

*"Much might be written about the rare and beautiful birds that abound in this country, many of which are remarkable for the gorgeous beauty of their plumage. The following have been met with: wild turkey..swan, brent, mallard duck, greenwinged teal, bluewinged teal, diver, blue crane, white crane, white heron, grey heron... ."* Irwin, B.J.D. (in Davis 1986) in 1857 on Sonoita Creek.

*"Mr. Fuller had killed a tiger in my absence and he and Grosvenor had quite a chase after a bear that ventured near the camp...Bears are very numerous here of these species, the black bear, the brown or as it is called the cinnamon bear and the fierce and dreaded grizzly... ."* Way, Phocian (in Duffen 1960) at Tubac in June, 1858.

*"Panthers* [mountain lions] *are found in greater or less numbers throughout the entire country traversed by the Boundary Commission... it... was observed by us as far* [west] *as Los Nogales in Sonora; in which State the Mexicans, who call it Leon, wage against it an unceasing warfare, on account of the ravages which it commits among the cattle.... Near Los Nogales, in the month of June, we pursued a female panther, which we succeeded in wounding very severely..."* Baird, S.F. (1859).

*"...he told me that there were some twenty turkeys a short distance off in the trees...*[near Tubac].

*"A white and black crane was killed today, cooked for supper and was quite palatable...* [wood ibis?]." Bell, James G. (1932) in 1854.

*"Wild game in abundance could be procured in the immediate vicinity, and by Christmas we had such a store of bear meat, deer, antelope, and fat wild turkeys, that no apprehension of short rations disturbed our enjoyment....* [Tubac]" Poston, Charles (1854).

**Lower Santa Cruz**

*"We saw numbers of very large rabbits and also some very large Tarantulas..."* Powell (1931) in 1852.

## Change in Wildlife

The relationship between changes in the river and changes in faunal distribution in the valley are not always conspicuous. Notable examples are the grizzly bear and the wolf. These large predators were described extensively by early explorers in the region. A list of other wildlife species noted by various explorers in the 1800s is compiled in Table 1.

Animals like shorebirds, waterfowl, fish, muskrat and beavers, which are dependant on water, as well as large predators like wolves and bears, have essentially been eliminated from the Santa Cruz Valley. Exceptions exist in some of the areas fed by effluent, where there is still a rich diversity of bird species, as there is in the perennial tributaries. The corridor created by the Santa Cruz River is used by migrating wildlife and many local species. Some species of State or Federally threatened or endangered wildlife and plants are currently found within the Santa Cruz Valley (United States Fish and Wildlife Service 1991). The number of listed species that can be found in the valley is approximately 50, as shown in Table 2.

## Climate

### Droughts

Droughts and floods have significant impacts on the flow of the Santa Cruz River. The weather patterns of the Arizona desert can be extreme in either situation. Early travelers described landscapes very differently from year to year depending on the amount of rain the region had. J. Ross Browne, on his travels through Arizona in 1864, noted the effects of a drought in southern California and Arizona:

> *The country through which we travelled for several days was not altogether new to me. I had passed through it before during a tour of exploration among the Southern Indians in 1860. But how different was it now! In former years the magnificent valleys, stretching all the way from Los Angeles to the borders of the Colorado Desert, were clothed in the richest verdure. Vast herds of cattle*

## Table 1. Wildlife Mentioned by Some 19th Century Explorers in the Santa Cruz River Valley

Some of the explorers that traveled in the Santa Cruz River Valley in the 1800s kept journals in which they noted wildlife. The names that the explorers used are sometimes outdated, local terms, or even guesses. The bracketed names ...[ ]... are explanations proposed by the editors. The numbers following the animal coincide with the sources at the end of the list.

Birds

Wild turkey 1, 2,
Black and white crane [Wood Ibis?] 1
Swan 4
Brent [Brandt?] 4
Mallard duck 4, 8
Greenwinged teal 4, 8
Bluewinged teal 4
Redwinged teal 8
Diver 4
Blue crane 4
White crane 4
White heron 4
Grey heron 4
Pisano or Prairie pheasant [road runner] 4
Massena partridge [Mearns' quail] 4
Black-crested quail [Gambel's quail] 4
Speckled quail [Scaled quail?] 4
Dove 4
Ringdove 4
Wild pigeon 4
Gray duck 8
Spoonbill duck 8
Canvass back 8
Widgeon 8
Spring tail 8
Butter 8
Fish duck [? merganser] 8
Snipe 8
Curlew 8
Plover 8

Fish

Carp 10
Fish and Tortoises of various kinds 9

Mammals

Bear 2, 5
Brown or cinnamon bear 4, 5
Black bear 5
Grizzly bear 3, 4, 5, 7
Antelope 2, 4
Deer 2
White-tailed deer 4
Black-tailed deer 4
Wolf 3
Coyote 3, 4
Panther [Mountain lion, Leon] 4, 6
Leopard [jaguar?] 4
Wild cat 4
Lynx 4
Grey wolf 4
Red fox 4
Grey fox 4
Badger 4
Pole cat 4
Weasel 4
Raccoon 4
Beaver 4
Rat 4
Mouse 4
Prairie dog 4
Gopher 4
Grey squirrel 4
Brown squirrel 4
Ground squirrel 4
Peccary or Mexican hog 4
Mustang or wild horse 4
Tiger 5

---


1. Bell, James G. 1854
2. Poston, Charles. 1854
3. Kennerly, C.B.R. 1856
4. Irwin, B.J.D. 1857
5. Way, Phocian. 1858
6. Baird. 1859
7. Clarke, A.B. 1849
8. Arizona Weekly Citizen. Nov. 17, 1883
9. Warner, Solomon. 1884 [see: Hayden no date-b]
10. Arizona Weekly Citizen. March 15, 1884.

## Table 2. Special Status Species, Santa Cruz River Valley*

| COMMON NAME | SCIENTIFIC NAME | STATUS |
|---|---|---|
| **Mammals** | | |
| Black Mountain rock pocket mouse | *Chaetodipus intermedius nigrimontis* | C2 |
| California leaf-nosed bat | *Macrotus californicus* | C2, SC, S |
| Cave myotis | *Myotis velifer* | C2, S |
| Greater Western mastiff-bat | *Eumops perotis californicus* | C2, S |
| Lesser long-nosed bat | *Leptonycteris curasoae verbabuenae* | LE, SE, S |
| Mexican free-tailed bat | *Tadarida brasiliensis* | S |
| Yellow-nosed cotton rat | *Sigmodon ochrognathus* | C2 |
| **Birds** | | |
| Fulvous whistling duck | *Dendrocygna bicolor* | C2 |
| Northern beardless-tyrannulet | *Camptostoma imberbe* | S |
| Northern gray hawk | *Buteo nitidus maximus* | C2, ST, S |
| Rose-throated becard | *Pachyramphus aglaiae* | SC, S |
| Thick-billed kingbird | *Tyrannus crassirostris* | CS, S |
| Tropical kingbird | *Tyrannus melancholicus* | SC, S |
| Yellow-billed cuckoo | *Coccyzus americanus* | ST, S |
| Zone-tailed hawk | *Buteo albonotatus* | S |
| **Reptiles/Amphibians** | | |
| Chiricahua leopard frog | *Rana chiricahuensis* | C1, ST, S |
| Gila monster | *Heloderma suspectum* | S |
| Great Plains narrow-mouthed toad | *Gastrophryne olivacea* | SC, S |
| Mexican garter snake | *Thamnophis eques megalops* | C2, SC, S |
| **Fish** | | |
| Desert pupfish | *Cyprinodon macularius macularius* | LE, SE, S |
| Desert sucker | *Catostomus clarki* | C2 |
| Gila topminnow | *Poeciliopsis occidentalis occidentalis* | LE, ST, S |
| Longfin dace | *Agosia chrysogaster* | C2 |
| **Plants** | | |
| Chiltepin | *Capsicum annuum glabriusculum* | S |
| Crested coral root | *Hexalectris spicata* | SR |
| Goodding ash | *Fraxinus gooddingii* | S |
| Large-flowered blue star | *Amsonia grandiflora* | C2, S |
| Lemmon cloak fern | *Notholaena lemmonii* | C2, S |
| Lyre-leaved twistflower | *Streptanthus carinatus* | S |
| Pima Indian mallow | *Abutilon parishii* | C2, S, SR |
| Pima pineapple cactus | *Coryphantha scheeri robustispina* | LE, S, HS |
| Pringle lip fern | *Cheilanthes pringlei* | S |
| Santa Cruz beehive cactus | *Coryphantha recurvata* | C1, S, HS |
| Santa Cruz star leaf | *Choisya mollis* | C2, S |
| Sonoran desert tortoise | *Gopherus agassizii* | C2, SC, S |
| Sonoran green toad | *Bufo retiformis* | S |
| Southern yellow bat | *Lasiurus ega* | SC, S |
| Speckled dace | *Rhinichthys osculus* | C2, S |
| Spotted bat | *Euderma maculatum* | C2, SC, S |
| Supine bean | *Macroptilum supinum* | C2, S, SR |
| Thornber fishhook cactus | *Mammillaria thornberi* | SR |
| Tumamoc globeberry | *Tumamoca mcdougalii* | S, SR |

STATUS CODES: **LE** - Listed Endangered; **PE** - Proposed Endangered; **PT** - Proposed Threatened; **C1** - Category 1 Candidate; **C2** - Category 2 Candidate; **3C** - Category 3 Candidate; **SE** - State Endangered; **ST** - State Threatened; **SC** - State Candidate; **S** - Sensitive; **HS** - Highly Safeguarded; **SR** - Salvage Restricted.

**Note*: Compiled from information provided by the Arizona Game & Fish Department, Heritage Data Management System; the species listed are documented as occurring within a 10-mile corridor centered over the Santa Cruz River; the information is current on November 20, 1995, and is subject to change at any time.

*roamed over them rampant with life. ... Now, after two years of drought, all was parched, grim, and melancholy. The pastures scarcely showed the first faint tinge of green, and the higher grounds were barren as the road over which we travelled. For hundreds of miles the country was desolated for want of rain. ... Thousands of cattle lay dead around the black, muddy pools. ... No more pitiable sight ever disturbed the eye of a traveller in this lovely region than the dreary waste of dead and dying animals* (Browne 1974: 42).

This is one of the periods of drought noted by Meko et al. (1995), whose study reconstructed tree-ring histories to identify droughts in the West and Southwest. Other droughts identified by the study include the periods ending in 1624, 1670, 1686, 1709, 1778, 1789, 1824, [1864], 1881, 1894, 1900, and 1956. One particularly intense period of drought from 1573-1592 apparently affected the entire western United States.

The effects of these droughts on the structure of the Santa Cruz River are hard to quantify; other factors coupled with loss of vegetation due to low rainfall may very likely lead to erosion and arroyo cutting (Betancourt 1990). Once the soil is exposed, it is vulnerable to the heavy rains that often come in the monsoon season. This was probably the case in southern Arizona in 1880, according to Dobyns (1981):

*Thus, intensity of rainfall perhaps interacted with parched soil conditions to magnify the erosive results. Still, the amount of channel entrenchment recorded in the summer rains of 1880 emphasizes that man's degradation of the environment was directly responsible for triggering massive erosion during a drought year* (p. 179).

Similar conditions were present when the drought/flood cycles in the 1880s led to the starvation of the majority of cattle in southern Arizona (see "Livestock in the Santa Cruz Valley"), and preceded the beginning of the entrenchment of the Santa Cruz River during the floods of 1890.

**Floods**

Although the Santa Cruz River Valley is sometimes scorched by drought, it is at other times washed with floods. Precipitation in southern Arizona typically falls in short, sporadic and intense sessions, especially during the summer monsoon season. Winter rains tend to be more regional and last longer. Occasional intense fall storms (margins of Pacific hurricanes) bring a great deal of rain over a period of days or weeks. Because of these conditions, flooding of the river is not uncommon. Heavy rains contribute to surface flow in otherwise dry stretches of the river, and it is during flooding events that the normally dry lower Santa Cruz River in Pinal County carries any surface flow. The *Arizona Daily Star* recorded a conversation with Tucson pioneer Samuel Hughes during the floods of 1891. Hughes was reminiscing about some past floods:

> *The Santa Cruz and other rivers which empty into the Gila were all running high, and so great was the snow and rainfall during that season and the two years following that the Santa Cruz flowed a surface stream from its source to the Gila during* [18] *'68, '69 and '70, something unheard of since, as the stream is subterranean more than three fourths of the length of the valley through which it flows* (28 February, 1891).

The monsoon season in Arizona is often so intense that flooding on the Santa Cruz River is not uncommon. Some floods are notable for the extent of the damage they created. It has already been stated that the floods of 1890 were the beginning of the entrenchment of the Santa Cruz River. Other extraordinary floods in the vicinity between 1870 and the early 1980s occurred in 1887, 1891, 1898, 1907, 1908, 1912, 1914, 1916, 1919, 1926, 1930, 1931, 1932, 1936, 1945, 1947, 1950, 1951, 1957, 1959, 1961, 1964, 1965, 1966, 1970, 1972-73, 1976, 1977-78, 1979, 1982 and 1983 (Brazel and Evans 1984).

The December flood of 1914 lasted less than a week, but resulted in loss of life and property. A dam below San Xavier was swept out, city wells damaged, the University farm on the Rillito damaged, and many houses lost. A dramatic rescue near Sahuarita featured the National Guard, which headed toward the area with a collapsible boat. They found, however, that the current was too strong and ultimately rescued stranded people by horseback, using ropes. (*Arizona Daily Star* and *Tucson Citizen*, Dec. 19-21, 1914).

In the same flood, the first recorded attempt at floating a boat down the Santa Cruz River took place. A small wooden boat, the "Nogales," left Nogales during particularly high water level on the Santa Cruz, hoping to reach Tucson. The three sailors expected it would take two days to make the trip, but the boat went aground south of Tubac, and the trip was never completed (*Arizona Daily Star* 30 December 1914; Holub and Bufkin 1987)

During most of the major floods, bridges were damaged or destroyed, stranding people. Since flood water seldom persisted for more than a few days, people waited out the floods until they could cross the river on horseback or wagon.

The loss of vegetation, the drop of the groundwater table, the cementing of the banks, construction of impervious surfaces such as roads, and the channelization of the Santa Cruz River all undoubtedly contribute to the increased severity of floods. Six of the seven largest floods ever recorded at Tucson have occurred after 1960 (Webb and Betancourt 1990). The floods of 1983 displaced about 10,000 people, destroyed crops, roads and homes, and caused damage of more than $200 million dollars (Brazel and Evans 1984).

# III. SPANISH/MEXICAN PERIOD TO THE 1840s

## Early Exploration

The exploration by the Spanish of the area that is now Arizona began in the 16th century. Over the ensuing 300 years, the influence of these explorers, and especially the Jesuit and Franciscan missionaries, played an important role in developing the structure that would promote travel through the area, and finally colonization. A concise history, as well as a map, of the journeys of Spanish explorers into what is now Arizona, may be found in Walker and Bufkin (1986).

The first Spanish to enter were Alvar Nuñez Cabeza de Vaca and three others who, rather accidentally, ventured through the extreme southeastern portion of the modern state of Arizona in 1536. Because of the tales of rich Indian cities further north, or the "Seven Cities of Cíbola," the viceroy of New Spain, Don Antonio de Mendoza, sent Fray Marcos de Niza to explore the region (Hanna and Kupel 1987). The following year de Niza returned on another expedition with a small group of Spanish explorers led by Don Francisco Vasquez de Coronado.

De Niza and Coronado did not venture up the Santa Cruz Valley, though Coronado may have gone through the San Rafael Valley (Hadley and Sheridan 1995). Nor did subsequent journeys by Don Antonio de Espejo (on a mineral expedition in 1583) or Don Juan de Oñate (in 1604-1605) bring them into southern Arizona. It was not until 1691 that the Santa Cruz Valley had its first *entrada* by a Spanish (actually Austrian by birth) explorer, the Jesuit missionary Father Eusebio Francisco Kino. In 1774 and 1775, Fray Francisco Garcés accompanied Captain Juan Bautista de Anza on two journeys down the Santa Cruz Valley. On the second journey, in 1775, Garcés and de Anza led approximately 300 people on a settlement trip to the Coast of California. De Anza started at the presidio of Terrenate, in Mexico, and collected settlers and supplies as he slowly moved up the Santa Cruz River to "his presidio" at Tubac (Garate 1995). Their successful expedition resulted in a new colony at what would become the city of San Francisco. Later, de Anza led two expeditions from Mexico, north along the Santa Cruz River toward the Gila. His letters reveal the premier importance of water in an area where it is often scarce:

> *Well, although there is a road more free of Apaches and with a savings of more than thirty leagues [between Tubac and Tucson], we are unable to use it for lack of watering places. I have affirmed this in previous reports, saying that I have taken this route through the Papago Nation between here and the said river. Because of their poverty I will not travel through their country again, so that we will not end up in their situation.* (Garate 1995).

What might have contributed to the poverty of the Papago Nation (the Indians at San Xavier del Bac) is discussed below, i.e., diseases introduced by the Spanish, and fighting with the Apaches.

## Development of Missions

The impact that Father Kino had on the Santa Cruz Valley, either directly or indirectly, should not be underestimated. Probably the first large settlement in the area was the Jesuit mission of Santa Maria Soamca, later known as Santa Cruz (Mexico), which was established by Father Kino. The valley was used extensively by the priest as a travel route into the northern portion of *Pimería Alta*. Kino's missionary efforts in the 20 years between his first entrance in 1691 and his death in 1711 also led to the establishment of missions at San Xavier del Bac and Guevavi. The mission at Tumacacori was not finished until 1822, well after Kino's death, but his influence certainly played a role in its construction. Some smaller missionary posts, or *visitas*, were established at Tubac and San Agustín del Tucson. Perhaps the greatest impact Kino and subsequent missionaries had on the Santa Cruz Valley, though, was the introduction of new technologies, crops, domestic animals, and disease (Sheridan 1988).

The headwaters region of the Santa Cruz River, in the San Rafael Valley, is primarily grasslands; in fact, because of the extensive pasturage, grazing has been perhaps the most important activity in the area since the time of Father Kino. He brought livestock into many areas along the Santa Cruz River Valley, promoting the idea of grazing. In the San Rafael Valley, the San Rafael de la Zanja Land Grant was contested before the Court of Private Land Claims (see below: Land Grants). The grant was awarded, and this officially established the valley as a range for the grazing of livestock for many years to come (Hadley and Sheridan 1995).

Father Kino also brought new information and new crop species to the Piman Indians in the Santa Cruz Valley, which led to the expansion of farming. As Hohokam agriculture had hundreds of years earlier, the crops of the missions relied on irrigation from Santa Cruz River surface waters flowing through irrigation canals. Kino brought cattle, sheep, and goats into the area from the herds he maintained further south in Mexico. According to Wagoner (1952), Kino viewed the possession of cattle as the most important tool in converting the natives. In a letter to Father Visitor Antonio Leal, April 2, 1702, Kino wrote:

> *There are already many cattle, sheep, and goats and horses...for although in the past year I have given more than 700 cattle to the four fathers who entered this Pimeria, I have for the new conversions and mission, which by the favor of heaven it may be desired to establish, more than 3,500 more cattle...* (quoting from Bolton 1919, pp. 357-358).

By the time Captain Juan Bautista de Anza began his journey down the Santa Cruz Valley in 1775, the missions were under many pressures. The Apaches were continually attacking travelers on the road that followed the Santa Cruz River, as well as the missions themselves, and taking food, livestock, and other goods. The *visita* at San Agustín del Tucson was established in 1757, and the Tubac Presidio was formed in 1751 - though it was defended only intermittently. The Jesuits had been expelled from New Spain in 1767, and Franciscans entered the area to take charge of a seriously deteriorated mission system. Although construction on the churches at San Xavier and Tumacacori was not completed until 1797 and 1822, respectively, they were still centers of missionary activity. Because of frequent fighting with Apaches, Tumacacori often had a population as intermittent as Tubac in its inhabitance.

Another European import, disease, had a devastating effect on Indian populations in the valley. Baldonado (1959), reported the census figures taken by Fray Antonio Ramos in 1774 for the missions and *visitas* in the Santa Cruz Valley. Mission San Jose de Tumacacori, at that time, had 98 Piman Indians, as well as 19 Spaniards; its *visita*, San Cayetano de Calabazas (Calabasas, or present-day Rio Rico), had 138 Pimas (many of which had migrated there from other pueblos abandoned because of Apache raids). The Mission San Xavier del Bac had 160 Pimas, and its *visita*, San Agustín del Tucson, 239. Although the introduction of new crop species and new agricultural technology provided more food per capita than at any other previous time in history, the European diseases introduced into the Santa Cruz River Valley by Spanish explorers and missionaries very nearly led to the complete destruction of communities of native Indians. According to Dobyns (1963), the Indian population in the Santa Cruz River Valley from 1700 to 1800 may have decreased by as much as 95% or more.

## Agriculture

The valley of the Santa Cruz River was one of the earliest and most widely farmed valleys in Arizona. Agriculture has been practiced in the Santa Cruz Valley since at least 1200 B.C., with farming communities established by 600 B.C. (Mabry 1995). The method for farming at this time was occasional dry farming during the rainy season, and irrigation by diversion of surface flows through complex systems of ditches. Agriculture and grazing introduced by Kino and others are described above.

One of the places where agriculture was practiced, by diverting surface flow of the Santa Cruz River into diversion ditches, was near Tubac, which has been continually irrigated for more than 400 years (Halpenny, personal communication, 1995). San Xavier has been almost continuously farmed from prehistoric times to the present.

## Mining

Mining in the Santa Cruz River Valley was practiced for centuries by Indians, primarily in small silver mines in the Santa Rita Mountains. After the arrival of the Spanish, moderate attempts at mining silver and gold were made. At this time the mechanics of the process made any large-scale attempt at mining unlikely. Not only was it difficult to haul the ore over the rugged terrain of the mountains, but the common Apache raids made it dangerous. Furthermore, the Jesuit missionaries of Pimería Alta looked unfavorably upon mining, mainly because of the questionable behavior of miners. Captain Manje, a Spanish soldier who frequently escorted and guarded Father Kino, found what appeared to be a large piece of silver ore at San Xavier del Bac in 1697. However, Fathers Luis Velarde and Jacobo Sedelmayr informed Manje that no mining had been done in Pimería Alta in the first twenty years of the missionary activities there (Wilson 1987).

## Land Grants

In the territory of New Spain in the 17th and 18th centuries, prior to United States acquisition of what is now southern Arizona, the Spanish government wanted to encourage settlement into Pimería Alta. Northward expansion by ranchers led to a process through which the Spanish government auctioned off land grants for the purpose of encouraging settlement and providing grazing land for livestock. A grant was to be four *sitios*, or four square leagues (17,350 acres); however, if a claimant later demonstrated a need for more land for his livestock, he could purchase "overplus," or an indeterminate amount of adjoining land, at the original auction price. When Mexico gained independence in 1821, its new government continued the practice. Many acres of land in the fertile river valleys in what is now southern Arizona and New Mexico were sold to the ranchers. This area was to become a part of the United States through the Gadsden Purchase in 1853, and the U.S. government had to decide how to deal with the claims.

It was decided that if evidence of title could be located in Mexican archives, the surveyor general of the territory must report on the validity of the claim, submit the information to the Secretary of the Interior, who then would give the information to Congress. This process was slow and Congress had not acted on any of the 13 claims by 1888; so, after many years of being pressured, they established the Court of Private Land Claims (CPLC) in 1891. The duty of the Court would be to examine and act on the claims. By 1904, when the Court disbanded, they had confirmed title to 116,540 acres of land out of 837,680 acres claimed (not including the famous and fraudulent Peralta-Reavis claim of 13,000,000 acres, which was submitted to the New Mexico Territory; the land included the Gila River Valley from the Arizona-New Mexico border, nearly to its confluence with the Salt River).

The grants had been located in areas with good grass forage for livestock; therefore, the properties were centered right over rivers and streams, including almost the entire Santa Cruz River and its tributaries, as well as some in the San Pedro River Valley. Following is a short list of facts regarding the land grants that were located on the Santa Cruz River:

Tumacacori/Calabasas

- Oldest land grant
- Requested by Indians at Tumacacori in 1806, full grant in 1807
- Sold several times until C.P. Sykes and John Curry requested sanction from the CPLC in 1880s, who denied the claim - the decision was upheld by the Supreme Court.

La Canoa

- Described in 1775 as being five leagues north-northwest of the Presidio of Tubac (de Anza expedition's first stop)
- In 1820, Tomas and Ignacio Ortiz requested four *sitios* known as "La Canoa", five leagues north of Tubac
- In July, 1821, the surveyor reported that the Santa Cruz runs through the land, but that it only runs water after rains
- Maish & Driscoll acquired half interest from the Ortiz heirs, and the CPLC was petitioned in 1893; the Court awarded title of 46,696.2 acres
- The government appealed, and the Supreme Court awarded title of 17,203 acres

Buena Vista, or Rancho de Maria Santissima del Carmen

- Jose Tuvera petitioned for the grant in 1826, on behalf of his father-in-law, Don Josefa Morales
- Requested four square leagues of "ancient abandoned place of Maria Santissima Carmen," partially in Arizona and partially in Sonora, Mexico
- Sold several times and finally purchased by Maish & Driscoll; petitioned CPLC in 1880s and were awarded 5,733 of 17,354 acres claimed

San Jose de Sonoita

- Title issued to Don Leon Herreras for 1.75 *sitios* in 1825 at Sonoita
- Sold several times; Matias Alsna submitted request to CPLC, Supreme Court allowed the claim after establishment of true boundaries; claim totalled 5,123 acres

El Sopori

- Adjacent to La Canoa and south of Mission San Xavier del Bac
- The Court rejected a claim for 141,722 acres in 1893

San Rafael de la Sanja (Zanga)

- Don Manuel Bustillo petitioned for four *sitios* in 1821, most within the boundary of Santa Cruz Presidio
- Supreme Court in 1902 maintained lower court's allowance of four square leagues

Aribaca (Arivaca)

- Ortiz brothers (of La Canoa) were awarded two square leagues in 1833 at Arivaca, which was 10 leagues northwest of Guevavi
- Charles D. Poston eventually became owner of the land, and he sold it to Arivaca Land and Cattle Company, who petitioned for title in 1893
- Supreme Court denied the claim

Los Nogales de Elias
- Don Jose Elias and his parents Don Francisco Gonzales and Dona Babanera Redondo petitioned for 7.5 *sitios* on the western side of Tumacacori grant
- Camou brothers obtained the claim and petitioned for 32,763 acres in 1892
- Supreme Court ruled against the claim

## The Mexican Period

The pressures of disease and Apache raids were not the only instabilities in the region at this time. Mexico went to war with Spain to gain independence, and achieved it in 1821. In 1846, Mexico again went to war, this time with the United States. With the Treaty of Guadalupe Hidalgo in 1848, the war ended and the United States gained possession of all of Arizona north of the Gila River. The U.S. was interested in expanding its frontier to the west and found that Mexico still controlled some important land; especially important so soon after the California Gold Rush. Therefore, through the Gadsden Purchase of 1854, all of Arizona south of the Gila River was added to the United States. This addition of land to the area of the U.S. was an important precursor to the completion of the railroad, which would finally connect the extreme Southwest with the East, ending the isolation of the region, bringing the settlers, and initiating the Territorial Period.

At various times during this period, and up to the 1870s, there was a great deal of instability because of Apache raids, and some areas were depopulated temporarily. Agriculture and grazing were less feasible during this period than they were in later periods.

## Spanish/Mexican Period Summary

In summary, the Santa Cruz River at this time probably remained much as it was before the Spanish arrived. It had perennial reaches from its headwaters to just north of Tubac, where it sunk into the sand only to rise again near Martinez Hill and through the grounds of Mission San Xavier del Bac. The waters would sink again and rise around the marshy cienegas at the base of Sentinel Hill, or "A" Mountain, at Tucson. Finally, it would disappear again north of Tucson, near what is now the Pima/Pinal County line and become virtually indistinguishable in the desert all the way to its confluence at the Gila River. The perennial reaches of the river supported the Spanish missions, as well as communities of Indians, much as it had probably done for millennia. It had no deep channel, but at least south of Tucson, and along the tributaries, it was frequently marked by gigantic cottonwoods that followed its channel winding through the broad and fertile Santa Cruz Valley, spoken of time and again by early explorers.

**Upper and Middle Santa Cruz River**

The was much activity around the river in Santa Cruz County during the Spanish/Mexican Period. Father Kino established the first significant missionary structure in the upper Santa Cruz River Valley in the 1690s and early 1700s. Among other things, he introduced new agricultural technologies and livestock. Most of Kino's activities were between Mission Soamca in Mexico and Mission San Xavier del Bac (Tucson at this time being a relatively insignificant *visita*). Although Kino introduced ideas and technologies that would lead to many changes in the future of the Santa Cruz, the river probably remained relatively unchanged through this period. The perennial reaches near the mission, and at Tucson, still supported surface flows, and no channelization had yet occurred.

**Lower Santa Cruz River**

The missionary activity of this period, and the later northward settlement, essentially bypassed Pinal County. Kino did not often travel beyond Tucson, and expeditions to the northern frontier proceeded to the Gila River and beyond it. The river, between Tucson and its confluence with the Gila, never supported perennial flow, or even much ephemeral flow, and this is how it remained throughout the Spanish/Mexican Period.

# IV. TERRITORIAL PERIOD 1850-1912

## Trappers Enter Arizona

In 1824, James Ohio Pattie and thirteen other men entered Arizona from the east on a beaver trapping expedition and started moving down the Gila River, which was at that time unexplored territory as far as the fur trappers were concerned. They explored tributaries such as the San Pedro and Salt Rivers, where they expected to find beaver. There is no indication that Pattie or any other trappers entered the Santa Cruz River Valley. From their vantage point on the Gila, it was undoubtedly (as it is today) beyond the marshes at the confluence a dry and barely distinguishable river bed to the south (and therefore not good beaver habitat). There are isolated accounts of beaver on Sonoita Creek, Pantano Wash and possibly the Santa Cruz River, but apparently beaver were not numerous in the area.

## Arizona Enters the Union

Since trapping did not have the allure to bring settlers into the area after the 1830s, it was another decade or more before more American settlers began to enter Arizona. The Treaty of Guadalupe Hidalgo in 1848 came at the end of the U.S. war with Mexico, and added all of modern Arizona north of the Gila River to the United States as part of the Territory of New Mexico. Almost immediately after the Treaty, gold was discovered in California, and a huge number of argonauts began passing through Arizona on their way to expected riches (Harris 1960). Reports by Couts (1961) in 1848, Evans (1945) in 1849, Forsythe (no date), Pancoast (1930), Hunter (no date), Powell (1931) in 1852 , Hayes (1929), Durivage (1937) in 1849, and others, provide information about this period.

Once the territory joined the United States, a survey of the boundary was conducted in 1851 in anticipation of the Gadsden Purchase of 1854. Gray conducted a survey for the railroad in 1854, with another boundary survey led by Emory in 1893, both of which provided valuable information about the river and its environs.

In anticipation of the immigration of pioneers, some entrepreneurs began to set up businesses in important locations along major routes of travel. One of these locations was

Tucson, along the Gila Trail (Walker and Bufkin 1986: Figure 40). At this time, however, Tucson was still a part of Mexico and certain instabilities in the region, including Apache raids and the fact that the area was isolated from either Mexican or United States protection, hindered expansion. It was not until well after the Gadsden Purchase was ratified in 1854, that Tucson held an active military presence. In fact, it was only with the conclusion of the Civil War in 1865 that a cohesive military presence, and the subsequent defeat of the Apaches, brought a relative stability to the region and led to the expansion of population and enterprise. The first notable enterprise that took place in the region was ranching.

## A Route for Travelers

The Santa Cruz River provided a useful route for many early travelers and explorers. For the Spaniards coming north from Sonora, the river was an ideal route, providing both water and food for animals and people. For people coming from the east, there were three feasible ways to enter the state: north of the White Mountains along the Little Colorado River; south of those mountains along the Gila River (approximately the present I-10 route); and, south of the Chiricahua Mountains. For many early travelers the Gila Trail, or southern route, was the safest, as Apaches controlled much of the middle route and mountainous conditions made the northern route less attractive. By the end of the 19th century, more travelers took the middle route once the Apaches were subdued. The Butterfield stage, and later the railroad and highway, all came this way.

Using the southern route, or the Gila Trail, travelers crossed the mountains at Guadalupe Pass, headed west toward the San Pedro River, and then usually turned south to the town of Santa Cruz and followed the Santa Cruz River all the way to the Gila River. Parties without wagons might take a shortcut along Sonoita Creek. This route and slight variations on it were used for exploration, travel to the California gold fields, prospecting, cattle drives, and many other purposes. The traveler could count on grass for the animals as far as about present-day Marana, as well as water and game. Some of those who took this route were the Mormon Battalion in 1846, Bartlett (1965) in 1852, Gray (1855) in 1854, and Emory (1857) in 1855.

One of the early travelers on the upper Santa Cruz River was John Spring (Gustafson 1960). In his diary, Spring gives one explanation of the origin of the name "La Canoa" (now Canoa, just south of Continental), and it is one of the few allusions to navigation on the river found in the literature:

> *A number of the newly-arrived squatters* [post-gold rush settlers] *followed the Santa Cruz River upward as far as Calabazas and Huebabe and settled there, while a party of about eighteen, including women and children, stayed at a place named then, as now, "La Canoa," so called because a Mexican settler already there had built a large canoe, or flat-bottomed boat, upon which he crossed the river whenever the lower, or western, road leading to Tubac became flooded by the summer rains, in which case the eastern road was chosen, as it led over the high ground along the ever-present foothills.* (Gustafson 1966: 53).

The portion of the route north of Tucson, however, usually offered the traveler little in the way of either food or water. Many travelers complained of lack of water and lack of forage all the way from the 9-mile waterhole north of Tucson to the confluence with the Gila River: "An Indian came into camp last night and reported 'no water until we get to the Gila' and as proof drank until he made himself sick; he stated that he had been two days without..."[camp just north of Tucson] (Bell 1932); "...we pushed on in order to procure water, and after driving till ten o'clock without breakfast, found some, but it was almost impossible to use it, being covered with a thick green scum" [about 22 miles north of Tucson] (Aldrich 1950); and, "Hence [from Tucson] to the Gila River was a desert plain without water. To have the advantage of the coolness of the night and shade, we started at sunset, traveling without order and camping in small squads. By sunrise we had mastered 30 miles; by sunset, 40 more. We rested till morning and at 10 or 11 a.m. reached water at the Gila River" (Harris 1960).

With the arrival of stagecoaches in 1858, and suppression of the Apaches by the 1870s, the more northern route became popular and the southern route fell into disuse. This route somewhat paralleled present I-10 highway and entered the Santa Cruz Valley along Cienega Creek-Pantano Wash. The railroad later also followed this alignment.

## Livestock in the Santa Cruz Valley

The area had been grazed periodically during the Spanish and Mexican periods and wild cattle were encountered by travelers, but the numbers of cattle in the late 19th century probably far surpassed earlier numbers.

The Southern Pacific Railroad was completed as far as Tucson in 1881, opening southern Arizona to commerce with the East. Furthermore, droughts in the ranges of California and Texas were forcing many ranchers there to move their cattle. A combination of these, and perhaps other forces, led to a huge immigration of ranchers with their cattle into Arizona. In the early 1880s, two ranches along Pantano Wash near Tucson, Empire and Vail, had an estimated total of 6,000 cattle and 23,000 sheep (Wagoner 1961). Between 1825 and 1843, there were from 2,000 to 5,000 head of cattle grazed in the San Rafael Valley annually (Hadley and Sheridan 1995).

When the livestock industry moved into southern Arizona in the 1880s, the economy of the region grew at an unprecedented rate. Much of the growth could reasonably be attributed to the completion of the railroad, the growth of the livestock industry, and the development of groundwater-pumping technology. Samuel Hughes, an early pioneer of Tucson, gives a concise description of Tucson in 1885:

> *Tucson now has a population of 9000, about 1/3 Americans. We have 1 Catholic church, 5 Protestant churches, 3 public schools, "one large brick school house," 9 teachers and 500 scholars... . We also have glass works, water works, electric light, 2 ice factories, two wagon manufacturies, 2 breweries, a sash door and blind factory and R. R. repair shops, a fine brick Court House, 5 hotels, about 20 restaurants. ... There are good mines all around Tucson from 3 ½ to 75 miles which will pay when properly developed. Good cattle ranges from edge of town. Pima Co. has about 10,000 head of cattle on ranges* (Page 1954: 64).

So, there were a large number of livestock grazing in the Santa Cruz Valley when severe weather patterns moved into the area in 1885. A series of very dry summers and very wet falls, coupled with the overgrazing of livestock, created a decade of dramatic change on the middle Santa Cruz River. Cattle and sheep grazed until much of the valley was denuded; short heavy rains in the fall months did not encourage new growth, but instead washed away much of the exposed soil. In early 1890, the previous four years of very dry summers, coupled with flooding in the fall and winter, culminated with the most damaging and extensive floods that had yet been recorded in the valley. The flood waters wrecked buildings, washed out dams (see below: Warner and Silver Lakes), and initiated the deep entrenchment of the Santa Cruz River that is characteristic today. The cattle industry peaked within a year; an official census showed 721,000 head of cattle in Arizona in 1890, although many estimated the count to be twice that. But a year later 50%-75% of the cattle were dead of starvation, and many more were being moved out of state or sold for beef (Wagoner 1961). The lush grasslands that existed for millennia, and that were written about with enthusiasm by explorers, have never recovered.

## Grazing and the Arroyo Debate

The role that grazing played in arroyo cutting in the southwest has been debated for years (Bryan 1925 and 1940, Antevs 1952, Hastings 1959, Cooke and Reeves 1976, Dobyns 1981, Betancourt and Turner 1990, Bahre 1991, and others). Some have argued that climatic change best accounts for arroyo cutting, some have argued that arroyo cutting and filling are natural processes that preceded cattle, and others have argued that a combination of factors best explains the fact that in many places in the southwest arroyos formed in the late 19th century. They further argue that the presence of too many cattle served as a trigger for arroyo cutting in the presence of a drought-flood cycle. Betancourt and Turner (1990) discuss the role that other human activities played in cutting the Santa Cruz River channel - poorly designed ditches, diversion dams and other activities.

## Agriculture

During the late 1800s and early 1900s, agriculture in the valley changed because of the introduction of new technologies, including relatively efficient groundwater pumping devices. Some major areas of agricultural development at this time were between Tucson and Tubac. This was undoubtedly due to the availability of the water supply and the broad, fertile flatlands.

Even though water was relatively plentiful, it was not always strictly reliable, as this quote from Bartlett (1965) shows:

> *The preceding fall* [of 1851] *after the place has been again occupied, a party of Mormons, in passing through on their way to California, was induced to stop there* [Tubac] *by the representations of the Mexican commandante. He offered them lands in the rich valley, where acequias were already dug, if they would remain and cultivate it; assuring them that they would find a ready market for all the corn, wheat and vegetables they could raise, from the troops and from passing emigrants. The offer was so good and the prospects were so flattering that they consented to remain. They, therefore, set to work, plowed and sowed their lands, in which they expended all their means, anticipating an abundant harvest. But the spring and summer came without rain; the river dried up; their fields could not be irrigated; and their labor, time, and money was lost. They abandoned the place, and, though reduced to the greatest extremities, succeeded in reaching Santa Isabel in California, where we fell in with them.*

Once Anglos began migrating into the Santa Cruz River Valley, some new technologies and techniques came with them. Agriculture in the mid- to late-1800s was characterized still by the diversion of surface flows. When the groundwater table began to drop, cross-cut ditches were dug across the river to intercept shallow subsurface waters. Sam Hughes' ditch was one that diverted subsurface waters to fields in and around Tucson. During the floods of 1890, it was probably at this cross-cut that the entrenchment of the Santa Cruz River began (Betancourt and Turner 1990).

Even before the arrival of groundwater pumping technology, large tracts of land were devoted to agriculture either through the diversion of surface waters or simply by dry farming. The extent of pre-pump farming in the valley is illustrated by the following quote:

> *That portion of the valley which is generally watered (for the Santa Cruz is much like your eccentric streams of Southern California, which sink out of sight sometimes for many miles) produces, like southern California two crops a year. Last year there were 40,000 acres of land in cultivation in Santa Cruz Valley proper, and nearly 45,000 acres in the net-work of valleys and canyons adjacent* (Bulletin 1879).

By 1890, pump technology arrived in southern Arizona. The pumping of groundwater changed the nature of agriculture in the Santa Cruz River Valley forever. New crops were introduced into the area, new land was devoted to agriculture, and the water table began to drop significantly. Wheat, alfalfa, citrus and pecan trees were all water-intensive crops introduced into the Santa Cruz Valley after the arrival of groundwater pump technology.

Another interesting attempt at agriculture occurred near Continental soon after statehood. In 1914, the Continental Rubber Company began growing guayule (*Parthenium tomentosum* X *P. argentatum*) for production of synthetic rubber. When World War I ended, the price of rubber dropped and the company was out of business. At its peak in 1920, 450 ha, or approximately 1100 acres, were in guayule production (Betancourt and Turner 1990).

**Calabasas Development Site**

Another interesting historical event around this time was that of the Calabasas development site. In 1878, Col. Charles Sykes bought the Tumacacori, Calabasas, and Guevavi land grants (see: Spanish/Mexican Period, Land Grants), which totaled about 80,000 acres of the river valley near the Sonoita Creek confluence. He published a pamphlet with artwork showing a lush, thriving city on the banks of the Santa Cruz River, including a fleet of steamboats at the waterfront. This may be one reason for the historical perception of a large, perennial river. The pamphlet was soon found to be a ridiculous exaggeration, and Sykes' land claim was found to be invalid by the Court of Private Land Claims (Holub and Bufkin 1987). Development around Calabasas had to await the Rio Rico subdivision in the 20th century.

## Mining

It was not until after the Gadsden Purchase that large-scale mining started in the Santa Cruz Valley, perhaps for two reasons: the entrance of the territory into the United States allowed for a solid military presence in the area for the first time; and, coincidentally, the Gadsden Purchase was ratified at a time shortly after the 1849 gold rush which inspired a huge migration of prospectors to the West, and quickly led to a scarcity of mineral resources and an excess of miners in California. The mining that took place prior to the Gadsden Purchase was centered in the Santa Cruz Valley because of the natural abundance of ore and the presence of other necessities. The valley in the 1800s,

> *in addition to all its mineral wealth, contained large areas of agricultural land with permanent water, wood and grass, contained twenty-five silver mines or*

*openings which were worked by the Mexicans before the Apache war, and became famous for their rich ore. The best known mines were San Jose, Santa Margarita, Basura, Blanca, Azonias, Tafitos, Amado, and La Purisima.* (Blake 1901: 4).

The "era of modern mining" in Arizona, according to Wilson, began in the Santa Cruz Valley in 1857 with the purchase of the Sopori and Arivaca land grants (Wilson 1987). The purchasers of the grants, including Charles D. Poston, formed the Sonora Exploring and Mining Company, and later the subsidiary Santa Rita Silver Mining Company. Despite considerable optimism about the richness of the mines, the operations never produced a significant profit. The status of major mining activity in the Santa Cruz River Valley at the turn of the century is described by Blake (1901), who laments the absence of adequate railway transportation as hindering the development of significant deposits of mineral wealth.

## Woodcutting

Woodcutting played an important role in changing the river environment. Not only was wood used to fuel pumps, it was used in increasingly large amounts for building houses, cooking, fueling mining operations, powering various kinds of engines, building and fueling the railroads, and warmth. Trees were cut to make way for agricultural fields, homes, and businesses. The trees closest at hand were usually cut first, followed by trees farther and farther out. By 1875 it was estimated that there were only 3 trees growing within Tucson city limits. Major tree planting efforts began in 1880, and the local water company provided free water for trees on city streets in 1888. While beautification efforts proceeded into the early 20th century, the riparian forests were rapidly being lost due to wood harvesting, lowering of the water table, and damaging floods. (McPherson and Haip 1988). The loss of riparian vegetation further contributed to degradation of the channel of the Santa Cruz River.

## The Railroad

During the 1870s and 1880s, the railroad slowly made its way across Arizona. Casa Grande was originally a temporary terminus of the Southern Pacific Railroad in 1879 (and was called "Terminus" for postal purposes for more than a year). Initially, water for the railroad community was brought by train from Maricopa, farther west until wells could be dug. After a year, enough railway ties and other equipment had been brought to finish the railroad to Tucson. This was the only real community along the Upper Santa Cruz, except for Maricopa Wells at the confluence with the Gila.

The railroad not only influenced grazing as described above, but also the growth of towns. Goods and people could be brought easily, and relatively cheaply, across the continent. Railway construction itself had an impact on Cienega Creek. The original track was along the creek and was washed out several times before being moved to the ridges above the creek where they remain. Two bridges span the creek. Construction of this section of the railroad was considered the most difficult portion of the track across southern Arizona.

Railroads also connected Nogales with the San Pedro Valley and Guaymas (traveling along Sonoita Creek). Another railroad connected Nogales with Tucson, paralleling the Santa Cruz. Nogales grew in size and importance because of the railroad.

## Water Management in the Tucson Area

### Irrigation Ditches

Farming was intensive in the San Xavier region. Maps from the 1880s and 1890s show the river being basically diverted fully into agricultural ditches (see Appendix A). A survey of the Martinez property about that time (between Martinez Hill and the mission) showed no river, only an agricultural ditch, although the river must have crossed this property (Arizona Historical Society, Martinez file).

The Manning and Farmers ditches diverted most of the low flow south of downtown Tucson by the turn of the century. Agricultural ditches watered some 140 acres north of the Mexican border and diverted most of the low flow. Greene's ditch north of the end of the Tucson Mountains diverted any existing flow west to Avra Valley.

**Warner's and Silver Lake**

Tucson in the 1880s, then, was a growing community with a need for new industry and recreation. This need was partially fulfilled in the development of two lakes on the Santa Cruz River near downtown Tucson.

Silver Lake was built in the 1860s by putting a dam across the Santa Cruz River about a mile south of Sentinel Hill, or "A" Mountain. In 1863, James Lee built a mill near the lake, grinding flour with power supplied by water from the lake. Warner Lake was built about one half mile north of Silver Lake by Solomon Warner in 1883-1884. Since all of the water from the Santa Cruz was impounded and diverted by James Lee, Warner built his dam far enough north to catch the waters seeping from the cienegas around the base of Sentinel Hill. Both of these mills ground grains to supply flour to the nearby community. Warner was fairly successful, so he added a three stamp mill to grind ore from local mines he was operating (Arizona Weekly Star 26 December, 1878).

These lakes became popular areas for a number of reasons. First, local people began to picnic by the waters, and then to swim. Also, the lakes were large enough that at least one flat-bottomed boat was launched on Warner's Lake for recreation both on the lake and "up the river" (Betancourt 1978). The water attracted a lot of waterfowl to the area, and some hunters obtained the right to hunt the ducks (Arizona Weekly Citizen 17 November, 1883). In 1888, Frank and Warren Allison had possession of the lake, and were harvesting over 500 pounds of the fish every day to sell in Tucson (Arizona Daily Star 7 June, 1888). Bath-houses were built on the lakeshores, and for some time the lakes near Sentinel Hill were probably the focal point of recreation for the community. Betancourt (1978) includes a detailed account of both Silver and Warner's Lakes. Portions of this account, as well as other sources that describe the lakes from their constructions to their demise follow, taken from Betancourt:

> *"The head of the millrace* [to Warner's Mill] *was a short distance below the ford on the Santa Cruz, near James Lee's water mill and pond. Its total length was about 1.5 km. The race crossed church lands southeast of the present intersection of Mission Lane and Grande Avenue, a tract then occupied by the mission garden (not*

*to be confused with the older mission orchard which was north of Mission Land and the mission buildings). The tailrace (the ditch that takes water away from the water wheel) also crossed church lands, apparently passing between the old convento structure and Mission Lane. It followed the mission fence to the east where it emptied into the old ditch or "Acequia Madre" from which the lands on the eastern side of the valley were irrigated. It may seem a discrepancy that the tailrace did not empty into the river; however, there was no stream below the dam at Lee's pond. Rather, the water from the dam had long been diverted to follow a system of acequias which irrigated the level bottomlands on either side of the valley."* Page 71.

Quoting the Arizona Citizen 30 October, 1875..."*The driving force* [of Warner's Mill] *is some six hundred cubic feet of water with an average fall of eleven and a half feet. To get this force Mr. Warner had to construct a ditch...which is quite a piece of engineering, but as Mr. Warner says, the only badly constructed thing about the mill."* Page 72.

*"Successful in his initial venture, in 1878 Warner added a three stamp mill to process ore from small mines he was working; to be run by borrowed power from the existing grist mill."* Quoting Arizona Weekly Star 26 December, 1878...page 72.

*"Warner's discontent with the millrace led him to explore other alternatives. In 1881, the Tucson Water Company, headed by Silvester Watts, dug a trench in the riverbed near the present location of the Valencia Road bridge about 10 km south of the mill (Schwalen and Shaw 1957: 89). During the following two years, the water level at Lee's pond dropped considerably due to the water development up stream. Because of this, Warner then considered damming the cienegas fringing the eastern slopes of the Tucson Mountains between San Xavier and Tucson (the present West Branch). He begin buying sufficient land south of 'A' Mountain to serve his purpose. In the summer of 1883, he began building an earthen dam to impound the water from the cienegas (The Arizona Citizen 11/17/1883). The dam started where the millrace first touched the hill and ran for 400 m along the side of the race towards Silver Lake (by 1880s Lee's Pond had changed its name), ending at a point of ground high enough to hold all the water needed. The top of the dam was wide enough for a roadway to connect with the road (the present Mission Road south of the mill) by the millrace. At the base of 'A' Mountain was a bulkhead (a wall or partition built to hold back water) ten feet wide and equipped with strong gates which were opened in case of flooding."* Page 72.

Warner, Solomon, 1884 "Personal Notes and Narratives" [see Hayden no date-b]...*"The watershed that supplies the cienega is quite extensive. It commences on the west side of the Sierritas...In some seasons the quantity of water running from the cienega is equal to from one quarter to one-half enough to run the mill several months a year...Tullies [cattail] and water grasses grew on all of the land and the pond covers with the exception of three or four acres on the south and east side...There were other depressions where the water remained all the time."* Page 73.

*"The lake attracted a variety of wild ducks and soon the area became a favorite of hunters. The lake was also stocked with carp obtained from the government* (the Arizona Citizen 3/15/1884)."

In July 1884, [Warner] received legal notice from Hereford Lowell, attorney for the Water Overseer and landowners below Warner's Lake:

*"You are hereby notified that you are interfering with the water in the Santa Cruz and obstructing the free and continuous passage of the same at your mill and lake and water being taken from and prevented from flowing in the public acequia without the consent of the water overseer and to the damage of the landowners thereto.*

*You are also notified that unless you desist from interfering with and using said water in the manner you are now doing that you will be proceeded against in accordance with the law* (letter of July 8, 1884, Solomon Warner Biographical File, on file at archives of Arizona Historical Society, Tucson)." Page 74.

*"Lucas and McCandless have a way of making visitors at Warner's Lake feel as if they were at a picnic. The lake itself is picturesque, being a large sheet of water, with wild ducks floating at a distance and white cranes perching on the shore. The waters contain good size carp, and an abundance of smaller fish of good quality. The leasees propose to put in a wharf at the landing, and launch a small steamboat on its waters."* (Arizona Mining Index, 24 Apr 1886).

*"According to Solomon Warner (1884), Lees' Pond (Silver Lake) was first built in 1856 and consisted of a low earthen dam south of present Silverlake Road. Originally, it had been built as a flood-control device to minimize damage to cultivated fields downstream and provide an easily-managed water supply from which to irrigate these same fields. Other uses came into being in 1857 when Alfred and William Rowlett (formerly of Virginia) built Tucson's first flour mill powered by a millrace which began at the pond. In 1859, they advertised that '...Those wishing to have their wheat ground into flour could take it to Rowlett's Mill ...having purchased in San Francisco the most improved milling stone and bolt, we defy competition'* (The Weekly Arizonian 10/27/1859)." Page 81.

*"In 1880, a man by the name of Smith was proprietor of George J. Roskruge's boating, swimming and bathing facilities at Silver Lake* (Arizona Daily Star 6/10/1880).

Around 1881, James Lee leased 20 acres to J. F. Ricky and J. O. Bailey for the purpose of setting up a resort along the shores of Silver Lake. The 1881 City of Tucson Directory describes the resort and lake in the following manner:

*...lake is caused by a dam of masonry in the Santa Cruz River and extends over several acres. Several boats for sailing and rowing up the river beyond the lake...A row of commodious bath houses for bathers and a stout rope extends across a portion of the lake for the convenience of persons learning how to swim. The hotel, bath houses, pavilion, lake, and grove occupy a space of 20 acres, leased and controlled by Ricky and Bailey, who also own the mile racetrack [presently Cottonwood Road] adjacent thereto and where the annual races are held. This is the*

*only race track near Tucson and only swimming baths in Arizona* (Barter 1881)." Page 86.

"*By 1885, the Silver Lake area was dotted with Chinese truck gardens* (Tom 1938)." Page 86.

Other descriptions of the lake and irrigation in the area follow:

"*...To illustrate how every gulch surround the Santa Cruz Valley contains a 'mine of wealth', let the case of Messrs. Miller and Warner's be cited. Finding that the 'rawhide' or pioneer method of dividing the water in the irrigating ditches in the Santa Cruz prevented them from running their flour and quartz mills with any certainty or regularity, they cast about for other help. On the south side of Picket Post butte (or Sentinel hill) there is a small gulch running around the hill. In this gulch were certain small springs, as indicated by the cienegas. These gentlemen went to work last November and built an earthen dam a quarter of a mile wide across the mouth of the gulch. The effect was that in a very few days they had a pond of water covering sixty acres, and that averaged eight feet in depth. They now have sufficient water on hand to not only guarantee a continuous run of their mills, but also to irrigate and render valuable many hitherto unused acres below them. They also procured a lot of carp from the Government and put in their pond. From the well known breeding character of these fish these gentlemen will soon have one of the finest fish farms in America.*"
Quoting Arizona Citizen, daily, 3/15/1884, 1-5.

"*Warner's Work. . . .The result of this big dam [Warner's Lake] has already been wonderful. The waters of the many springs of the different cienegas on the Warner land have been held back by the dam, and have risen till they have covered some twenty acres of land, creating a sheet of water that is beautiful to look upon. Already the wild fowl have made it their resort, and an organization of hunters have obtained the exclusive right to shoot upon its waters. A flat-bottomed boat sails over its surface. The different kinds of ducks killed there are the gray and spoonbill, the green and red winged teal, mallard, canvass back, widgeon, spring tail, the butter and a new kind never seen before called the fish duck. It has saw-shaped teeth. The snipe, curlew and plover appear abundantly.*

*When the dam is completed and the waters have occupied all their space, about fifty acres will be covered. . . . None of the water of this big pond comes from the Santa Cruz river. It is all from the land owned by Mr. Warner, and the economical measures he hast taken to save this water for his own use first, and after that for the farmers below him is to be commended. . . . The waters of the Santa Cruz river still flow in the old ditches undisturbed by this new and great improvement by Mr. Warner.*" Arizona Weekly Citizen, Tucson, 11/17/1883 3:3. Warner, Solomon (Hayden no date-a).

"Mrs. Moss Sees 50-year Change"...[Mrs. Moss is the daughter of James Lee] "*You probably never heard of the old flour mill out at Silver Lake,' she said, 'but my* *father owned and ran that for years. You see, there was one built and run there before the Civil War in order that Tucson might have white flour and a place for the grinding of grain...Silver Lake was formed south of Tucson by putting a dam across the Santa Cruz. That supplied power for the mill which father rebuilt in 1863. He operated it until 1880, the year the railroad came, and he also opened certain amusement concessions on the lake. After his sale to Maish & Driscoll, they put in more facilities for boating and swimming..."* clipping from Arizona Star, Lee, James (see Hayden no date-a).

The same drought and flood cycles that confounded the overgrazing of cattle in southern Arizona in the late 1880s also affected Warner's and Silver Lake. The dams that created both lakes were periodically washed out and rebuilt during this period. It was the intense flooding of February, 1890, that dealt the final blow to Tucson's only boating, fishing and bathing ponds. The floods washed out the dams, and the entrenchment that occurred at the same time necessarily meant that the hydrology of the Santa Cruz River was very much different than it had ever been in recorded history, so neither the dams nor the lakes were rebuilt.

## Groundwater Pump Technology

The entrenchment that occurred in the riverbed near Tucson radically changed the hydrology of the river. The development of pump technology that first became available in 1891 (Holub and Bufkin 1987), initiated the extensive groundwater pumping that excluded any reasonable chance of recovery by natural processes.

Pumping also affected the tributaries of the Santa Cruz River. The part of Rillito Creek that is today near Craycroft Road was chosen as the site for Fort Lowell in 1871 because of its water supply and its plentiful supply of grass for the livestock. Although at first the fort had a steady water supply, demands soon rendered the supply inadequate. In 1873 windmills were constructed, but these were also unsatisfactory. Acequias were then dug to bring water to the fort, but by 1885 these too were inadequate. Wells to a depth of 150' were dug without success, and a plan to bring water from Sabino Canyon seven miles north also did not work out. Finally in 1887, a new steam pump was procured along with large new water tanks (Smith 1910). The water delivery problem was solved, but de-watering of the river proceeded quickly.

At this time the population of Tucson was growing, and it is difficult to say, now, if pump technology led to an increase in the population or if the expanding population accelerated development of new pump technology. In the first decade of the 20th century, the first full decade after the introduction of pump technology to the area, the population of Tucson nearly doubled (Figure 2). On the eve of the new century in the late 1890s, Tucson was for the first time dependent on groundwater, and likewise on the wood for fueling the pumps, and it was in shortage of both. The water table at the San Xavier District was dropping, as reported by the superintendent of the Tucson Water Company in June, 1895:

> *This fact is determined by the well from which the city supply of water comes. Originally the well was but 18 feet deep and the process of sinking is still going on. Formerly the city supply came through submerged sluices in the river bed and to some extent these still furnish all that is necessary, but the company has been obliged to run their pump 27 months in the last two and a half years. To do this it required 1,782 cords of wood at an expense of $4500. Tucson uses an average of 13 million gallons of water per month* (Arizona Daily Star 13 June, 1895).

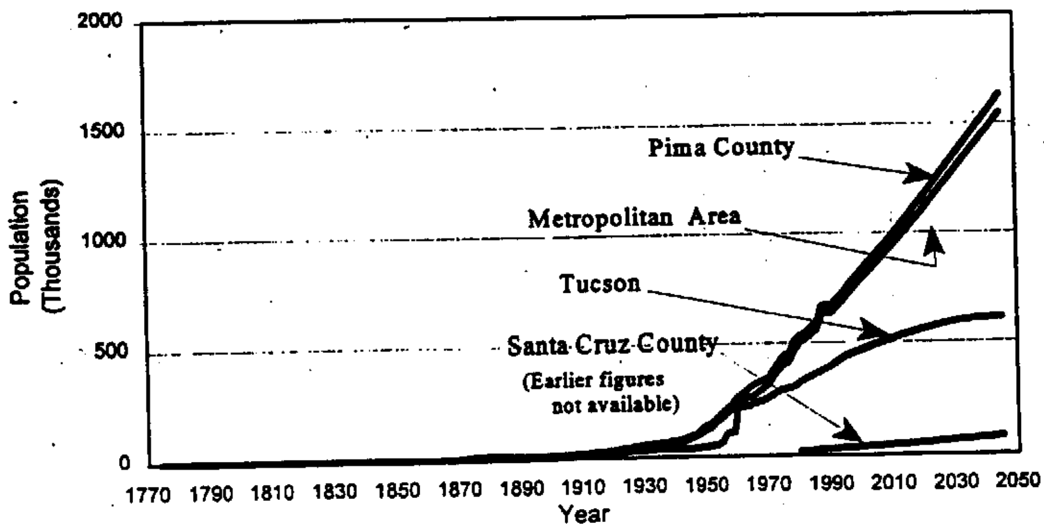
Papago Indians furnished most of this wood (Arizona Daily Star 17 November, 1895), presumably from what they gathered in the surrounding area. A cord of wood is a stack four feet high, four feet wide, and eight feet long, or 128 cubic feet. Also, as a matter of comparison, Tucson Active Management Area used an average of well over 9.2 billion gallons of water per month in 1990 (Eden and Wallace 1992), and average depth to the water table within the Tucson Active Management Area in 1985 was 240 feet (Arizona Department of Water Resources 1991).

## Territorial Period Summary

In summary, the Territorial Period in the Santa Cruz River Valley was a time of significant change. The river was put under tremendous pressures from a new population

# Figure 2. Population from 1774-2045

Santa Cruz River Valley



of settlers in the area. The completion of the railroad in 1881 opened up the previously isolated southwest to both settlement and commerce. A period of heavy grazing in the 1880s, along with extreme weather patterns, culminated in the beginning of the entrenchment of the Santa Cruz River during the extraordinary floods of early 1890. The introduction of pump technology in the 1890s led to the first era of groundwater dependence in the valley, and perhaps played a part in the near doubling of the population in Tucson from 1900 - 1910. This period, immediately before statehood in 1912, marked the beginning of the changing vegetative structure, erosion of the channel, and drop of the water table that is now characteristic of the modern river.

At the end of the Territorial Period, in 1912, the Santa Cruz River was a very different river, but it was probably still perennial in many of the same reaches that historically had surface flow, from the headwaters to just north of Tubac, near Mission San Xavier del Bac, and again near Sentinel Hill at Tucson; albeit a surface flow that was, at least at the latter location, somewhat lower due to water use and the entrenchment of the river that occurred during this period.

**Upper Santa Cruz River**

The upper Santa Cruz River, in Santa Cruz County, was historically perennial from the headwaters into Mexico and back again to Tubac. In addition to a surface flow, the river here frequently diffused into broad cienegas, especially near the mouths of some tributaries like Potrero Creek, Sonoita Creek, Nogales Wash, and others. In fact, the marshy areas near Calabasas were reported to be the cause of a problematic outbreak of malaria in the 1870s (Hendrickson and Minckley 1984). Some were drained.

The river in Santa Cruz County, although exposed to many human impacts in the Territorial Period, probably remained relatively unchanged - all of the perennial reaches and many of the cienegas remained intact at least until the early 1900s.

Halpenny (1988) summarizes historical references to where the upper Santa Cruz River went subsurface. This information is reproduced in Table 3.

## Table 3. Historical References to Where the River Went Underground

*Source*: Halpenny 1988: pp. 5-6

| Year of Travel | Name of Observer | Source Reference | Where River Ceased to Flow |
|---|---|---|---|
| 1775 | Pedro Font | Bolton 1931 | South of campsite, which was 7.8 miles downstream from La Canoa |
| 1804 | Manuel de Leon | McCarty 1976 | At Tubac |
| 1804 | Jose de Zuniga | McCarty 1976 | 5 miles downstream from Tubac |
| 1821 | Ignacio Elias Gonzales | Surveryor General 1880 | 1.3 miles downstream from Tubac |
| 1848 | Cave Couts | Couts 1961 | Shortly downstream from Tubac |
| 1848 | John Durivage | Durivage 1937 | 8 miles downstream from Tubac |
| 1849 | H.M.T. Powell | Powell 1931 | 9 miles downstream from Tubac |
| 1852 | J.R. Bartlett | Barlett 1854 | 9 miles downstream from Tubac |
| 1856-57 | W.R. Emory | Emory 1857 | Shortly downstream from Tubac |
| 1867 | W.A. Bell | Bell 1869 | At Canoa (Ranch) |
| 1872 | T. White | White 1872 | Present Canoa Ranch Headquarters |

**Middle Santa Cruz River**

In Pima County, the middle section of the Santa Cruz River experienced perhaps the most dramatic changes of any other portion of the river during the Territorial Period. The river was always ephemeral from Tubac to San Xavier del Bac, and then again between the mission and Sentinel Hill at Tucson. The perennial reaches at the mission and near Tucson probably continued to flow supersurface beyond statehood.

However, this was an important period of change in the river. The settlement of Tucson and subsequent demands put on the river's flow became unsustainable in the late 1800s. For the first time the population became dependent on groundwater. The river was dammed and deep diversion structures were built to capture shallow subsurface flows. A combination of these and other impacts led to the beginning of the entrenchment of the Santa Cruz River near Tucson, which quickly worked its way upstream. By the time of statehood in 1912, the river was channelized as much as 10 meters all the way from Tucson to Mission San Xavier del Bac (Betancourt and Turner 1990).

**Lower Santa Cruz River**

The river through Pinal County was depicted on several old maps as discontinuous, stopping entirely, then starting again with the influx of some minor tributaries shortly before the confluence with the Gila River near Maricopa Wells. At this location marshes abounded and extensive agriculture was practiced by the Pimas and Maricopas, and later by Anglos. Maricopa Wells became an important stopping point for travelers, stagecoaches, the Butterfield route, and later the railroad. Little water was available for travelers or for settlers until pump technology was developed.

The "Ninety-Mile Desert" through which the Santa Cruz River flows from Tucson to its confluence with the Gila River has never had regular surface flow. Travelers who used this route often found it a long and miserable journey.

Elsewhere in Pinal County settlement was based on the Gila River, rather than the Santa Cruz River (both prehistorically and historically).

# V. THE MODERN PERIOD, 1912 TO THE PRESENT

Some citizens had become discontented with being a part of the Territory of New Mexico. Yuma residents, for example, had to travel over 700 miles to visit the capitol at Santa Fe. So President Lincoln signed the Arizona Organic Act in 1863, which created a separate Arizona Territory (Dreyfuss 1972). It was not until February 14, 1912, that Arizona finally became the 48th State in the Union.

## Mining

Thousands of small mining operations were established in the area, but only a small portion of those have yielded significant amounts of minerals.

The major mining efforts along the Santa Cruz River Valley have been in copper, sand & gravel, and molybdenum, with some extraction of silver, gold, cement, lead, clays, gypsum and perlite. Since water is necessary to process the minerals, mining was historically near sources of water.

Groundwater pumping and water transport have allowed an expansion of this industry. Today, open pit copper mining predominates. By 1962, groundwater pumping between San Xavier and Tubac had lowered the water table there some 70 feet (Halpenny 1962). Annual pumping for these large open pit copper mines was 20,000 acre feet in 1994, down considerably from its peak in the 1950s-70s.

## Population Growth

The population in the vicinity of Tucson at statehood in 1912 was probably around 14,000. A graph of the population growth in the region indicates the beginnings of exponential growth at about the same time that some perennial reaches of the river dried up, around 1940 (Figure 1). In 1995, there are about 700,000 people in the Tucson metropolitan area, and projections by the Pima Association of Governments (PAG) and the SouthEastern Arizona Governments Organization (SEAGO) project the population in Pima and Santa Cruz Counties to be approximately 1.7 million by the year 2045 (Pima Association of Governments 1995; SouthEastern Arizona Governments Organization 1995).

The population of Nogales, Arizona increased dramatically after the arrival of the railroads. Nogales, Sonora is several times the population of Nogales, Arizona (population figures conjectural) and continues to impact both water supply on the river and water quality. A major wellfield along the Santa Cruz River south of the border effectively eliminates surface flow for over 10 miles.

Tubac, Carmen and Tumacacori remain small towns, but urban development is encroaching upon them. Green Valley has grown rapidly since its beginnings in the 1960s. Incorporated areas within Pima County include Sahuarita, Tucson, South Tucson, Oro Valley, and Marana. In Pinal County, Casa Grande is the largest Santa Cruz River town. It was a very small railroad community with limited agriculture until 1940 when high-powered pumping technology made modern agriculture (primarily cotton) in the area feasible. In 1910 the population of the town was only 250. Between 1940 and 1950 the population jumped to 4,181. Casa Grande is growing rapidly with the advent of industry and regional shopping centers. Smaller towns include Eloy, Picacho, and Maricopa.

## Agriculture

Agriculture has been the major water user throughout the basin since the 1880s. Today agriculture is still an important industry in Arizona, although of decreasing importance with the expansion of urban areas and increased costs of water. The three counties that the Santa Cruz River passes through in Arizona, Pima, Pinal and Santa Cruz, had nearly 225,000 acres of land in irrigated crops in 1987 (some of which were in the Gila drainage, not the Santa Cruz drainage). The primary crops have been cotton, alfalfa and wheat, with pecan groves in the Green Valley area. Irrigation of these acres is partially through groundwater pumping of aquifers in the Santa Cruz River Valley.

The groundwater overdraft in the Tucson Active Management Area (AMA), which comprises most of the Santa Cruz Valley, is 207,000 acre-feet per year (Eden and Wallace 1992). The Tucson and Santa Cruz AMAs are operated with a goal of "safe yield" while the Pinal AMA is not, since the groundwater supply is so depleted. Because of the increased cost of pumping water, agriculture in the Pinal AMA has declined, although the Central Arizona Project (CAP) has brought in new water supplies for those that can afford it. Agriculture on the Ak-Chin and Salt River Pima Reservations is thriving, thanks to CAP water. Very little agriculture is possible now in the San Xavier District because of the presence of hundreds of sinkholes in the former agricultural areas. The cause of these sinkholes is under study and may be related to the decline of the water table, the loss of the mesquite bosque, the agricultural use of the area, or other causes.

## Water Management and Use

The Modern Period in the Santa Cruz River Valley, beginning with statehood in 1912 and continuing to the present, has been both a time of change and of expectations met. The receding water table, reliance on groundwater, and eroded river channel mostly devoid of vegetation were now, regardless of sentiment, an accepted standard. The pump technology that had been discovered and introduced into the region in 1891 was becoming more advanced. The pumps no longer relied on wood-fired steam power, wells were sunk deeper and deeper, and the water table continued to drop. The entrenched river appears to have acted as a drain, moving waters downstream.

It is not entirely clear when some perennial sections of the river went subsurface. Although some have proposed that in certain places the Santa Cruz River went subsurface due to groundwater pumping in the 1890s (Ohmart 1982: 356), it is very likely that the portions of the river that were historically perennial flowed until the early 1900s. Halpenny (1962) proposes that the river near San Xavier Indian Reservation was perennial until World War II, despite increasing groundwater pumping. Studies by Robert Rush Miller, an ichthyologist, support Halpenny's theory. In his investigation of the state of the fish fauna near Mission San Xavier del Bac, he found that:

> *For many years the Santa Cruz River, intermittent from near Nogales almost to Tucson, rose to the surface shortly above San Xavier Mission, about 8 miles south of Tucson. Here, in March 29, 1904, Chamberlain obtained 5 species:* Agosia chrysogaster, Gila robusta intermedia, Catostomus insignis, Pantosteus clarki, *and* Poeciliopsis occidentalis. *By April 25, 1937, when Allan R. Philips sampled this perennial flow, only the resistant Agosia remained, and this is the only species that I found there on July 12, 1939. By April 13, 1950, the flow had disappeared, and I was*

> *informed by Raymond Hock (then of the University of Arizona) that it went dry for the first time during the previous winter. Even in early historic time, the Santa Cruz ordinarily had no surface flow from some distance below Tucson to its confluence with Gila River. It formerly maintained a permanent flow in the headwaters, near Lochiel, but pumping in the San Rafael Valley eliminated this surface water and its fishes (Gila, Agosia, Poeciliopsis) between 1950 and 1956.* (Miller 1961: 379).

The water table at San Xavier was high enough to support a great old mesquite bosque, described by Brandt in the 1940s:

> *"Ten miles south of Tucson in the broad intermountain valley of the Santa Cruz River, and just beyond the ancient twin-towered mission of famed San Xavier, there once flourished a noble woodland of mighty mesquite trees. This virgin forest bordered both banks of the Santa Cruz at its broadest part, tapering back to the river on either side. Here we enjoyed the only important trace of semitropical forest cover that we encountered in southeastern Arizona. It reminded me very much of a semiarid, hotland Sinalòa jungle, with its lively community of strange animals and plants.... In 1935 many a grand old patriarch still ruled here that had evidently already looked down on several centuries of desert droughts and savage storms. .... Here, there are, indeed, trees of heroic dimensions; the bole of one stately specimen that we measured reached a girth of 13 feet 6 inches, and a diameter of more than 4 feet, 3 inches; while the height of another capitol-domed giant was calculated to be 72 feet... "* (Brandt 1951).

Brandt goes on to say that, when he revisited the bosque in 1945, the big trees had been hacked away for firewood. The bosque had its final demise in the 1960s when the water table dropped below the root zone (Halpenny 1962).

After the 1940s, highly efficient pumps and a population explosion both contributed to groundwater depletion. Between 1940 and 1965, over 4 billion cubic meters (over 1 trillion gallons) of water were pumped from the Tucson Basin aquifer (Betancourt and Turner 1990).

Floods continue to affect the river, leading to increasing entrenchment south of the mission where the river goes through a veritable badlands of eroded lands. In order to reduce erosion near the San Xavier Mission, the entire flow of the West Branch of the Santa Cruz River was diverted through a man-made channel into the East Branch in 1914 (Cooke and Reeves 1976). Efforts to control the river have continued to present times. Erosion since construction of I-19 is exacerbated by the bridge which funnels flood waters directly towards the mission and a curve of the river.

## Changed Water Supply in the River

The U.S. Geological Survey "Streamgage Summaries" report that essentially the entire flow of surface waters from the river were diverted both at Nogales and Tucson gaging stations by irrigation ditches (United States Geological Survey 1907, 1912). The first gages in the area were set up in 1905 at the Congress Street Bridge and in 1907 five miles north of the Mexican border.

The University of Arizona Agricultural Extension office set up more elaborate gaging stations and by 1915 had seasonal information on flows on the Rillito and the Santa Cruz to Maricopa (Table 4).

The conclusion reached from their studies of 1916 (an average rainfall year) was:

> *It will be seen from the table that practically all of the Santa Cruz run-off was absorbed into the ground and the residual flow that reached the Gila River was a small percentage of the total. The sum of the Santa Cruz and Rillito discharges near Tucson in 1916 was 90,500 acre feet. Of this amount 64,900 acre-feet sank into the river bed between the Tucson gauging stations and Sasco, a distance of 32 miles, while the remaining 25,600 acre-feet passed Sasco. Just west of Sasco the stream divides, part flowing northwest to Eloy and part west to an abandoned reservoir and thence northwesterly to Maricopa. Of the former portion the amount that reached Eloy was 4500 acre-feet. This amount is again subdivided and probably less than one-third of it reaches the Gila. Of the second portion only 2200 acre-feet reached Maricopa.* (Agricultural Experiment Station 1916).

## Modern Period Summary

A brief review of the status of the Santa Cruz River in the Modern Period shows that the changes that face the river now are related to the pressures of population growth. The population of the Santa Cruz River Valley has grown exponentially since World War II,

Table 4. Santa Cruz River Flow in 1916
(condensed from Agricultural Experiment Station, 1917).

| Month | Santa Cruz/ Tucson | Rillito River/ Tucson | Santa Cruz/ Red Rock | Santa Cruz/ Maricopa |
|---|---|---|---|---|
| | ACRE-FEET | ACRE-FEET | ACRE-FEET | ACRE-FEET |
| January | 24700 | 37400 | 20690 | 1800 |
| February | 600 | 2220 | 0 | 310 |
| March | 0 | 3630 | 0 | 0 |
| April | 0 | 58 | 0 | 0 |
| May | 0 | 0 | 0 | 0 |
| June | 0 | 0 | 0 | 0 |
| July | 2720 | 920 | 720 | 0 |
| August | 8210 | 7840 | 4040 | 170 |
| September | 1340 | 690 | 130 | 560 |
| October | 140 | 28 | 0 | 0 |
| November | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 |
| TOTAL | 37700 | 52800 | 25580 | 2840 |

which when combined with the development of efficient groundwater pumping technology has led to an immense annual overdraft of water.

In two locations, the Santa Cruz River has once again come to life: downstream of the Nogales wastewater treatment plant for about 15 miles, and downstream of the Roger Road and Ina Road wastewater treatment plants in Tucson for about 15 miles. The Nogales section probably contains more water today than it has for many years and supports a lush cottonwood-willow forest, home to many species of birds and aquatic creatures. This flow stops at about the same spot the flow did historically because of the underlying geology. The Tucson section does not provide nearly as good a wildlife habitat because the stream is so entrenched and because portions of it have been soil-cemented for flood control purposes. The water flow, however, is probably greater than it was 100 years ago. A small effluent flow at Casa Grande supports a saltcedar forest.

**Upper Santa Cruz River**

The headwaters of the river in the San Rafael Valley have remained relatively pristine, although most of the cienegas have disappeared and the origins of the headwaters have often moved downstream. Although Miller (1961) reports that the native fish fauna had disappeared in the 1950s in the San Rafael Valley, some perennial waters persist. The river usually flows much of the way from the headwaters into Mexico and almost back to the border at Arizona, although at a lessened level. A Nogales wellfield south of the border takes most of the flow at that point, and much of the surface flow downstream of the Nogales Wastewater Plant is now effluent. Water quality has become an issue, especially with regard to untreated flows from Mexico in Nogales Wash. The effluent flow goes underground at about the same location that the river went underground historically.

Two perennial streams remain in the Nogales area: Sonoita Creek and Sycamore Creek. A natural cienega still exists near Nogales. Important parts of Sonoita Creek today are owned by the Nature Conservancy and Arizona State Parks (including a recreational manmade lake in the river).

## Middle Santa Cruz River

The historically perennial reaches of the river, at Mission San Xavier del Bac and at Sentinel Hill in Tucson, no longer flow under normal circumstances. Miller (1961) showed that the perennial water at San Xavier flowed until 1949-50, and that at least one species of native fish was present there until later than 1939.

The springs have all stopped flowing near the river, although a few remain in outlying areas. Three perennial streams still flow near the Tucson area: Sabino Creek, Cienega Creek, and Honeybee Canyon. The river, which was once slow and shallow through Tucson, has become a deeply entrenched channel with no surface flow except during unusual flooding events. The banks have been cemented or otherwise altered in an effort to prevent erosion and damages from floods like those suffered in 1983, which amounted to perhaps more than $200 million dollars. The average water table has been lowered over 400 feet in the valley, with cones of depression near Green Valley (mines and agricultural pumping), and San Xavier (mines and City of Tucson pumping). Effluent flows from the Pima County treatment plants have kept the water table relatively high in the Marana area, where water is extracted for agriculture.

## Lower Santa Cruz River

The lower Santa Cruz River in Pinal County, again, was the sight of relatively little historical activity until the arrival of the railroad and later efficient pumping technology. This stretch of the river never supported much flow, and it still does not. Agricultural activity arose here during the Modern Period, one of the most important communities being Casa Grande. Currently the water table is highly overdrafted and subsidence has caused numerous changes, including influencing the direction of water flow in at least one case.

# VI. SUMMARY

The Santa Cruz River has long been an important transportation route for Native Americans, missionaries and Spanish explorers, colonizers and wanderers, miners and cattlemen, and new residents. It was an easy route as far as Tucson, providing water, forage and food for the traveler. For people who lived near it, the river provided water, wood, food and shelter. Farmers diverted the surface water of the river for millennia. Millers, both of flour and ore, powered their grinders with Santa Cruz water and entrepreneurs dammed the river, and the lakes that were created were used by the public for fishing, boating, picnicking and swimming. Much of the settlement in southern Arizona, to this day, is within the valley of the Santa Cruz River.

## Changes in the River

The three distinct sections of the river have had very different histories. The upper and middle sections were used extensively by native peoples, Spaniards and later Americans, and the lower section, having much less dependable water was used much less. Because of underlying geology, and the fact that population eventually centered in the Tucson area, the middle Santa Cruz suffered much more extreme changes than either the Upper or Lower sections.

### Upper Santa Cruz River

The Upper Santa Cruz has lost most of its marshes and has been affected by groundwater pumping near Nogales, but because of effluent flow it still supports a lush cottonwood-willow forest from Rio Rico to Tubac. The streams of the headwaters are much as they were for centuries, despite a history of mining in the 19th century and ranching up to the present. While mining, agriculture, grazing, urbanization and other influences had major impacts on downstream stretches of the river, the San Rafael Valley remained relatively undisturbed. Some of these impacts, especially mining, grazing and woodcutting, did impact the valley. The ranchers that dominated the valley did not relinquish their ownership of large tracts of land for development, and therefore, "The San Rafael Valley has largely escaped the transformations that have changed the economic, cultural and physical landscapes of so many other rural areas of Arizona since World War II." (Hadley and Sheridan 1995)

The areas settled early by the Spanish and later the Americans from the Mexican border to the Santa Cruz County line have been changed by agriculture (with its pumping and water diversion) and the development of Nogales, Tubac and Green Valley. By 1912 enough water was being diverted near the border to take up all the low flow of the river. (United States Geological Survey 1910). The river was replenished by springs and runoff from tributaries. Agriculture and small communities, however, began to divert and pump more and more groundwater. Groundwater pumping from City of Nogales, Sonora wellfields have depleted the river flow drastically, so that no low flow leaves the wellfield area and the river is mostly dry (with the addition of some spring-fed waters north of the border) until it reaches the wastewater treatment plant. The construction of a wastewater plant upstream from Calabasas (Rio Rico) allowed the river to flow once again, and the healthy cottonwood forest developed and flourishes to this day.

**Middle Santa Cruz River**

The Middle Santa Cruz has changed from a shallow, wide meandering stream fed by numerous springs to a dry, deeply entrenched channel constrained by flood control structures through much of the metropolitan area. The river near San Xavier is nothing like its former self and the ancient mesquite bosque is gone. Groundwater pumping for agriculture, mining and urban use has driven the water table far below a level which can support trees. Sink holes of uncertain (but definitely manmade) origin have rendered many acres of land unusable there. Farther downstream, the river is dry with little vegetation until the wastewater discharge is reached at Sweetwater Drive, on the north side of Tucson. From there through Marana the river flows again, with a more dependable supply of water than it ever had historically. All the historic springs are gone.

The year 1890 was a turning point in the structure of the middle Santa Cruz River. Until then, the river structure had remained relatively stable - perennial reaches from its headwaters in the San Rafael Valley through Mexico and again into Arizona just north of

Tubac, sinking there for the first time below the sand to rise again near Mission San Xavier del Bac and again at Tucson. It was a shallow river, with large trees marking the ill-defined channel of the river, which lay in a broad and fertile valley. After the unprecedented grazing in the valley in the 1880s left it exposed and vulnerable to erosion, manmade structural changes (dams and diversion ditches) were built. Extreme weather patterns peaked in early 1890. Years of plentiful rain were followed by years of drought and followed once again by huge amounts of rain. The dams and ditches on the river near Tucson were washed out, and the re-routing and entrenchment of the river from north of Green Valley through Tucson had begun.

Every year that the monsoon rains fell in southern Arizona, the entrenchment worked further upstream. By the time of statehood in 1912, there was a deep channel, perhaps more than 20 feet deep, well into what is now the San Xavier Indian Reservation. Pump technology had been developed in the 1890s, but at this time the primitive state of the science made it difficult to extract much water. Diversions, however, had taken all the low flow from both north of the Mexico border and south of Congress Street in Tucson.

It was not until around World War II that the population in the valley exploded and groundwater pumping led to the disappearance of the Santa Cruz River's perennial flow at Tucson and San Xavier.

**Lower Santa Cruz River**

The Lower Santa Cruz is still a dry channel at all but flood times. Before the days of modern pumps agriculture was largely by floodwater irrigation or centered around the much more dependable Gila River to the north. In modern times, extensive groundwater pumping has lowered the water table throughout central Pinal County and in some places long subsidence fissures opened. Only at flood time can the river's course be easily discerned and only at high flood time does it discharge to the Gila River. This is probably somewhat different from previous times, but that section of the river has long been ephemeral and offered little to the traveler who might have had to travel for days without fresh water. Any underflow that once carried waters regularly to the Gila River is no longer possible. The cienegas that once existed at the confluence with the Gila River no longer support wildlife.

### The Tributaries

The tributaries have very different histories. A few streams, including Sabino Creek, Sonoita Creek, Cienega Creek, Honeybee Canyon and some mountain streams still flow most of the year and support diverse wildlife, others, however, especially Rillito Creek, Pantano Wash, the Cañada del Oro, and Altar-Brawley washes are greatly changed and seldom flow. Through the urban areas flood control structures predominate, especially along entrenched reaches. In rural areas, Patagonia Lake impounds waters from Sonoita Creek for recreational purposes such as boating, and Parker Lake, also a recreational lake where boating is popular, impounds tributary waters in Parker Canyon.

### Wildlife

The corridor created by the Santa Cruz River is used by migrating wildlife, and habitats of some state and federal threatened and endangered species are within the Santa Cruz Valley. Some animals that are now extirpated from Arizona were once found there, and others that were once common, such as the wild turkey, are no longer found in the region. The beavers that once built dams along the Rillito River clearly can no longer survive in the dry streambed. In some of the areas fed by effluent, however, there is still a rich diversity of species, as there is in the perennial tributaries. Manmade lakes, a Nature Conservancy Preserve, a Pima County Preserve on Cienega Creek and Forest Service riparian areas (most notably Sabino Canyon) still provide excellent habitat for some wildlife.

## The History of Navigation

### Probable Condition of the River in 1912

At the time of statehood, the river was probably still perennial in some of the reaches that had historic surface flow, but intermittent in more areas than previously. An important difference was that the vegetative structure of the valley was much different and the entrenchment of the river meant that surface waters visible in 1912 were much lower than 25 years earlier. In many areas, riparian vegetation had been cut for wood or lumber and farms or homes used much of the water riparian trees had formerly used. Diversions, at both the Mexican border area and south of Tucson, were said to have taken all the low flow of the river. Agricultural water use in the Tubac, Tucson, and San Xavier areas used most of the available surface water and also intercepted groundwater and subsurface flow. Diversions and pumping also diminished flows on tributaries, especially the Rillito. It was estimated in 1910, that flow from the Rillito reached the Gila River one year in 15 (Smith 1910).

The San Rafael Valley headwaters were shallow flows, much as they are today, although there were more cienegas then there are today . The river through Mexico probably still flowed dependably. From the border to the Sonoita Creek confluence, the river may have been dry much of the time because of diversions. With the addition of Sonoita Creek waters, the river again came to life, but much of that water was diverted for agriculture along the river from Calabasas to the north. The springs were drying up in the San Xavier area, and diversions and pumping took most if not all the flow, but a high water table still supported a lush mesquite bosque south of the mission. The City of Tucson and many others had dug wells in numerous locations, some as far south as San Xavier which intercepted flow and lowered the groundwater table. In 1915, the first year such measurements were systematically taken, the Santa Cruz River and Rillito flowed less than half the year. The deeply entrenched channel carried some flows through Tucson, but all the low flow was diverted before the Congress Street bridge. Springs and groundwater still supported some agriculture downstream of Tucson, but there was little perennial flow.

By 1912, the Rillito, too, had largely dried up and pumping was necessary to support agriculture though the water table remained high and shallow wells were possible. Cienega Creek still was perennial, as were Sonoita Creek, Sabino Creek and most of the other small tributaries.

The lower Santa Cruz continued to have little flowing water except in years of high rainfall.

## Summary of Recorded Navigation Incidents

Although the river was an important transportation route, it was not normally used for navigation except for the following accounts found in the literature:

1. A land speculator portrayed the river at Calabasas (west of Nogales) as capable of floating steamboats in the 1880s. This was pure fiction, but gave rise to the belief, that surfaces occasionally even today, that the river was navigated by large ships.

2. During the 1880s, Silver Lake (a manmade lake just south of downtown Tucson on the Santa Cruz River) was a popular recreation area, featuring boating, fishing and swimming. A paddle boat on the lake was a major attraction. Boating both by rowing and sail was popular in the lake and upstream. This lake was washed out in the 1891 flood and not rebuilt.

3. In December 1914, during a flood period, a group of adventurers attempted to float the Upper Santa Cruz River, but were grounded. The boat was later located buried in mud. Also in the 1914 flood, numerous people were stranded on rooftops and windmills near Sahuarita. The Arizona National Guard went to rescue them with an inflatable boat, but the current was too strong and the effort was unsuccessful. Later, the people were rescued with horses.

4. Occasionally in recent times a canoer or rafter has floated the river during flood time. Tubers floated the Santa Cruz River in the 1970s during flood time. The Tucson Weekly featured a canoer traveling the effluent-dominated stretch in July 1990, a trip which he repeated during flood time for the Tucson Weekly photographer (Malusa 1990). The Citizen reported travelers in canoers on the Rillito during the 1990 flood (Tucson Citizen, July 25, 1990). The same canoers have also traveled on the Santa Cruz and Agua Caliente at various times in the 1990s. These canoers, Wayne Van Vorhees and his wife, stated that when they also traveled the river during the winter of 1989-90 it was "a reasonable canoeing river," but when they made the trip in the summer, it was "more like the Grand Canyon" in terms of difficulty. They are deeply involved with local boating groups, but are unaware of any attempts to boat the upper Santa Cruz River, although they state that it is certainly feasible. Mr. Malusa believes that the Santa Cruz can just barely be navigated by canoe with 4" of water, but that the channel topography is a limiting factor as sand bars are frequent. (Jim Malusa and Wayne Van Vorhees, personal communications, 1996).

5. There are no stories of boating at any time on the lower Santa Cruz, although during one high flood event Tucsonan Sam Hughes said that, in his opinion, the river was "big enough to float a steamboat all the way to the sea."

6. There are no records of ferry service anywhere on the river. Fords and crossable washes are marked on numerous maps. When the bridges went out during floods, people were stranded and had to wait until the river could be crossed by horse. No evidence was found of boats being used to cross the river at flood time.

7. No evidence was found of the river being used to transport goods such as logs.

8. John Spring recorded in his diary that there was an old Mexican settler who had carved a canoe to cross the upper Santa Cruz River when flooding made it too high to cross on the road. According to Spring, this is the origin of the name for that area of the Santa Cruz Valley, "La Canoa."

There were a few instances of boating on the river, but the perennial flow that existed on the river historically was such that it was never regularly navigated. It was, however, a very important transportation corridor for travelers going from the eastern U.S. west, or from Mexico to the Gila River. Without its waters, forage, and food, travelers would often probably not have survived.

There is no evidence that the Hohokam or O'odham people had boats at any time in the past. The river was much too shallow most of the time for small boats, even in the perennial stretches. The river from San Xavier to Tucson could have potentially been navigable, if there had been been a dependable supply of water because of the much deeper channel. By 1912, however, the U.S. Geological Survey reported that the entire low flow of the river was diverted at both the Nogales and Tucson gages making navigation highly unlikely. The only times one might be able to navigate the waters of the Santa Cruz now are during unusual high water, i.e. during flooding events.

# VII. CHRONOLOGY AND POPULATION FIGURES

## CHRONOLOGY

**1539** - Fray Marcos de Niza probably reached the headwaters of the Santa Cruz.
**1687** - Kino starts missions in Sonora.
**1689** - Kino starts missions at three sites along the Santa Cruz in present Sonora.
**1690s** - Warfare between Apaches and Pimas.
**1691** - Missions established at Guevavi and Tumacacori. Indian population estimated at 30,000.
**1695** - Pima rebellion followed by open warfare against the Spanish in Sonora which lasted many years.
**1697** - Manje counts 900 Indians at Bac and 800 at Tucson.
**1701** - Founding of San Xavier, south of Tucson - abandoned then restaffed in 1732. Present mission started in 1779, finished in 1797.
**1736** - Silver discovered south of Nogales, starting mining boom.
**1752** - Presidio of Tubac founded.
**1762** - Spanish move Sobaipuris from the San Pedro River to the Santa Cruz, settling them at Tucson, leading to increased Apache depredations as there was no longer a good line of defense away from the Santa Cruz River.
**1767** - Jesuits expelled.
**1771** - Fortified walls and church built at Tucson.
**1775** - De Anza leads group from Tubac to San Francisco Bay.
**1775** - Relocation of presidio of Tubac 40 miles father north to Tucson. Founding of Tucson.
**1782** - Major Apache attack on Tucson, repelled by Spanish, but followed by frequent warfare.
**1787** - Presidio founded at Santa Cruz, Sonora.
**1820-30s** - Sonoran ranchers start to colonize grasslands of SE Arizona using the Land Grant.
**1821** - Mexico wins independence from Spain; Canoa Land Grant awarded.
**1823** - First Anglo trappers reach Arizona, but probably did not reach the Santa Cruz.
**1826-1831** - Five major Spanish land grants awarded.
**1836-1847** - War between U.S. and Mexico, resulting in Treaty of Guadalupe de Hidalgo.
**1843** - Apaches drive settlers out of San Rafael Valley.
**1844** - Tumacacori declared abandoned by Mexico and land auctioned off, driving off what few Pimas remained.
**1846** - Dec. 17 - Lt. Col. Phillip St. George Cooke's Mormon Battalion takes possession of Tucson and raises the American flag in Tucson without encountering Mexican garrison. [Pres. Polk declared war with Mexico on May 13, 1846]
**1846** - Kearny passes through Tucson on military expedition to the Pacific, laying out wagon road.
**1848** - Oct. 25 - U.S. First dragoons reach Tucson en route to California.
**1848** - Treaty of Guadalupe Hidalgo.
**1848** - Lt. Couts with military expedition from Mexico to California, describes Santa Cruz Valley.
**1849** - California gold rush begins. For next several years, Santa Cruz River is on the route of would-be miners going to California. Numerous cattle drives from Texas to the gold fields passed along the Santa Cruz through Tucson and on to the Gila River.
**1850** - Sep. 9 - Congress passes the "Omnibus Bill" making Arizona and New Mexico one territory, with the proviso, "Nothing in this act shall be construed to inhibit the United States from dividing said Territory into two or more territories."
**1852** - John Bartlett describes the Santa Cruz Valley.
**1853** - Dec. 30 - Under terms of the Gadsden Purchase the United States agrees to pay Mexico ten million dollars for 45,535 acres of land below the Gila River from the Rio Grande to the

Colorado. Of this land, 31,535 square miles are eventually included in the Territory of Arizona.

**1854** - Gadsden Purchase ratified.

**1856** - Feb. 28 - Solomon Warner reaches Tucson from Yuma at head of train of 13 mules loaded with merchandise for first Arizona general store.

**1856** - Mar. 10 - U.S. Army quarters four companies of dragoons in Tucson.

**1856** - Mar. 24 - Charles D. Poston organizes the Sonora Exploring and Mining Co. With Maj. S. P. Heintzelman as president, he purchases the Arivaca Ranch west of Tubac and begins operation of mines.

**1856** - Americans establish fort at Calabasas.

**1857** - Jun. 22 - U.S. government signs contract with James E. Birch for semimonthly mail and passenger service from San Antonio to San Diego, via Tucson. Became known as the 'Jackass Mail' because passengers frequently had to ride a mule between Fort Yuma and the coast.

**1857** - John Reid describes the Santa Cruz Valley.

**1858** - Oct. 10 - First Butterfield Overland Mail coach enters Arizona through Stein's Pass; reaches Tucson.
Oct. 2, 6:15 p.m. and crosses into California on Jaegers' ferry, Oct. 5, 6:15 a.m.

**1858** - William S. Oury introduces first herd of fine cattle to Arizona, pasturing 100 heifers and four bulls in the Santa Cruz Valley near Tucson.

**1858** - Phocian Way describes the Santa Cruz Valley.

**1859** - Mar. 3 - *Weekly Arizonian*, first Arizona newspaper printed in Tubac. Vol I. No. One, reports 19 acts of murder and robbery by Indians between Jan. 1 and Feb. 21.

**1859** - Aug. 4 - Lieut. Sylvester Mowry buys *Weekly Arizonian* and publishes it in Tucson.

**1859** - Nov. 12 - Forty-six thousand sheep pass through Tucson en route to California.

**1860** - Lieut. Sylvester Mowry buys the Patagonia Mine east of the Santa Cruz Valley and renames it the Mowry Mine.

**1860s** - Silver Lake constructed by damming the Santa Cruz.

**1860s-1880s** - Large numbers of cattle introduced in the area during unusually rainy period.

**1862** - Jan. 18 - Confederate Congress passes enabling act, making Arizona and New Mexico Confederate Territories; Jefferson Davis signs, Feb. 14.

**1863** - Feb. 20 - Congress passes Arizona Territorial Bill which becomes law Feb. 24.

**1863** - Lee builds water-powered flour mill near lake.

**1864** - May 8 - Governor John N. Goodwin proclaims Tucson and incorporated city and appoints officials.

**1864** - J. Ross Browne describes the Santa Cruz Valley.

**1866**- Oct. 3 - Third Territorial Legislature convenes in Prescott under Governor McCormick. Governor makes gloomy report; Territory is deep in debt; there are no stagecoach lines; roads are extremely poor; Apaches are very active; total amount of taxes collected, $355.

**1867** - Mar. 18 - Military headquarters in the Territory are moved from Prescott to Tucson.

**1867** - Nov. 1 - Tucson becomes the Capital of the Territory.

**1871** - May 17 - Village of Tucson buys two sections of land from federal government and begins to sell lots and issue deeds.

**1873** - Jan. 6 - Seventh Territorial Legislature convenes in Tucson. . . . Gov. A.P.K. Safford ... asks Congress to promote sinking of artesian wells.

**1873** - Mar. 19 - Tucson garrison is moved to site on Rillito Creek, and important permanent post is built and named Fort Lowell. Abandoned April 10, 1891.

**1874** - Sep. 28 - *Tucson Citizen* announces first cotton grown near Tucson by Steven Ochoa.

**1875** - Jan. 6 - Eighth Legislature convenes in Tucson under Governor Safford. Reward of $3,000 offered for discovery of first artesian water; net profits of mines taxed; Pinal County created.

**1877** - Feb. 7 - City of Tucson incorporated by legislative enactment.

1877 - Mar. 9 - Congress passes Desert Land Act which permits settler to get title to 640 acres of desert land, provided that he irrigates it within three years and pays small sum per acre.
1878 - Land speculator promotes Calabasas development with brochure showing steamboats docked at the busy river. Tombstone Epitaph reveals hoax. Area not developed until 1960s.
1879 - Founding of Casa Grande, aka Terminus.
1880 - Mar. 20 - First train over Southern Pacific reaches Tucson and is greeted by roar of cannon and a wild celebration.
1880 - Railroad arrives in Tucson.
1881 - Tucson Water Co. Builds water distribution system starting at Valencia Road in river bed.
1882 - Railroad completed from Benson to Sonora through Calabasas.
1883 - Warner's Lake constructed, followed by construction of flour mill and stamping mill. Reaches 37 acres in size.
1885 - Chinese truck gardens established in Tucson.
1886-1890 - Very rainy period. Santa Cruz is more than a mile wide and deep enough to float a steamboat.
1887 - Jan. 17 - Speaking at the first council meeting of the year Mayor Stevens of Tucson warns members that they must be prepared to do something about watering the city streets in the summer months.
1887 - Jan. 17 - First Pullman train rolls into Tucson and citizens turn out to marvel at the wonder.
1888 - Sam Hughes builds diversion ditch which begins to erode that summer.
1890 - Jan. 31 - Empire Ranch starts driving 1,000 head of cattle to California to escape excessive freight rates.
1890 - Major floods wash out the dams that created Silver and Warner's Lakes, and Hughes ditch, and change river from shallow meandering stream to incised channel.
1890-1904 - Drought sets in and many cattle die. Tucson's population declines by 2000 down to 5000 people.
1891 - Jan. 16 - Herd of 2,000 steers passes Tucson as cattlemen continue drives to coast to avoid railroad charge of $7 a head.
1891 - Feb. 8 - T. A. Gulley, director of University's Experiment Station, proves practicability of pumping underground water for irrigation on UA campus.
1891 - Sep. 6 - Tucson sprinkles 17,000 gallons of water daily on down-town streets to lay the dust.
1891 - Pump well technology reaches Arizona. Hartt develops farm depending on water pumped from underground.
1893 - Plagued by a long drought and the effects of overgrazing the ranges, cattlemen of Southern Arizona experience a 50 to 75 per cent mortality among their stock and ship 200,000 head of all classes out of the state.
1894 - Mar. 30 - Court of Private Land Claims voids Spanish land grants along the border. Nogales, Huachuca, and Tombstone hold all night celebration with bonfires and salutes.
1895 - Jul. 14 - Indians of the Pima villages go to court and charge Arizona Canal Company with stealing water guaranteed Pimas under contract.
1898 - Major improvements to the Nogales Water Works.
1899 - Nogales-Tucson rail link completed.
1899 - Jan. 16 - Governor Murphy meets with Twentieth Territorial Legislature. Fifteen year tax exemption granted for water development...
1901 - Nogales water supply report says Nogales Water Company has "an inexhaustible supply from 3 wells, tapping the underground flow of Potrero Creek."
1901 - Aug. 2 - Director of U.S. Census reports that Arizona has 5,800 farms covering 1,935,287 acres of which 254,521 acres are improved land.
1905 - Tucson gets 24" of rain (twice normal) mostly in winter.

**1907** - Jan. 17 - Santa Cruz River runs full to the bank and races through Tucson at eight miles an hour.

**1910** - Tucson Farms Company formed (became Flowing Wells Irrigation District in 1912).

**1910 - 1920** - Mexican revolution spreads and more than a million people are killed in Mexico. Pancho Villa seizes Nogales, then retreats in 1916.

**1911** - Aug. 8 - U.S. Senate passes resolution granting statehood to both New Mexico and Arizona.

**1911** - New water lines built in Nogales and the first well is sunk near the Santa Cruz.

**1911** - Aug. 9 - House concurs in Senate statehood resolution.

**1912** - Feb. 14 - President Taft signs necessary proclamation making Arizona a state. George W. P. Hunt is inaugurated as governor and entire state celebrates wildly.

**1913** - May 2 - Great Western Power Co's. government permit to water rights in Sabino Canyon expires. City of Tucson sends officials to file claim at midnight if the Power Company's claim is not extended.

**1914** - Feb. 15 - Tucson sinks a new well and gets a flow of one million gallons a day.

**1914** - Dec. 23 - Swollen by week of rain the Santa Cruz River floods valley and runs one and one-half miles wide at Amado where destruction is heavy.

**1914** - During flood period, sailors attempted to sail a boat from Nogales to Tucson, but boat got stuck near Tubac. Claim is that this is the first time in 28 years that there has been enough water to float a boat.

**1916** - Dec. 27 - Phoenix, Tucson, Douglas, and Bisbee plagued by intense cold weather and coal shortage. Demand for mesquite is heavy.

**1917** - First Border fence erected in Arizona.

**1917** - Nov. 7 - U.S. Council of defense report shows 491,867 acres of land under cultivation in Arizona.

**1919** - Mar. 26 - Legislature appropriates $100,000 to co-operate with U.S. Dept. of Interior on surveys and preliminary studies for construction of storage or diversion dams, etc., to increase productivity of the land.

**1920** - Jun. 23 - Board of Health urges all citizens of Tucson to boil drinking water 10 minutes. Contaminated well has filled the mains.

**1920** - Jul. 11 - Tucson suffers from a water famine. Irrigation of lawns barred in daytime.

**1920** - Jul. 13 - Special committee reports to the city council that all Tucson wells are either contaminated or subject to contamination.

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*NOTE*: This chronology draws extensively from Martin 1963, 1966.

# POPULATION FIGURES

## A Short List of Historical Population Figures

**1790s** - Non-Indian population, 300-500 people in Tucson, 300-400 at Tubac and 100 at Tumacacori.

**1831** - Census lists 465 Mexican inhabitants in Tucson.

**1835** - Census lists 486 individuals in Tucson.

**1860** - U.S. decennial census of Arizona population given as approximately 6,482.

**1864** - May 24 - U.S. Marshal Milton B. Duffield completes the first census of Arizona and reports to Governor Goodwin that the population totals 4,573, including U.S. soldiers. Arizona had sworn to Congress that the population was 6,500.

**1866** - Oct. 3 - Territorial census shows population is 5,526.

**1870** - U.S. Census report Arizona population as 9,658.

**1875** - Jan. 6 - County assessors' reports place population at 11,480.

**1880** - U.S. Census reports Arizona population as 40,440, a gain of 318.7 percent in 10 years.

**1890** - Dec. 31 - U.S. Census reports Arizona population as 88,243; a gain of 118.2 per cent. U.S. Census credits Arizona with 1,526 farms and 104,128 acres of improved land.

**1898** - Ambos Nogales population estimated at 2000 in Arizona and 2500 in Mexico.

**1900** - U.S. Census reports Arizona population as 122,931, a gain of 39.3 percent.

**1901** - Nogales, Arizona population estimated at 5300.

**1909** - Census figures show population for Nogales, Arizona 2503.

**1910** - U.S. Census reports Arizona population as 204,354, a gain of 66.2 per cent in 10 years.

# VIII. NOTE ON SOURCES

A rich variety of resources regarding the history of the Santa Cruz River Valley is available, especially in Tucson. The University of Arizona Main and Science Libraries have most of the general reading documents listed in the bibliography, such as books, journal articles, and bulletins. The University's Special Collections Library keeps an extensive collection of historic and rare documents. Some of the manuscripts, journals, diaries, and hard-to-find documents used in this report are housed in Special Collections. Another extremely valuable library is that of the Arizona Historical Society in Tucson. Manuscripts, journals, and old or rare newspaper articles and photographs are more likely to be found at the Arizona Historical Society Library, both because of its extensive collection and an admirable cataloguing system. Another historical society library, Pimeria Alta, is in Nogales, Arizona, and was found to have few materials relating to the history of the river and very little indexing. However, the library may have some information regarding the upper Santa Cruz River, and should not be entirely overlooked.

Some general works on the history of the Santa Cruz River were particularly useful in preparing this document. Holub and Bufkin (1987) speak of the navigability question specifically. Betancourt and Turner (1990) provide background on the question of arroyo cutting on the Santa Cruz River in Pima County; however, the information provided could be considered a comprehensive history of the river in Pima County, and is extremely useful in deciphering the complex history of the Tucson area. Another work by Betancourt (1978) presents archaeological evidence of prehistoric and early-historic inhabitance along the river in the Tucson area. The Halpennys have studied the hydrology of the river, especially as it concerns historic irrigation in the Santa Cruz Valley. Several of their works, including those from 1962 and 1988, are of general interest. Hadley and Sheridan (1995) provide a comprehensive history of the headwaters of the Santa Cruz River in the San Rafael Valley.

Walker and Bufkin (1986) is an excellent resource for general information about historical influences across Arizona and in the Santa Cruz Valley. Other general works that include useful information on the Santa Cruz River are Wilson (1987), Bahre (1991), and Dobyns (1981).

Parker (1993) is an analysis of channel change on the Santa Cruz River, and provides general information about the river's perennial flow through time.

Hendrickson and Minckley (1984) review the cienegas in southern Arizona, including those on the Santa Cruz River and its tributaries. This publication is an important source of comparative maps showing historical and recent status of surface waters.

Meko et al. (1995) uses tree-ring analysis to construct a long-term climatic history of the southwest. Betancourt and Turner (1990) present climatological data for the Santa Cruz River Valley in order to determine the impact of drought/flood cycles on arroyo cutting.

A number of books have been written about the Spanish/Mexican period of history in the Southwest. Because his primary work was in the Santa Cruz Valley, Father Kino's memoirs are particularly useful; Bolton (1919) presents these memoirs. Hammond (see 1929, 1931, 1940, and Hammond and Howes 1950, Hammond and Rey 1953) has studied the history of the Spanish and Mexican period through analyses of Kino, Zuniga, Coronado, and Oñate, as well as the history of the gold rush in 1849.

A map of land grants in the Santa Cruz Valley is available in Walker and Bufkin (1986). Mattison (1967 and no date) provides a description of some of these land grants, as well as a general history of the topic.

Many early explorers, pioneers, and travelers described the vegetation and wildlife of the Santa Cruz River in their journals and diaries, some of which are now published. Bahre (1991) describes historic human impact on vegetation in southern Arizona.

Davis (1986) compiles information about many of the old pioneers' manuscripts and is a useful index to the occurrence of wildlife in Arizona in the 1800s. Brandt (1951) has information about the birds in the Santa Cruz Valley, as well as some description of related vegetation. The occurrence of fish in the Santa Cruz River and its tributaries is an important factor in determining the status of perennial water. Miller (1961) is interested in the changing fish fauna of southwestern rivers, and provides information about perennial water in the Santa Cruz River near San Xavier, Tucson, and in the San Rafael Valley. Minckley is the premier fish biologist of Arizona's rivers, and his 1973 book is generally considered a classic work.

The beginning of Anglo settlement in Arizona and the Santa Cruz Valley is chronicled through the journals of early settlers. Among these see Spring (1966), Couts (1961), Evans (1945), Gustafson (1966), Forsythe (no date), Pancoast (1930), Hunter (no date), Powell (1931), Hayes (1929), and Durivage (1937). Harris (1960) describes the gold rush migration along the Gila Trail, which included the Santa Cruz Valley. These descriptions may be some of the most important documents in attempting to determine the status of the river in 1912. Other important documents are U.S. Geological Survey reports (streamgage summaries that list annual streamflow at measuring stations) and some of the University of Arizona's early Agricultural Experiment Station Bulletins.

Wilson (1987) talks about the sky islands of southern Arizona, and presents a history of land use. Bell (1932) and Loomis (1962) talk about the early cattle industry in southern Arizona. Dunning (1959) is a comprehensive history of the early mining industry.

Betancourt and Turner (1990) and Hadley and Sheridan (1995) describe the impact of livestock grazing on the river near Tucson and in the San Rafael Valley.

The modern status of the river is described in some of the general works listed above. Also useful are Eden and Wallace (1992) who present data on water use in the Tucson Active Management Area. Halpenny (1962) and Halpenny (1988) review the hydrology of the river near Tubac and the San Xavier Indian Reservation. The Tucson Active Management Area occasionally presents summary information on the status of water use in the Tucson area and related groundwater information. General information about the extent of the watershed and the recent status of perennial waters is available in Arizona Department of Environmental Quality (1994).

Population growth is directly related to water use in the Santa Cruz Valley, and information on population growth there can be obtained from government organizations. The Pima Association of Governments (PAG) and the SouthEastern Arizona Governments Organization (SEAGO) both keep historic population information and periodically project population growth.

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# X. APPENDICES

## APPENDIX A -- HISTORIC MAPS

Listed below are some of the many maps available. Most are in published form and easily accessible as indicated. In addition the three major nineteenth century surveys, Bartlett, Gray and Emory contain useful maps . Finally, the Arizona Game and Fish Department mapped perennial streams in 1994 and has maps of the perennial sections of the river and tributaries, showing vegetation and other features.

Betancourt 1990

| | |
|---|---|
| A-I | <u>Page</u> 30 - "Figure 3. Map of the Santa Cruz River Valley, with places mentioned in the text." |
| A-II | <u>Page</u> 75 - "Figure 11. Map of the northeast portion of the San Xavier Indian Reservation in 1882 (after Roskruge, 1882). In this map, and on later ones (Figs. 12-13), the course of the Santa Cruz north of Martinez Hill is not indicated, suggesting that the channel had long been replaced by ditches in carrying floodflows." |
| A-III | <u>Page</u> 76 - "Figure 12. Map of the San Xavier Indian Reservation in 1888 (Chillson, 1888)." |
| A-IV | <u>Page</u> 77 - "Figure 13. Map of San Xavier Indian Reservation in 1891 (Surveyor General's Office, 1891)." [shows Santa Cruz River being diverted into ditches around the Reservation] |
| A-V | <u>Page</u> 100 - "Figure 21. Map of northern Sonora and southern Arizona, showing hydrological effects of the 1887 earthquake (after Dubois and Smith 1980)." |
| A-VI | <u>Page</u> 136 - "Figure 40. Plan of the Tucson Farms Company Crosscut and distribution system (Hinderlider 1913)." |
| A-VII | <u>Page</u> 142 - "Figure 47. Map of Greene's Canal and lower Santa Cruz River." |

Bolton

| | |
|---|---|
| A-VIII | Map of Pimeria Alta 1687-1711. Shows Kino's routes, etc. |

Carleton 1864

| | |
|---|---|
| A-IX | Military Map of New Mexico. Shows a discontinuous Santa Cruz River north of Tucson. |

Cooke and Reeves 1976

| | |
|---|---|
| A-X | <u>Page</u> 52 - "Figure II.9 Santa Cruz Valley: data from Olberg and Schanck (1913)" [shows man-made channel being constructed to join the West and East Branches of the Santa Cruz River south of Mission San Xavier del Bac] |

Eckhoff, E.A. 1880

| | |
|---|---|
| A-XI | Official Map of the Territory of Arizona. Shows "supposed underground passage of the Santa Cruz River" north of Tucson. |

Emory 1857

A-XII Leaflet on back page - sketch of the Gila River Basin, including the Santa Cruz River.

Fergusson 1862

A-XIII "Cultivated Fields in and about Tucson" - at Arizona Historical Society

Hadley and Sheridan 1995

A-XIV Page 2 - "Figure 1. San Rafael Valley Area."

A-XV Page 29 - "Figure 2. Early Trails and Roads." [in San Rafael Valley]

A-XVI Page 45 - "Figure 5. Major Mines of the San Rafael/Lone Mountain Study Area."

A-XVII Page 110 - "Figure 12. Forest Service Ranges, 1917." [in San Rafael Valley]

A-XVIII Page 111 - "Figure 13. Forest Reserve Grazing Allotments, 1940's." [in San Rafael Valley]

A-XIX Page 207 - "Figure 20. Homesteads In the study area." [in San Rafael Valley, circa 1913-1930]

Halpenny 1962

Numerous maps throughout of the San Xavier District.

Halpenny 1988

A-XX Page 16 - "Figure 5. Water-level changes, 1953-1982, southern Santa Cruz River Valley."

Hendrickson and Minckley 1984

A-XXI Page 135 - "Figure 3. Sketch map of southeastern Arizona, with some place names mentioned in the text. Historical and present status of surface streamflows are indicated as adapted from Brown, Carmony, and Turner (1981)."

A-XXII Page 150 - "Figure 12. Sketch map of the Santa Cruz Valley, Arizona, with some place names mentioned in the text and some present-day aquatic and semiaquatic habitats (excluding stock tanks)."

A-XXIII Page 151 - "Figure 13. Sketch map of the Santa Cruz Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records."

Mattison 1946

A-XXIV Inset - "Spanish and Mexican Land Grants in Arizona...Photostat of General Land Office Map of 1887."

Parker 1993

A-XXV Page 10 - "Figure 3. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century."

Walker and Bufkin 1986

Historical Atlas of Arizona - various maps illustrating travel routes, land grants, Spanish exploration, military forts and presidios, missions, and others.

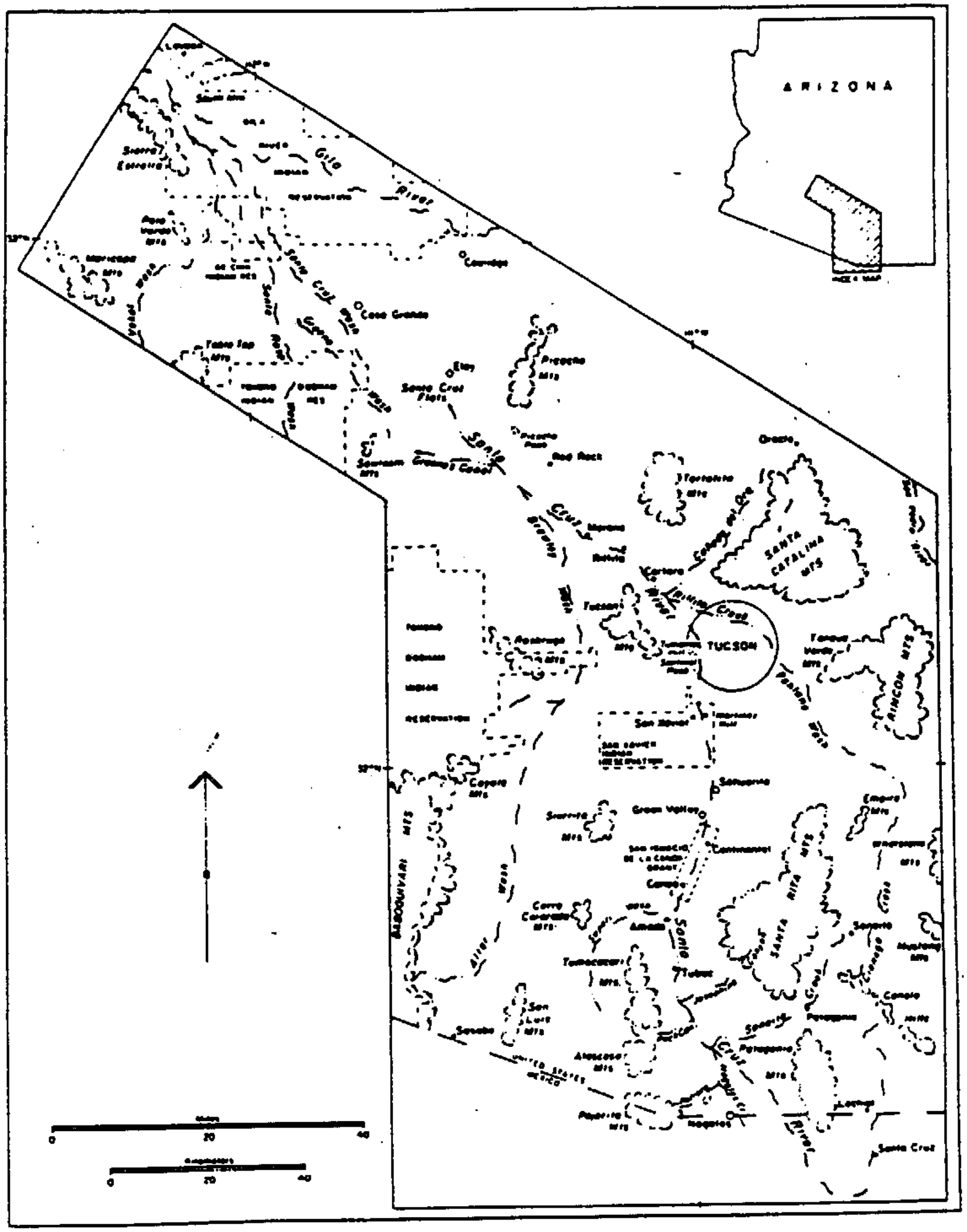



Figure 3. Map of the Santa Cruz River valley, with places mentioned in the text.

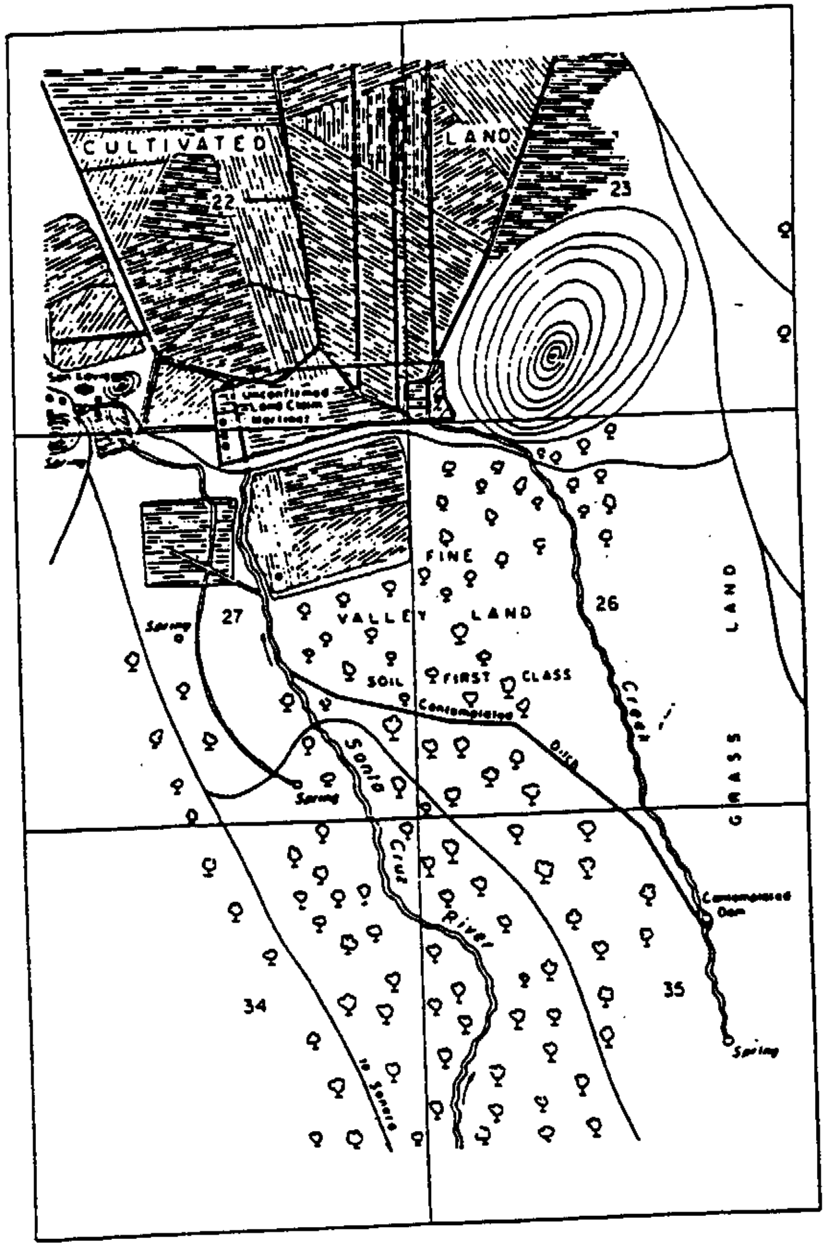



Figure 11. Map of the northeast portion of the San Xavier Indian Reservation in 1882 (after Roskruge, 1882). In this map, and on later ones (Figs. 12-13), the course of the Santa Cruz north of Martinez Hill is not indicated, suggesting that the channel had long been replaced by ditches in carrying floodflows.

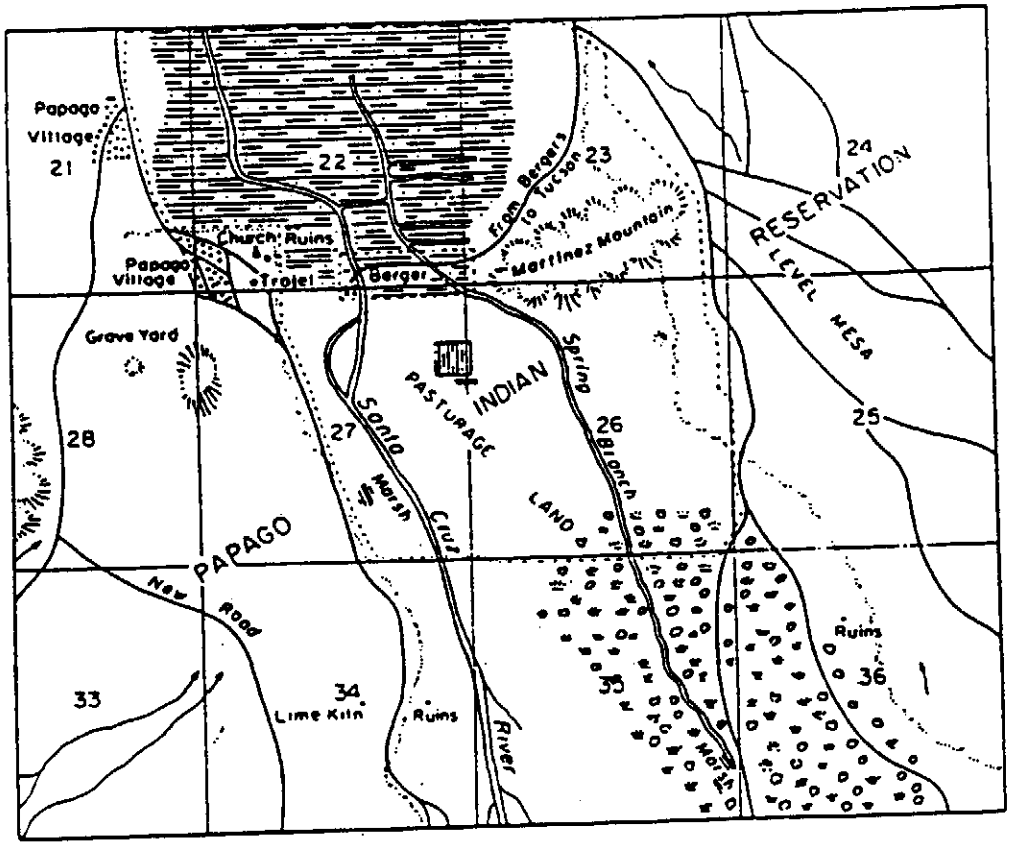



Figure 12. Map of the San Xavier Indian Reservation in 1888 (Chillson, 1888).

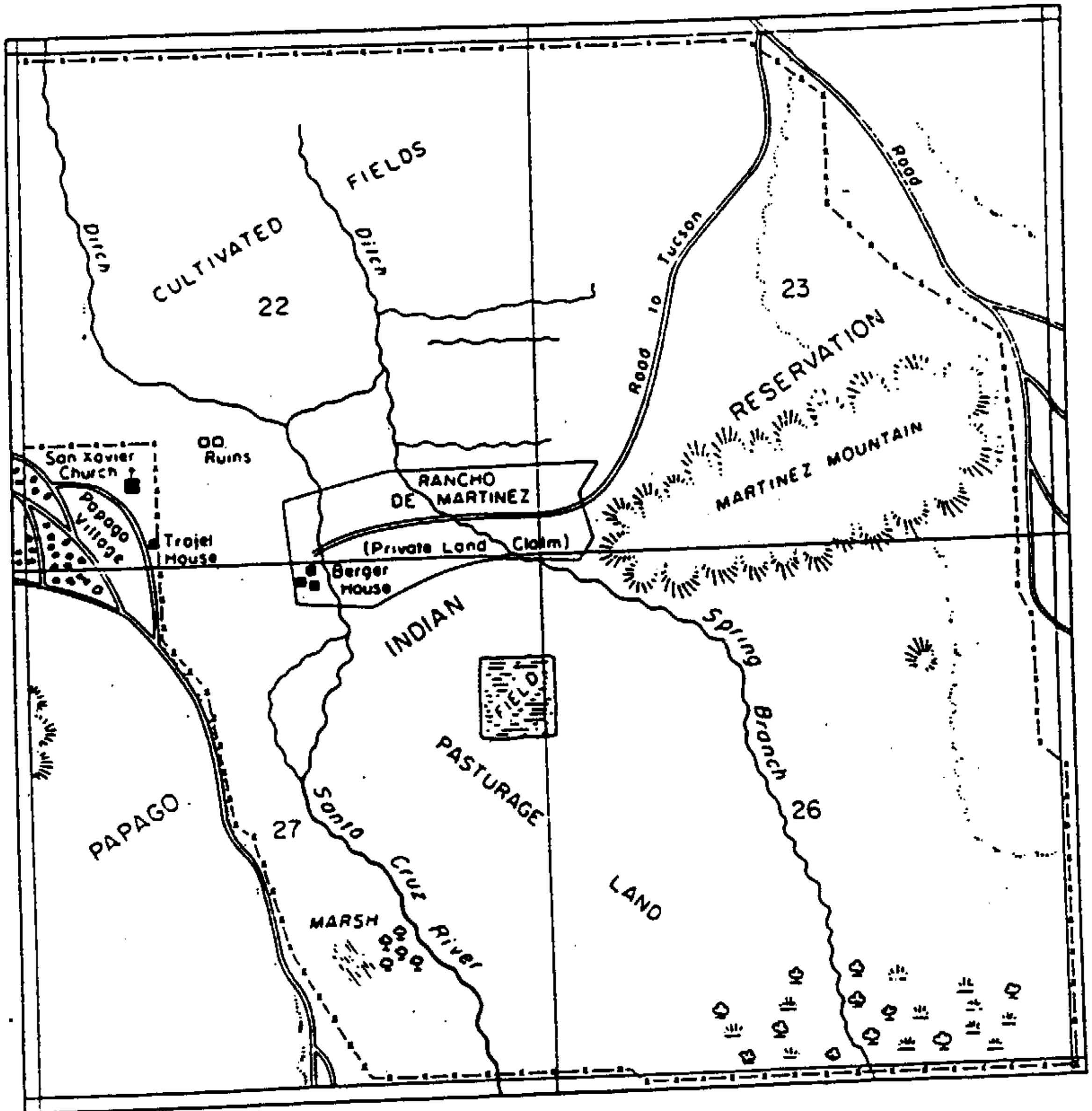



Figure 13. Map of San Xavier Indian Reservation in 1891 (Surveyor General's Office, 1891).

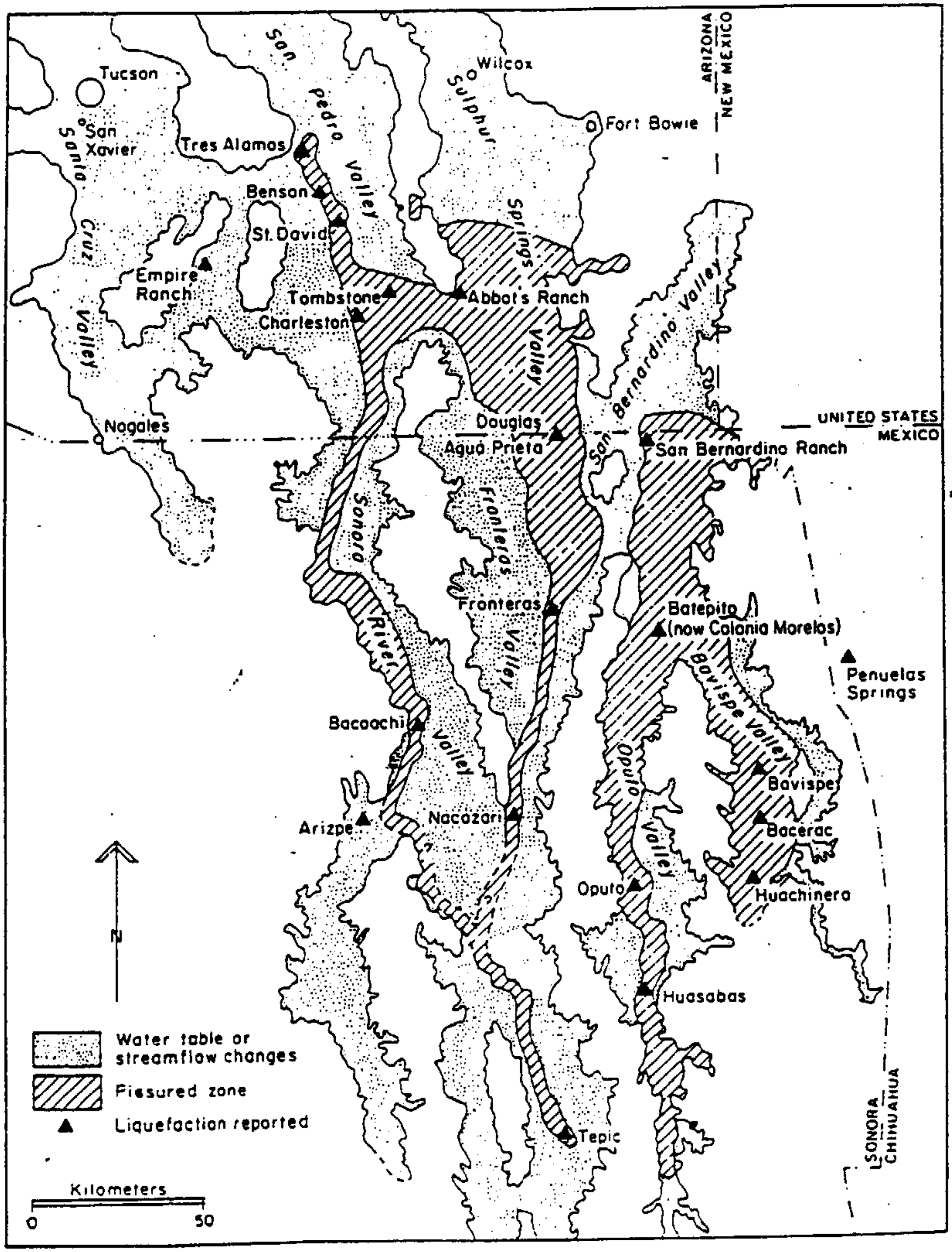



Figure 21. Map of northern Sonora and southern Arizona, showing hydrological effects of the 1887 earthquake (after Dubois and Smith 1980).

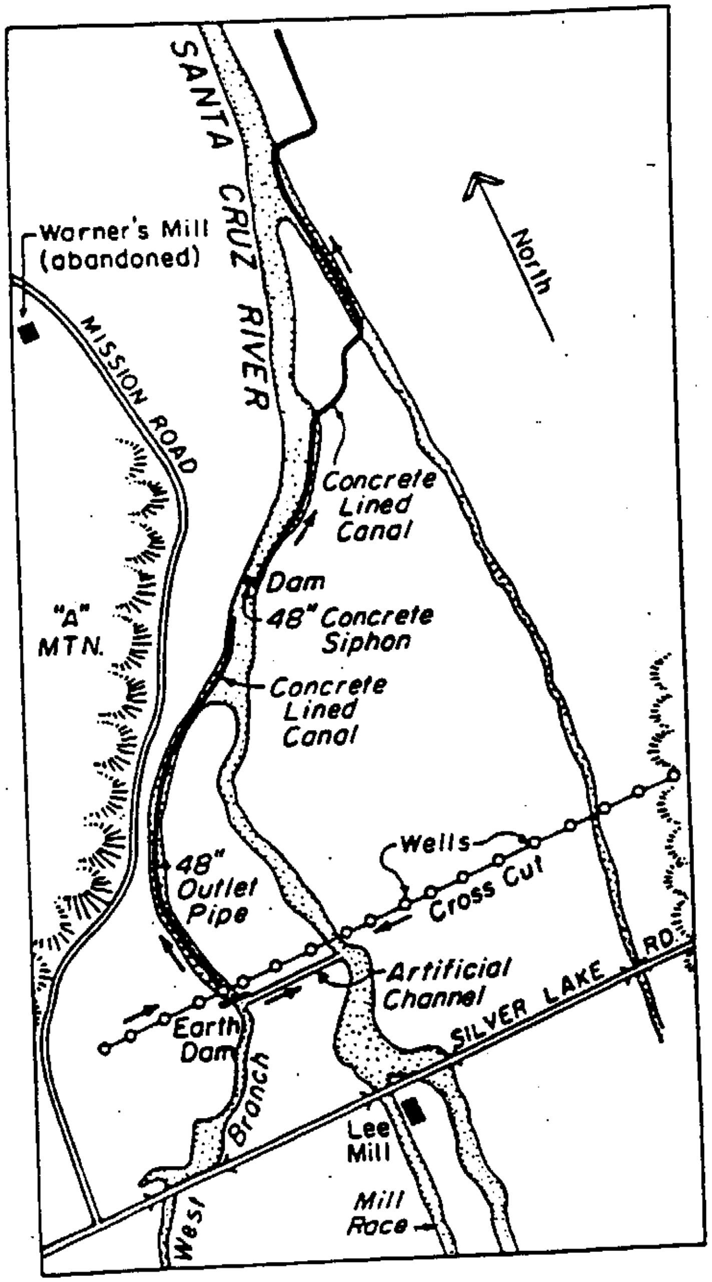
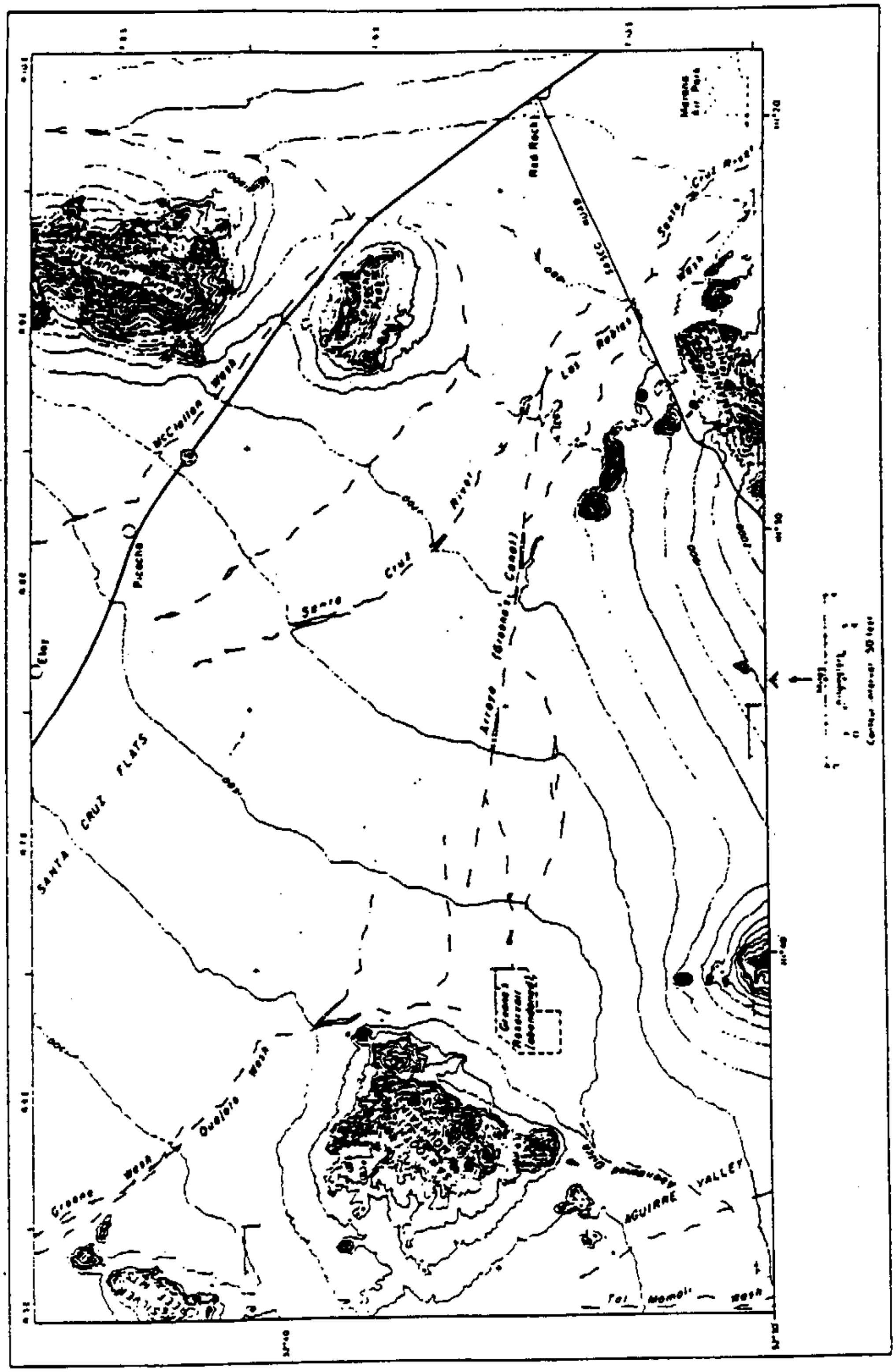



Figure 40. Plan of the Tucson Farms Company Crosscut and distribution system (Hinderlider 1913).

Figure 47. Map of Greene's Canal and lower Santa Cruz River, based on U.S.G.S. 15' Quadrangles.



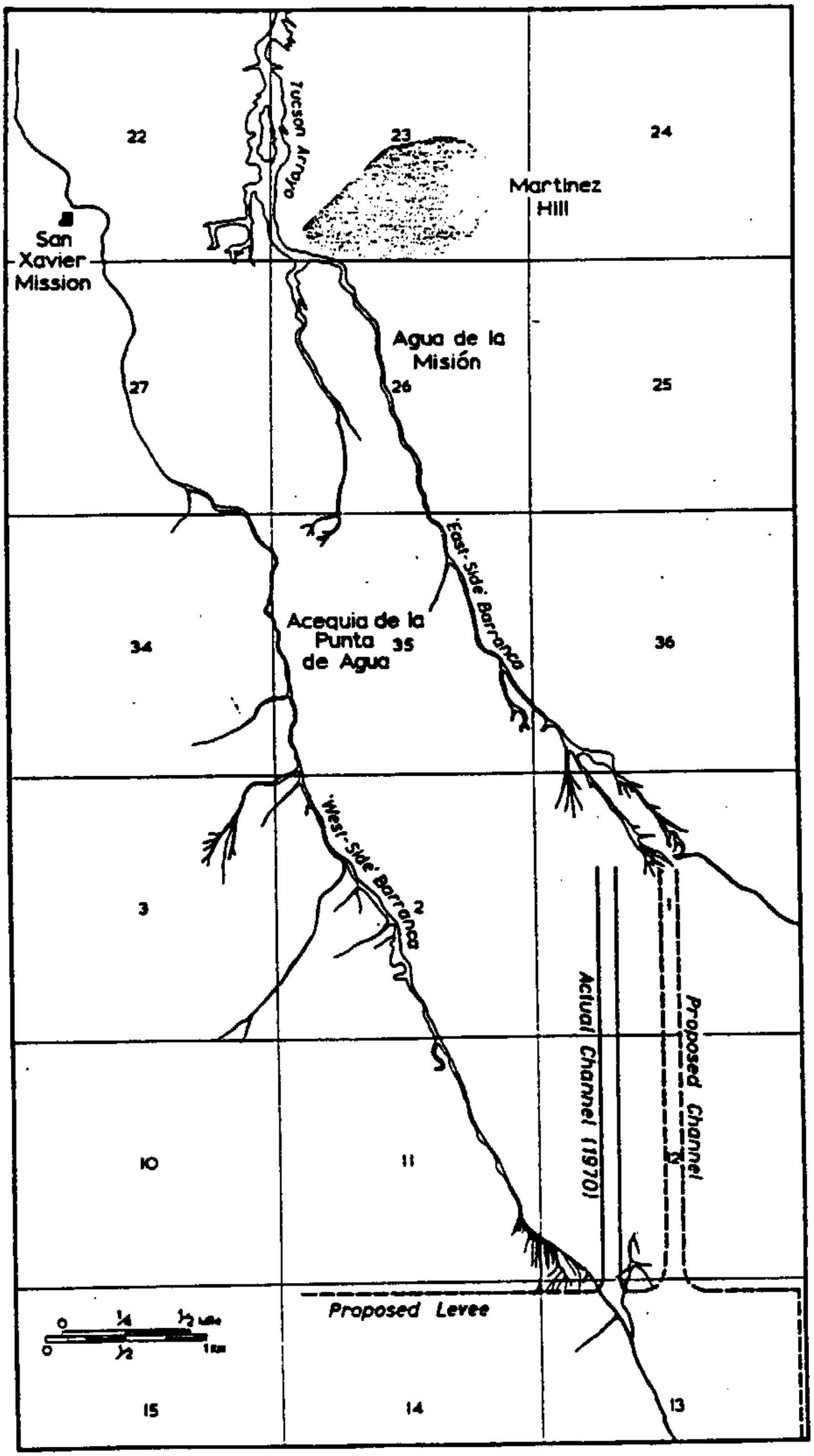
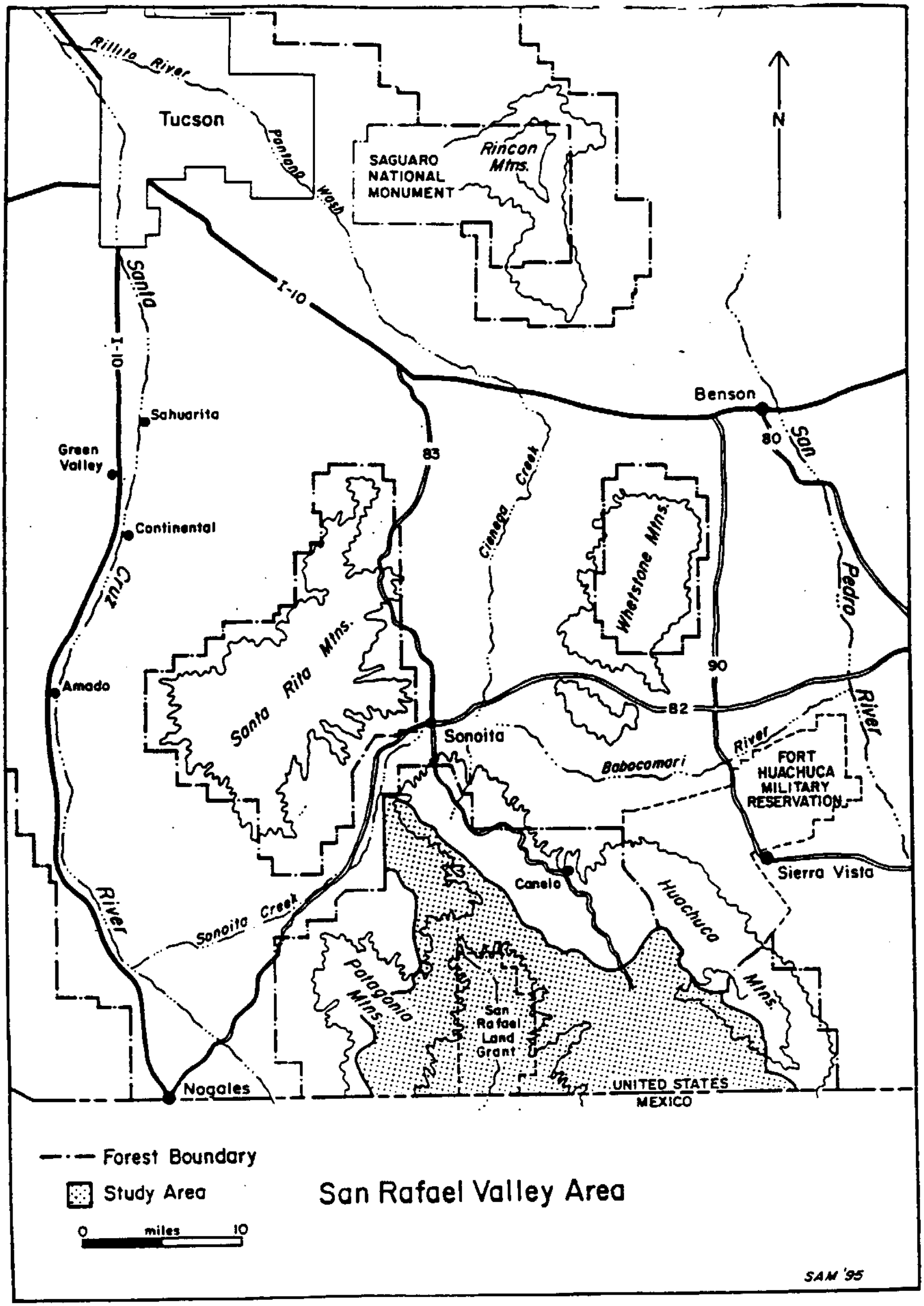



Figure II.9 Santa Cruz Valley: data from Olberg and Schanck (1913)



Rillito River
Tucson
Pantano Wash
SAGUARO NATIONAL MONUMENT
Rincon Mtns.
N
I-10
Santa Cruz River
Sahuarita
Green Valley
Continental
Amado
83
Benson
80
San Pedro River
Cienega Creek
Whetstone Mtns.
90
82
Santa Rita Mtns.
Sonoita
Babocomari River
FORT HUACHUCA MILITARY RESERVATION
Sierra Vista
Canelo
Huachuca Mtns.
Sonoita Creek
Patagonia Mtns.
San Rafael Land Grant
Nogales
UNITED STATES
MEXICO
Forest Boundary
Study Area
0 miles 10
San Rafael Valley Area
SAM '95


Figure 1

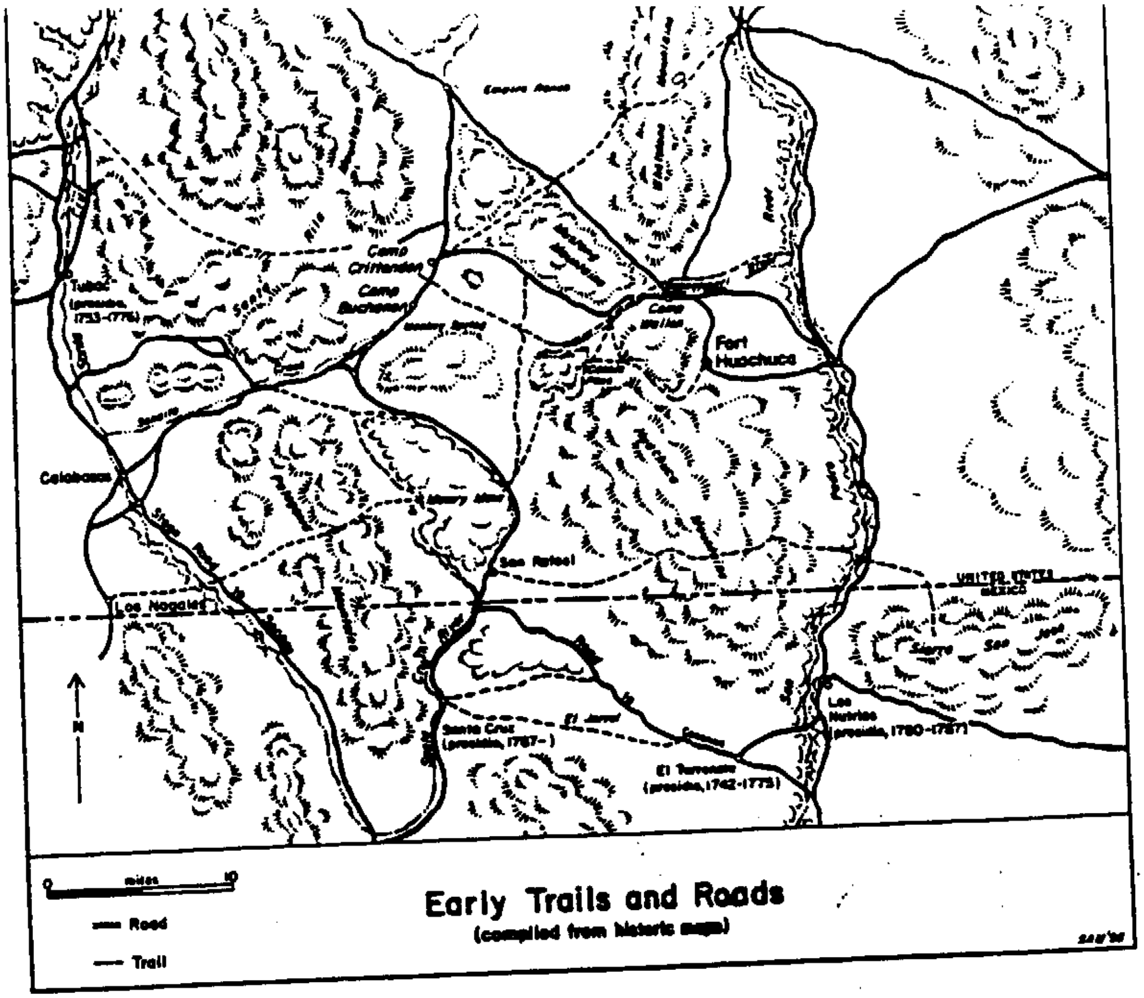



Figure 2

leans *Daily Picayune*, went to Santa Cruz, Major Graham's tracks were still fresh. Durivage's party followed Graham's mistaken first attempt to find a route over the steep slopes until they reached the place where "it was evident that Major Graham had turned back" (Bieber 1937:206). His party also turned back, subsequently found the wagon road, and reached Santa Cruz with ease.

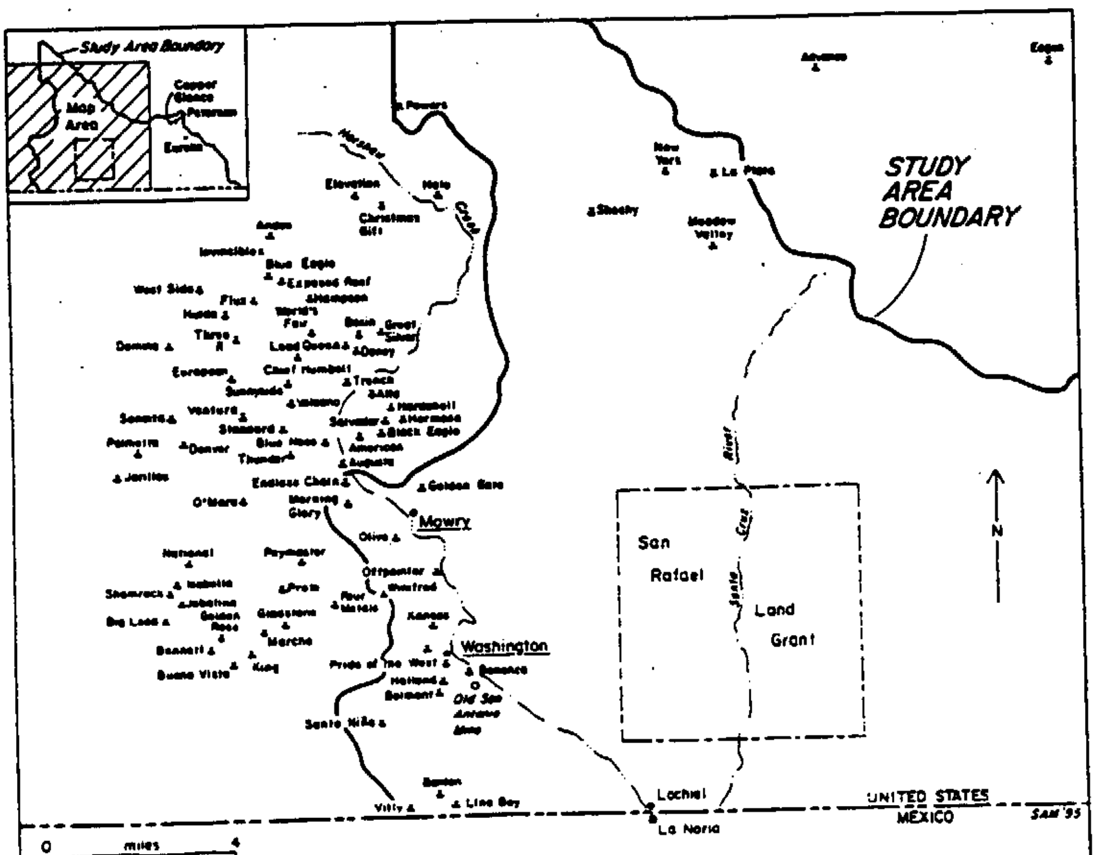
On August 12, after a heavy rain, George W. B. Evans and the Ohio Company took the shorter route to Santa Cruz. They departed from Colonel Cooke's trail and made what Evans described as a "very steep" ascent up a rocky road into unnamed mountains. On the descent, his party had gone only two miles when they were forced to camp near the highest peak of the mountains. Departing from this camp in the morning, they reached Santa Cruz by 3:00 p.m., stopping to repair a broken wheel en route. After reaching Santa Cruz by the shorter, steeper trail, several members of the Ohio Company abandoned their wagons and continued to California as a pack train (Dumke 1945:145–46).

In early September, John Robert Forsyth of the Peoria Company took the shorter route to Santa Cruz. He noted that the road began at "three deserted Ranches some of the walls still in a good state of preservation & at one of them large piles of melted metal resembling lead or silver" [Terrenate or Las Nutrias]. The descent of the road into the southern portion of the San Rafael Valley passed through a canyon where "there was not six Inches more room than was required by the Wagons." He noted that the rocks on this portion of the road were 300 to 400 feet perpendicular and overhung the valley below. The road continued through a "fine rich valley" which had the appearance of an "English Landscape" (Forsyth ms:69–70). Charles Pancoast, who traveled with the same company, recalled a "steep descent of about fifty feet where we had to lower our wagons with ropes" (Hannum 1930:233). Since Pancoast wrote his memoir many years after his journey, his recollections are unreliable. However, it is possible that the descent required braking with ropes. Although these two diarists do not state which trail they had taken, it is

# Mining and Settlement

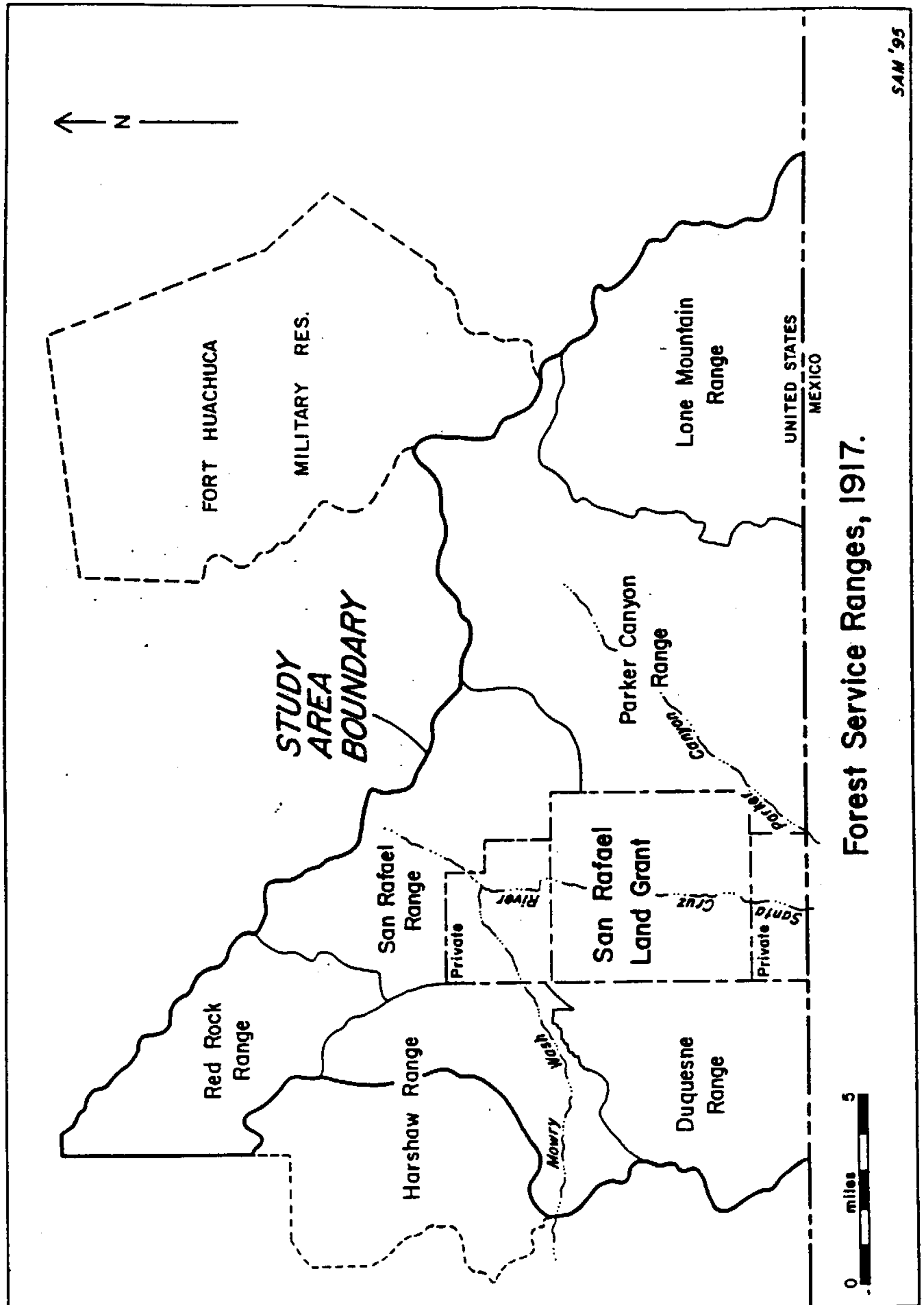
Scattered throughout the mountainous parts of the study area are the remains of old mines, prospects, primitive adobe smelters, and timeworn slag piles. Mining has taken place within the study area since the Spanish and Mexican periods (see Appendix 5.2). However, impacts from mining and the many subsidiary activities associated with mining became intense during the late 1870s and lasted until the 1960s (see Appendix 5.3). The study area contains three significant mining areas: Mowry and Washington Camp/Duquesne in the Patagonia Mountains, and Sunnyside on the western slopes of the Huachucas (Fig. 5). Located slightly north of the study area is Harshaw, the largest of the nearby mining camps and the only location in this part of Santa Cruz County that experienced a true mining boom. Because of its proximity to the study area and the important influences that its mining activity had on the study area, Harshaw is included in this report.

Although the activity of mining itself may be restricted to a specific location, subsidiary activities associated with mining produce a web of ecological impacts that extend far beyond the mining site itself. These associated activities include: road construction; fuelwood cutting, particularly during the period when smelting relied on charcoal and machinery operated from steam boilers; the development of mining camps and nearby towns; extraction of water from surface and underground water courses; the creation of waste dumps; chemical and mineral leakage from tailing and slag piles; removal and relocation of earth from mine shafts and workings; and the




Major Mines of the San Rafael / Lone Mountain Study Area.
(from Robert Lenon Map, 1950)

Figure 5



Forest Service Ranges, 1917.
N
SAM '95
FORT HUACHUCA
MILITARY RES.
STUDY
AREA
BOUNDARY
Lone Mountain
Range
UNITED STATES
MEXICO
Parker Canyon
Range
Parker
Canyon
San Rafael
Range
Private
San Rafael
Land Grant
Santa
Cruz
River
Private
Red Rock
Range
Harshaw Range
Mowry
Wash
Duquesne
Range
0
miles
5


Figure 12

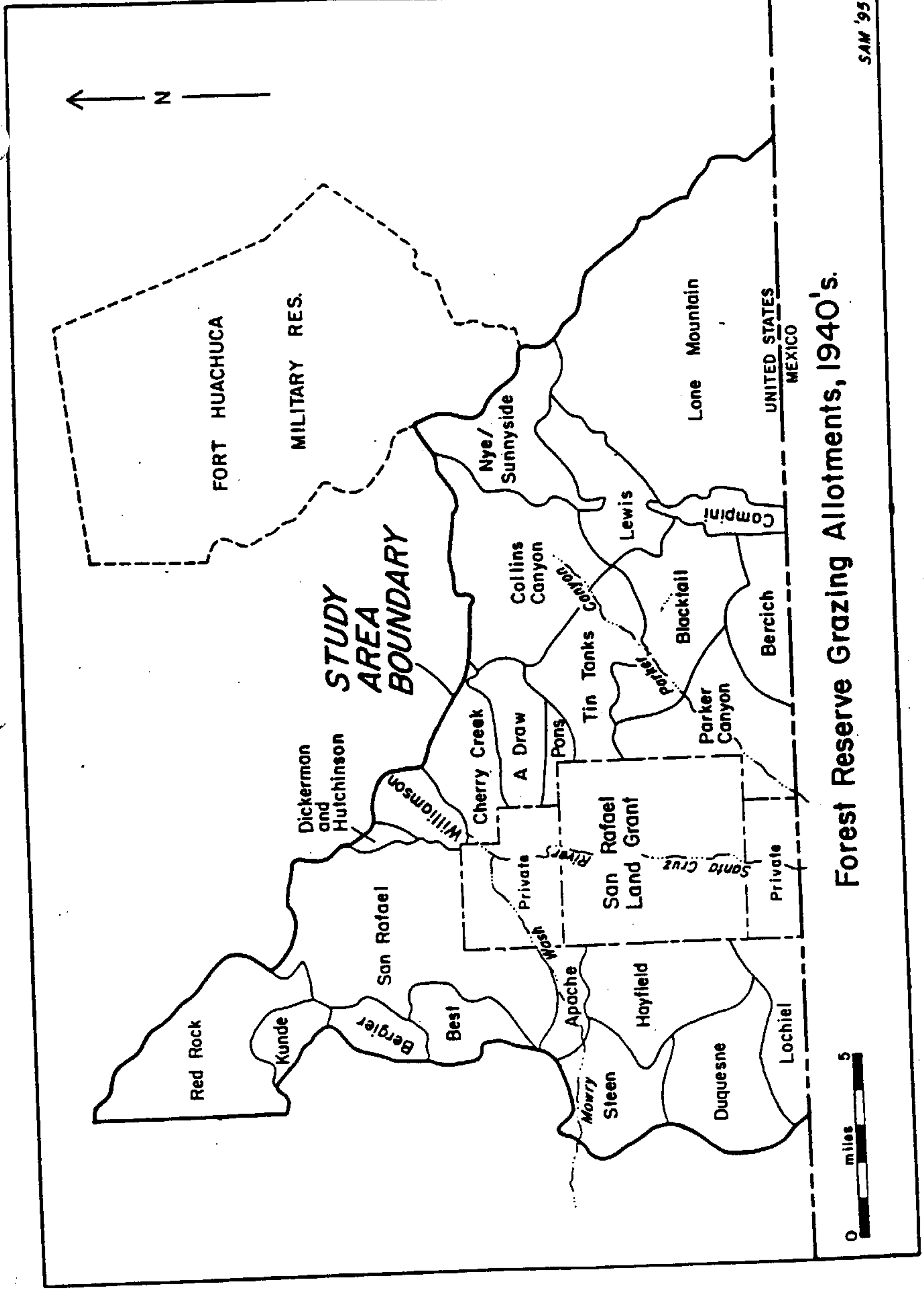

Forest Reserve Grazing Allotments, 1940's.
N
FORT HUACHUCA
MILITARY RES.
STUDY AREA BOUNDARY
Red Rock
Kunde
Bergier
Best
San Rafael
Dickerman and Hutchinson
Williamson
Cherry Creek
A Draw
Pons
Tin Tanks
Collins Canyon
Nye/ Sunnyside
Lone Mountain
Lewis
Blacktail
Campini
Bercich
Parker Canyon
Private
San Rafael Land Grant
Santa Cruz River
Wash
Apache
Hayfield
Steen
Mowry
Duquesne
Lochiel
UNITED STATES
MEXICO
0
miles
5
SAM '95

Figure 13

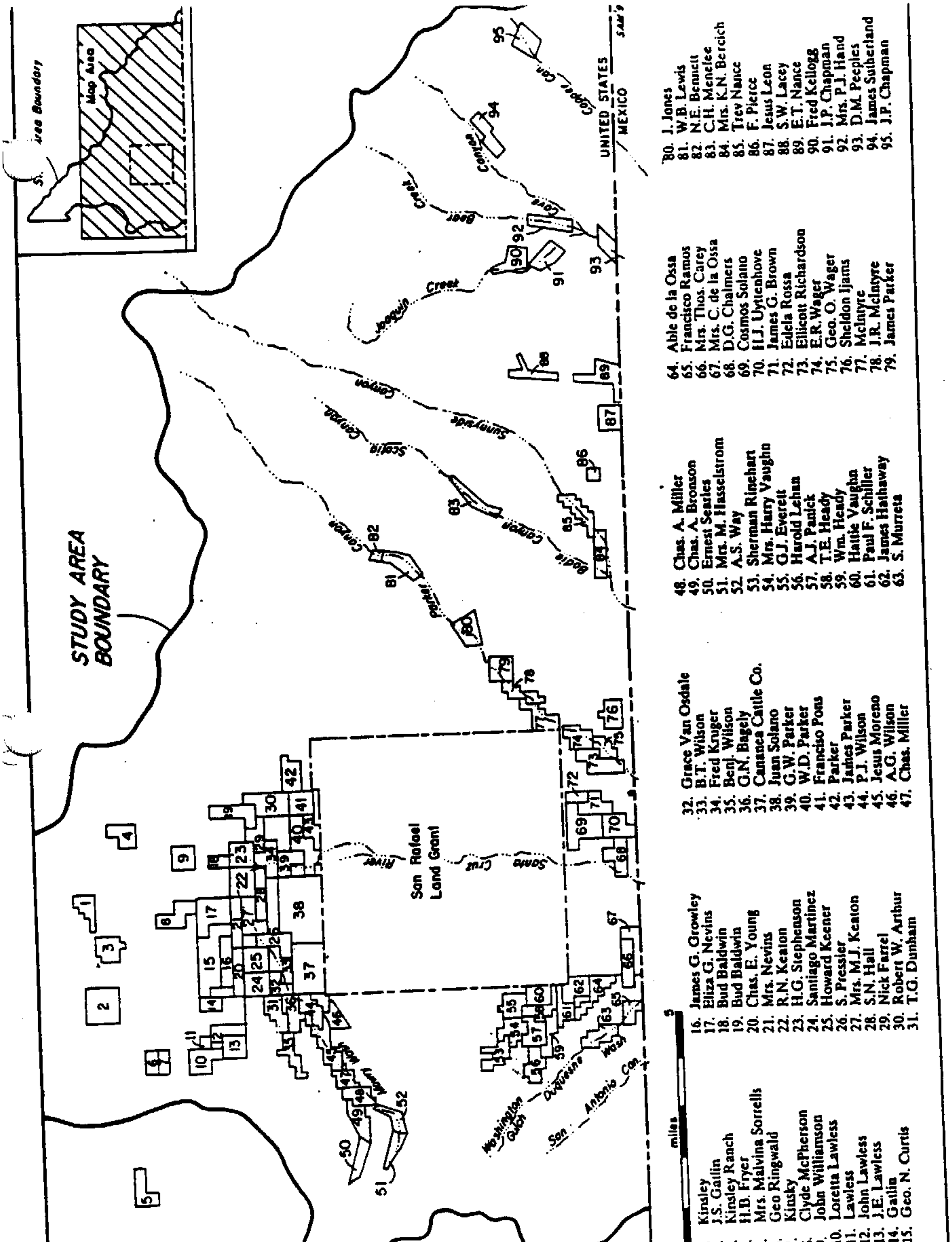



Figure 20—Homesteads in the study area.

Hendrickson + Minckley 1984

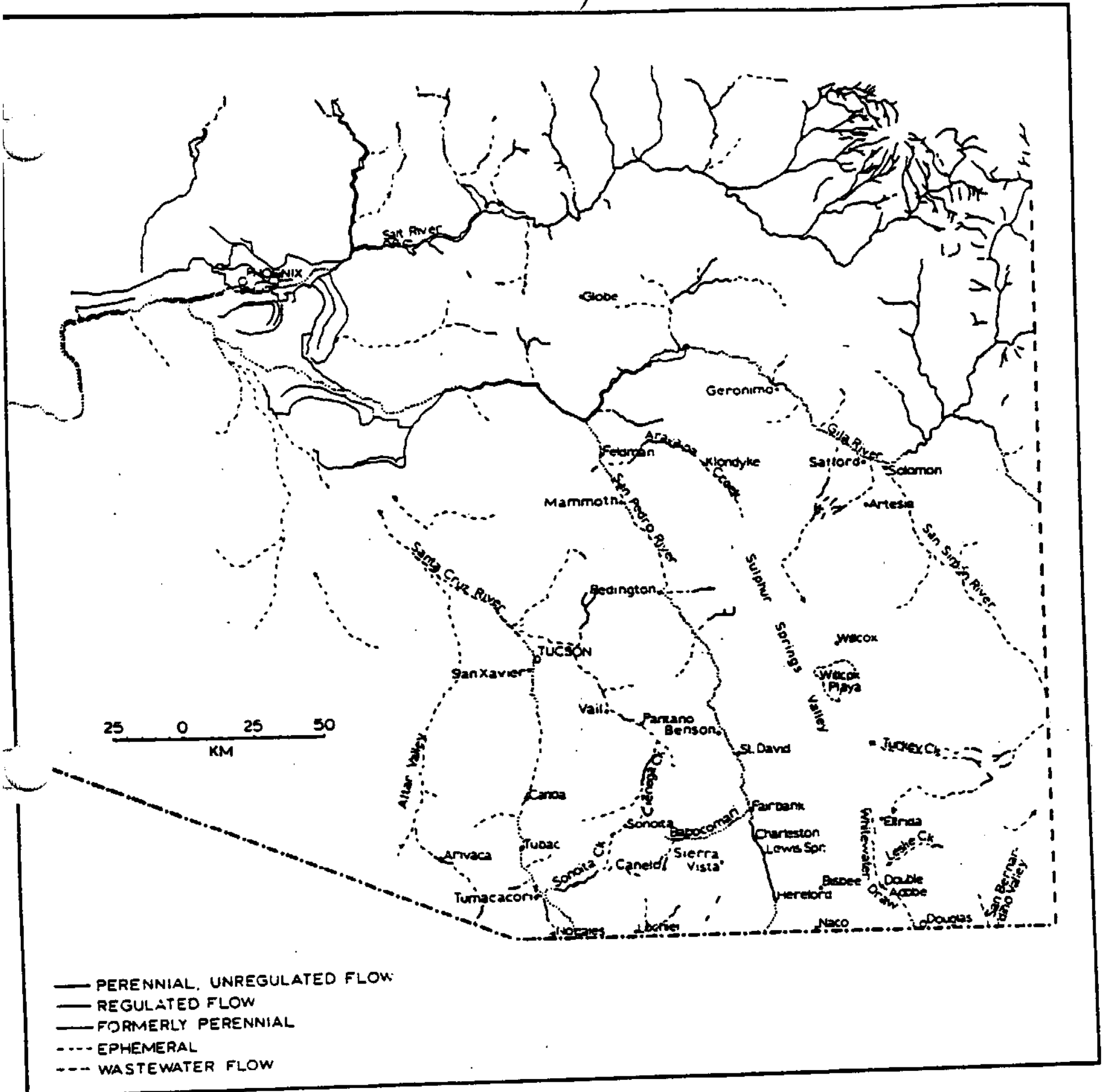



*Figure 3. Sketch map of southeastern Arizona, with some place names mentioned in the text. Historical and present status of surface streamflows are indicated as adapted from Brown, Carmony, and Turner (1981).*

ranges. Mostly hunters and gatherers, these groups practiced little agriculture.

Older residents were the Pimas Altos of the Santa Cruz and San Pedro valleys. These rancheria peoples lived in semi-permanent settlements wherever perennial surface water was available. They subsisted primarily by floodplain and irrigated farming (Bryan, 1929, 1941), supplemented with wild food gathering. Adjacent rancheria peoples were the Opatas who lived on northern Rio Yaqui tributaries in the area of Rancho San Bernardino and the upper Rio Sonora drainage in México, and the Pimas Bajos who occupied lower reaches of these same drainages. Papagos inhabited more arid deserts west of the Pimas Altos, and they were bordered on the west by Yumans of the lower Gila and Colorado rivers (Sauer 1934; Crosswhite, 1981). Size of these Indian populations 4 to 8 centuries ago was larger than the total European and Indian population of 1880 (Hastings and Turner, 1965).

Spanish colonization brought new impacts on the environment. However, descriptions of their missionary settlements are rare and provide few data for comparison with recent landscapes. A major impact of Spanish conquest on aboriginal populations predated that culture's arrival in the study region. Smallpox, introduced in 1520

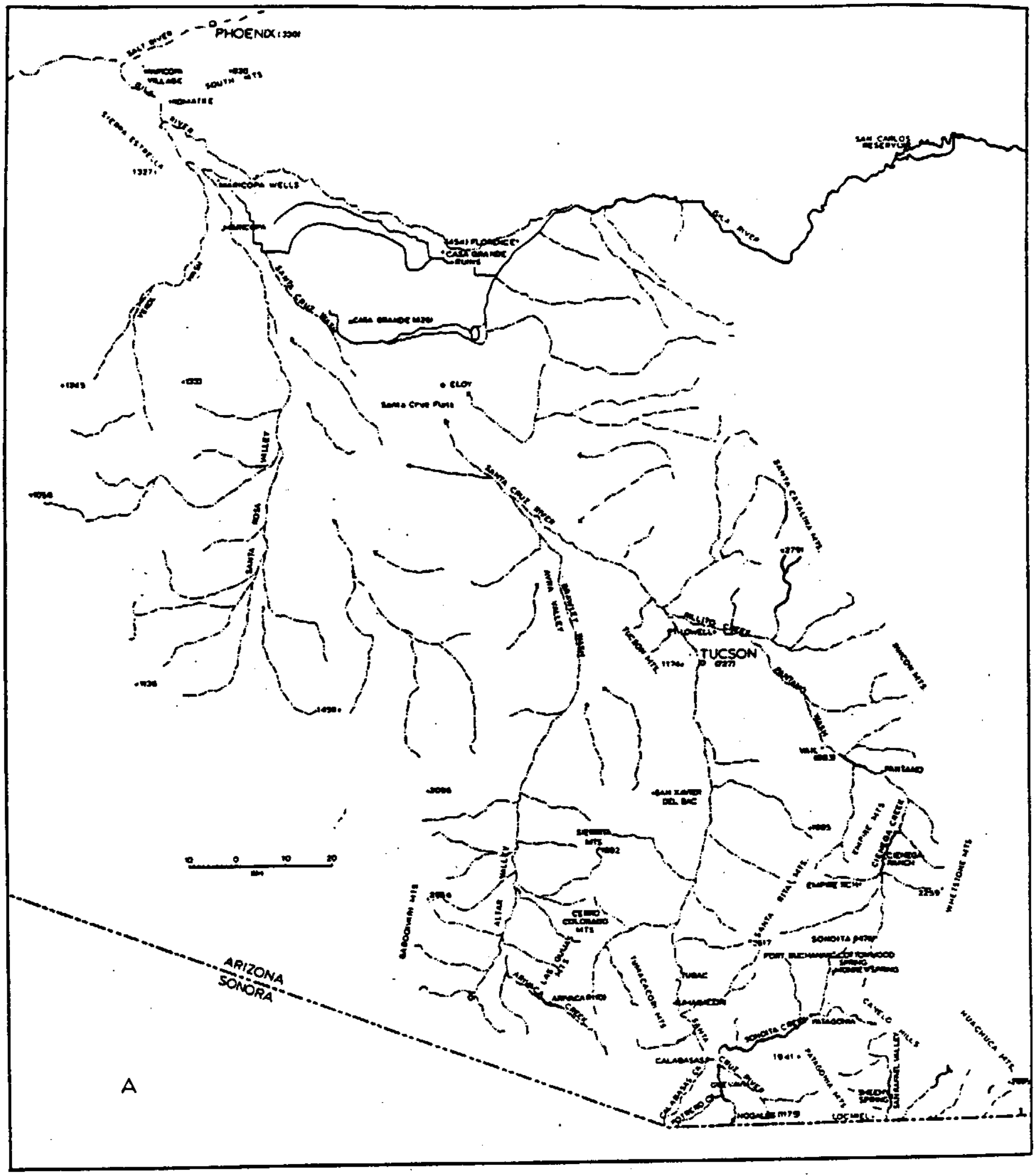



*Figure 12. Sketch map of the Santa Cruz Valley, Arizona, with some place names mentioned in the text and present-day aquatic and semiaquatic habitats (excluding stock tanks). Elevations are in meters. Symbols are as in Figure 4.*

we visited in 1981. Cook's lake is similarly dominated by Willows, but also has peripheral Cottonwoods. Open water is essentially absent, although present when Smith and Bender (1973a, 1974d) did their survey. In the interim between their work and ours, *Typha* sp. completely closed the open-water area. Cattail and Watercress also cover an adjacent area of tree-dominated swamp, which is drained *via* a broad, diffuse, shallow channel choked by Cattail, to a small artificial lake. Both these systems are best defined as wooded swamps, resembling such associations in the southeastern United States.

**Santa Cruz Basin.** Headwaters of the Rio Santa Cruz (Figs. 12, 13) drain the north, west, and south slopes of the Canelo Hills, and all sides of both the Patagonia and Santa

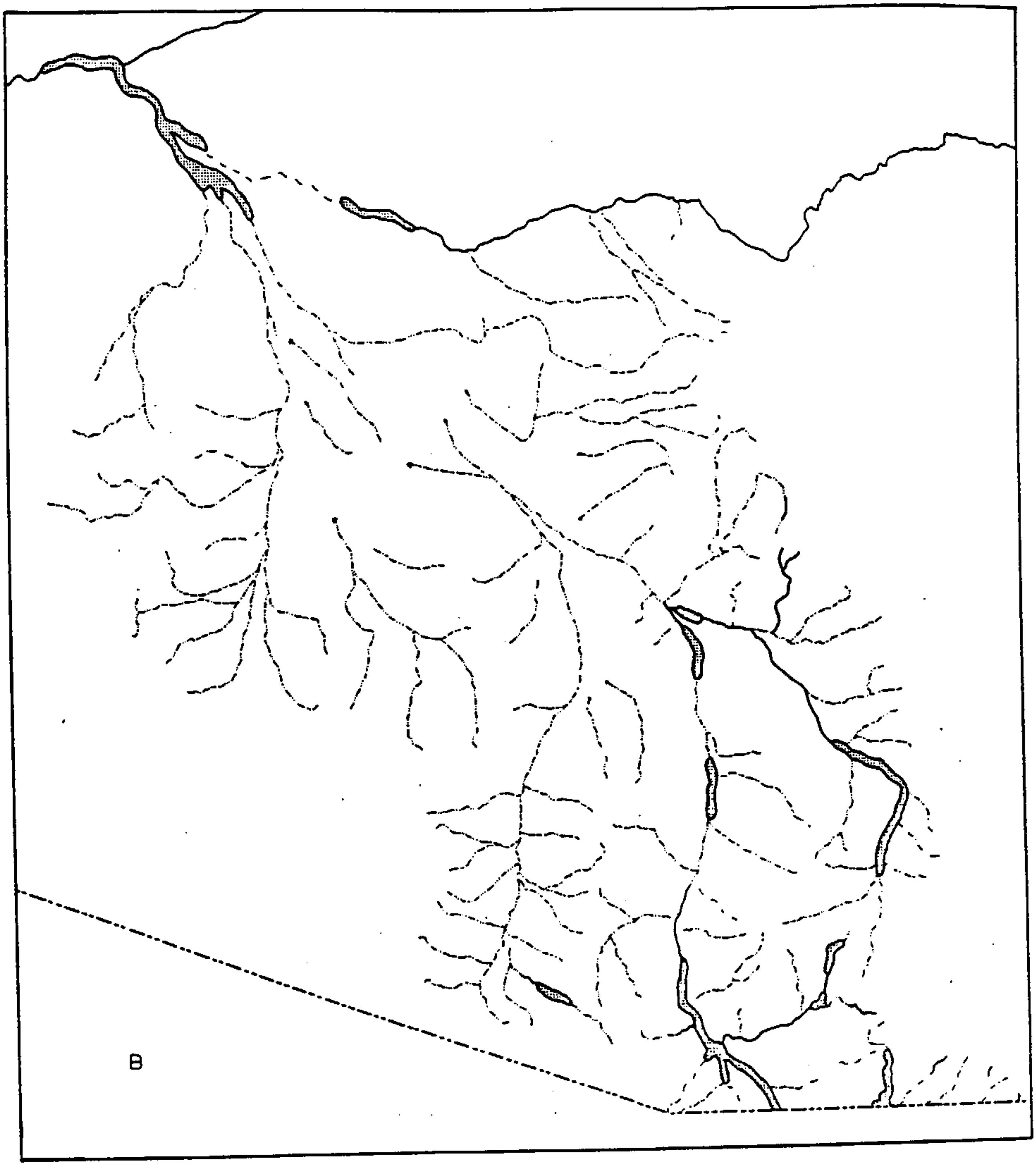



*Figure 13. Sketch map of the Santa Cruz Valley, with aquatic and semiaquatic habitats before 1890 as inferred from historic records. Symbols are as in Figure 4.*

Rita Mountains. Maximum elevations range from 1,900–2,600 m. The mainstream flows south through the San Rafael Valley, receiving tributaries from the Huachuca Mountains on the east. Entering Sonora it loops south of the Patagonia Mountains to flow into Arizona. It then receives discharge from the western Canelo Hills *via* Sonoita Creek, which passes between the Santa Rita and Patagonia Mountains. The valley broadens as it passes between the Santa Rita and Sierrita mountains and continues north to Tucson. North of Tucson, Rillito Creek enters from the east with drainage from the north slope of Canelo Hills *via* Cienega Creek and Pantano Wash. Further downstream the broad Avra-Altar Valley enters from the southwest, draining the area between the Baboquivari and Sierrita mountains. The Rio Santa Cruz historically disappeared into its bed, except in flood, in the vicinity of

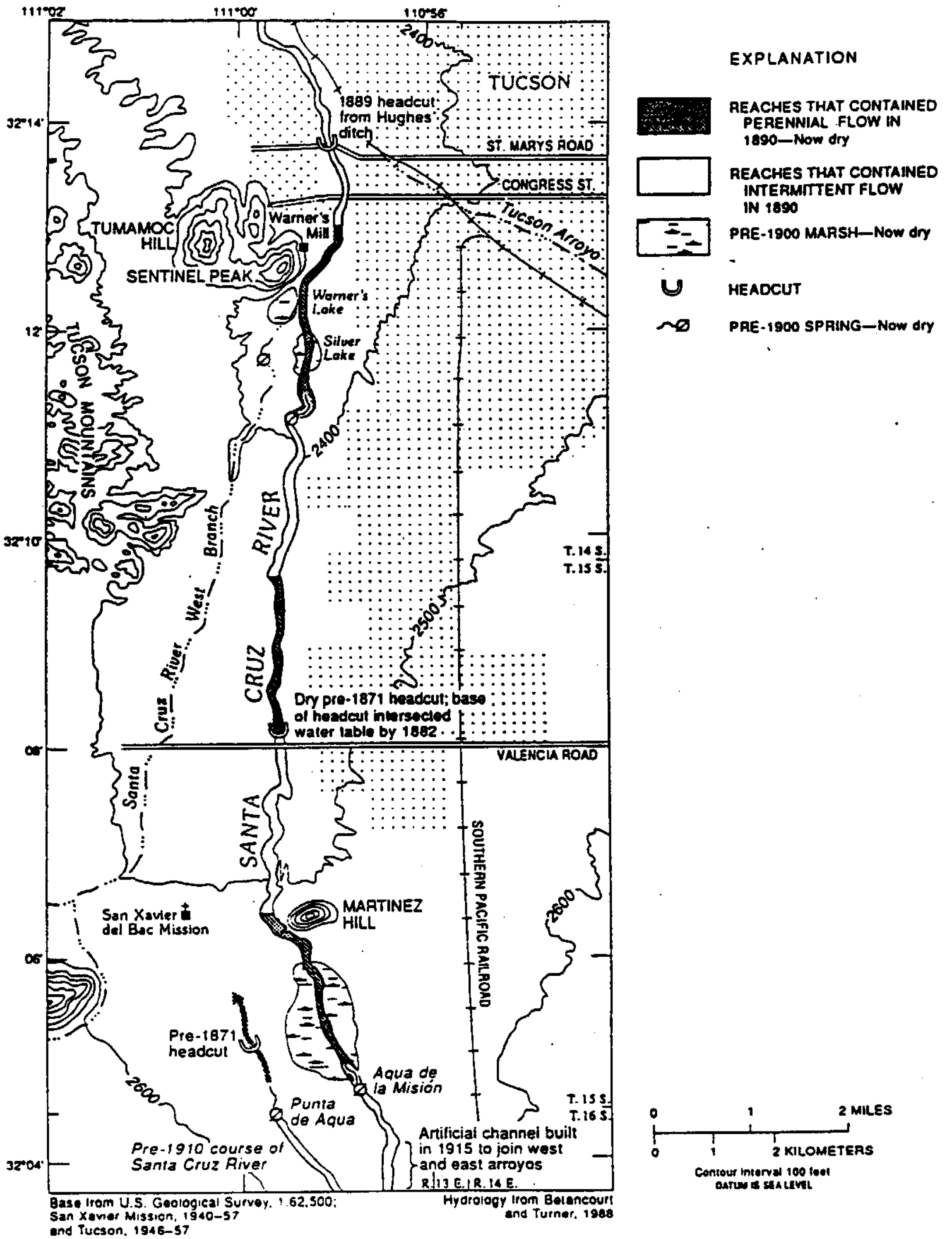



Figure 3. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century.

## APPENDIX B -- HISTORIC PHOTOS

The Arizona Historical Society and Special Collections at the University of Arizona Library have a wealth of photos relating to the Santa Cruz River. Unfortunately, many of these photos are inadequately labeled. For example, one may say "person crossing Santa Cruz River" without giving date or place. A series of photos of the Santa Cruz County portion of the river was made by a surveyor, but the exact locations are unknown. Recently the Buehman Collection was made available at the AHS Library, consisting of some one million photos. Only about a fourth have been cataloged, however, and few have dates or locations. Other AHS collections of value include the Roskruge file, Arizona-places-Santa Cruz River, Arizona-Santa Cruz River-floods and Arizona-places-ranches. A fine collection of photos is available at the Tumamoc Hill office of the U.S. Geological Survey, the collection from which the photos in The Changing Mile are drawn. The Turner photos listed below are from that collection.

Most of the photos listed below are available at the AHS as well as in their published form which is the one listed if applicable.

Betancourt 1990

B-I Page 32 - "Figure 4. Aerial view of Tucson reach of the Santa Cruz River, Looking southeast on October 9, 1983."

B-II Page 49 - "Figure 7. Upstream view in 1912 of Acequia de Punta de Agua, a streambed spring along the Santa Cruz River south of the San Xavier Mission (from Olberg and Schanck, 1913)."

B-III Page 53 - "Figure 8. Looking west across Silver Lake in the 1880s. Structure on the right was a hotel."

B-IV Page 53 - "Figure 9. Same view as Figure 8, taken on December 16, 1981."

B-V Page 83 - "Figure 14. Solomon Warner's house and mill in 1880, looking southeast from lower slope of Sentinel Peak, with the Santa Cruz Valley in the background."

B-VI Page 84 - "Figure 15. The Santa Cruz Valley from the base of Sentinel Peak looking east ca. 1880. Warner's Mill is the structure at left margin of photograph. White structure at center right is Leopoldo Carrillo's ice house, which was cooled by water from the mill's tail race."

B-VII Page 84 - "Figure 16. Same view as Figure 15 on December 1, 1981."

B-VIII Page 85 - "Figure 17. East view of Santa Cruz Valley and Tucson from Sentinel Peak in 1882, showing the San Agustin Mission (center) and Warner's Mill Complex at lower left. The Acequia Madre, which was fed by Silver lake, runs from right to left across center of photograph. The Acequia may have followed the mainstem of the Santa Cruz River, which at that time had no discernible channel."

B-IX Page 85 - "Figure 18. Same view as Figure 17 on December 1, 1981."

B-X Page 93 - "Figure 19. Southeast view of Warner's Lake in 1883. The shallow channel of the Santa Cruz River is visible downstream of the dam at extreme left of the photograph."

B-XI Page 93 - "Figure 20. Approximately the same view as Figure 19 on December 31, 1988."

B-XII Page 105 - "Figure 22. Upstream view of the heading of Sam Hughes' intercept ditch at the St. Mary's Road crossing in October 1889."

B-XIII Page 105 - "Figure 23. Taken on the same day, a slightly different view of the headcut in Figure 22, with Sentinel Peak at upper right."

B-XIV Page 111 - "Figure 25. View looking directly west across the St. Mary's Road crossing in August 1890, with newly formed arroyo threatening homestead on opposite bank."

B-XV Page 111 - "Figure 26. Same view as Figure 25 on February 4, 1982."

B-XVI Page 112 - "Figure 27. Downstream view of the Santa Cruz river during the flood of August 1890, taken from east bank at the St. Mary's road crossing."

B-XVII Page 112 - "Figure 28. Upstream view of the Santa Cruz River on the same day and from same location as Figures 26 and 27."

B-XVIII Page 116 - "Figure 29. View looking upstream at Congress Street in 1902. The deep arroyo that eroded in 1890 and 1891 made river crossings more difficult."

B-XIX Page 116 - "Figure 30. Downstream view of the Santa Cruz river in 1902."

B-XX Page 118 - "Figure 32. The San Agustin Mission or Convento Ruins as sketched by John Spring in 1871, looking west across the Acequia Madre."

B-XXI Page 118 - "Figure 33. The San Agustin Mission in 1903, looking across to the west bank of the Santa Cruz River."

B-XXII Page 119 - "Figure 34. The San Agustin Mission, most likely in the 1910s, from roughly the same vantage point as Figures 32 and 33."

B-XXIII Page 120 - "Figure 35. Downstream view of the confluence of the West Branch and the Santa Cruz River, looking northeast from the lower slope of Sentinel Peak in 1904."

B-XXIV Page 120 - "Figure 36. Same view as Figure 35 on December 17, 1981."

B-XXV Page 131 - "Figure 37. Head of the Manning Ditch in 1907, with the Santa Cruz River and Sentinel Peak in the background."

B-XXVI Page 132 - "Figure 38. Same view as Figure 37 on February 4, 1982."

B-XXVII Page 137 - "Figure 41. East view of the Crosscut in 1913, with trenching for concrete conduit in progress and well casing in foreground."

B-XXVIII Page 137 - "Figure 42. West view of the Crosscut under construction in 1912."

B-XXIX Page 138 - "Figure 43. Outlet from the Crosscut in the streambed of the West Branch in 1913."

B-XXX Page 139 - "Figure 44. Same view as Figure 43 on February 4, 1982."

B-XXXI Page 140 - "Figure 45. Diversion point for water developed by the Crosscut, about 3 km downstream along the bed of the Santa Cruz River, in 1912."

B-XXXII Page 140 - "Figure 46. Sector of finished concrete lined canal inside the east bank of the Santa Cruz River in 1913."

B-XXXIII Page 145 - "Figure 48. Upstream view from Martinez Hill in 1912, with dense mesquite growth in the valley bottom. By this date, a channel 9m deep marked the course of the Spring Branch, with a steep headcut terminating just below the dam in the center of the photograph."

B-XXXIV Page 145 - "Figure 49. Similar view as Figure 48 on December 15, 1981."

B-XXXV Page 150 - "Figure 50. The Santa Cruz River in flood at Congress Street on December 23, 1914."

B-XXXVI Page 151 - "Figure 51. Upstream view of the Congress Street Bridge on the morning of January 31, 1915, as the east approach to the bridge began to give way."

B-XXXVII <u>Page</u> 151 - "Figure 52. In this northwest (downstream) view of the 1915 flood, onlookers stand perilously close to the eroding east bank of the Santa Cruz River, just downstream of the Congress Street Bridge."
B-XXXVIII <u>Page</u> 152 - "Figure 53. Southwest (upstream) view of Santa Cruz River in flood in February 1915."
B-XXXIX <u>Page</u> 153 - "Figure 54. The Congress Street Bridge after erosion of east bank in January 1915, looking northwest."
B-XL <u>Page</u> 153 - "Figure 55. A similar view as Figure 54 in July 1915."
B-XLI <u>Page</u> 154 - "Figure 56. North (downstream) view of the Santa Cruz River from the Congress Street Bridge in November 1907. Note narrow channel."
B-XLII <u>Page</u> 154 - "Figure 57. Similar view as Figure 56 on July 29, 1916 after the 1915 flood widened the Santa Cruz River Channel."
B-XLIII <u>Page</u> 156 - "Figure 58. In March 12, 1910, Ellsworth Huntington, the noted geographer, took this photograph..."
B-XLIV <u>Page</u> 156 - "Figure 59. Same view as Figure 58 taken on November 30, 1983."
B-XLV <u>Page</u> 160 - "Figure 60. Santa Cruz River in flood, November 1926, showing road embankment on the east approach from Congress Street."
B-XLVI <u>Page</u> 160 - "Figure 61. Same view as Figure 60 taken on September 12, 1983."
B-XLVII <u>Page</u> 162 - "Figure 62. View south from summit of Sentinel Peak in 1919, looking upstream along the Santa Cruz River."
B-XLVIII <u>Page</u> 162 - "Figure 63. Same view as Figure 62 on January 6, 1988."
B-XLIX <u>Page</u> 163 - "Figure 64. View from Sentinel Peak on May 30, 1927, looking east across Santa Cruz River."
B-L <u>Page</u> 163 - "Figure 65. Same view as Figure 64 taken on October 6, 1987."
B-LI <u>Page</u> 164 - "Figure 66. View east-northeast from Sentinel Peak on May 30, 1927, with Santa Cruz River in foreground."
B-LII <u>Page</u> 164 - "Figure 67. Same view as Figure 66 on October 6, 1987."
B-LIII <u>Page</u> 165 - "Figure 68. View northeast from Sentinel Peak on May 30, 1927 with Santa Cruz River running from right to left."
B-LIV <u>Page</u> 165 - "Figure 69. Same view as Figure 68 on October 6, 1987."
B-LV <u>Page</u> 168 - "Figure 70. In 1935, the Works Projects Administration (WPA) constructed several flood control features along the Santa Cruz River. In the reach just south of Sentinel Peak (left), the river's flow was deflected into pilot channels by means of revetments, in this case fashioned from old automobile frames."
B-LVI <u>Page</u> 168 - "Figure 71. Same view as Figure 71 on May 11, 1982. The WPA measures were largely effective in eliminating the sharp meanders."
B-LVII <u>Page</u> 172 - "Figure 72. South view from Martinez Hill in June 1942."
B-LVIII <u>Page</u> 172 - "Figure 73. Same view as Figure 72 on May 29, 1981. Note the broad river bottom and badly denuded bottomlands."
B-LIX <u>Page</u> 173 - "Figure 74. Upstream view of the Santa Cruz River bridge at Continental on June 4, 1940."
B-LX <u>Page</u> 174 - "Figure 75. Same view as Figure 74 on November 16, 1978, showing deepening of the channel by ca. 1 m."
B-LXI <u>Page</u> 175 - "Figure 76. East view of the Santa Cruz River Valley and Tucson from Sentinel Peak in 1932."
B-LXII <u>Page</u> 175 - "Figure 77. Same view as Figure 76 on July 8, 1981."

B-LXIII Page 176 - "Figure 78. Southeast view of the Santa Cruz River, looking upstream from a point just south of the Congress Street Bridge."
B-LXIV Page 176 - "Figure 79. Same view as Figure 78 on February 26, 1982."
B-LXV Page 177 - "Figure 80. Downstream view of the Rillito-Santa Cruz confluence, looking north in 1939."
B-LXVI Page 177 - "Figure 81. Same view as figure 80 on November 9, 1983."
B-LXVII Page 178 - "Figure 82. East view of Congress Street and the then active floodplain of the Santa Cruz River, taken from West Congress Terrace in the 1890s."
B-LXVIII Page 178 - "Figure 83. Approximate view as Figure 82 in the 1930s."
B-LXIX Page 179 - "Figure 84. Same view as Figure 83 on February 26, 1982."

Betancourt 1978

B-LXX Page 67 - "Figure 13. Confluence of the West Branch and the Santa Cruz in 1904."
B-LXXI Page 67 - "Figure 14. The new confluence of the West Branch and the Santa Cruz."
B-LXXII Page 69 - "Figure 15. The Convento structure of the San Augustin Mission (Arizona Historical Society)." [no date]
B-LXXIII Page 70 - "Figure 16. Warner's Mill around 1880 (Arizona Historical Society)."
B-LXXIV Page 85 - "Figure 23. Silver Lake, the Silver Lake Hotel, and the residence of a Mr. Kelley to the left. Photograph (taken in 1880) looks west across the lake toward the Tucson Mountains in the background (Arizona Historical Society)."

Hadley and Sheridan 1995

B-LXXV Page 41 - "Figure 3. San Rafael Valley during the drought of 1892-93. From the 1893 U.S. Border Report Survey."
B-LXXVI Page 140 - "Figure 18. San Rafael Valley, looking east from Monument 110. From the 1893 U.S. Boundary Survey Report."
B-LXXVII Page 141 - "Figure 19. San Rafael Valley, 1917. U.S. Forest Service. Exact location unknown, probably north end of study area, near Meadow Valley."

Halpenny 1962

B-LXXVIII Page 21 - "Figure 2. -- Photographs of river channel and of desert vegetation."
B-LXXIX Page 28 - "Figure 3. -- Photographs of bottom lands taken from the air."
B-LXXX Page 38 - "Figure 4. -- Photographs of dead mesquite."
B-LXXXI Page 40 - "Figure 5. -- Photographs of dead mesquite."

Photo Files from Arizona Historical Society, Tucson

Pictures - Places - Tucson - Businesses - Milling Companies
[photos of Warner's Mill]
Pictures - Places - Tucson - Santa Cruz River
[photos of Santa Cruz River, most during floods of unspecified date]
Picture - Places - Tucson - Warner's Lake
[a few photos of Warner's Lake circa 1880s]

Betancourt 1990



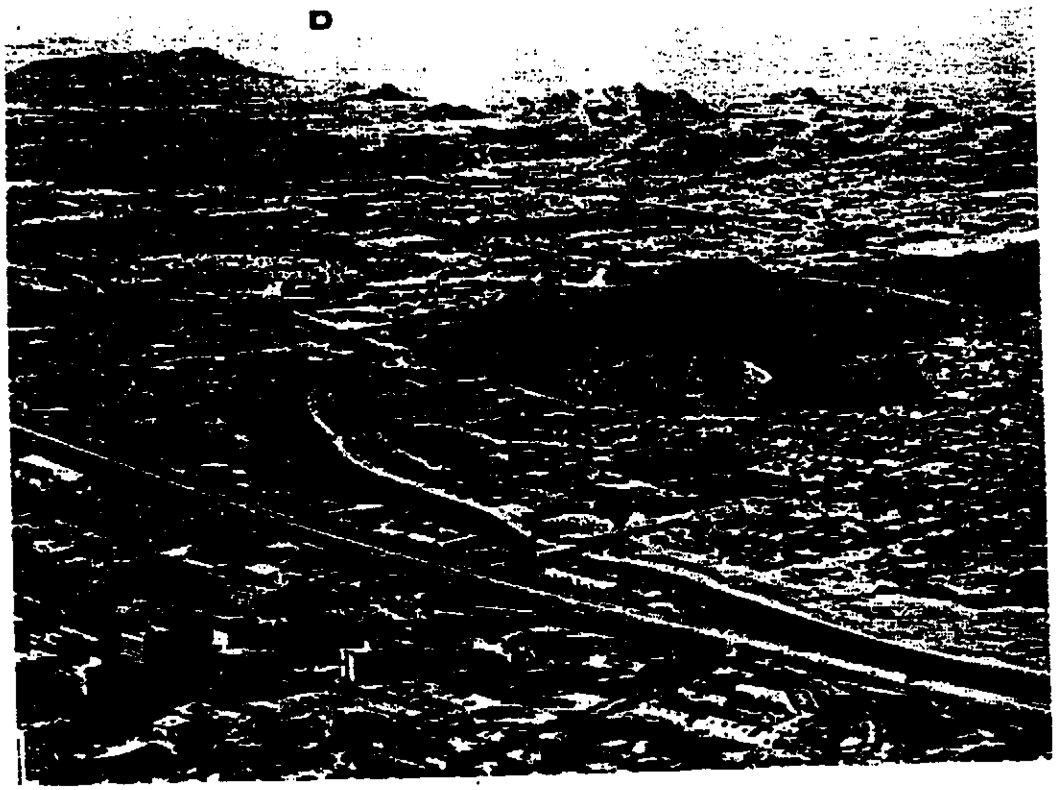



Figure 4. Aerial view of Tucson reach of the Santa Cruz River, looking southeast on October 9, 1983. Downtown Tucson is at lower left. Identified features are: A. Congress Street Bridge, B. Sentinel Peak, C. Tucson Mountains, D. Sierrita Mountains, E. Black Mountain, F. Former site of Silver Lake, G. former site of Warner's Lake, H. West Branch of the Santa Cruz River (Photograph by Peter Kresan).

Figure 7. Upstream view in 1912 of Acequia de Punta de Agua, a streambed spring along the Santa Cruz River south of the San Xavier Mission (from Olberg and Schanck, 1913).

B-III

Figure 8. Looking west across Silver Lake in the 1880s. Structure on the right was a hotel (Arizona Historical Society, Tucson, Negative No. 18335; U.S.G.S. Stake 1060).

B-IV

Figure 9. Same view as Figure 8, taken on December 16, 1981 (Photograph by R.M. Turner, U.S.G.S. Stake 1060).

Figure 14. Solomon Warner's house and mill in 1880, looking southeast from lower slope of Sentinel Peak, with the Santa Cruz Valley in the background (Photograph by Carleton Watkins, Arizona Historical Society, Tucson, Negative No. 14846).

Figure 15. The Santa Cruz Valley from the base of Sentinel Peak looking east ca. 1880. Warner's Mill is the structure at left margin of photograph. White structure at center right is Leopoldo Carrillo's ice house, which was cooled by water from the mill's tail race (Arizona Historical Society, Tucson, Negative No. 6608; U.S.G.S. Stake 1052).

B-VII

Figure 16. Same view as Figure 15 on December 1, 1981 (Photograph by R.M. Turner, U.S.G.S. Stake 1052).

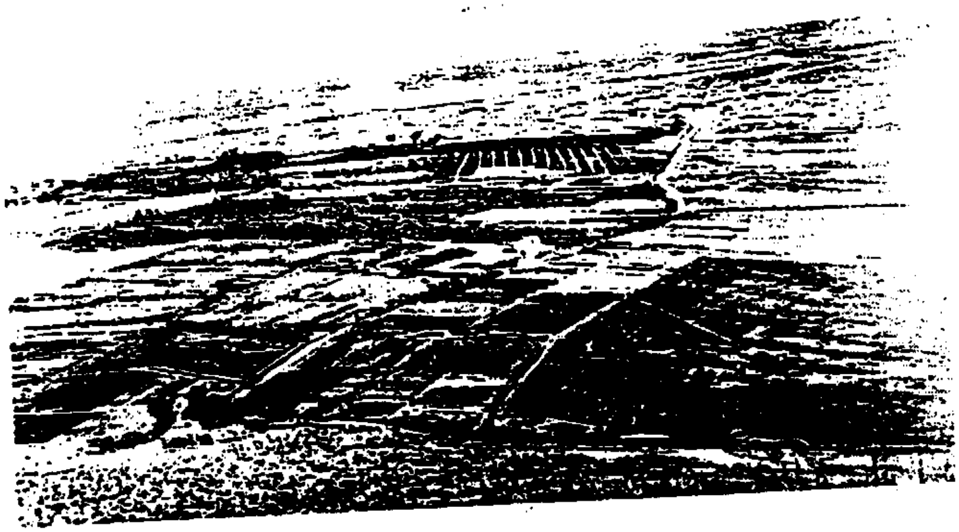


Figure 17. East view of Santa Cruz River Valley and Tucson from Sentinel Peak in 1882, showing the San Agustin Mission (center) and Warner's Mill Complex at lower left. The Acequia Madre, which was fed by Silver lake, runs from right to left across center of photograph. The Acequia may have followed the mainstem of the Santa Cruz River, which at that time had no discernible channel (Arizona Historical Society, Negative No. 18233; U.S.G.S. Stake 1053).

B-IX

Figure 18. Same view as Figure 17 on December 1, 1981. The only recognizable feature in both photographs is Solomon Warner's house in lower left corner. Most of the modern floodplain has been elevated a few meters by landfills (Photograph by R.M. Turner, U.S.G.S. Stake 1053).

Figure 19. Southeast view of Warner's Lake in 1883. The shallow channel of the Santa Cruz River is visible downstream of the dam at extreme left of the photograph (Arizona Historical Society, Tucson, Negative No. 12565; U.S.G.S. Stake 1055).

B-XI

Figure 20. Approximately the same view as Figure 19 on December 31, 1988. The course of the Santa Cruz is obscured by saltcedars at lower left. Elevated road is 22nd Street (Photograph by R.M. Turner, U.S.G.S. Stake 1055).


Figure 22. Upstream view of the heading of Sam Hughes' intercept ditch at the St. Mary's Road crossing in October 1889. The heading here behaved as a headcut actively eroding even with minor flooding. Note that in 1889, this reach was unentrenched and even moderate flows would inundate the valley (Photograph by H. Buehman, Special Collections, University of Arizona Library, Tucson).

B-XIII


Figure 23. Taken on the same day, a slightly different view of the headcut in Figure 22, with Sentinel Peak at upper right (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative No. 2922).

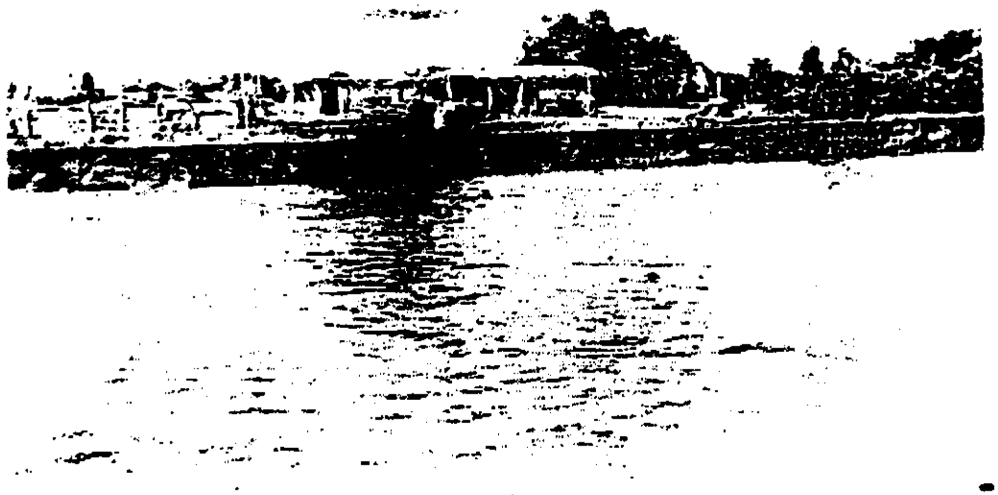


Figure 25. View looking directly west across the St. Mary's Road crossing in August 1890, with newly formed arroyo threatening homestead on opposite bank (Photograph by G. Roskruge, Arizona Historical Society, Negative No. 45854; U.S.G.S. Stake 1065A).

B-XV

Figure 26. Same view as Figure 25 on February 4, 1982. St. Mary's Road Bridge appears on extreme far right. Landfill occupies the upper 1-2 m of the floodplain (Photograph by R.M. Turner, U.S.G.S. Stake 1065A).

Figure 27. Downstream view of the Santa Cruz river during the flood of August 1890, taken from east bank at the St. Mary's Road crossing. Note erosional remnants in the middle of the newly-formed arroyo (Photograph by G. Roskruge, Arizona Historical Society, Tucson, Negative No. 45851).

B-XVII

Figure 28. Upstream view of the Santa Cruz River on the same day and from same location as Figures 26 and 27. On August 8 or 9, the headcut forked into two channels, their confluence shown in this photograph. Note cottonwood with distinctive, asymmetrical crown on right bank. The same tree appears in Figure 31. Also, compare with Figure 22, which was taken only 10 months before (Photograph by G. Roskruge, Arizona Historical Society, Tucson, Negative No. 45852).

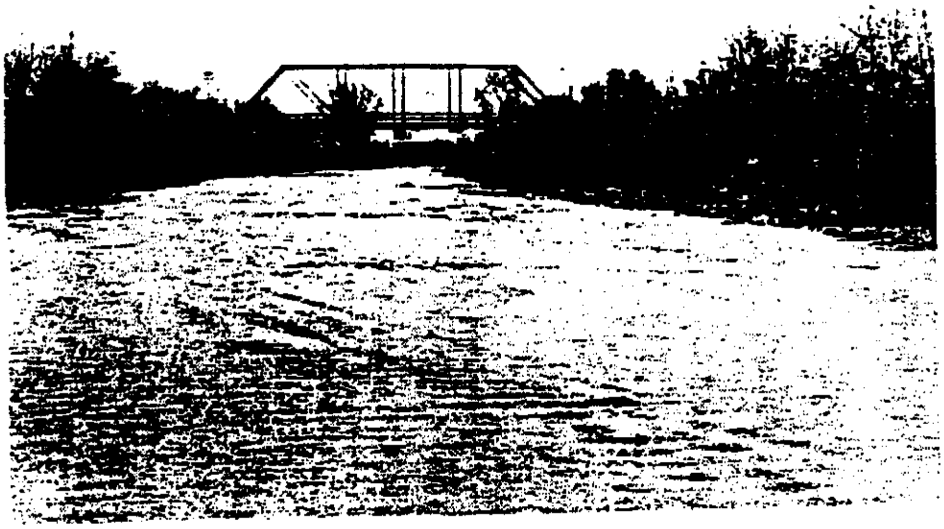


Figure 29. View looking upstream at Congress Street in 1902. The deep arroyo that eroded in 1890 and 1891 made river crossings more difficult. By 1902, a Pratt Truss steel bridge had been erected to span the river at Congress Street. This photograph shows a young stand of willows and cottonwoods that were probably established after the 1890 flood (Arizona Historical Society, Tucson, Negative No. 26698).

B-XIX

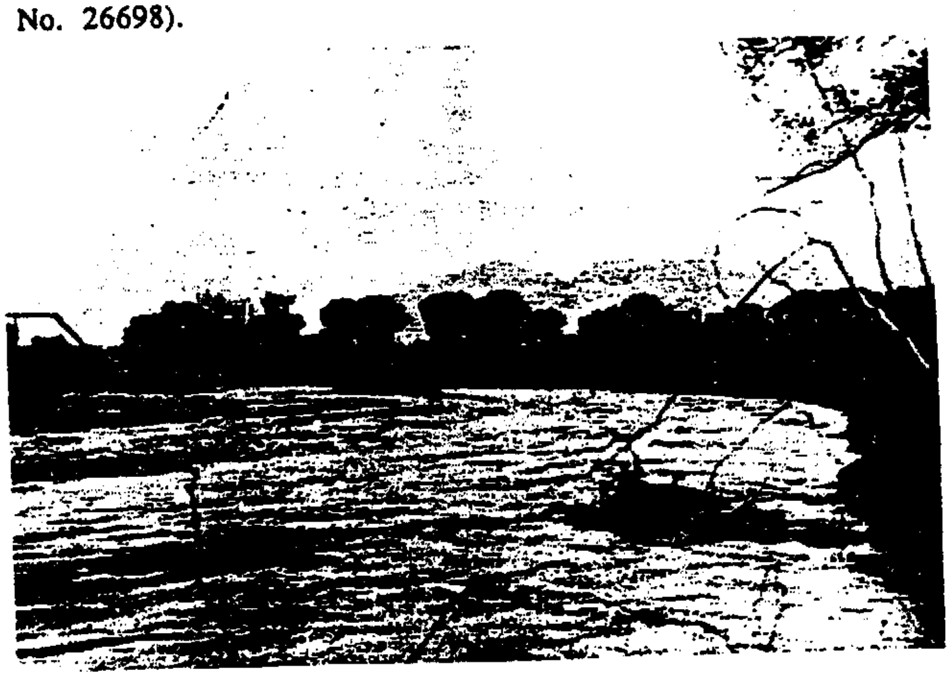


Figure 30. Downstream view of the Santa Cruz river in 1902. This photograph shows active erosion where the meandering thalweg strikes the right bank. Congress Street is on far left and is seemingly in a precarious position should the meander continue eroding downstream. The Santa Catalina Mountains are in the background (Arizona Historical Society, Tucson, Negative No. 26699).

Figure 32. The San Agustin Mission or Convento Ruins as sketched by John Spring in 1871, looking west across the Acequia Madre. In 1890-1891, the arroyo from Hughes' ditch extended headward along the Acequia Madre. Compare with Figures 33 and 34.

B-XXI

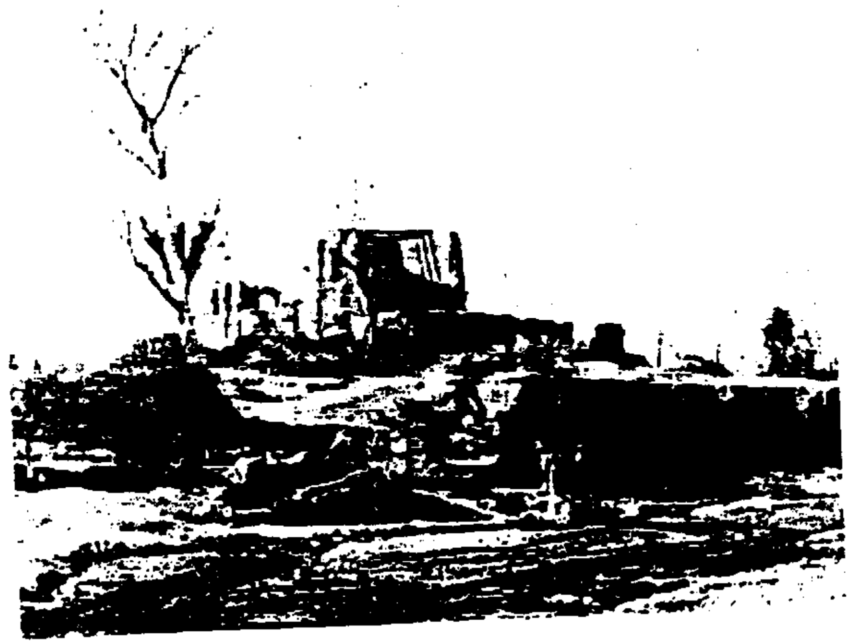


Figure 33. The San Agustin Mission in 1903, looking across to the west bank of the Santa Cruz River. The ditch at left center was the tail race or waste channel from Warner's Mill into the Acequia Madre. The tail race postdates John Spring's 1871 sketch (Figure 32) (Photograph by B.R. Bovee, Arizona Historical Society, Tucson, Negative No. 52644).

Figure 34. The San Agustin Mission, most likely in the the 1910s, from roughly the same vantage point as Figures 32 and 33 (Arizona Historical Society, Tucson, Negative No. 24802).

Figure 35. Downstream view of the confluence of the West Branch and the Santa Cruz River, looking northeast from the lower slope of Sentinel Peak in 1904. The lower half of the photograph incorporates the former area of Warner's Lake (see Fig. 19). A remnant of Warner's Dam is visible at left center, just upstream of the confluence. By 1904, the headcut from Sam Hughes' Ditch had extended along the Santa Cruz mainstem and the West Branch (Photograph by Walter Hadsell, Arizona Historical Society, Tucson, Negative No. 24868; U.S.G.S. Stake 1026).

**B-XXIV**

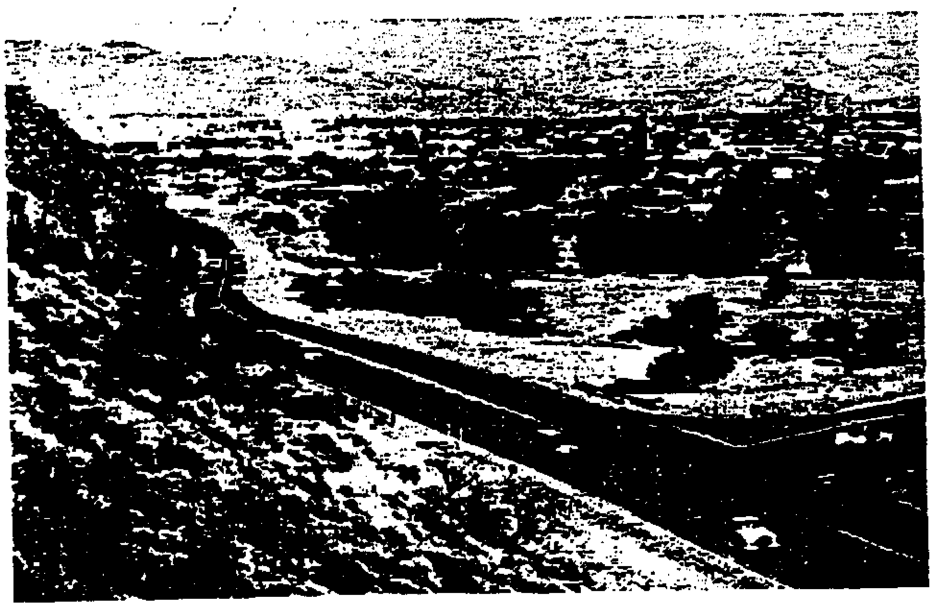


Figure 36. Same view as Figure 35 on December 17, 1981. The West Branch was filled in artificially in the 1960s and is now marked only by a shallow depression lined with a few mesquites. The Santa Cruz proper is bordered by taller saltcedars. The intersection of Mission Road and 22nd Street is in lower right (Photograph by R.M. Turner, U.S.G.S. Stake 1026).

Figure 37. Head of the Manning Ditch in 1907, with the Santa Cruz River and Sentinel Peak in background. The men in the photograph are dumping copper sulfate in the ditch, presumably to retard accumulation of moss. Even though the stream had become entrenched throgh this reach in the 1890s, it remained perennial. In fact, the flow may have increased with deeper intercept of the water table (Special Collections, University of Arizona Library, Tucson, Negative No. 2709; U.S.G.S. Stake 1073).

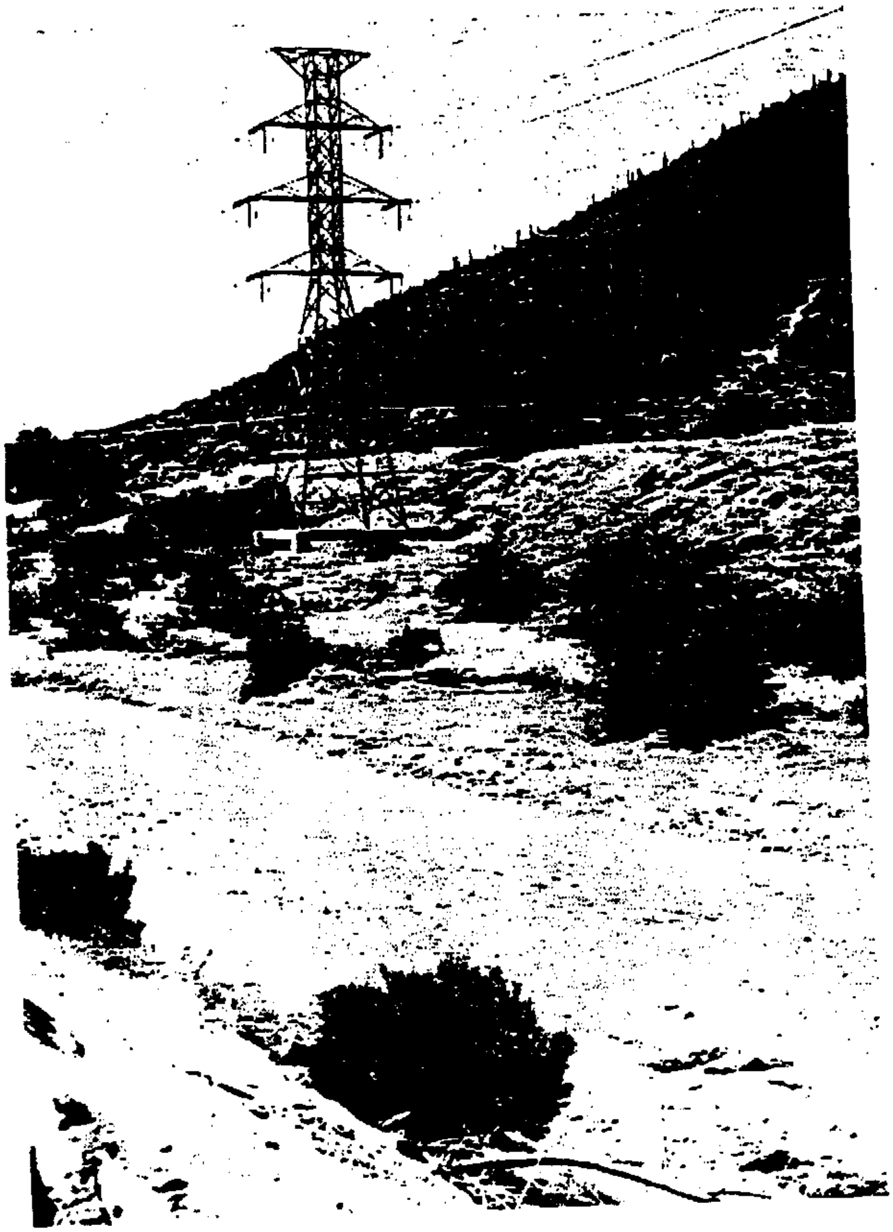


Figure 38. Same view as Figure 37 on February 4, 1982 (Photograph by R.M. Turner, U.S.G.S. Stake 1073).

Tucson Farms Crosscut - 19 wells across Santa Cruz
1913

Figure 41. East view of the Crosscut in 1913, with trenching for concrete conduit in progress and well casing in foreground. The channel of the Santa Cruz River runs from right to left across center of photograph (Photograph by Percy Jones, Special Collections, University of Arizona Library, Tucson, Negative No. 2803).

B-XXVIII

Tucson Farms Co
Crosscut 1912

Figure 42. West view of the Crosscut under construction in 1912 (Photograph by Percy Jones, Special Collections, University of Arizona Library, Tucson, Negative No. 2758).

Figure 43. Outlet from the Crosscut in the streambed of the West Branch in 1913 (Photograph by Percy Jones, Special Collections, University of Arizona Library, Tucson, Negative No. 2709; U.S.G.S. Stake 1066).

**Figure 44.** Same view as Figure 43 on February 4, 1982. The West Branch was filled in ca. 1965. The shrubbery in the foreground marks the course of the Crosscut (Photograph by R.M. Turner, U.S.G.S. Stake 1066).

Figure 45. Diversion point for water developed by the Crosscut, about 3 km downstream along the bed of the Santa Cruz River, in 1912. (Photograph by Percy Jones, Special Collections, University of Arizona, Tucson).

B-XXXII

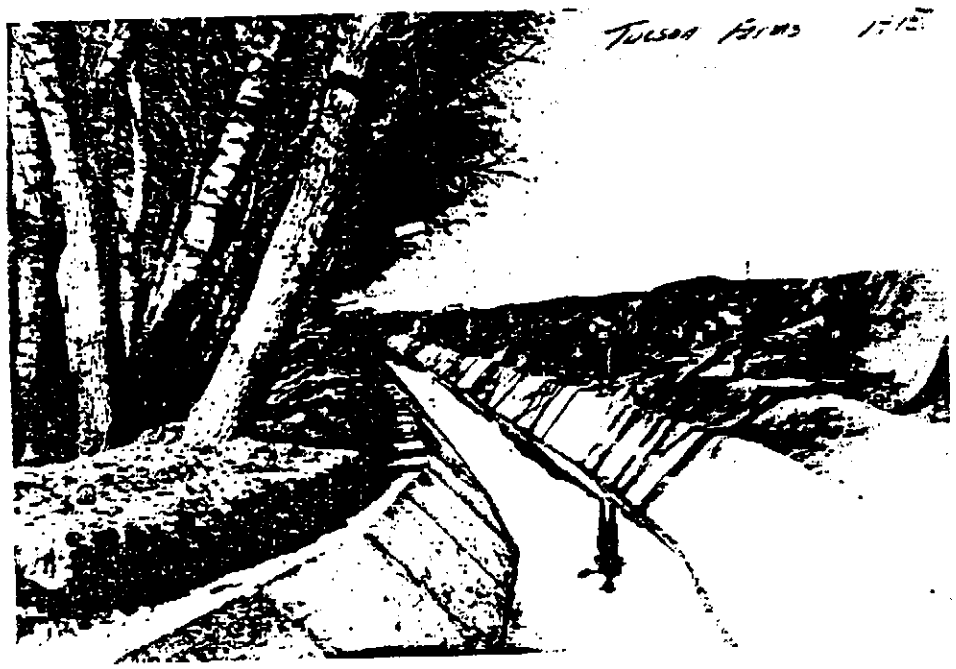



Figure 46. Sector of finished concrete lined canal inside the east bank of the Santa Cruz River in 1913 (Photograph by Percy Jones, Special Collections, University of Arizona Library, Negative No. 2713).

Figure 48. Upstream view from Martinez Hill in 1912, with dense mesquite growth in the valley bottom. By this date, a channel 9 m deep marked the course of the Spring Branch, with a steep headcut terminating just below the dam in the center of the photograph (from Olberg and Schanck 1913, National Archives, U.S.G.S. Stake 1057).

B-XXXIV

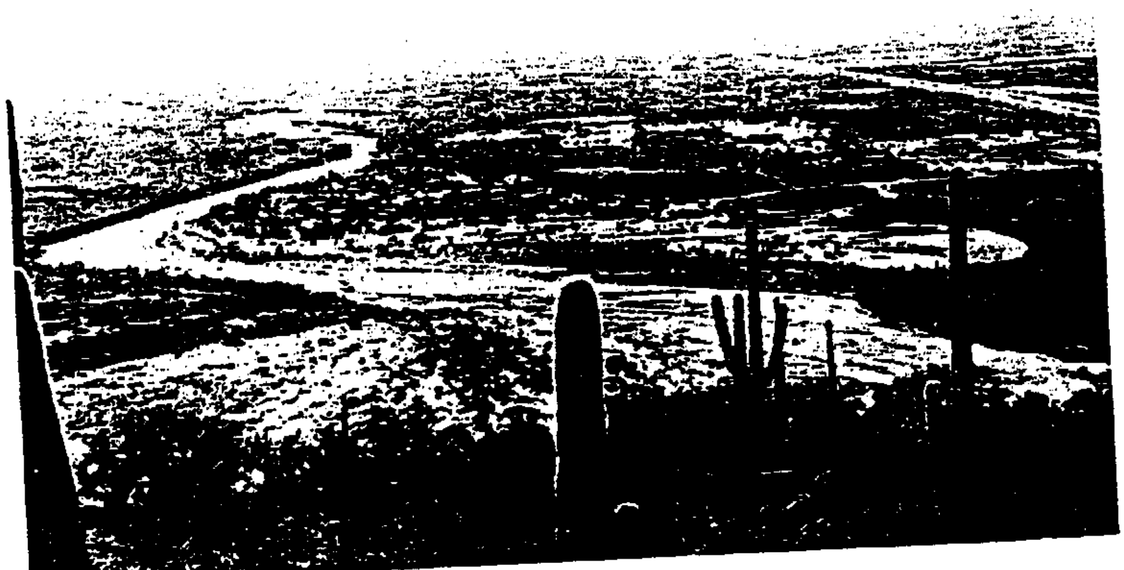


Figure 49. Similar view as Figure 48 on December 15, 1981. The floodplain is now sparsely vegetated due to a substantial drop in the water table, the consequence of heavy pumping since 1940. The Santa Cruz now courses along what was formerly the Spring Branch in a deeply entrenched and broad channel (Photograph by R.M. Turner, U.S.G.S. Stake 1057).

Figure 50. The Santa Cruz River in flood at Congress Street on December 23, 1914. This was the peak flow (420 cms) for the 1915 water year. Heavy flows continued into January, eventually destroying the meander where the people in the foreground are standing (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative No. 93470).

**Figure 51.** Upstream view of the Congress Street Bridge on the morning of January 31, 1915, as the east approach to the bridge began to give way. Note sinking piers of the bridge (Arizona Historical Society, Tucson, Negative No. 17439).

B-XXXVII

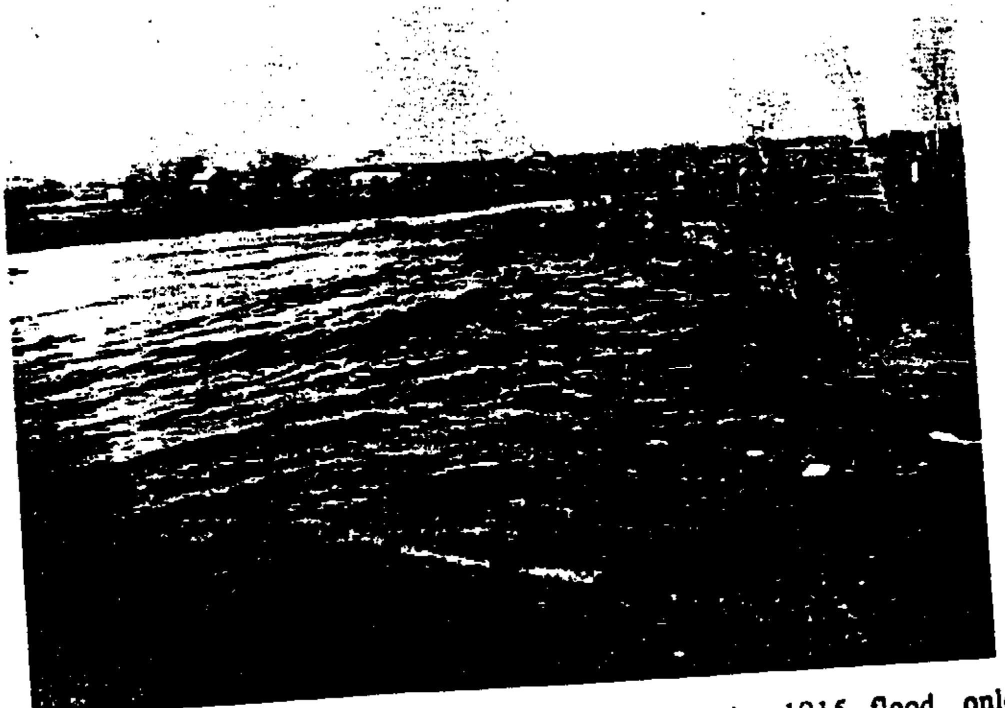


Figure 52. In this northwest (downstream) view of the 1915 flood, onlookers stand perilously close to the eroding east bank of the Santa Cruz River, just downstream of the Congress Street Bridge. Note undercutting of the east bank at right center of photograph (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative no. 38373).

stock on 'em they're destroyin' the range" (Parker ms:187). Parker was expressing his resentment over the study area's first closing of the open range, which in reality may have resulted in preservation of rangeland rather than the perceived destruction. As can be seen from the Water Resources Appendix 7.2, a substantial number of wells and stock tanks were installed at a surprisingly early period. Although the San Rafael Valley suffered from the "tragedy of the commons," overstocking within the study area was probably less severe than in other parts of southern Arizona.

Despite the early penetration of highly capitalized ranching, however, the study area did undergo periods of severe stress. The most important factor in alteration of the grassland ecology has been drought. Three major droughts—the first in the 1880s and 1890s, the second following World War I between 1918 and 1921, and the third at the onset of the Great Depression in 1933–34—did considerable damage to San Rafael rangelands. The first drought was more severe, lasted longer, and came at a time when ranchers in southern Arizona had little understanding of arid lands cattle ranching and no plans or ability to enact an emergency offtake strategy. (See Fig. 18 of the San Rafael Valley during the drought of 1893.) In 1885–86, 1892, and again in 1902, large numbers of cattle starved to death on the range. During this drought, many ranchers in the study area lost the majority of their cattle. Mrs. de la Ossa lost all but one head (Ashburn 1994). James Parker lost such a high percentage of his herd that he had to "start over again." Parker family memoirs recall that by June 1885, many cattle in the valley were dying. When rain finally came, watercourses flooded and the floodwaters carried away many of the weakened, starving cattle.

After two "good years" in 1888 and 1889, the drought returned. This time, some of the area ranchers were better prepared. Parker's granddaughter, Mary Fenter, was married to Tom Turner, foreman of the Vail and Gates cattle company. Before the drought

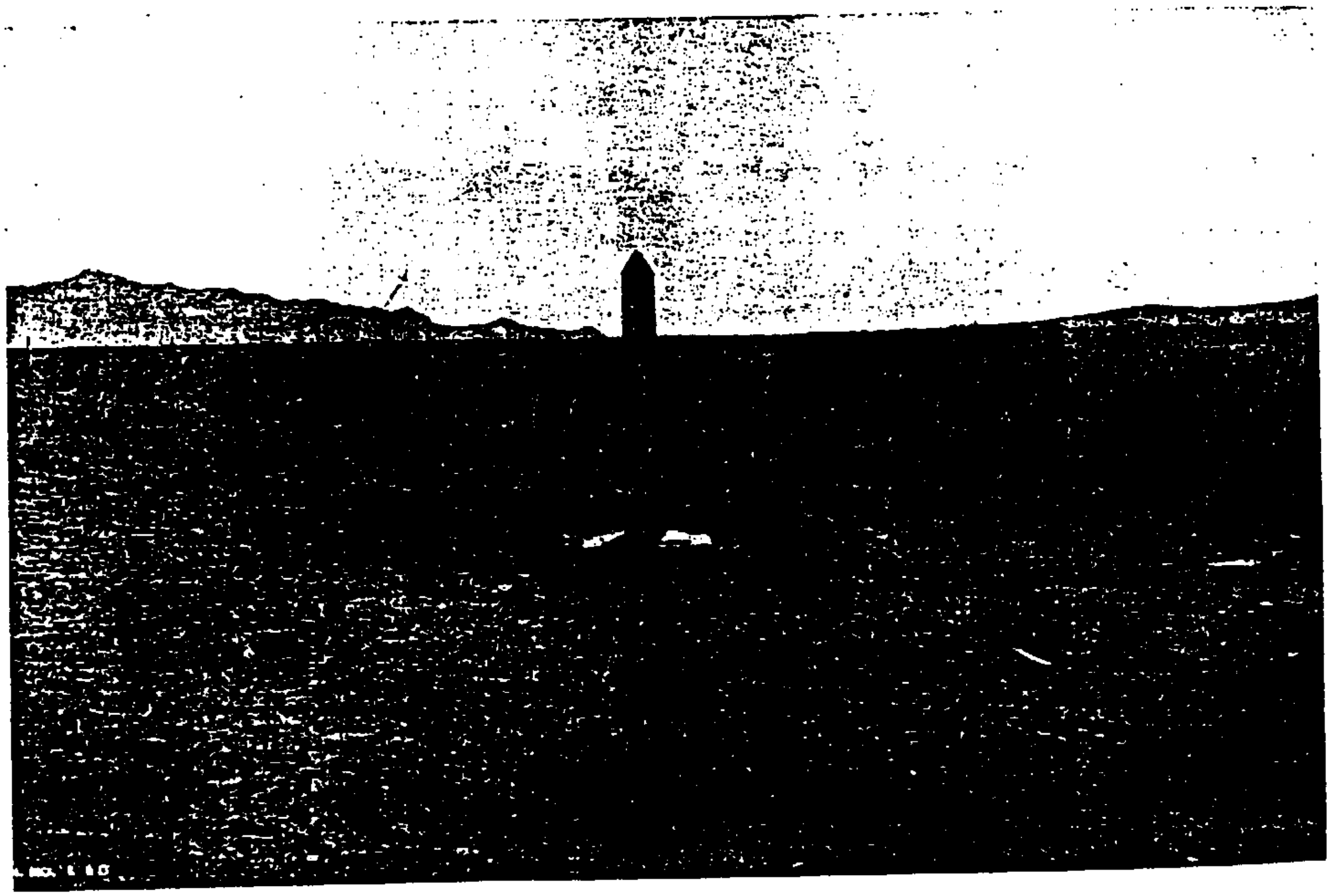


Figure 18—San Rafael Valley, looking east from Monument 110. From the 1893 U.S. Boundary Survey Report. (Note: small portion of fence at left of photo, possibly along the international boundary, and evidence of overgrazing during the drought.)

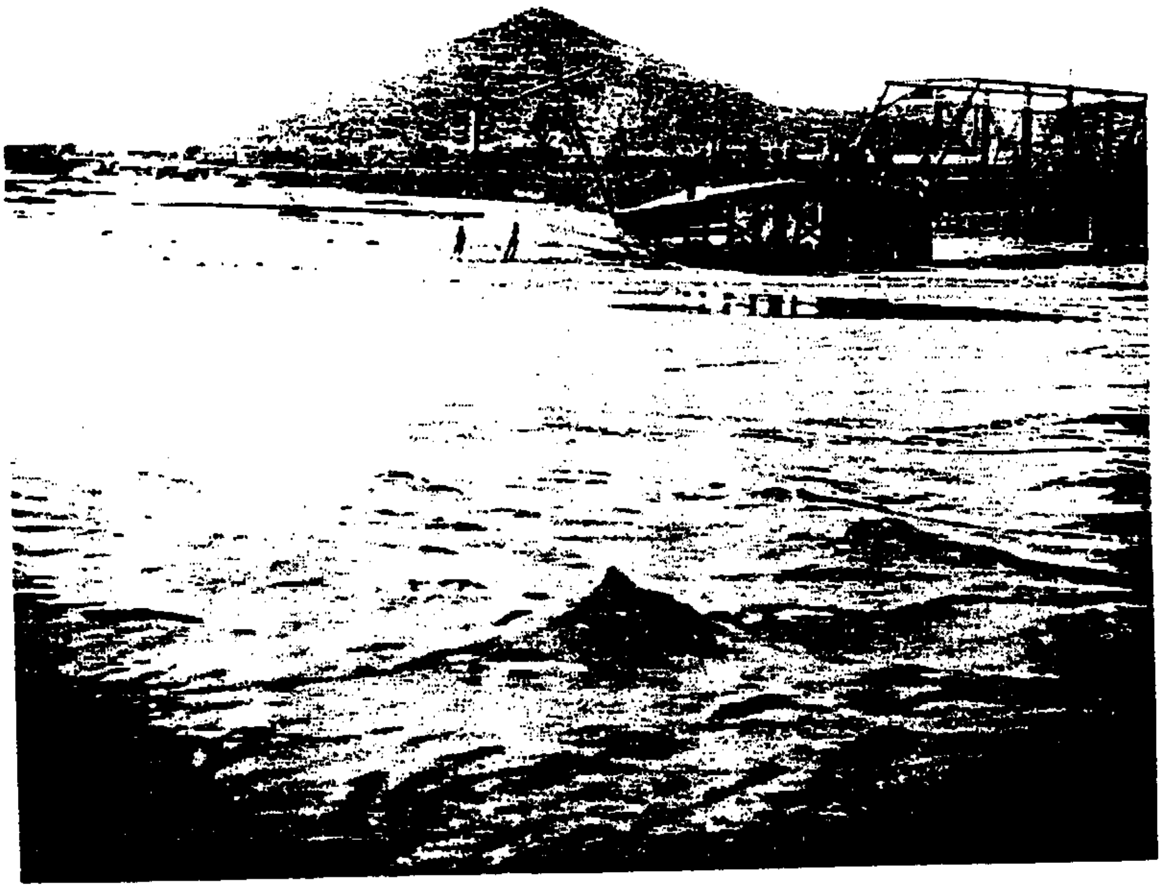


Figure 53. Southwest (upstream) view of Santa Cruz River in flood in February 1915. The thalweg shifted several tens of meters to the west bank, abandoning its former course under the Congress Street Bridge (Photograph by H. Buehman, Arizona Historical Society, Tucson, Negative No. 93468).

Figure 54. The Congress Street Bridge after erosion of east bank in January 1915, looking northwest. The cottonwood stand evident in 1902 (Fig. 29) was completely removed during the 1915 flood (Special Collections, University of Arizona Library, Tucson).

B-XL

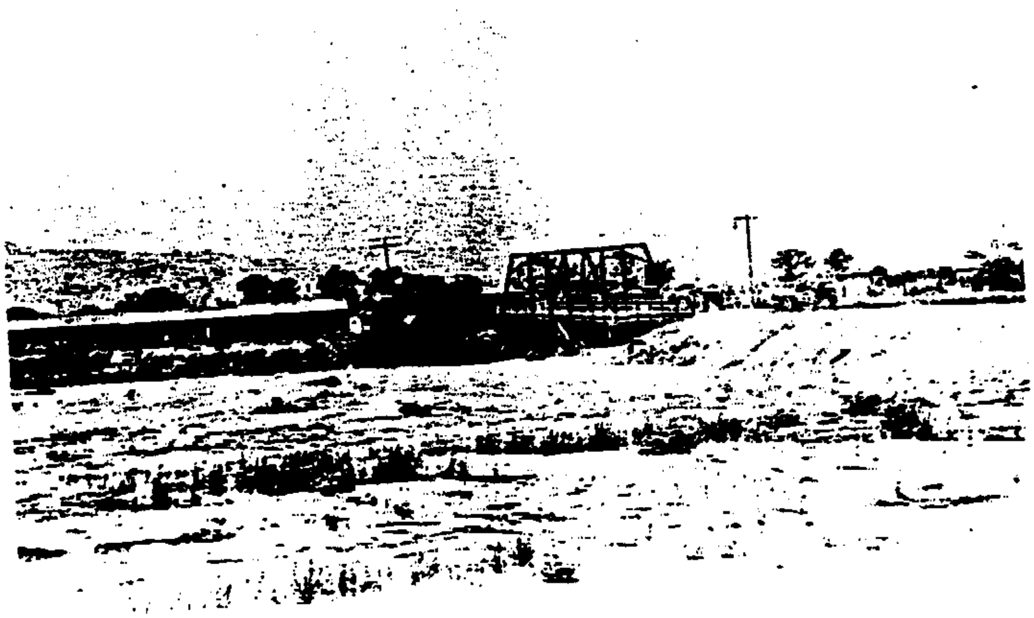


Figure 55. A similar view as Figure 54 in July 1915. A berm was built to join the east approach to the bridge (Special Collections, University of Arizona Library, Tucson).

Figure 56. North (downstream) view of the Santa Cruz River from the Congress Street Bridge in November 1907. Note narrow channel (Photograph by W.T. Hornaday, Arizona Historical Society, Tucson, Negative No. 11669).

B-XLII

Figure 57. Similar view as Figure 56 on July 29, 1916 after the 1915 flood widened the Santa Cruz River channel (Special Collections, University of Arizona Library, Tucson).

Figure 58. In March 12, 1910, Ellsworth Huntington, the noted geographer, took this photograph and described it as follows in his unpublished journal, "looking northwest from end of Tucson Mountains [Rillito Peak] at Santa Cruz Valley, now dry, near where this river finally merges into a large playa....The dry channel of the river...here possibly 5 feet [1.5 m] below the terrace (Yale Universi*y Library, New Haven; U.S.G.S. Stake 1105).

**B-XLIV**

Figure 59. Same view as Figure 58 taken on November 30, 1983. Note the relatively narrow channel at extreme right and the widening that occured to the left of it during the flood of October 1983 (Photograph by R.M. Turner, U.S.G.S. Stake 1105).

Figure 60. Santa Cruz River in flood, November 1926, showing road embankment on the east approach from Congress Street. As is customary for normally-dry rivers such as the Santa Cruz, the flood attracted a crowd of onlookers (Arizona Historical Society, Tucson, Tucson, Negative No. 28765; U.S.G.S. Stake 1084).

B-XLVI

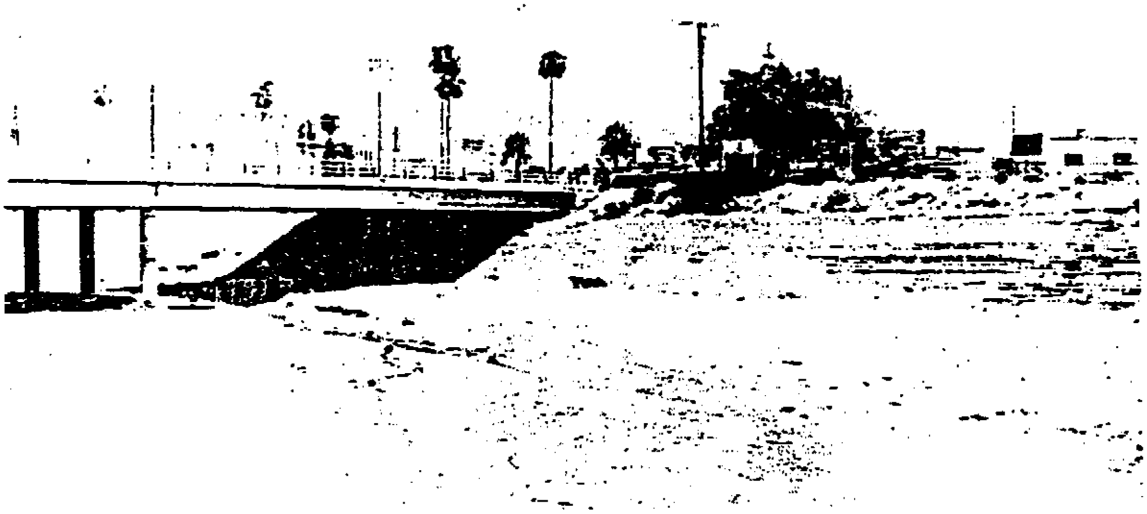


Figure 61. Same view as Figure 60 taken on September 12, 1983. The new bridge was constructed in 1972. The channel has been narrowed artificially, eliminating the embankment on the east approach. This narrowing contributed to renewed downcutting and a considerable lowering of the streambed in the period from 1950 to 1980. Note soil-cemented east bank (Photograph by R.M. Turner, U.S.G.S. Stake 1084).

Figure 62. View south from summit of Sentinel Peak in 1919, looking upstream along the Santa Cruz River. Note the Tucson Farms Company Crosscut running from left to right across center of photograph. The entrenched channel of the West Branch is in lower right (Photograph by Godfrey Sykes, Arizona Historical Society, Tucson; U.S.G.S. Stake 1306).

B-XLVIII

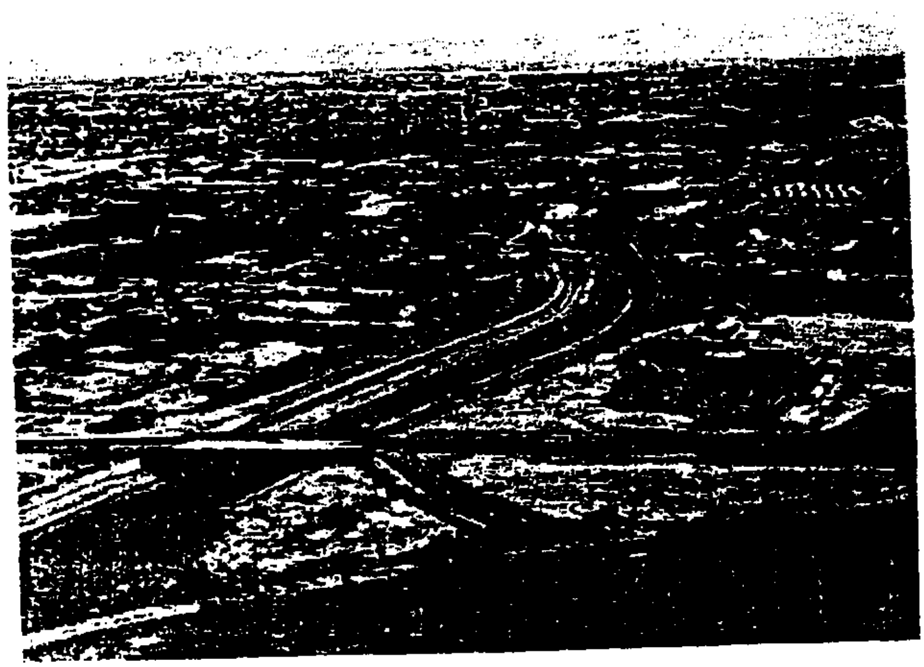


Figure 63. Same view as Figure 62 on January 6, 1988. Note bank stabilization with soil cement and the modified confluence of the West Branch and the Santa Cruz. The bridge in the foreground is 22nd Street, which was routed across the former site of Warner's Lake (Photograph by R.M. Turner, U.S.G.S. Stake 1306).

Figure 64. View from Sentinel Peak on May 30, 1927, looking east across Santa Cruz River. The east bank is visible across bottom of photograph. Note secondary mesquite growth across formerly cultivated fields. Photograph is part of a panorama, which includes Figures 64-69 (Photograph by Norman Wallace, Arizona Historical Society, Tucson, Negative No. 518; U.S.G.S. Stake 1307d).

B-L

Figure 65. Same view as Figure 64 taken on October 6, 1987. Soil-cemented banks of the Santa Cruz River are visible across bottom of photograph and 22nd Street in center (Photograph taken by R.M. Turner, U.S.G.S. Stake 1307d).

Figure 66. View east-northeast from Sentinel Peak on May 30, 1927, with Santa Cruz River in foreground (Photograph by Norman Wallace, Arizona Historical Society, Tucson, Negative No. 522; U.S.G.S. Stake 1307c).

B-LII

Figure 67. Same view as Figure 66 on October 6, 1987 (Photograph by R.M. Turner, U.S.G.S. Stake 1307c).

Figure 68. View northeast from Sentinel Peak on May 30, 1927 with Santa Cruz River running from right to left (Photogrpah by Norman Wallace, Arizona Historical Society, Tucson, Negative 502; U.S.G.S. Stake 1307b).

B-LIV

Figure 69. Same view as Figure 68 on October 6, 1987 (Photograph by R.M. Turner, U.S.G.S. Stake 1307b).

Figure 70. In 1935, the Works Projects Administration (WPA) constructed several flood control features along the Santa Cruz River River. In the reach just south of Sentinel Peak (left), the river's flow was deflected into pilot channels by means of revetments, in this case fashioned from old automobile frames (right). By the following year, summer flows had filled the area behind the revetment with about 1 m of sediment. The intent was to eliminate sharp meanders and to reclaim the areas they incorporated for cultivation (Photograph by R.C. Baker, State of Arizona Archives, Phoenix, U.S.G.S. Stake 1074).

B-LVI

Figure 71. Same view as Figure 71 on May 11, 1982. The WPA measures were largely effective in eliminating the sharp meanders (Photograph by R.M. Turner, U.S.G.S. Stake 1074).

Figure 72. South view from Martinez Hill in June 1942. A gallery of cottonwoods flanks the river channel and dense mesquite occupied the bottomlands, then a haven for nesting and roosting whitewing doves. As late as 1942, one could dig by hand and find water in the streambed (Arizona Game and Fish Commission, Phoenix; U.S.G.S. Stake 937).

**B-LVIII**

Figure 73. Same view as Figure 72 on May 29, 1981. Note the broad river channel and badly denuded bottomlands. The latter resulted from a considerable drop in the water table since 1940 (Photograph by R.M. Turner, U.S.G.S. Stake 937).

Figure 74. Upstream view of the Santa Cruz River bridge at Continental on June 4, 1940 (U.S.G.S. Stake 940).

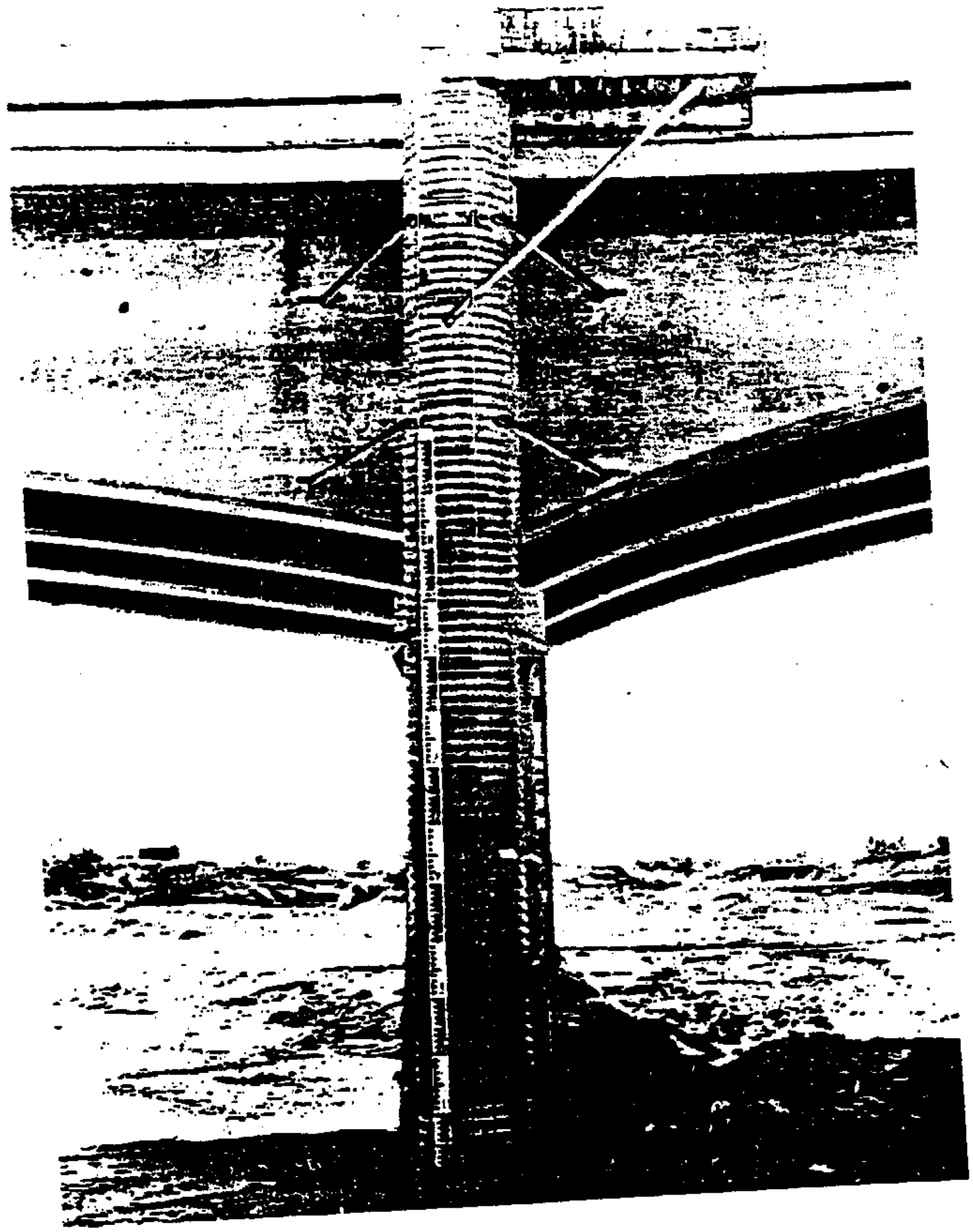


Figure 75. Same view as Figure 74 on November 16, 1978, showing deepening of the channel by ca. 1 m, as indicated by the exposed pier (Photograph by R.M. Turner, U.S.G.S. Stake 940).

Figure 76. East view of the Santa Cruz River Valley and Tucson from Sentinel Peak in 1932. The river runs from right to left across center of photograph, with the Congress Street Bridge at far left. Note the broad entrenched channel lined with cottonwoods. Solomon Warner's house and the ruins of his mill are in lower left corner (Arizona Historical Society, Tucson, Negative No. 26758; U.S.G.S. Stake 1044).

B-LXII

Figure 77. Same view as Figure 76 on July 8, 1981. Since 1950, landfill operations and construction of an interstate highway have constricted the channel. Much of the floodplain surface has been elevated by landfill, in some places by 2-3 m. The only non-elevated part of the floodplain is the former Mission garden in the lower center of both photographs (Photograph by R.M. Turner, U.S.G.S. Stake 1044).

Figure 78. Southeast view of the Santa Cruz River, looking upstream from a point just south of the Congress Street Bridge. This photograph shows the sweeping meander along the east bank, as it eroded on January 31, 1915 (Special Collections, University of Arizona Library, Tucson, Negative No. 6518; U.S.G.S. Stake 1067).

B-LXIV

Figure 79. Same view as Figure 78 on February 26, 1982. Landfill operations, which began in 1950, have narrowed the channel and thus promoted further downcutting (Photograph by R.M. Turner, U.S.G.S. Stake 1067).

Figure 80. Downstream view of the Rillito-Santa Cruz River confluence, looking north in 1939 (Special Collections, University of Arizona Library, U.S.G.S. Stake 1102).

B-LXVI

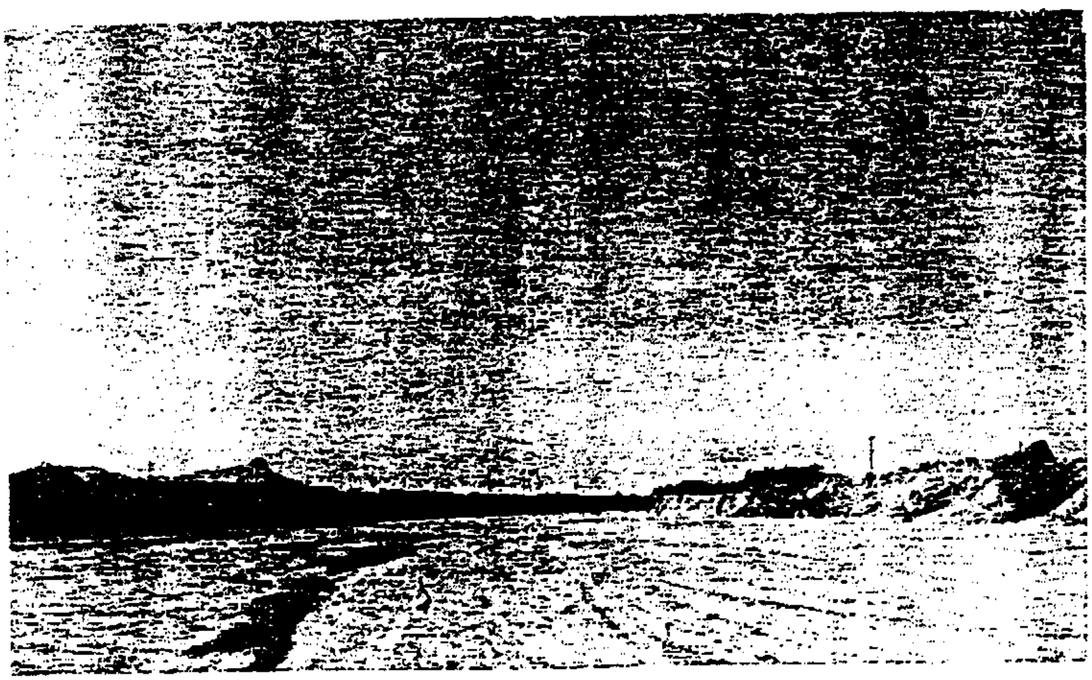


Figure 81. Same view as figure 80 on November 9, 1983. Note entrenched banks and the general lack of vegetation, compared to 1939 (Photograph by R.M. Turner, U.S.G.S. Stake 1102).

Figure 82. East view of Congress Street and the then active floodplain of the Santa Cruz River, taken from West Congress Terrace in the 1890s (Photograph by George Roskruge, Arizona Historical Society, Tucson, Negative No. 46397; U.S.G.S. Stake 1061).

B-LXVIII

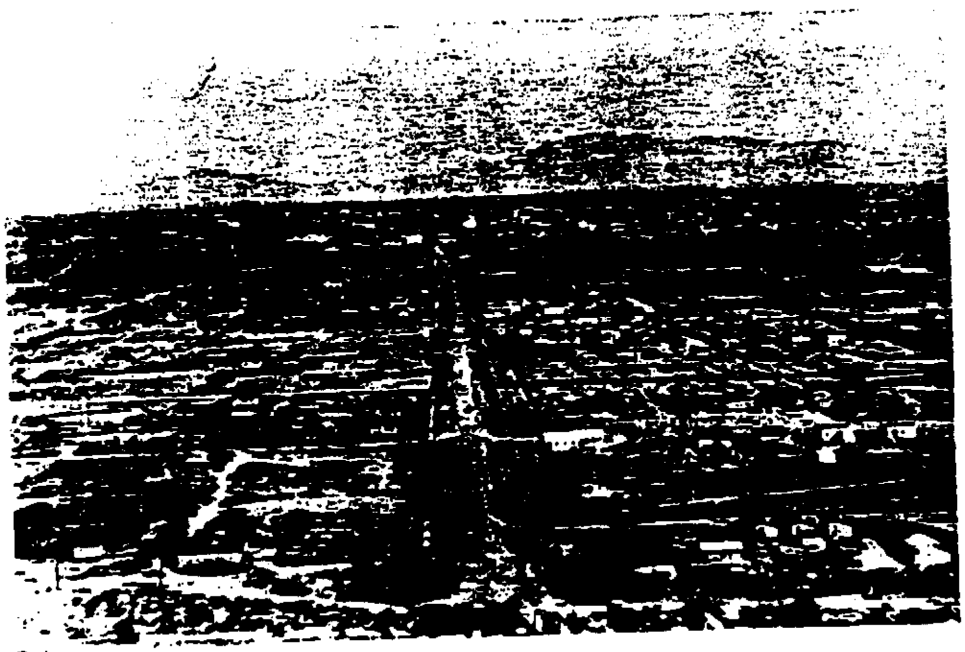


Figure 83. Approximate view as Figure 82 in the 1930s. Entrenchment of the Santa Cruz arroyo enhanced drainage and thus encouraged urbanization of the inactive floodplain (Photograph by Ed Ronstadt, Special Collections, University of Arizona Library, Tucson, U.S.G.S. Stake 1061).

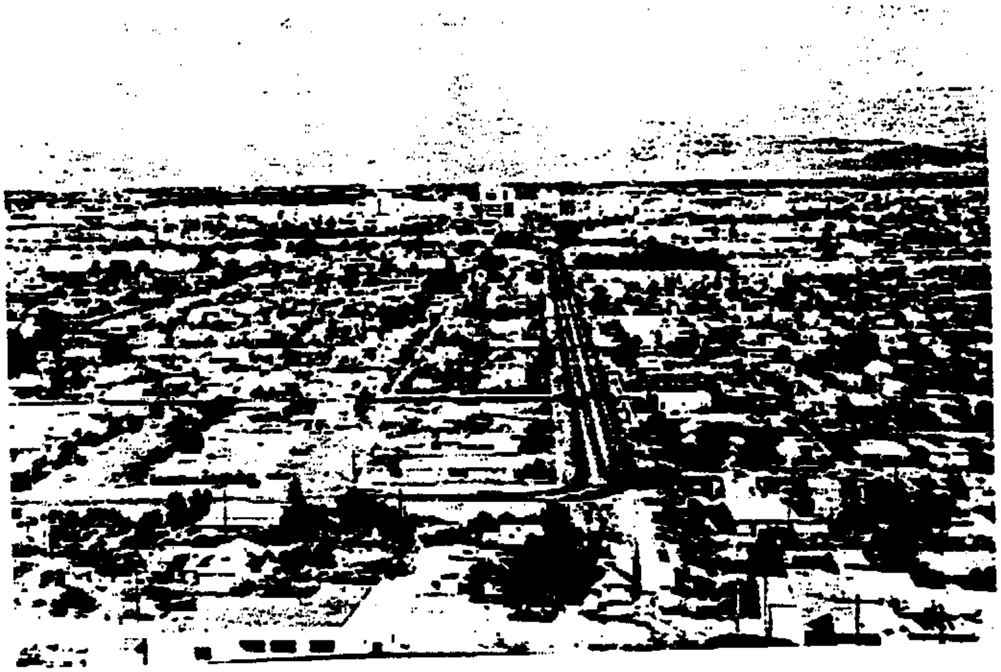


Figure 84. Same view as Figure 83 on February 26, 1982. The once-active floodplain is now completely urbanized within the downtown Tucson reach (Photograph by R.M. Turner, U.S.G.S. Stake 1061).

Figure 13. Confluence of the West Branch and the Santa Cruz in 1904. Photograph was taken looking northeast from the southeastern slope of "A" Mountain (Arizona Historical Society).

B-LXXI

Figure 14.

The new confluence of the West Branch and the Santa Cruz. This recent photograph was taken from the northeastern slope of "A" Mountain looking south. Martinez Hill is shown in the background. Note the denuded condition of the river environs.

managed to ... mission buildings and the compound wall surrounding the mission before the site was destroyed. The foundations were large basalt boulders set in adobe mortar, the basalt probably obtained from the slopes of Tumamoc Hill. Some evidence for the use of lime plaster on the convento walls was found. A few of the plaster fragments had been painted in red and white. The compound wall had been built on a basalt-boulder foundation which measured about 75 cm wide. It was noted that the western portion of the site, containing the granary and some outlying buildings (Wasley 1956), was more-or-less intact.

In 1975, ASM excavated a series of backhoe trenches, to determine if anything remained of the mission complex within the right-of-way of a proposed sewage interceptor route. The fill from these trenches was filled with modern garbage. Archaeological clearance was granted (Doelle and Hard 1978).

of BB:13:6 have been either destroyed or excavated. The portion that does remain includes the foundations to the granary and other outlying buildings of the mission complex. In the 1960s, Sidney Brinckerhoff and Kieran McCarty (1978, personal communication) exposed the walls of the granary to determine what, if anything, remained. The site was visited during the present survey and it was noted that a portion of the granary foundation had indeed been excavated.

An adequate study of previously recovered materials is lacking. The mission's history is also far from complete. There is a need to find primary documents which may yield more accurate information on the mission's early beginnings. The manuscript by Smiley and others (1953) on excavations in 1949-1950 is badly in need of careful review and editing. All of this should be accomplished before any excavation of the western and intact portion of the site is undertaken.

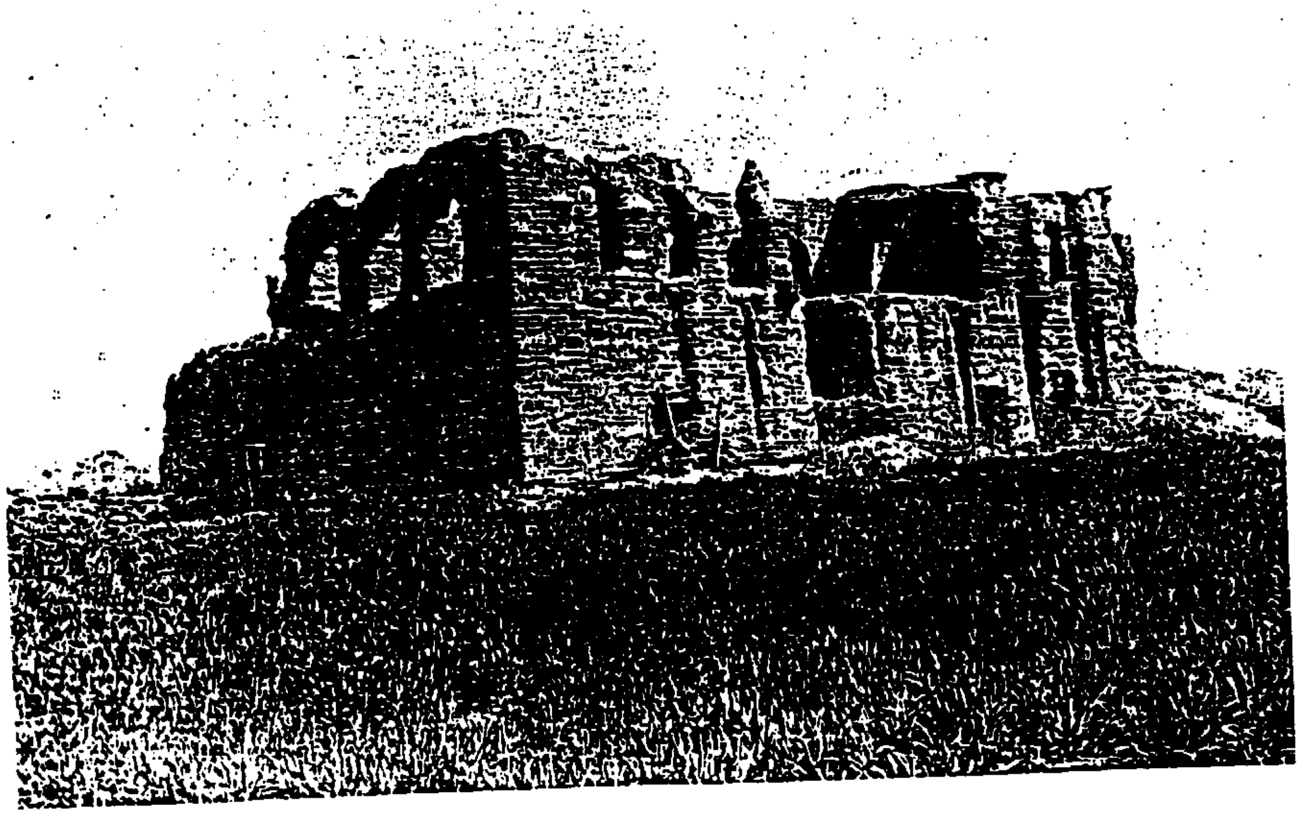


Figure 15.
The Convento structure of the San Augustin Mission (Arizona Historical Society)

Some measure for protection of the western portion of the site (that area immediately adjacent to Brickyard Lane) should be taken. A fence could be constructed around the site. The disadvantage would be that any marker would attract the curious and may result in vandalism. On the other hand, leaving the site in its present condition may lead to inadvertent destruction. For instance, someone needing large boulders for backyard landscaping may inadvertently remove the basalt boulders which delineate the foundations to the granary and the compound wall.

BB:13:22

Description. This site was completely destroyed by landfill operations in 1957-1958. It was initially recorded as a large sherd and lithic scatter. The site was predominately Tanque Verde phase, although there was some mixing with Rillito phase materials. The site is located at the foot of "A" Mountain along the west bank of the river.

Recommendations. The site has been totally destroyed. No further work can be done.

BB:13:57, Warner's Mill Complex

Description. The site of Warner's Mill complex is located at the foot of "A" Mountain just west of the intersection of Mission Lane and Grande Avenue. The house is in excellent condition considering its age. The mill structure is dilapidated and in ruins. Once a large two-storied structure (Figure 16), all that remains today are the basalt masonry walls of the first story. The second story was torn down by a subsequent owner after the building had been abandoned and become a hazard to neighborhood children. Several pot holes have been dug in the rubble fill inside the structure.

An adequate biography of Solomon Warner is provided by Cosulich (1953: 101-13) and Lockwood (1953: 50-56). Here, it is sufficient to say that by

Figure 16. Warner's Mill around 1880 (Arizona Historical Society).

sists of basalt-boulder structural foundations and historic trash. Square nails appear throughout this portion of the site. Also found were Papago Red-on-brown sherds, which are the earliest known Papago pottery within the Tucson area, oyster shell fragments, and purple glass.

A long-time resident in the area, Albert Ormsby (1978, personal communication), claims that the structural foundations and historic trash belong to the old Silver Lake Hotel (Figure 23). Since the hotel was constructed along the western shore of the lake, evidence for the former lake should be visible immediately to the east of the site. This evidence was found in the form of low, wide benches below the present riverbank on opposite sides of the river. Below the western bank, the bench has been covered by fill obscuring its extent. Prior to landfilling, the bench was shaded with large cottonwoods and was a favorite picnic area as late as the early 1960s. The shore of the lake no longer visibl Aerial photographs taken prior to the 1950s should show the extent of this bench and thus show the area formerly occupied by Silver Lake. George J. Roskruge's official map of Pima County (1893) shows Silver Lake to be located in the southern half of Section 23, T14S, R13E, and places the hotel on the western shore of the lake. No other historic maps showing Silver Lake were found.

In 1880, a man by the name of Smith was proprietor of George J. Roskruge's boating, swimming and bathing facilities at Silver Lake (Arizona Daily Star 6/10/1880). Around 1881, James Lee leased 20 acres to J. F. Rickey and J. O. Baily for the purpose of setting up a resort along the shores of Silver Lake. The 1881 City of Tucson Directory describes the resort and lake in the following manner:

> *...lake is caused by a dam of masonry in the Santa Cruz River and extends*

Figure 23.
Silver Lake, the Silver Lake Hotel, and the residence of a Mr. Kelley to the left. Photograph (taken in 1880) looks west across the lake toward the Tucson Mountains in the background (Arizona Historical Society)

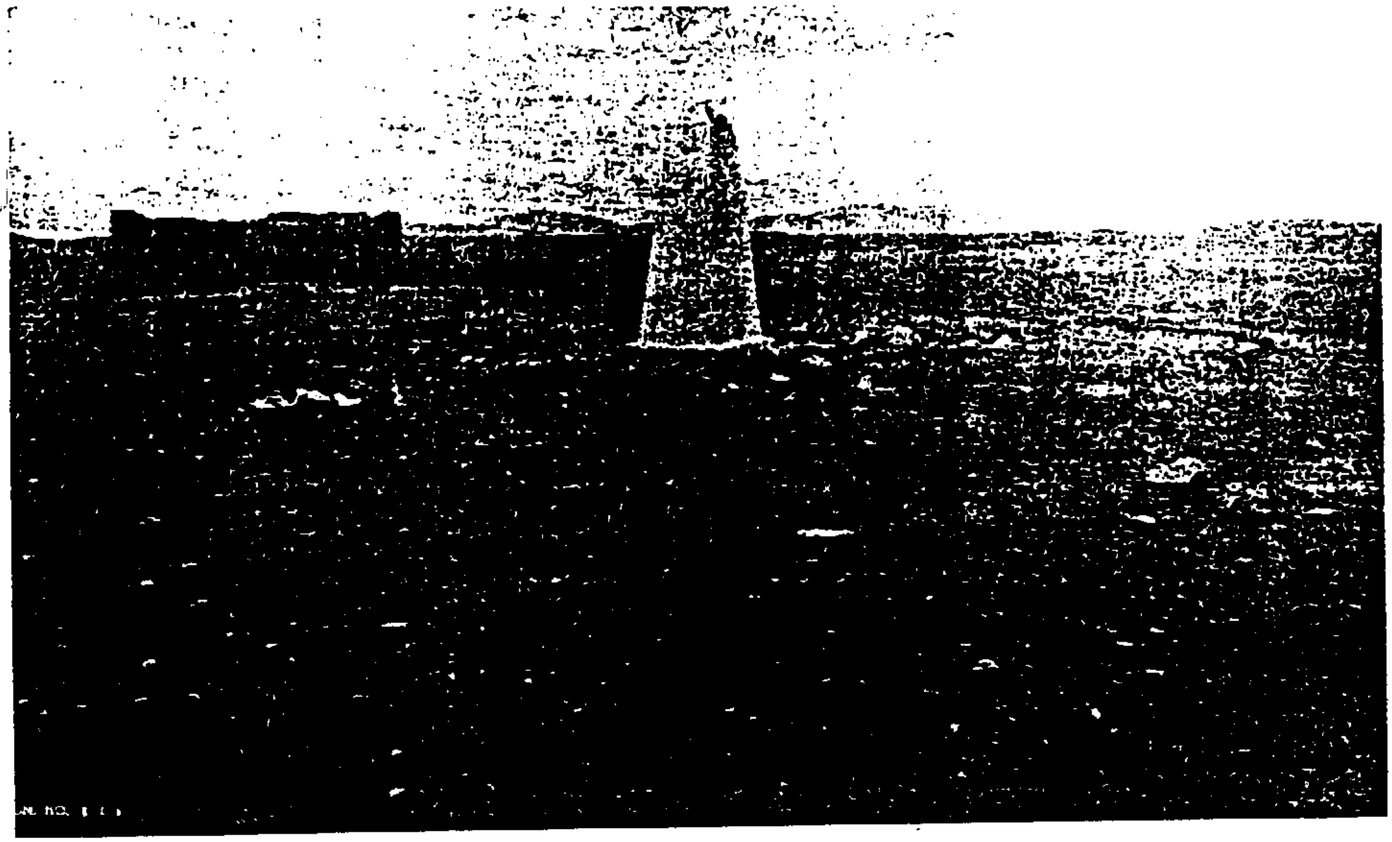


Figure 3. — San Rafael Valley during the drought of 1892–93. From the 1893 U.S. Border Report Survey.

to twelve inches in length, weighing from one to two pounds (Gustafson 1966:113). Fish of the same size are described by other army officers near Camp Wallen, who observed that deer and coyotes abounded on the plain between Wallen and Crittenden. Flocks of geese and ducks could be found at almost any time along the Santa Cruz River, where they particularly gathered in cornfields that were scattered along the river (Gustafson 1966:208).

The reflections of John Spring, written several decades after he was stationed at Camp Wallen, shed considerable light on the depletion of wildlife. His memoirs include several examples of hunting excesses. During the 1860s and 1870s, miners, wood haulers, and army personnel were easily able to supply their camps with wild meat. "The men in the wood camp were really not in any need of fresh meat, as they had killed several wild turkeys that very morning, and had game of some kind at all times" (Gustafson 1966: 113). Spring also gave examples of hunting practices which he thought injurious to population levels. For hunting the "numerous herds of antelope" near the post, Spring described a method the Apache scouts had taught the troopers. It proved so successful that "before long the excitement of hunting them wore off, as it resembled more a deliberate butchery than the sport of the chase. . . ." Using the Apache technique, several army herders would circle around an antelope herd and drive them toward a ravine where the hunters were hiding next to a long pole driven into the ground with a handkerchief fastened to it. The antelope were attracted by the fluttering cloth and would move into shooting range and were quickly shot. This procedure could be repeated several times a day, without creating apprehension among the antelope. According to Spring, overhunting in combination with "the numerous cattle herded all over Arizona since the forced pacification of the Apaches" had made both deer and antelope scarce and those that remained had become very shy (Gustafson 1966:111–13).

During the two decades following Spring's description of the San Rafael Valley, the United States Army increased its presence in southern Arizona and

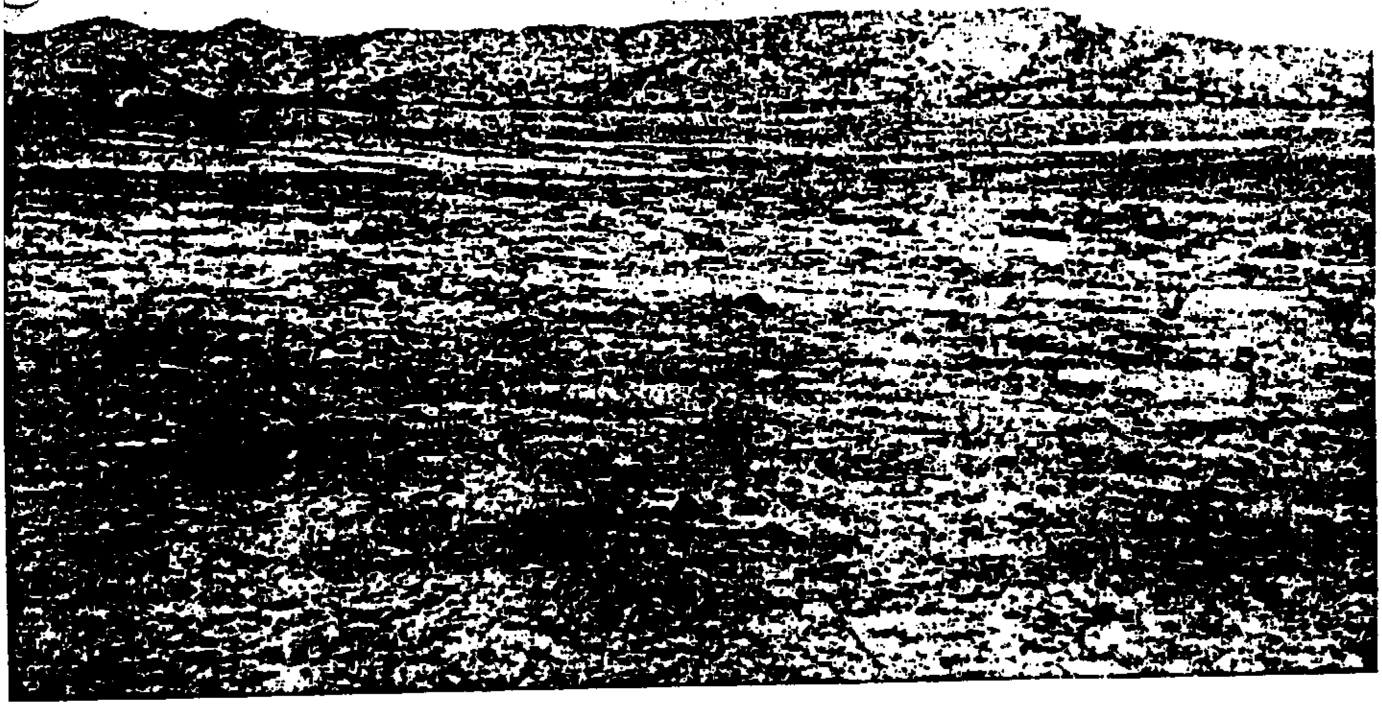


**Figure 19—San Rafael Valley. 1917. U.S. Forest Service. Exact location unknown, probably north end of study area, near Meadow Valley.**

ached its peak in 1892, Turner left for California, trail rding approximately 1,700 steers. He encouraged ner cattlemen to do the same, thereby avoiding exor- ant railroad shipping charges (Parker ms: 183–87).

Despite some limited off-take, however, damage the valley in 1892 was severe. With no fences, cattle owded around the few remaining sources of wa- r, particularly the Santa Cruz River, where many them died. Two of James Parker's granddaugh- rs recalled that the "heavy clumps of sacaton and iles, which had regrown since the first drought, ere eaten into the ground." Water holes had become ogs, which trapped the weakened cattle. "Bleached ones of horses and cattle were strewn over the val- ys and hills and along the road sides, a grim re- inder for years of that great tragedy." When the ains finally returned, flooding performed the much eeded service of washing cattle corpses and bones ut of watercourses (Parker ms: 181–188).

During the drought, ranchers employed many tac- save their cattle. James Parker drove all the cattle that could walk into the foothills of the Huachucas and then sent his sons George and Duke to set up a camp in the hills so that they could cut any tender growth from the oak and ash trees to feed the cattle on a daily basis. The Parkers recalled that the cattle "followed them like dogs from tree to tree." They also recalled "tailing up" the cattle that were too weak to walk. James Parker even made a swing to support them on their feet (Parker ms: 181–88). After the drought of the 1880s–1890s, many former springs and cienegas disappeared. Although ranchers had done considerable work to drain some of the cienegas, the drought contributed to the drying process.

The second and third droughts caused more range deterioration. The post World War I drought coin- cided with a depression. Many ranchers did not have the financial resources to buy feed for their cattle, leaving the animals entirely dependent on range for- age. After this drought, George and Duke Parker lost their ranch. Ranchers believed that the misinformed generation of homesteaders, who arrived in 1915 and

a. Channel of Santa Cruz River incised about 25 feet into flood plain, at location (D-16-13) 12 ccd.

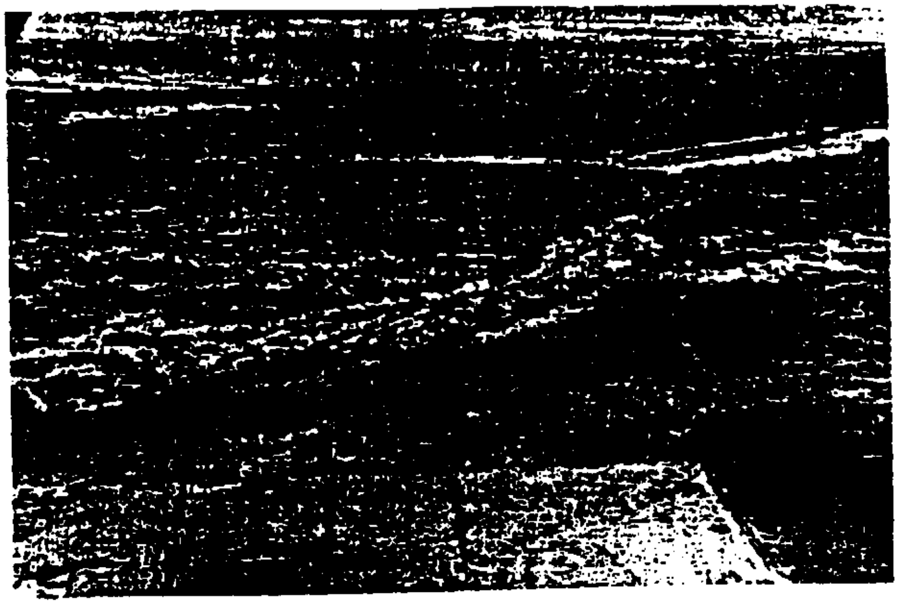
b. Mesquite about 12 feet high growing along wash in area where depth to water is about 75 feet, at location (D-15-13) 23 adb.

Figure 2. -- Photographs of river channel and of desert vegetation.

a. Aerial view of bottom lands. Most of the mesquite trees are dead owing to decline of the water table. The live growth in the middle foreground follows the course of a channel which collects runoff from desert washes on the east side of the river. The live growth surrounding the fields in the background is supported by waste irrigation water and by runoff from washes entering the river bottom from the west.

b. Close-up of general view shown above. The cottonwoods at the right side are presently dying because of declining ground-water levels.

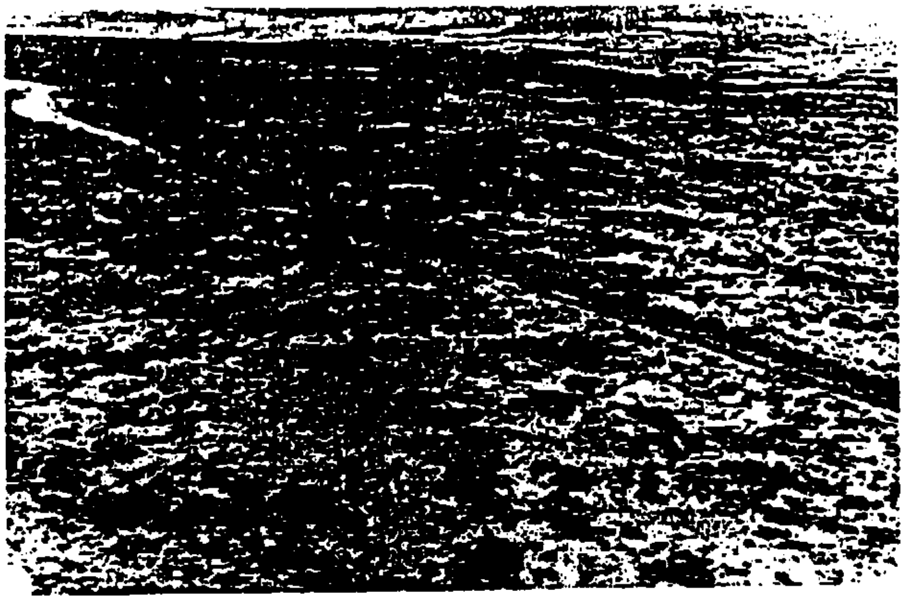
Figure 3. -- Photographs of bottom lands taken from the air.



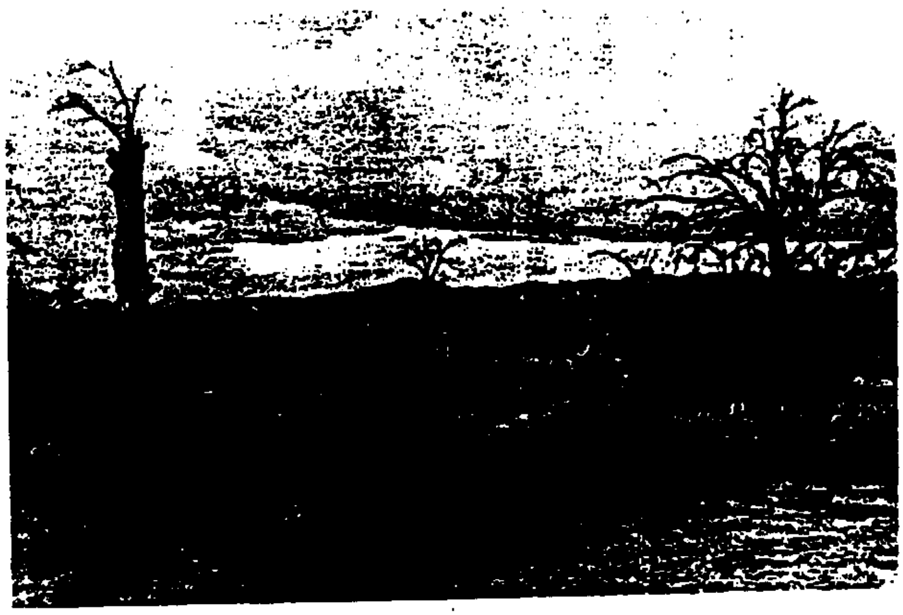
a. Air view northwest along side wash which enters river at (D-16-13) 1 bdb. Note dead mesquite; note course of abandoned canal parallel with river on west side.

b. Dead mesquite in abandoned canal on west side of river at locality (D-15-13) 35 dba; the plants have died in spite of the fact that the canal bottom is about 15 feet below the prevailing land surface. There is one salt cedar shown in the lower right corner; it was still alive in September 1962.

Figure 4. -- Photographs of dead mesquite.



a. Aerial view northeast showing dead mesquite in bottom lands and present channel of river. The narrow borders of live growth live on the occasional river flows.



b. Stumps of dead mesquite in bottom land at location (D-16-13) 2; their size indicates these former phreatophytes grew under favorable conditions for many years.

Figure 5. -- Photographs of dead mesquite.

Arizona State Land Department

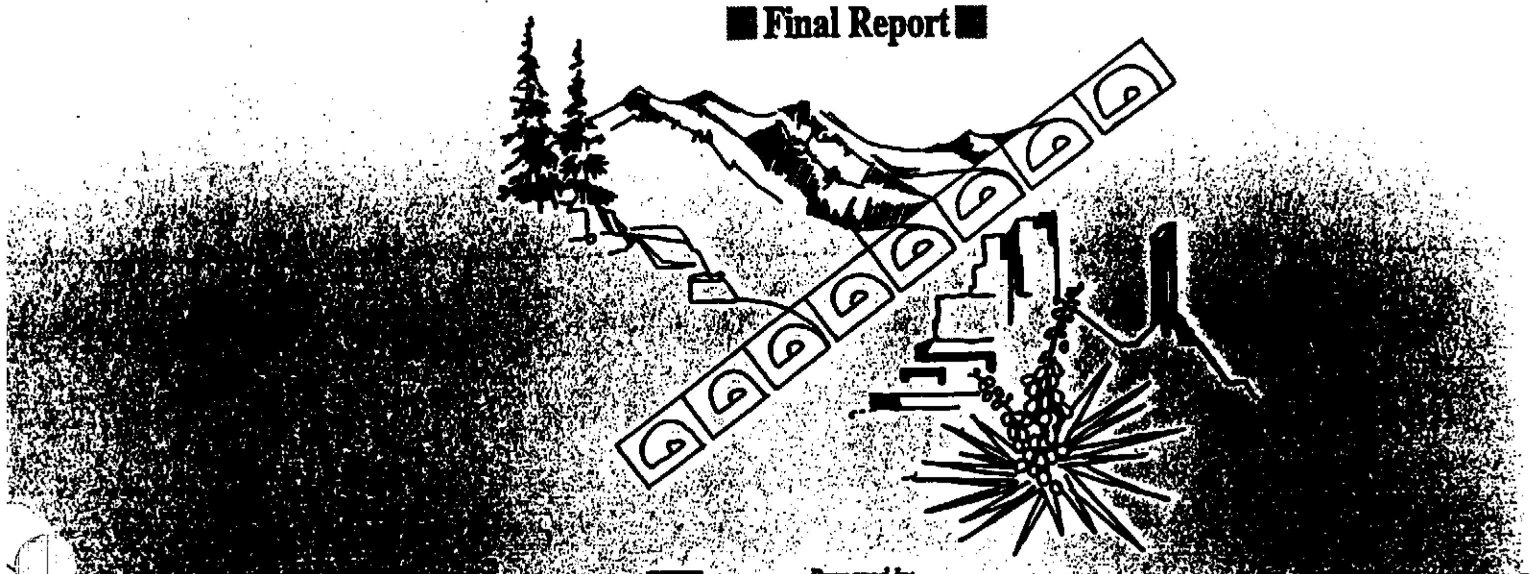
# ARIZONA STREAM NAVIGABILITY STUDY

*for the*

# SANTA CRUZ RIVER

**Gila River Confluence to the Headwaters**

**Final Report**



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*and the*

**Arizona Geological Survey**

November 1996

SECTION 4

# Historical Geomorphology and Hydrology of the Santa Cruz River

**A Report Submitted to the Arizona State Land Department**
**- Final Draft -**

Michelle Lee Wood, P. Kyle House, and Philip A. Pearthree
Arizona Geological Survey
November, 1996

## EXECUTIVE SUMMARY

This report provides baseline information on the physical characteristics of the Santa Cruz River to be used by the Arizona Stream Navigability Commission in its determination of the potential navigability of the Santa Cruz River at the time of Statehood. The primary goals of this report are: (1) to give a descriptive overview of the geography, geology, climatology, vegetation and hydrology that define the character of the Santa Cruz River; and, (2) to describe how the character of the Santa Cruz River has changed since the time of Statehood with special focus on the streamflow conditions and geomorphic changes such as channel change and movement. This report is based on a review of the available literature and analyses of historical survey maps, aerial photographs, and U.S. Geological Survey streamgage records.

The Santa Cruz River has its source at the southern base of the Canelo Hills in the Mexican Highlands portion of the Basin and Range province. The river flows south through the San Rafael Valley before crossing the international border into Mexico. It describes a loop of about 30 miles before it re-enters the United States six miles east of Nogales, and continues northward past Tucson to its confluence with the Gila River a few miles above the mouth of the Salt River. The "upper" Santa Cruz River (the river south of Marana) and the "lower" Santa Cruz (the river north of Marana) are often discussed separately in this report because of their different geomorphic and hydrologic characteristics. Along the upper Santa Cruz River, the channel is located in an inner valley that was created within broad, dissected pediments and alluvial basin deposits, and flanked by mountains. The well-defined, often entrenched channel in the upper reaches contrasts strongly to the ill-defined system of braided channels that exist north of Rillito Peak at the northern end of the Tucson Mountains near Marana. In this lower part of the basin, the Santa Cruz River flows into the great adobe flats known as the "Santa Cruz Flats," a broad plan of indistinct, noncontinuous channels in Pinal County. Floodwaters spread over a wide area with flow concentrated in numerous small washes. A well-defined channel exists only at Greene's Canal and near the Santa Cruz River's confluence with the Gila.

Both the upper and lower reaches of the Santa Cruz River have been subjected to a complex combination of climatic and geomorphic processes and human activities that have resulted in both subtle and dramatic changes in its geomorphic and hydrologic character.

While arroyo development is the most obvious type of channel change to occur since the 1890s in the upper Santa Cruz River, most of the initial channel incision occurred before the time of Statehood. Since 1912, various reaches of the upper Santa Cruz River have been dominated by such processes and activities as meander migration and cutoff, channel widening, arroyo widening, channelization, and the effects of vegetation growth resulting from the discharge of sewage effluent. The channel locations in different reaches have shifted on the order of a few feet to a few thousand feet, depending on the processes that resulted in the movement, and often change could be detected from one year to the next.

The lower Santa Cruz River, which overall is characterized by aggradation of its streambeds, experienced changes of a completely different magnitude from the upper Santa Cruz. Changes in the location of the channel in the lower basin can be measured in miles, and, due to the nature of the causes of the changes, the timing spans decades. Before the construction of Greene's Canal in 1910, the Santa Cruz River downstream from Marana was a broad, flat alluvial plain with intermittent channels. Now the transition from defined channel to alluvial plain occurs near Chuichu, Arizona. Prior to and during the floods of 1914-1915, flood flows followed routes down the North Branch of the Santa Cruz Wash and McClellan Wash through the Casa Grande area. The influence of Greene's Canal and its subsequent development as an arroyo have caused flood flows since 1915 to take more westerly paths *via* Greene's Canal.

The hydrology of the Santa Cruz River, like its geomorphology, has been affected by natural geomorphic and climatic processes and by human activities. Historically (~1890), the Santa Cruz River had year-round (or perennial) flow from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the international border during the 1930 to 1950 drought period, has resulted in no flow in the channel in Sonora, Mexico, and discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales (the earliest in that region) indicates that by the time of Statehood, the Santa Cruz River at Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The winter discharge averaged about 15 cubic feet per second (cfs), except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. A survey of the daily data for the rest of the Nogales record indicates that during wet years there were only a few days of no-flow conditions, while during dry years there were entire months that passed with no flow recorded in the channel. At present, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley. A separate perennial reach occurs north of Nogales due to the discharge of sewage effluent from the Nogales International Wastewater Treatment Plant that began in 1972.

The Santa Cruz River historically had several springs and marshes (*cienegas*) within its channel from Tubac to Tucson, and a marsh at its confluence with the Gila River at Laveen. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River. A review of the daily discharge record at Tucson indicates that there was some semblance of baseflow with an average of about 12 cfs during the fall and winter of 1912-1913. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons. The Laveen gage recorded nearly year-round flow from its beginning date, 1940, until June of 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low-flow conditions and had peaks as high as 5060 cfs during the wet periods. By 1960, the Santa Cruz at Laveen also was experiencing no-flow conditions for months at a time. In contrast to the reaches near Tucson and in the lower Santa Cruz River basin, the reach of the Santa Cruz River near Marana and Cortaro now has perennial flow due to the discharge of sewage effluent from the Ina Road and Roger Road sewage treatment plants.

Not only has the location of perennial flow in the Santa Cruz River changed since the time of Statehood, but the seasonality and magnitude of flows also have shifted as a result of climate change in this region. Though the majority of flow events occur during the summer season, the magnitude and number of flows that occur in the fall and winter was higher before 1930 and after 1960 than during the 1930-1960 period. Also, annual peak discharges increased significantly after 1960. For example, six of the seven largest floods on the Santa Cruz River at Tucson occurred after 1960.

In the lower Santa Cruz River basin, human activities as well as climate change have had notable effects on the magnitude of peak flows. Since 1962, the construction of flood-control channels in the washes of the lower Santa Cruz basin have resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the attenuation (the downstream decrease of the flood peak) of peak discharges. For example, the attenuation of peak flow was greater during the 1962 floods than during the 1983 floods because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 floods was efficiently transmitted downstream by the flood-control channels, resulting in higher flood peaks in downstream reaches.

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## I. INTRODUCTION

This report provides baseline information on the physical characteristics of the Santa Cruz River to be used by the Arizona Stream Navigability Commission in its determination of the potential navigability of the Santa Cruz River at the time of Statehood. The primary goal is to give a descriptive overview of the geography, geology, climatology, vegetation and hydrology that define the character of the Santa Cruz River. A secondary goal is to describe how the character of the Santa Cruz River has changed since the time of Statehood, with special focus on the streamflow conditions and geomorphic changes such as channel change and movement. This report is based on a review of the available literature, and analyses of historical survey maps, aerial photographs and U.S. Geological Survey streamgage records. Unfortunately, there is little data presented in the literature or in the gage records, aerial photographs and maps of the Santa Cruz River for the year 1912. Therefore, the character of the river at the time of Statehood must be interpolated from descriptions made before and after that year.

The Santa Cruz River has been subjected to a complex combination of processes that have resulted in changes in its character. These changes have taken many forms, including changes in the types and density of vegetation in the river basin, the average flow or magnitude of peak flows, the presence of surface water, and even the location of the river channel itself. Human activities clearly have played a role in changing the geomorphology and hydrology of the Santa Cruz River, but it is difficult to separate the effects of human impact from the effects of climate change and "natural" riverine processes. Where possible we have noted the causes of specific changes, whether they be anthropogenic or naturally induced.

Each of the following chapters, except for the chapter on geography and geology, begins with a general overview of the topic, followed by a description of the changes that have occurred since the time of Statehood. The "upper" Santa Cruz River (the river south of Marana) and the "lower" Santa Cruz (the river north of Marana) are often discussed separately in the following chapters because of their different geomorphic and hydrologic characteristics. The concluding chapter provides a comparison of the hydrological and geomorphological characteristics at the time of Statehood to those of the present day. Throughout this document, key words are highlighted by bold, italicized print. These words have been defined in the "Glossary" section that follows the last chapter. Ten ground photographs that illustrate the key differences between the different reaches of the upper and lower Santa Cruz River are given in Appendix A. Appendix B is a detailed description of the mapping of ordinary low and high watermarks. Appendix C explains the creation and use of stage-discharge rating curves. Appendices D, E and F provide lists of the contacts and resources we developed in our search for historical maps, aerial photographs and previous channel change studies. Appendix G is an extended bibliography containing relevant references that were not included in the text of the report.

## II. GEOGRAPHY & GEOLOGY

The Santa Cruz River has its source at the southern base of the Canelo Hills in the Mexican Highlands portion of the Basin and Range province (Figure 1). Its waters gather into a shallow, perennial channel that flows south through the San Rafael Valley before crossing the international boundary into Mexico. The river describes a loop of about 30 miles with a 348-square-mile contributing drainage area before re-entering the United States 6 miles east of Nogales. Its channel continues northward past Tucson to the Gila River a few miles above the mouth of the Salt River, a distance of about 225 miles.

Along the upper Santa Cruz River, south of Marana (refer to Figure 2), the channel lies within an inner valley created within broad, dissected pediments and alluvial basin deposits, and flanked by mountains (Cooke and Reeves, 1976; Bryan, 1925b). The well defined, commonly entrenched channel in the upper reaches contrasts strongly to the discontinuous system of channels that exist north of the northern end of the Tucson Mountains near Marana. In this lower part of the basin, the Santa Cruz River flows into the great ***adobe flats***[1] known as the "Santa Cruz Flats," a broad plain of indistinct, noncontinuous channels in Pinal County. On most United States Geological Survey (USGS) maps, the term "Santa Cruz Flats" is restricted to the area south and west of Eloy, extending west to the Sawtooth Mountains, south to the alignment of Greene's Canal, and north to the Casa Grande Mountains. In this region, floodwaters spread over a wide area with flow concentrated in numerous small washes. Distinct channels exist only along the

[1] Bold, italicized words are defined in the Glossary following the final chapter.

**Figure 1. Physiographic Features in the Santa Cruz River Basin.**

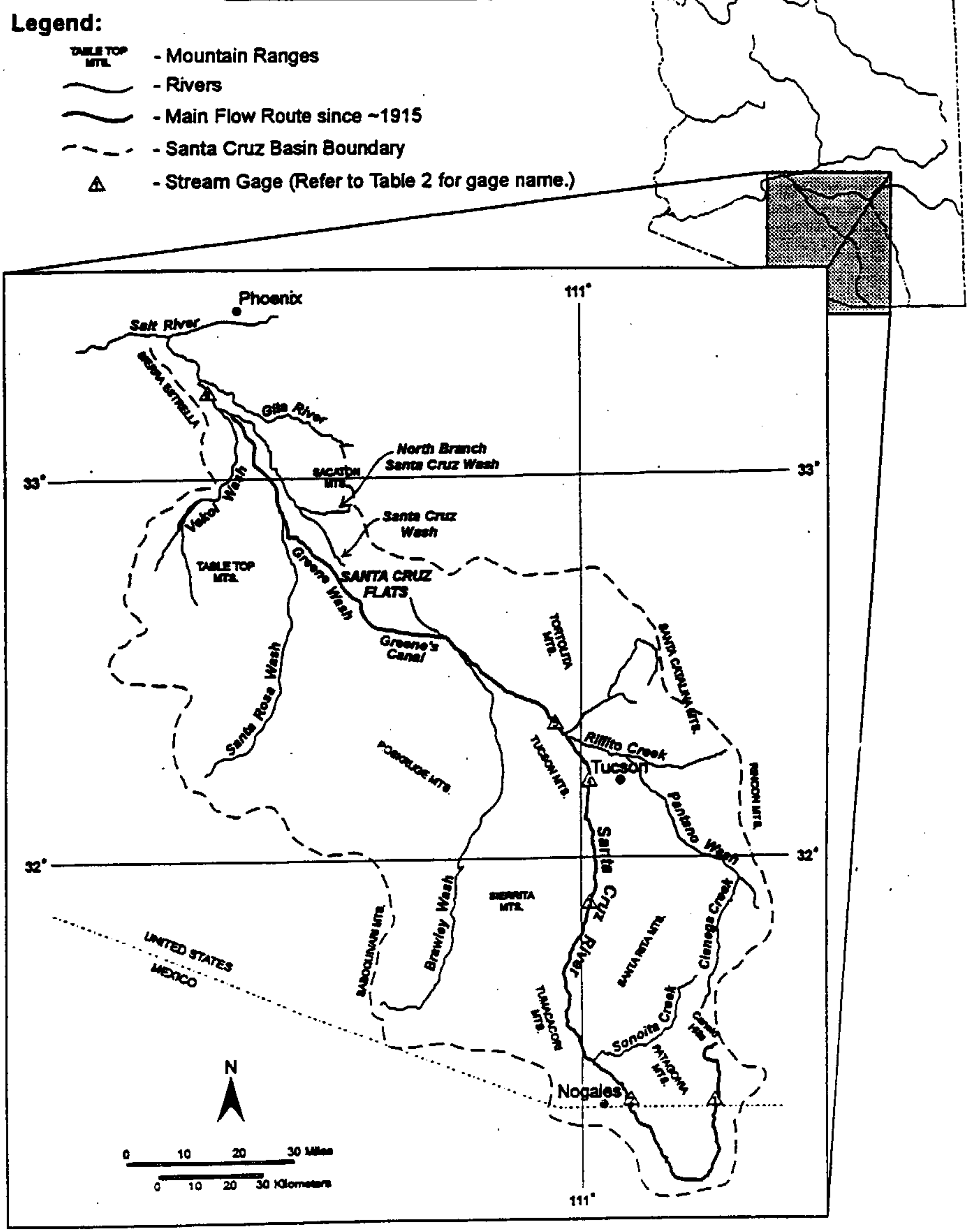
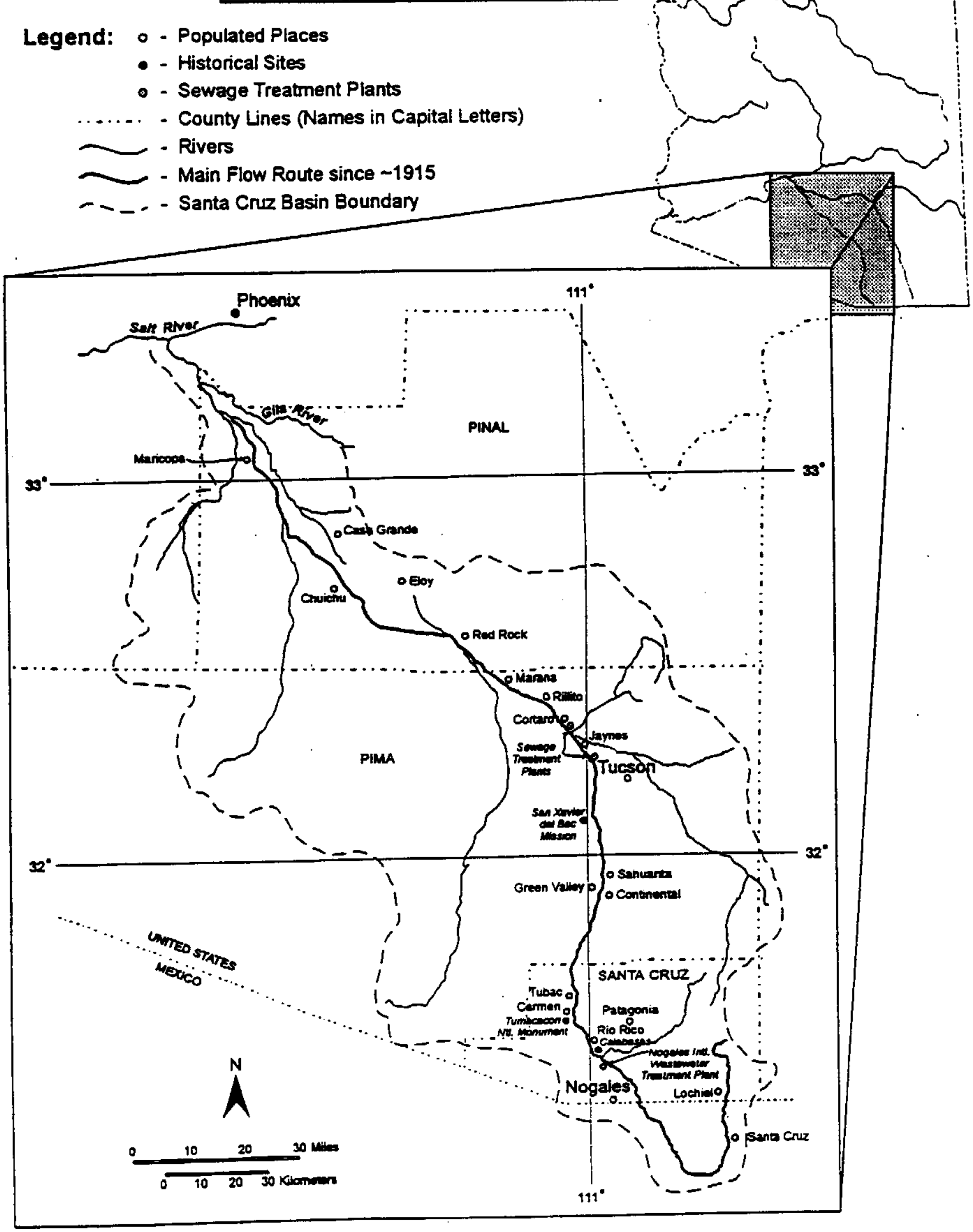


**Figure 2. Santa Cruz River Basin: Places mentioned in the text.**



former alignment of Greene's Canal and near the Santa Cruz River's confluence with the Gila River.

## III. CLIMATE

Climate plays both direct and indirect roles in defining the character of the Santa Cruz River. Temperature and precipitation control the amount of evaporation that occurs, which in turns affects the amount of water that flows into and remains in the river channel, the amount of ***infiltration,*** the type and vigor of vegetation along the river banks, and the character of vegetation throughout the basin. The amount and nature of the precipitation plays an even stronger role in defining the character of the river because both the surface and groundwater supplies of the drainage basin have as their primary source the precipitation that occurs in the basin (Schwalen, 1942).

This chapter provides a brief overview of the seasonal changes in temperature. Seasonal, annual, and decadal changes in the source and nature of precipitation events will be described in more detail because of the role average and unusual precipitation conditions play in defining the hydrology and geomorphology of the Santa Cruz River system.

### A. Temperature

Average January temperatures range from about 40° F in the higher elevations to about 50° F in the lower lying regions, with mean minimum temperatures averaging near or below freezing. Average July temperatures range from 65° in the higher elevations to 85° and 90° in the lower regions, with mean maximums ranging from 80° to 105°, depending on the elevation. The spring and fall months are characterized by large daily temperature changes that average 30° or even 40° (Santa Cruz-San Pedro River Basin Resource Inventory, 1977; Sellers and Hill, 1974).

### B. Precipitation

Annual precipitation in the Santa Cruz River basin tends to increase with altitude and is extremely variable from year to year (Condes de la Torre, 1970). Two distinct seasons of precipitation are evident in the mean monthly precipitation of the Santa Cruz

River Basin, with slightly greater precipitation in the summer than in the winter (Sellers and Hill, 1974). This pattern is illustrated by two rain gage records in the basin (Figure 3). Hirschboeck (1985) and Webb and Betancourt (1992) provided thorough reviews of the sources of the precipitation and identified the circulation anomalies that are associated with variations in monthly and peak streamflow for the Santa Cruz River. The following sections describing seasonal precipitation patterns and variability are based primarily on their work.

***Summer.*** The summer rainy season occurs from the latter part of June through September. During the summer rainy season, the thermally induced high-altitude anticyclonic circulation centered over the southern and southwestern United States entrains moist air from the Gulf of Mexico, the Pacific Ocean and the Gulf of California (Reed, 1933; 1939). The summer rains are often referred to as "monsoon" rains because of the similarity of the southwestern atmospheric circulation pattern to the monsoonal circulation in other parts of the world (Tang and Reiter, 1984). The storm centers of summer thundershowers are the result of convective air currents set up in the lower atmosphere by extremely high temperatures next to the earth's surface, and the effects of local topographic features. Summer precipitation is characterized by widespread and locally scattered thunderstorms. The summer storms tend to result in locally intense rainfall on any given day, yet for short periods during the summer, rainfall may occur in the entire drainage basin (Schwalen, 1942). In the upper Santa Cruz River basin, the precipitation during the summer rainy season is the most dependable and generally is greater than the total for the remaining eight months of the year (Schwalen, 1942; Condes de la Torre, 1970). From north to south in the drainage basin, the ratio of summer rainfall to total annual rainfall increases (Schwalen, 1942).

***Winter.*** The winter rainy season occurs during the period December through March. This second rainy season results primarily from trailing cold fronts associated with large-scale low pressure systems steered into the region by very deep troughs over the western United States in the belt of upper air westerly wind flow. Winter rains in the Santa Cruz River basin are associated with the eastward passage of the cyclonic storm centers

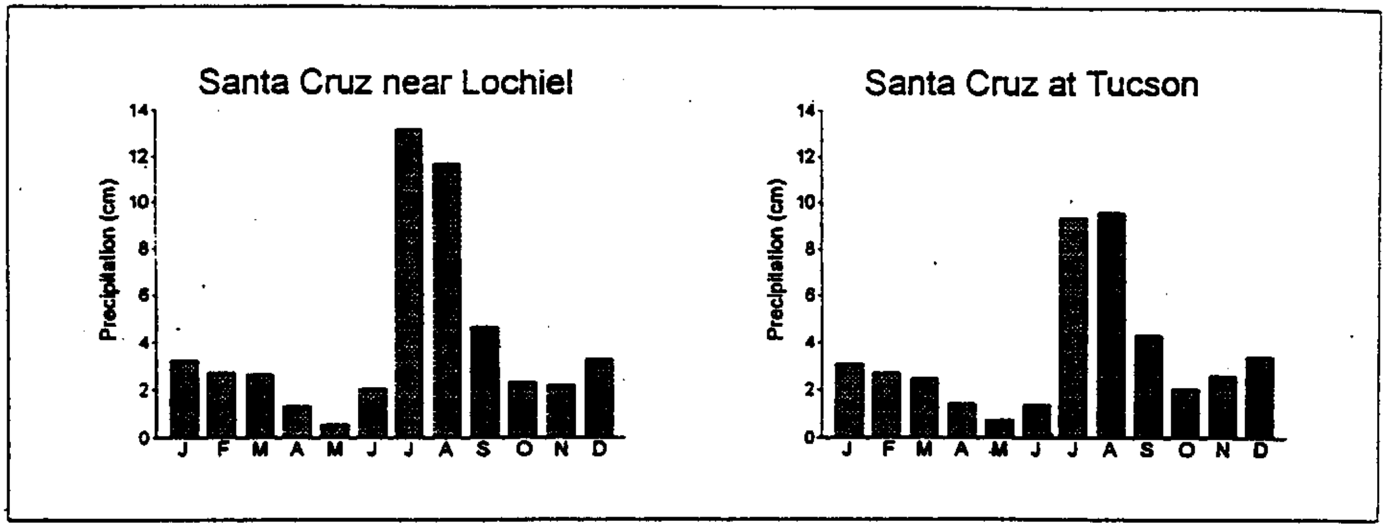



**Figure 3. Monthly precipitation at two gages in the Santa Cruz River Basin.**
[Source: Hirschboeck, 1985]

originating on the Pacific Ocean. Although individual storms may persist for several days, have wide spatial extent (i.e. one storm system may cover the entire state of Arizona), move slowly, and have fairly steady intensity, winter rains themselves show a wider variation in their seasonal totals and are more irregular in monthly distribution than the summer rains (Schwalen, 1942; McDonald, 1956). Though the majority of flow events on the Santa Cruz River occur in the summer rainy season, the second largest flood measured at Tucson was caused by a series of winter frontal passages. The fronts were steered along a southerly displaced storm track into the region (House and Hirschboeck, 1995).

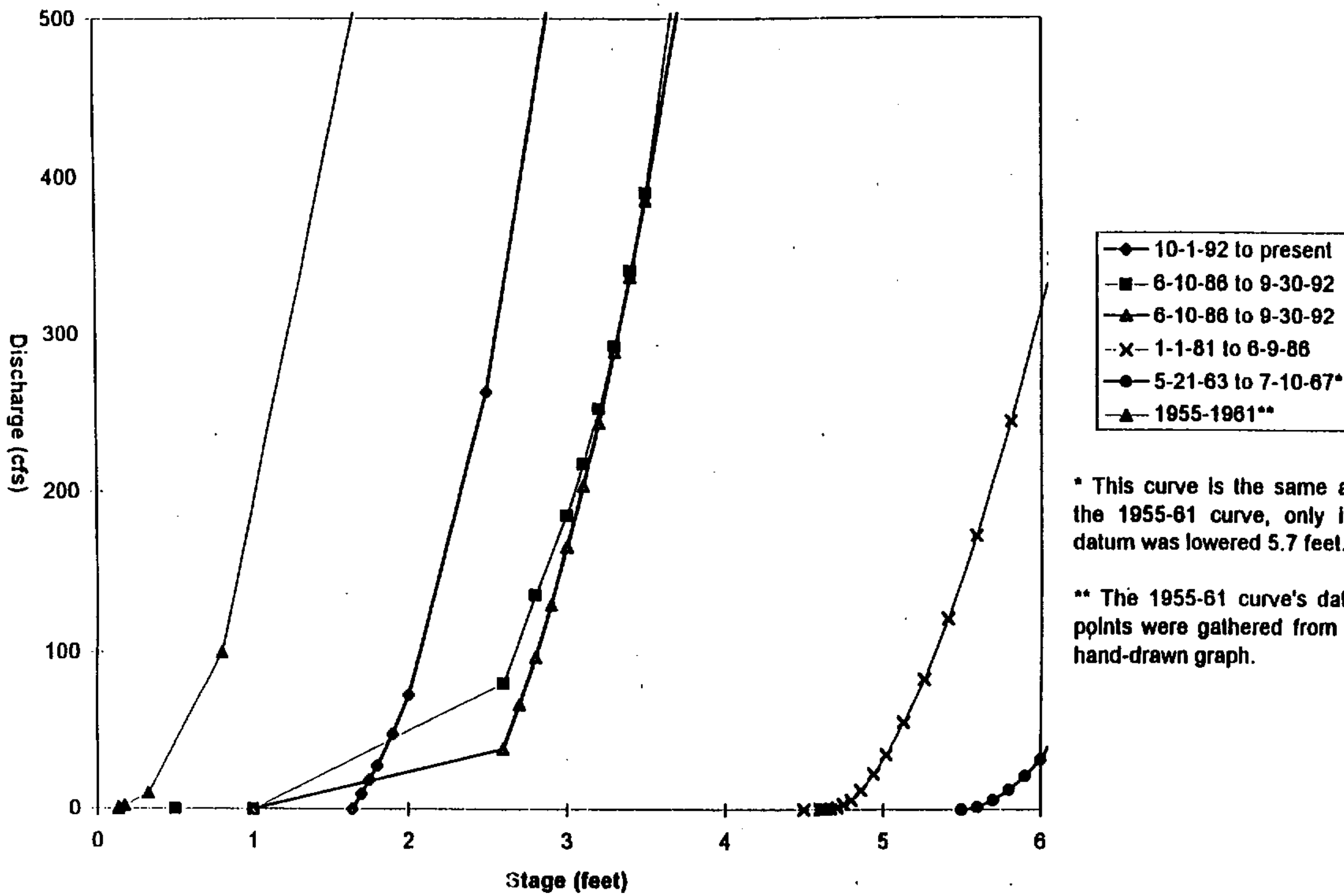
***Fall and Spring.*** The spring and fall months in Arizona are usually characterized by clear skies and little precipitation (SC-SP River Basin Resource Inventory, 1977; Sellers and Hill, 1974). While winter frontal storms and summer convectional storms are the most common sources of precipitation in this region, tropical storms and cutoff lows also contribute significant amounts of precipitation (Douglas and Fritts, 1973; Douglas, 1974; Hirschboeck, 1985). Tropical storms tend to influence the precipitation of the region during the months of August through October (Douglas and Fritts, 1973; Hirschboeck, 1985; Smith, 1986). For example, remnants of Tropical Storm Claudia in 1962 caused flooding on the Santa Cruz River at and north of Tucson, Santa Rosa Wash, and Brawley Wash (Lewis, 1963).

Cutoff cyclones tend to develop in the upper atmosphere off the west coast of North America during the fall (September - November) and late spring (May - June) periods, times that are typically dry in the Santa Cruz River basin. Hirschboeck (1985) observed that tropical storms at the surface were often associated with troughs or cutoff lows in the upper atmosphere. Tropical Storm Octave in late September and early October 1983 is an example of such an interaction between a tropical cyclone and a cutoff low pressure system that caused the flood of record on the Santa Cruz River (Roeske *et al*, 1989; Webb and Betancourt, 1992).

### C. Historical Climate Change in the Santa Cruz River Basin

During the past two decades, more and greater flood flows have occurred in the fall and winter seasons and fewer in the summer (Webb and Betancourt, 1992; Hirschboeck,

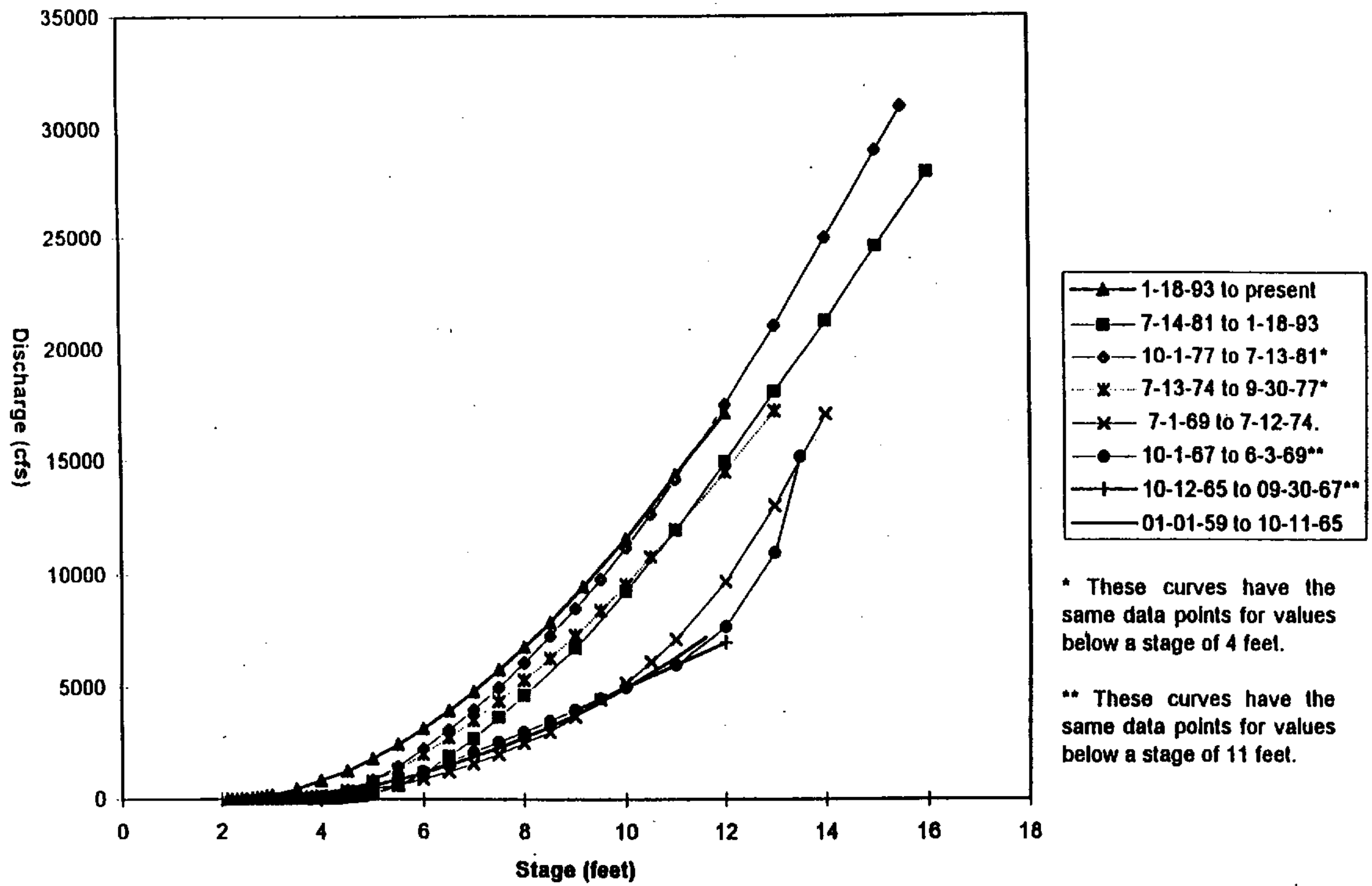
**Figure C-4. Stage-rating curve for the Santa Cruz River at Tucson.**
Enlarged view of the stage-discharge relationship at low flows for selected periods.




* This curve is the same as the 1955-61 curve, only its datum was lowered 5.7 feet.

** The 1955-61 curve's data points were gathered from a hand-drawn graph.

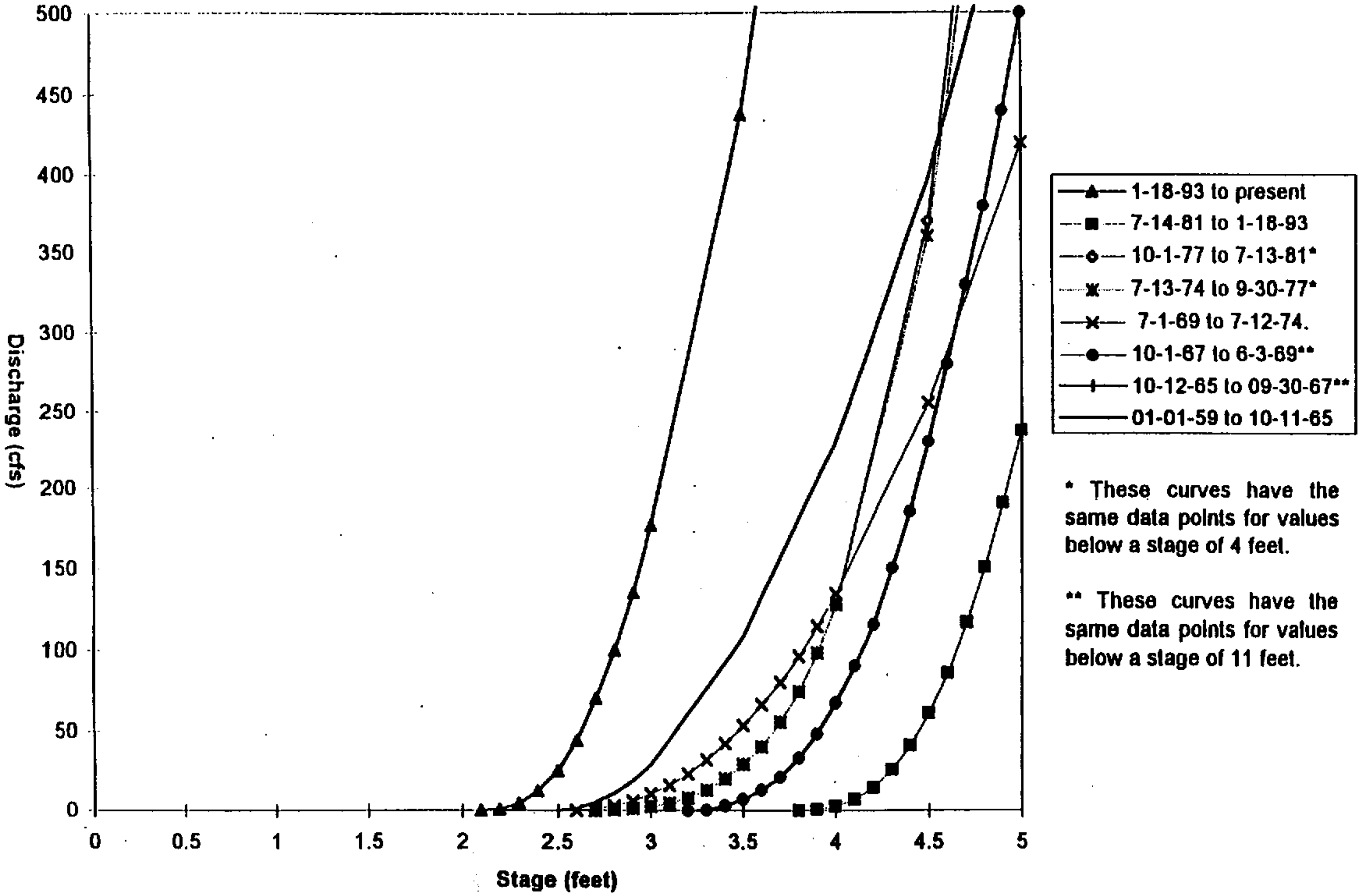
Figure C-3. Stage-rating curves for the Santa Cruz River near Nogales
Each line represents the stage-discharge relationship for a different period.




* These curves have the same data points for values below a stage of 4 feet.

** These curves have the same data points for values below a stage of 11 feet.

**Figure C-5. Stage-rating curve for the Santa Cruz River near Nogales.**
Enlarged view of the stage-discharge relationship at low flows for selected periods.




* These curves have the same data points for values below a stage of 4 feet.

** These curves have the same data points for values below a stage of 11 feet.

The following is an example of how to extract information from these rating curves. Figure 10 of Section 4 shows that the Santa Cruz River at Tucson experienced a daily discharge mean of 18 cfs on January 12, 1981. Figure C-4 contains an enlarged illustration of the rating-curve used for the period January 1, 1981, to June 9, 1986. According to this rating curve, a discharge of 18 cfs would have a corresponding stage of 4.9 feet. Because a discharge of zero corresponds to a stage of 4.5 feet, the actual water depth for a discharge of 18 cfs would be 0.4 feet (4.9 minus 4.5 feet) in the channel. [Note: it is common for a discharge of zero *not* to correspond to a stage of zero.[B-1]]

The earliest rating tables we retrieved from the USGS date to the mid-1950's. Because of the multitude of channel changes that have occurred in the upper reaches of the Santa Cruz River in the early part of this century (refer to Chapter VI), the reader is advised not to use the 1950's curves to determine the stages corresponding to earlier discharges presented in this report except to get very rough estimates of stage. Also, these rating curves do not represent the stage-discharge relationships that exist at the Lochiel, Continental, Cortaro and Laveen gage sites. The table below provides a comparison of the estimated stage-discharge values for the gages at Tucson and near Nogales. Though the stage-rating curves in Figures C-4 and C-5 appear to be very different because of the lowering and raising of the stage datum, the stage values derived from these curves that correspond to low discharges remain about the same over time. The stage values that correspond to higher discharges are markedly different.

Table C-1

| Discharge (cfs) | Stage (feet) | | | |
|---|---|---|---|---|
| | *Nogales* | | *Tucson* | |
| | early 1900's | late 1900's | early 1900's | late 1900's |
| 10 | 0.3 | 0.3 | 0.2 | 0.1 |
| 100 | 1.0 | 0.7 | 0.7 | 0.4 |
| 1000 | 3.3 | 2.1 | 2.6 | 1.9 |

## Appendix D

## Agencies Contacted

| Agency | Contact | Telephone # |
|---|---|---|
| Aridlands Information Center | Michael Hazelteen | 520-621-7897 |
| | Martin Karpiscak | 520-621-8589 |
| Aridland and Watershed Management | Dave Goodrich | 520-670-6381 |
| AZ Dept. of Water Resources, Pinal AMA | Lisa | 520-836-4857 |
| | Duncan | 520-836-4857 |
| AZ Dept. of Water Resources, Tucson AMA | Lee | 520-770-3800 |
| AZ Dept. of Water Resources, Santa Cruz AMA | Placido Dos Santos | 520-761-1814 |
| | Keith Nelson | 520-761-1814 |
| Arizona Historical Society Museum | Deborah Shelton | 520-628-5774 |
| Arizona State Land Department | | 520-628-5480 |
| Arizona State Museum | Kathie Hubenschmidt | 520-621-2445 |
| Bureau of Land Management | Karen | 520-722-4289 |
| Cella Barr Associates | Nemecio "Tiny" Trevino | 520-750-7474 |
| City of Nogales Public Works (and Floodplain Management) | Alejandro Barcenas | 520-287-7245 |
| Cooper Aerial Survey Co. | Beverly | 520-884-7580 |
| Desert Botanical Gardens - Phoenix | Joseph McAuliffe | 602-947-6029 |
| | Pat Comus | 602-996-9391 |
| Earth Science Information Center | Diane Murray | 520-670-5584 |
| | Justin | 520-670-5584 |
| Farm Service Agency (Pinal County) | Pat Fox | 520-836-2028 |
| Forest Service - Coronado | Wally Craig | 520-670-4552 |
| LANDIS Corporation | Shelly Knight | 520-617-0076 |

| | | |
|---|---|---|
| **Pima County Flood Control District** | David Jones | 520-740-6350 |
| | Terry Hendrix | 520-740-6350 |
| **Pima County Planning/Maps & Records** | Barry Rothrock | |
| | Paul Matty | Rm 205, County Bldg. |
| **Pinal C. Flood Control District** | Juanita | 520-868-6411 |
| **Pinal County Planning and Development** | Louis Felix | 520-868-6549 |
| **Rio Rico Properties** | Jay Moyes | 602-640-9335 |
| **Santa Cruz County Flood Control District** | Frank Crupp | 520-761-7800, x3071 |
| | Angie | 520-761-7800 |
| **Soil Conservation Service (Tucson Field Office)** | Bud Bowers | 520-670-6492 |
| **Soil Conservation Service (Pinal C.)** | Mark Felix | 520-836-2048 |
| **UA - Dept. of Geography and Regional Planning** | Sharon | 520-621-1652 |
| **UA - Dept. of Hydrology and Water Resources** | Dr. Robert MacNish | 520-621-3041 |
| **USGS (UA office, Tucson)** | Brenda Houser | 520-670-5509 |
| **USGS (Tumamoc Hill, Tucson)** | Robert Webb | 520-670-6821 |
| | Julio Betancourt | 520-670-6821 |
| **USGS - Water Resources Division** | Jonathon Parker | 520-670-6671 |
| | Doug Ufkes | 520-670-6671 |
| **WLB Engineering Group** | Jim Dean | 520-881-7480 |
| **Water Resource Research Center** | Barbara Tellman | 520-792-9591 |
| | Rick Yarde | 520-792-9591 |

## Appendix E

## Availability of Aerial Photographs

### Pima County:

| Year | Agency | Contact | Comments |
|---|---|---|---|
| 1995 | AZ Dept. Water Resources, Tucson Active Management Area | Lee | Only for TAMA region; north to just past Red Rock. We can borrow them for 24 hours at a time. 1'=1200ft, by LANDIS Aerial Surveys (recent) |
| | Pima County Mapping & Records | Barry Rothrock | St. Mary's Rd. to Ft. Lowell of the SCR; very large scale; shot by Cooper Aerial. |
| 1994 | Pima County Flood Control District | David Jones | Stereoscopic photos; complete. |
| 1993 | Cooper Aerial* | Beverly | Flood coverage; does not go south of the water treatment plant in Santa Cruz County; does include Pinal County. |
| 1990-91 | AZ Dept. Water Resources, TAMA | Lee | 1'=1200ft., LANDIS. We can borrow them for twenty-four hours at a time. |
| 1988 | AZ Dept. Water Resources, TAMA | Lee | 1:12,000; Cooper Aerial Survey. We can borrow them for 24 hours at a time. |
| 1986 | AZ Dept. Water Resources, TAMA | Lee | 1"=1200'; LANDIS Aerial. We can borrow them for 24 hours at a time. |
| 1986 | Pima County Planning and Dev. | Paul Matty | 1"=1200'; B/W; ** |
| 1985 | Pima County Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |
| 1983 | Cooper Aerial | Beverly | Flood coverage; includes Pinal and Santa Cruz Counties |
| 1983/1984 | USGS, UA office | Brenda | Color Infrared; 1:60,000. Has good index. Coverage: just north of the Tucson Mts (~Marana); most/almost all of S.C. County. Can borrow this photoset with no problem; it is quite portable. |
| 1983 | USGS, UA office | Brenda | B/W; 1:80,000. Coverage: very small area, north to mid-Tucson and south to just before the Mexican border. |
| 1983 (Oct.) | P.C. Planning and Dev. | Paul Matty | 1"=10000'; B/W; ** |
| 1983 (Sep/Oct) | AZGS | Tom McGarvin | Color, photos taken before and after the flood are mixed together, coverage = north of Tucson south to sewage treatment plant. |
| 1982 | P.C. Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |
| 1980 | AZ Dept. Water Resources, TAMA | Lee | For TAMA region and south to Nogales; north to just past Red Rock. We can borrow them for 24 hours at a time. |
| 1980 | P.C. Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |

| | | | |
|---|---|---|---|
| 1979/80 | AZGS | Tom McGarvin | Cooper Aerial; 1:12,000; "Poor" coverage |
| 1978 | P.C. Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |
| 1977 | Cooper Aerial | Beverly | Flood coverage; does not include Pinal County; does include Santa Cruz County. |
| 1976 | P.C. Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |
| 1974 | AZ Dept. Water Resources, TAMA | Lee | No index, but the maps look nice. |
| 1974 | P.C. Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |
| 1974 | P.C. Planning and Dev. | Paul Matty | 1"=2mi; B/W; Infrared film positives - NASA flight 74-022** |
| 1972/73 | AZGS | Tom McGarvin | "Good" coverage; 1:4000; N.A.S.A. photography |
| 1972 | P.C. Planning and Dev. | Paul Matty | 1"=2000'; B/W; Orthophotoquads;** |
| 1972 | | | |
| 1967 | P.C. Mapping & Records | Barry Rothrock | DHQ "2HH" & "3HH" Series; coverage seems good but no index (a lot of work....). |
| 1967 | P.C. Planning and Dev. | Paul Matty | 1"=800'; B/W; ** |
| 1965 | P.C. Mapping & Records | Barry Rothrock | 1965 Flood photos! very large scale; much of Pima County; some photos have yellow post-its marked "'66;" no index. |
| 1965 | P.C. Mapping & Records | Barry Rothrock | Blanton/Cole Series; only "mid" part of SCR; missing area south of Tucson that was covered in 1964 photoset; stops north of PC/SC line. |
| 1964 | P.C. Mapping & Records | Barry Rothrock | Blanton/Cole Series; only Tucson area; 1':800'; can work at their office ($3.00 per sheet to copy). |
| 1964 | P.C. Planning and Dev. | Paul Matty | 1"=800'; B/W; ** |
| 1963 | P.C. Planning and Dev. | Paul Matty | 1"=600'; B/W; ** |
| 1960 | P.C. Planning and Dev. | Paul Matty | 1"=800'; B/W; ** |
| 1958 | P.C. Mapping & Records | Barry Rothrock | DHQ "V" Series; very incomplete coverage 1:20,000; can work at their office ($3.00 per sheet to copy). |
| 1958 | P.C. Planning and Dev. | Paul Matty | 1"=400'; B/W; ** |
| 1956 | P.C. Planning and Dev. | Paul Matty | 1"=1000'; B/W; ** |
| 1955 | P.C. Planning and Dev. | Paul Matty | 1"=400', 660' or 800''; B/W; ** |
| 1954 | P.C. Mapping & Records | Barry Rothrock | DHQ "N" Series; good coverage; can work at their office ($3.00 per sheet to copy). |
| 1953/56 | AZGS | Tom McGarvin | None for southern-most Santa Cruz County |

| | | | |
|---|---|---|---|
| 1953 | P.C. Planning and Dev. | Paul Matty | 1"=800'; B/W; ** |
| 1950 | P.C. Planning and Dev. | Paul Matty | 4"=650'; B/W; ** |
| 1950 | P.C. Planning and Dev. | Paul Matty | 1"=200'; B/W; ** |
| 1949 | P.C. Mapping & Records | Barry Rothrock | DHQ "F" Series; missing north Tucson reach of SCR (the %F sub-series); looks like only the SCR area of Tucson & "mid" was purchased. |
| 1946 | P.C. Mapping & Records | Barry Rothrock | XXA Series; good coverage 1:20,000; can work at their office ($3.00 per sheet to copy). |
| 1941 | P.C. Planning and Dev. | Paul Matty | 3"=1mi; B/W; * |
| 1936 | P.C. Planning and Dev. | Paul Matty | 4"=1'; B/W; "L" Pima - Papago Reservation; ** |
| 1936 (37/38) | Soil Conservation Service (Tucson Field Office) | Bud Bowers | Give a call to the field office to make an appointment to come see the photos. |

* Beverly could come up with older photos of Pima County but not Pinal and Santa Cruz Counties. Oldest of Pima = 1953. Oldest of broad cc of Santa Cruz region is 1960.

**P.C. Planning photosets compiled by Paul Matty. Many of these photosets were incomplete and/or had no index.

## Pinal County:

| Year | Agency | Contact | Comments |
|---|---|---|---|
| 1994 | Pinal County Planning & Dev. | Pete McGrath & Jaunita Silvernagel | 1 map = 9 sections. Mondays all day, Tuesday mornings and Fridays are best; call ahead to make an appointment to use the "hearing room" in which to work. |
| 1993 | Pinal County Planning & Dev. | Pete McGrath & Jaunita Silvernagel | Flood photos. See notes above. |
| (1992) | Farm Service Agency (Pinal C.) | Pat Fox | In process of cataloging. |
| 1987 | Pinal C. Flood Control | Juanita | |
| 1983 | SCS-Pinal County | Mark Felix | During flood; shot by Cooper Aerial. Call to make an appointment. |
| 1983 | Pinal C. Planning & Dev. | Pete McGrath & Jaunita Silvernagel | Flood photos. See notes above. |
| 1982 | SCS-Pinal County | Mark Felix | These are mixed with some '79 photos. Call to make an appointment. |
| 1979/80 | AZGS | Tom McGarvin | Cooper Aerial; 1:12,000; Need to double check for coverage of Pinal County |
| 1979 | ADWR - Pinal AMA | Lisa | Their office has a light table where we can work. |
| 1978 | Farm Service Agency (Pinal C.) | Pat Fox | 8":1 mile; 2 1/2' photos. |

| | | | |
|---|---|---|---|
| 1972/73 | AZGS | Tom McGarvin | 1:4000; N.A.S.A. photography; need to double check for Pinal County coverage |
| ~1969 | Farm Service Agency (Pinal C.) | Pat Fox | Call to make arrangements to visit. |
| 1964 | Pinal C. Planning & Dev. | Pete McGrath & Jaunita Silvernagel | 9 south, 8 east, sections 31 &32; 10S, 8E, Ss 5-8, 17-20, 29 & 30; 6S, 5E, Ss 8-9, 16-17, 20-21, 28-29, 32-33; 7S, 5E, Ss 4-5. |
| 1954-58 | Pinal C. Planning & Dev. | Pete McGrath & Jaunita Silvernagel | complete around the SCR; better than the 1964 photoset. |
| 1953/56 | AZGS | Tom McGarvin | None for southern-most Santa Cruz County; need to double check for Pinal County |
| ~ 1954 & '56 | SCS-Pinal County | Mark Felix | incomplete with poor indices |
| 1936 | Desert Botanical Gardens | Pat Comus | Complete photoset. |

**Santa Cruz County:**

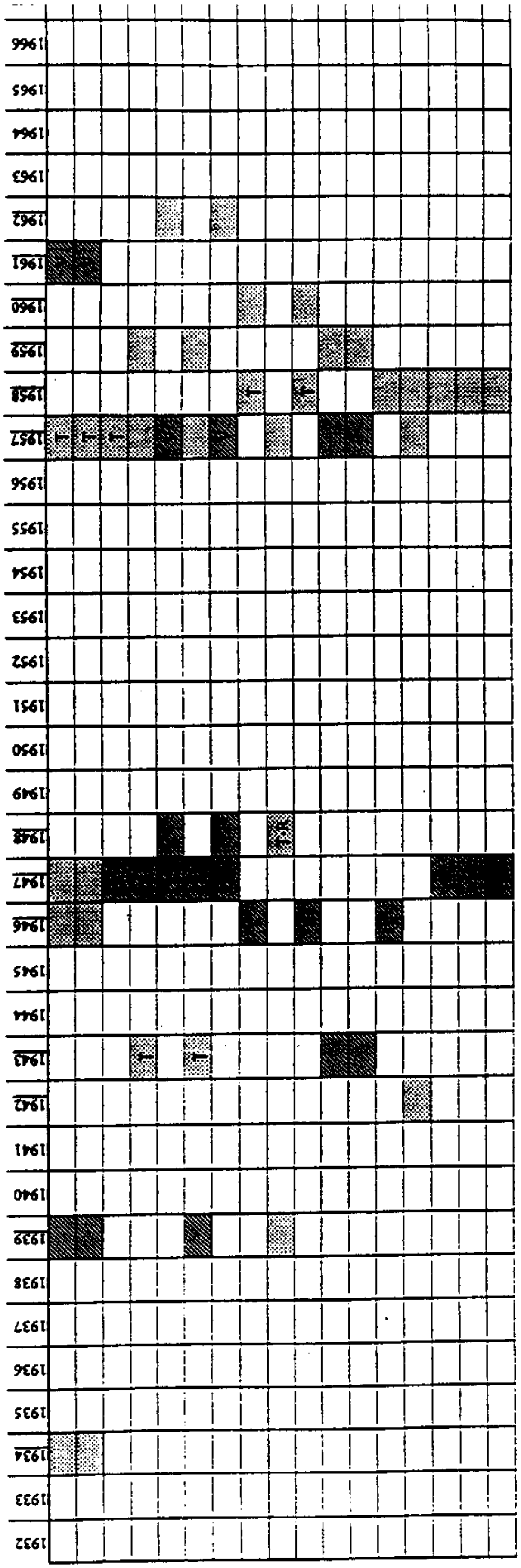
| Year | Agency | Contact | Comments |
|---|---|---|---|
| 1995 | AZ Dept. of Water Resources, SCAMA | Placido Dos Santos | Excellent photoset! Complete coverage of the Santa Cruz Active Management Area, color photos, ~1:24,000. |
| 1983/1984 | USGS, UA office | Brenda | Color Infrared; 1:60,000. Has good index. Coverage: just north of the Tucson Mts (~Marana); most/almost all of S.C. County. Can borrow this photoset with no problem; it is quite portable. |
| 1983 | Cooper Aerial | Beverly | Flood coverage; includes Pinal and Santa Cruz Counties. |
| 1979/80 | AZGS | Tom McGarvin | Cooper Aerial; 1:12,000; "Poor" coverage |
| 1977 | Cooper Aerial | Beverly | Flood coverage; does not include Pinal County; does include Santa Cruz County. |
| ~1978 | ESIC | Diane | Color photos of ~ 2 miles area on both sides of the international border. |
| 1972/73 | AZGS | Tom McGarvin | "Good" coverage; 1:4000; N.A.S.A. photography |
| 1953/56 | AZGS | Tom McGarvin | None for most of Santa Cruz County |
| 1936 (37/38) | Soil Conservation Service (Tucson Field Office) | Bud Bowers | Give a call to the field offfice to make an appointment to come see the photos |

# Appendix F
## Upper Santa Cruz River Basin - Collection of Topographic Maps

Note: all the maps prior to 1962 are 15 minute quadrangles or smaller scaled. After 1962, the maps are all 7.5 minute quadrangles unless otherwise indicated.

| 7.5' U.S.G.S. Quadrangle Names | | $ | 1902 | 1903 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 | 1920 | 1921 | 1922 | 1923 | 1924 | 1925 | 1926 | 1927 | 1928 | 1929 | 1930 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ruelas Canyon | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Jaynes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tucson North | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cat Mountain | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tucson | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Xavier | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tucson SW | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sahuarita | | | • | | | | | | | | | | | | | | | | | R | | | | | | | | | | | |
| Esperanza Mill | | | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Green Valley | | | • | | | | | | | | | | | | | | | | | R | | | | | | | | | | | |
| Amado | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tubac | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Cayetano Mtns. | | | | | | | | | | | | | | | | | | | | | | R | | | | | | | | | |
| Peña Blanca Lake | | | | | | | | | | | | | | | | S-04 | | | | | | | | | | | | | | V | |
| Rio Rico | | $ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cumero Canyon | | $ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Kino Springs | | $ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

KEY:
- Map located at AZGS.
- Map located in the UA Map Collection
- T - Map located at Tumamoc Hill (Julio Betancourt)
- O - Orthophotoquad series located in the UA Map Collection
- P - Photo-revised version
- R - Reprint
- V - Revised version
- S-## - Survey year, 19##
- $ - pre-Statehood
- 15 - Map is a 15' quad. rather than 7 1/2'.
- • - San Ignacio de la Canoa Private Land Claim Map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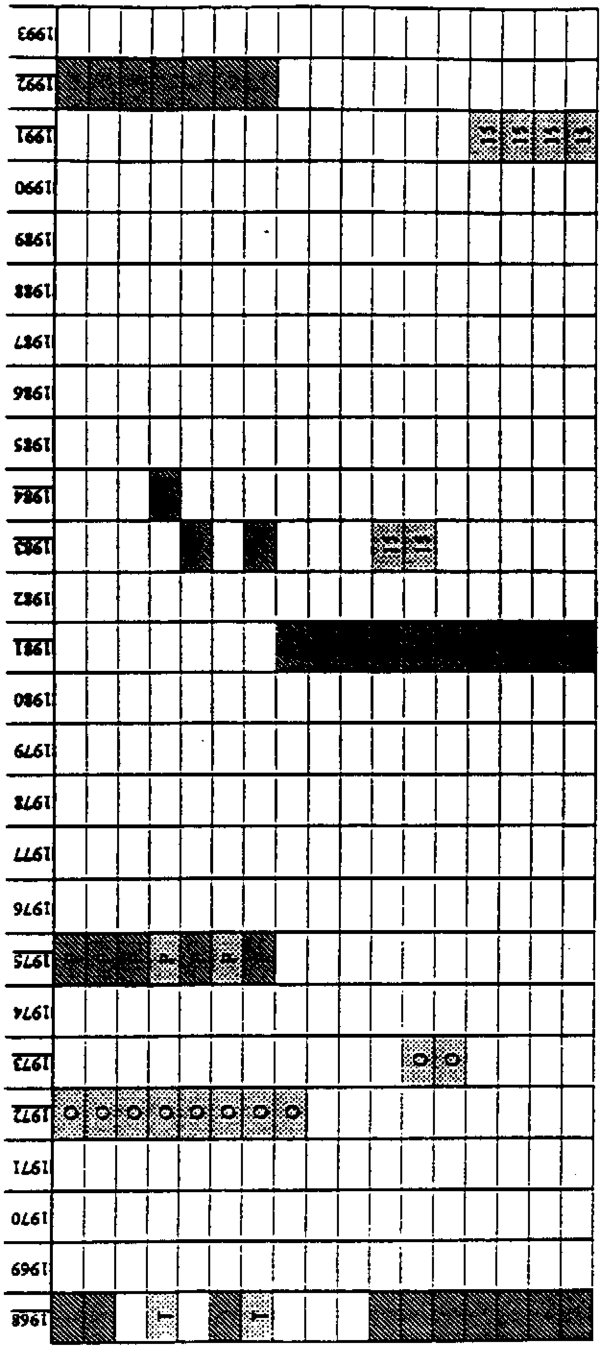
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## Appendix G

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Arizona State Land Department

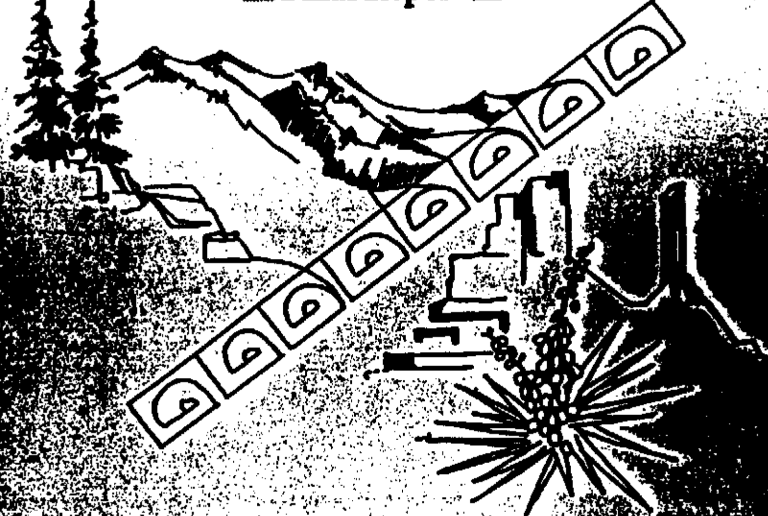
# ARIZONA STREAM NAVIGABILITY STUDY

*for the*

# SANTA CRUZ RIVER

**Gila River Confluence to the Headwaters**

**Final Report**



*Prepared by*

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**SWCA, Inc. Environmental Consultants,**

**University of Arizona Water Resources Research Center,**

*and the*

**Arizona Geological Survey**

November 1996

SECTION 5

**Navigable Rivers Land Use GIS**

## I. Methodology

A Geographic Information System (GIS) was developed depicting the 100-year floodplain and land ownership/use within the floodplain (see Appendix A for data organization). The GIS was designed not to aid in the determination of navigability, but to help study the impacts should the river be found navigable. Information regarding the ownership and use of land in the vicinity of the river may be depicted as maps or as statistics.

The general land ownership categories depicted by the GIS are as follows:

| Ownership Categories |
|---|
| Private |
| State of Arizona |
| Bureau of Land Management (BLM) |
| U.S. Forest Service |
| National Wildlife Refuge |
| National Park Service |
| Indian Reservation |
| Other / No Data |

The general land use categories depicted by the GIS are as follows:

| Land Use Categories |
|---|
| Vacant Land |
| Residential - Single Family |
| Residential - Multiple Family |
| Hotel - Motel - Resorts |
| Condominiums |
| Commercial Property |
| Industrial Property |
| Farm/Ranch Property |
| Public Utilities |
| Natural Resources |
| Special Use Property |
| General Service Use |

Additional data are also contained in the GIS, such as: county, township, range, section, book, map, parcel, source, legal parcel area, state land use code, and owner descriptions.

### A. Base Data

The base layers for the GIS, including rivers, counties, and public land survey system, were obtained from the Arizona Land Resources Information System (ALRIS) maintained by the

Arizona State Land Department (ASLD). Additional river data were obtained from 1:100,000 scale Digital Line Graph (DLG) files maintained by the United States Geological Survey (USGS).

**B. Floodplain**

The 100-year floodplain was digitized from Federal Emergency Management Agency (FEMA) maps of varying scales. Georeferencing (i.e. registration of map data to real world coordinates) was accomplished via section corners and, in a few circumstances, street intersections. Arbitrary lines were digitized at junctions with tributary floodplains. Adjacent maps were edgematched; significant mismatches were not adjusted but were closed using straight line segments.

**C. Land Ownership/Use**

Where GIS parcel datasets already existed, they were reprocessed and merged directly into the final product. This was only the case with the Pima County portion of the Santa Cruz River:

1) Parcels were requested from the Pima County GIS Project by section,

2) Section tiles were combined into a single coverage and reprocessed,

3) The Santa Cruz River parcel dataset was updated with the Pima County data and sliver polygons removed, and

4) Parcels outside the floodplain were assigned zero attributes and dissolved.

Otherwise, parcels were digitized from paper County Assessor maps. Georeferencing was accomplished using the following:

1) Section corners or subdivisions (e.g. quarter-quarter-section corners),

2) Legal descriptions using a section corner or subdivision as a reference point,

3) Distances, based on map scale, from a section corner or subdivision,

4) Corresponding features in a smaller scale map (e.g. a map of a housing development might be registered via its corresponding outline depicted in a section map), and/or

5) Adjacent features.

Digitizing was accomplished as follows:

1) Clearly delineated parcel boundaries were digitized as depicted. Lines in large scale maps generally took precedence over corresponding lines in small scale maps.

2) Areas of parcel overlap were assigned to one parcel or the other as deemed best. Unclear boundaries between two parcels were digitized according to best judgement.

3) Parcels of vague or undepicted location were not digitized unless an outline could be obtained from an alternate source (e.g. ALRIS data or USGS 1:100,000 DLG files).

4) Linear (non-polygonal) parcels, depicting railroad right-of-way (ROW), were not digitized. An exception was made if adjacent parcels clearly depended on a ROW edge, in which case a 200' wide corridor was applied.

When necessary, adjacent maps were edgematched. Small scale features were adjusted to large scale features. Attributes were assigned in a fashion consistent with ASLD's standards utilized for the Gila River coverage:

1) Parcel numbers were assigned where clearly designated, unless the parcel clearly was non-private (State, BLM, etc.), in which case a "non-private" parcel code (AZ, BLM, etc.) was assigned.

2) Parcels which were not numbered, but were clearly labeled (Arizona, U.S.A., etc.) were assigned non-private codes as appropriate. Where a conflict existed between assessor maps and ALRIS data over USA versus State ownership, the ownership reflected in the ALRIS data was assigned.

3) Unlabeled or questionable parcels, uncoded road and rail ROW parcels, parcels outside the floodplain, and undigitized regions were assigned a zero parcel number.

4) Sections outside the study area were assigned "background" (BACK) parcel codes.

Relate files, containing land ownership and use data, were generated from State Revenue data. A list of parcel values was generated from the digitized parcels and submitted to the State Revenue office. Data received from the State Revenue office were converted to a table and reprocessed. If, after a quality check, the ID of a digitized parcel was not listed in the State Revenue data (e.g., if a parcel split or merge had not yet been depicted on the County Assessor map), it was assigned "Other / No Data" ownership.

**D. Plots**

Once all datasets were assembled, checked, and finalized, they were transported to the State Land Department building in Phoenix. Annotation coverages were created for the final plots, and existing scripts and tables adapted to production of the final plots. One complete series was created for each river reach.

## II. Results and Discussion

The study area was divided into fourteen map sheets for plotting purposes. The 100-year floodplain was digitized for the entire study area, except within the Gila River, Ak-Chin, and San Xavier Indian Reservarions. All parcels in the Pinal County and Santa Cruz County portions of the study area were digitized from paper maps. All study area parcels in Pima County were obtained from the Pima County GIS Project.

Two problem areas have been identified in Santa Cruz County: the Baca Grant region and the headwaters of the Santa Cruz River.

A significant gap in the data exists within the former Baca Grant in Santa Cruz county. Parcel data are available in digital form for that region, but access has not been granted by the Santa Cruz County Planning and Zoning Department. Marlene Shields of ASLD is currently investigating the situation, but the final GIS submitted to ASLD will not contain data for that area.

A discrepancy has been noted regarding the alignment of the headwaters of the Santa Cruz River. Data obtained from ALRIS depict the headwaters passing through Sheep Ranch Canyon in Township 22S, Range 17E, whereas other maps show the river passing through Meadow Valley in the same Township and Range. Parcels have been digitized along both reaches.

## Appendix A: GIS Data Organization

### A. Base and Reference Layers from ALRIS

| Name | Contents |
|---|---|
| AZTRS | Public Land Survey System of Arizona |
| COUNTIES | County Boundaries |
| HYDRO | Hydrology |
| LAND | Surface Management |
| RAILS | Railroads |
| TRANS123 | Major Roads |

### B. Data Organization

A separate workspace is created for each river reach. The principal ARC/INFO coverages contained in each workspace are FLOOD, depicting the 100 year floodplain, PARCELS, containing digitized parcels, RIVER, depicting the river itself, and SHEETS, depicting the mapsheets.

#### 1. FLOOD

The FLOOD coverage has polygon topology wherever possible. The PAT contains the following item:

| ITEM NAME | WIDTH | TYPE | N.DEC |
|---|---|---|---|
| IN_OUT | 3 | C | 0 |

**IN_OUT Values:**
in = Part of floodplain
out = Not part of floodplain

#### 2. PARCELS

The PARCELS coverage has polygon topology. The PAT contains the following items:

| ITEM NAME | WIDTH | TYPE | N.DEC |
|---|---|---|---|
| TOWNSHIP | 4 | C | 0 |
| RANGE | 4 | C | 0 |
| SECTION | 2 | C | 0 |
| COUNTY | 2 | N | 0 |
| BOOK | 3 | C | 0 |
| MAP | 3 | C | 0 |
| PARCEL | 4 | C | 0 |

| ITEM NAME | WIDTH | TYPE | N.DEC |
|---|---|---|---|
| CODEDATE | 8 | D | 0 |
| OWN_CODE | 12 | C | 0 |
| SOURCE | 20 | C | 0 |
| CATEGORY | 10 | C | 0 |

Items TOWNSHIP, RANGE, SECTION, and COUNTY conform to the data dictionary of the ALRIS LAND layer.

Parcels which have a book, map, and parcel number, are coded as follows:

| ITEM | Example |
|---|---|
| COUNTY | 9 |
| BOOK | 103 |
| MAP | 043 |
| PARCEL | 1A |
| OWN_CODE | 091030431A |

Other parcels are coded as follows:

STANDARD CODES FOR NON-PRIVATE PARCELS

| ITEM | Example |
|---|---|
| BOOK | 101 |
| MAP | 040 |
| PARCEL | 0 |
| OWN_CODE | 0 |

**PARCEL Values:**
0 = No data or "other" (e.g. Right-of-Way)
AKCH = Ak-Chin (Maricopa) I.R.
ASNF = Apache-Sitgreaves NF
AZ = State of AZ
BLM = BLM
BWR = Bill Williams N.W.R.
CONF = Coronado National Forest
GILA = Gila River I.R.
NAV = Navajo I.R.
PFNP = Petrified Forest NP
SANC = San Carlos I.R.
SANX = San Xavier I.R.
SALT = Salt River I.R.
SRWR = Salt River N.W.R.

**PARCEL Values:**
TOHO = Tohono O' Odham (Papago) I.R.
TONF = Tonto National Forest
TONM = Tonto National Monument
WMA = White Mountain Apache I.R.

"Background" parcels, i.e., sections outside the study area, are coded as follows:

| ITEM | Example |
|---|---|
| BOOK | 999 |
| MAP | 999 |
| PARCEL | BACK |
| OWN_CODE | BACK |

The CODEDATE item contains the date of completion of the coverage. The principal source used to determine the geometry of a particular parcel is documented via the SOURCE item.

**SOURCE Values:**
ASLD Base = Base data from AZ State Land Dept. (AZTRS)
County/Paper = County Assessor paper maps
County/Digital = County Assessor digital maps
County/GIS = County GIS
USGS 100K DLG = USGS 1:100,000 DLG files
ALRIS LAND = ALRIS LAND coverage
Various = Various Sources

The CATEGORY item is a temporary item used in the generation of status maps.

Each PARCEL coverage has a relate file, OWNDATA, with the following structure:

| ITEM NAME | WIDTH | TYPE | N.DEC |
|---|---|---|---|
| OWN_CODE | 12 | C | 0 |
| OWNER | 2 | N | 0 |
| LC | 2 | C | 0 |
| DEL_FLAG | 1 | C | 0 |
| STATUS_DAT | 8 | D | 0 |
| LAND_USE | 4 | C | 0 |
| AREA | 8 | C | 0 |
| UNITS | 1 | C | 0 |
| OWNER1 | 40 | C | 0 |
| OWNER2 | 40 | C | 0 |
| OWNER3 | 40 | C | 0 |

OWN_CODE is the relate item to the PARCELS coverage. OWNER is the ownership lookup code and LC the use lookup code, used for querying and plotting. DEL_FLAG is a State Revenue record code, probably indicating a record slated for future deletion. STATUS_DAT is the date of the record. LAND_USE is the four-digit State land use code. AREA is the legal area of the entire parcel. UNITS is the units of the legal area (acres or square feet). OWNER1 through OWNER3 are the first three fields of the taxpayer name and address section.

### 3. RIVER

The RIVER coverage has line topology. There are no additional attribute items.

### 4. SHEETS

The SHEETS coverage has line topology. The AAT contains the following item:

| ITEM NAME | WIDTH | TYPE | N.DEC |
|---|---|---|---|
| SHEET | 2 | N | 0 |

Values correspond to the mapsheet number.

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Arizona State Land Department

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**Arizona Geological Survey**

November 1996

SECTION 6

## SUMMARY

A.R.S. §37-1101 through §37-1156 specify the procedures and criteria for determining the navigability or non-navigability of watercourses in Arizona. The key findings of the research into the archaeology, history, hydrology, hydraulics, geomorphology, and land use of the Santa Cruz River are presented below in a sequence compatible with the criteria itemized in A.R.S. §37-1128. This information is summarized to support a decision by others regarding the navigability, susceptability to navigation, or non-navigability at the time of statehood of the Santa Cruz River from the confluence with the Gila River to the headwaters.

**General Criteria of Non-navigability**

A.R.S. §37-1128, C. stipulates that the Arizona Navigable Streams Adjudication Commission (ANSAC) shall find and recommend that a watercourse was non-navigable if, as of 14 February 1912, the watercourse either: 1) was not used or susceptible of being used for both commercial trade and travel; or 2) flowed only in direct response to precipitation and was dry at all other times.

Commercial Trade and Travel

In the case of the Santa Cruz River, archaeological research indicates that the river valley functioned as a communication, transportation, and trade corridor in prehistoric times. The Tucson Basin served as a local node in the Hohokam regional system. Interregional exchange is evident by the presence of Mogollon ceramics from the mountainous regions to the east and by shell artifacts from the Sea of Cortez. Further, the Santa Cruz River was the line of communication for the dissemination of new types of pottery throughout the northern and southern extremities of the river. No evidence was found to suggest that the early inhabitants of the valley used boats on the river.

In historic times, the Santa Cruz River has been an important transportation route for Native Americans, missionaries and Spanish explorers, colonizers and wanderers, miners and cattleman, and new residents. It was a well established route from the south and the east into present-day Arizona as far as Tucson, providing water, forage, and food for the traveler. Although the river was an important transportation route, it was not normally used for navigation except for isolated accounts found in the literature. A few instances of boating on the river are reported, but the perennial flow that existed on the river historically was such that it was never regularly navigated.

Hydrologic Characteristics

Historically (circa the 1890's), the upper Santa Cruz River was perennial from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the international border during the 1930 to 1950 drought period, resulted in no flow in the channel in Sonora, Mexico, and discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales (the earliest in that region), indicates that by the time of statehood, the Santa Cruz River near Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer, and fall. The 1913 winter discharge averaged about 15 cubic feet per second (cfs), except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. Based on interpolation of the stage-discharge curve for the Nogales gage plotted from the USGS data measured in 1959, an average winter discharge of 15 cfs in 1913 corresponds to a water depth of approximately 0.3 feet (3.6 inches). A survey of the daily data for the rest of the Nogales record indicates that, during wet years, there were only a few days of no flow recorded in the channel.

The middle Santa Cruz River historically had several springs and cienegas within its channel from Tubac to Tucson. A review of the daily discharge record indicates that there was some semblance of baseflow with an average of about 12 cfs during the fall and winter of 1912-1913 at the Tucson gage. An average daily discharge of 12 cfs corresponds to a water depth of approximately 0.2 feet (2.4 inches) based on interpolation of the stage-discharge curve developed from USGS data measured in 1955. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons.

There is no record indicating that the lower Santa Cruz River ever supported perennial flow. Only the very largest floods were sustained from the headwaters to the confluence with the Gila River, according to the historical record. The Laveen gage recorded nearly year-round flow from its beginning date in 1940 until June 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions and had peaks as high as 5,060 cfs during wet periods. Historically, the Santa Cruz River had a marsh at its confluence with the Gila River near Laveen. By 1960, the Santa Cruz River at Laveen was experiencing no flow conditions for months at a time.

**Specific Criteria of Non-navigability**

A.R.S. §37-1128, D. states that unless there is clear and convincing evidence that a watercourse was navigable, it is presumed, and the Commission shall find and recommend, that the watercourse was non-navigable if, with respect to the watercourse as of 14 February 1912, any of the following apply:

1. no sustained trade and travel occurred both upstream and downstream in the watercourse;

   *Although the Santa Cruz River was an important transportation and trade route in both upstream and downstream directions, it was not normally used for navigation except for a few isolated accounts found in the literature.*

2. no profitable commercial enterprise was conducted by using the watercourse for trade or travel;

   *No evidence of navigation of the river for the purpose of commercial trade and travel was found.*

3. vessels customarily used for commerce on navigable watercourses in 1912, such as keelboats, steamboats or powered barges, were not used on the watercourse;

   *A land speculator portrayed the river at Calabasas (west of Nogales) as capable of floating steamboats in the 1880's. This, however, was pure fiction but gave rise to the belief that surfaces, occasionally even today, that the river was navigated by large ships.*

4. diversions were made from the watercourse to irrigate and reclaim land by persons who made entries under the Desert Land Act of 1877, as amended (43 United States Code Sections 321 through 339), any other Federal act or to provide water to lands that are included in a Federal reclamation project or an Indian reservation that would have been inconsistent with or impediments to navigation;

*The U.S. Geological Survey Streamgage Summaries report that essentially the entire flow of surface waters from the river were diverted both at the Nogales and Tucson gaging stations by irrigation ditches (USGS 1907,1912). Agricultural water use in the Tubac, Tucson, and San Xavier areas used most of the available surface water and also intercepted groundwater and subsurface flow.*

5. any boating or fishing was for recreational and not commercial purposes;

*The Santa Cruz River provided water, wood, food, and shelter for the people who lived near it. Early inhabitants supplemented their diet with the fish caught from the river. The perennial waters near San Xavier persisted until 1949, and supported native fish until at least 1937.*

*During the 1880's, Silver Lake (a manmade lake just south of downtown Tucson on the Santa Cruz River) was a popular recreation area, featuring boating, fishing, and swimming. A paddle boat on the lake was a major attraction. Boating both by rowing and sail was popular in the lake and upstream. Silver Lake was damaged by a combination of floods in the late 1880's, and finally destroyed in 1890.*

*Warner Lake was built about one-half mile north (downstream) of Silver Lake by Solomon Warner in 1883-*

*1884. Betancourt and Turner (1990) cited the Arizona Daily Star, 7 June 1888 as reporting up to 500 pounds of fish having been harvested from Warner Lake in 1888 for sale in Tucson. Review of the cited issue of the paper found the only reference to fish to be Tucson's "lakes and ponds are filled with carp, whose rapid growth is wonderful reaching five pounds or more in three years." A noted natural historian in Arizona offered the opinion that it is unlikely that the lake could have supported as much as 500 pounds of fish biomass (Neil Carmony, personal communication, 1996). No evidence of commercial fishing of the Santa Cruz River was found.*

6. any flotation of logs or other material that occurred or was possible on the watercourse was not and could not have been regularly conducted for commercial purposes;

*No evidence was found of the river being used to transport goods such as logs.*

7. there were bridges, fords, dikes, manmade water conveyance systems or other structures constructed in or across the watercourse that would have been inconsistent with or impediments to navigation;

*During Anglo settlement of the Tucson valley, perennial water was used for irrigation. In the 1880's, two dams were constructed near Tucson to provide water for grain and ore mills. The lakes behind the dams also provided the community with recreational swimming, boating, and fishing. By 1912, the U.S. Geological Survey reported that the entire low flow of the river was diverted at both the Nogales and Tucson gages, making navigation highly unlikely in low flow conditions.*

*In the lower Santa Cruz River, the construction and subsequent flood damage of Greene's Canal resulted in dramatic geomorphic changes. Before the construction of Greene's Canal in 1910, the river transformed from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain at a point in the Marana area. Prior to and during the floods of 1914-1915, flood flow had the opportunity to follow routes down the North Branch of the Santa Cruz Wash and McClellan Wash. After the development of the arroyo in the channel of Greene's Canal, subsequent flood flows follow westerly paths away from the main river channel.*

8. transportation in proximity to the watercourse was customarily accomplished by methods other than by boat;

*The archaeological record contains no evidence to suggest that the early inhabitants of the valley used boats on the river. According to the historical record, at least one major travel route followed the course of the river; however, boating is documented on portions of the Santa Cruz River <u>only</u> on rare occasions and <u>not at all</u> in the lower reach. Transportation in proximity to the river was customarily accomplished by methods other than by boat. Those methods well documented in the record include travel by horseback or freight wagon.*

9. the United States did not regulate the watercourse under the Rivers and Harbors Act of 1899 (33 United States Code Sections 401 through 467e).

*The Santa Cruz River was not regulated under this Act.*

**Specific Criteria of Navigability**

A.R.S. §37-1128, E. states that in finding whether a watercourse was navigable, the ANSAC shall not consider:

1. waters that had been appropriated for beneficial uses on or before 14 February 1912 as being within the ordinary and natural condition of the watercourse;

    *By 1910, it was reported that the entire base flow of the Santa Cruz River at both the Mexican border and near the Congress Street bridge in Tucson was diverted for agriculture.*

2. the use of ferries to cross a watercourse;

    *There are no records of ferry service anywhere on the river. Fords and crossable washes are marked on numerous maps. When the bridges went out during floods, people were stranded and had to wait until the river could be crossed by horse. No evidence of boats being used to cross the river at flood time were found.*

3. fishing from the banks of a watercourse;

    *Although research indicates that native fish were caught for recreation and for human consumption, no documentation was found as to the manner in which the fish were caught.*

4. uses of the watercourse under flood conditions.

    *Most accounts of boating on the river occurred during flood events.*

A.R.S. §37-1128, F. states that in finding whether a watercourse was navigable, the Commission shall consider the existence of dams and diversions of water and the impact of other human uses that existed or occurred at the time of statehood as part of the ordinary and natural condition of the watercourse.

# GLOSSARY

**Acequia** - An irrigation ditch or canal.

**Aggradation** - Progressive deposition of sediment, raising the elevation of the streambed. See Degradation.

**Alluvial** - See Alluvium.

**Alluvial Fan** - A large fan-shaped accumulation of sediment; usually formed where a stream's velocity decreases as it emerges from a narrow canyon onto a flatter plain at the foot of a mountain range.

**Alluvial Stream** - A stream whose bed and banks are formed in sediment transported by the stream itself; a stream with a non-bedrock channel.

**Alluvium** - A general term for eroded rock material, including soil, deposited by rivers; loose sediment, often from the recent geologic past.

**Anecdotal** - Undocumented evidence or accounting of an event.

**Aquifer** - A water-bearing bedrock or alluvium layer.

**Archaeology** - The systematic recovery, and scientific study, of material evidence of human life and culture from past ages. The study of antiquity.

**Arroyo** - A term used in the southwest to describe an entrenched, dry wash.

**Average Flow** - See Mean Flow.

**Avulsion** - In geomorphology, an avulsion is the sudden relocation of a stream away from its original flow path, usually due to catastrophic sediment deposition in the original flow path.

**Bajada** - A piedmont comprised of coalescing alluvial fans.

**Base Flow** - Stream discharge which does not fluctuate in response to precipitation. The minimum discharge in a stream.

**Base Level** - The minimum elevation to which a stream can erode.

**Basin and Range** - One of three physiographic provinces in Arizona. The Basin and Range is characterized by elongated, parallel mountain ranges trending northwest to southeast, with intervening basins filled by alluvium eroded from the mountains.

**Braided** - A braided stream is one flowing with branching and reuniting channels. May be ephemeral or perennial.

**Cadastral Survey** - A land (legal) survey.

**Central Mountain Province** (Transition Zone) - One of three physiographic provinces in Arizona, characterized by deeply eroded mountains composed of granitic bedrock.

**CFS** - Abbreviation for cubic feet per second, a measure of the rate of stream flow.

**Channelization** - The process of a stream changing from a broad unconcentrated flow path to a more confined, or single flow path.

**Confluence** - The point where two streams join.

**Continuous Gage** - A type of stream measuring equipment that records water surface elevations continuously throughout a flood, or over a long period of time regardless of flow conditions. Water surface elevations in the stream can be related to discharge rate.

**Control** - The river reach or structure which governs stream flow characteristics at a stream gage is called the control. A gage with reliable, consistent stream flow characteristics has "good control."

**Crest Stage Gage** - A type of stream measuring equipment that records only the highest water surface elevation during a flood or flow event. Water surface elevation can be related to stream discharge rate through use of a rating curve. See Continuous Gage.

**Degradation** - Channel bed erosion resulting in a topographically lower streambed.

**Dominant Discharge** - The dominant discharge is the stream flow rate responsible for forming a stream's geometry. This theory is tenuous when applied to streams in Arizona or bedrock streams.

**Empirical** - Empirical methods are based on experimentally derived equations, rather than theoretically derived equations.

**Entrenchment** (Entrench) - Progressive degradation of a streambed or channel resulting in a topographically lower channel bottom usually with steep or vertical banks; a process associated with arroyo formation.

**Ephemeral Stream** - A stream which flows only in direct response to rainfall. It receives little or no water from springs and no long continued supply from snow or other sources. Its channel is at all times above the water table.

**Equilibrium** - Balance. When applied to streams, equilibrium means lack of change.

**Erosion** - Removal of bedrock or alluvium by water or wind.

**Flash Floods** - Floods which reach their peak discharge rate very quickly are flash floods. In Arizona, the term is often used to describe a flood or flow event moving down a previously dry river channel.

**Flow Duration Curve** - A cumulative frequency curve depicting the percent of time a given discharge on a stream is equaled or exceeded in a specific period. For instance, a 10 percent flow of 20 cfs means that the stream discharge only exceeds 20 cfs, 10 percent of the time;

a 90 percent flow of 1 cfs means that the stream flows at discharges greater than 1 cfs, 90 percent of the time; the 50 percent flow is the median (not average) flow rate.

**Fluvial** - Relating to stream flow.

**Fluvial Geomorphology** - The branch of geomorphology relating to streams. See Geomorphology.

**Ford** - A river crossing; usually, but not necessarily, with shallow flowing water.

**Frequency Distribution** - A table which presents data in a number of small classes for use in statistical treatments of the data.

**Geomorphic** - Parameters or variables relating to geomorphology.

**Geomorphology** - A branch of geology concerned with the formation, characteristics, and processes of landforms, including rivers.

**GIS** - Geographic Information System. A database which relates information to spatial characteristics of some land area.

**Ground Water** - Water stored or moving beneath the ground surface, usually in pore spaces in alluvium, or voids in bedrock.

**Ground Water Decline** - Lowering of the elevation or volume of ground water relative to the ground surface.

**Ground Water Discharge** - Transfer or flow of water from underground sources into surface water; a spring.

**Headcutting** - A process of channel bed erosion whereby a sharp break in the average channel bed slope moves upstream, rapidly lowering the channel bed elevation.

**Headwaters** - The point, or area, where a stream originates; or the most upstream point of a stream.

**Holocene** - The most recent epoch of geologic history, usually the past 10,000 years before present; part of the Pleistocene geologic period.

**Hydraulics** - The science or technology of the behavior of fluids. Characteristics of stream flow such as depth, velocity, and width.

**Hydrology** - A branch of engineering concerned with water. In the context of this report, hydrology means the characteristics of water flow.

**Incised Channel** - A stream or waterway which has eroded its bed, creating steep or vertical stream banks. An arroyo, or degraded stream channel.

**Infiltration** - The process whereby water passes through an interface, such as from air into soil.

**Instantaneous Flow Rate** - Stream discharge at an instant in time, as opposed to a discharge averaged over a period of time. See Mean Flow.

**Intermittant Stream** - A stream which flows only for portions of the year, but has sustained flow for a period after rainfall. See Perennial Stream and Ephemeral Stream.

**Mean Flow** - The mean flow of a river is determined by dividing the total runoff volume by the time in which that volume was discharged, i.e. mean annual flow is the average rate at which the average yearly flow volume would be discharged.

**Median Flow** - The flow rate which is exceeded 50 percent of the time (conversely, the rate is not exceeded 50 percent of the time).

**Morphology** - The shape or geometric characteristics, especially of a stream or stream reach.

**Navigable** (Navigable Watercourse) - A watercourse, or portion of a reach of a watercourse, that was in existence on February 14, 1912, and that was used or was susceptible to being used, in its ordinary and natural condition, as a highway for commerce, over which trade and travel were or could have been conducted in the customary modes of trade and travel on water.

**Perennial Stream** - A stream which flows year round; non-zero base flow.

**Permanent Water** - Perennial stream flow.

**Permeable** - A rock or soil unit which is permeable will allow water to pass through it.

**Phreatophytes** - Deep-rooted plants that obtain water from the water table or the layer of soil just above it.

**Physiographic Province** - A region of similar geology. In Arizona, three physiographic provinces are recognized: the Basin and Range, the Central Highland (Transition Zone), and the Colorado Plateau.

**Pleistocene** - The most recent geologic period, usually the past 1,000,000 years before present.

**Point of Zero Flow** - The stage on a rating curve or gage record where no discharge occurs.

**Quit claim** - A transfer of one's interest in a property, especially without a warranty of title to give up claim to property by means of a quit claim deed.

**Quit claim deed** - A deed that conveys to the grantee only such interests in property as the grantor may have, the grantee assuming responsibility for any claims brought against the property.

**Rating Curve** - A graph which relates stream discharge to some other measurable stream characteristic such as stage, width, depth, or velocity.

**Reach** - A segment of a stream, usually with uniform characteristics.

**Riparian** - Refers to that which is related to, or located near, or living along a watercourse whether natural, man-made, ephemeral, intermittent, or perennial.

**Salt Cedar** - A non-native, undomesticated tamarisk tree.

**Scour** - Removal of streambed material by flowing water.

**Seep** - A small, diffuse spring generally of low discharge rate.

**Sinuosity** - A measure of how sinuous a stream is: the ratio of the length along the thalweg to the length along the stream valley. Always greater than one.

**Sinuous** - The "curviness" of the channel planform; the degree of meandering.

**Spring** - The point where underground sources of water discharge at the surface.

**Stage** - A term used in stream gaging to describe the elevation of the water surface of a stream relative to some datum (fixed elevation). Stream stage is analogous to stream depth.

**Stream Gage** - A site operated for the purpose of measuring the rate or volume of water discharge in a stream. Accumulated data from a stream gage are called stream gage records.

**Subflow** - See Underflow.

**Tamarisk (salt cedar)** - Non-native riparian plants. Presently the dominant vegetation on the floodplain of many streams due to opportunistic growth in channel systems in the southwestern United States.

**Terrace** (Bench) - A relatively flat geologic or geomorphic surface which parallels a stream and is elevated above the floodplain, and was formed when the river flowed at a higher elevation.

**Thalweg** - The centerpoint, or low flow channel, of a stream.

**Topwidth** - The distance across the water surface, perpendicular to the channel, of a flowing stream.

**Transition Zone** - See Central Mountain Province.

**Transmission Losses** - Reductions in stream flow due to infiltration of water into the streambed and subsurface.

**Underflow** - A term used interchangeably with subflow to describe the ground water underlying the surface of a stream's channel.

**Unentrenched** - See Entrenchment.

**Wash** - A river or stream with low banks and numerous channels.

**Water Table** - The upper surface of the underground zone of saturation; the plane which represents the elevation of ground water.

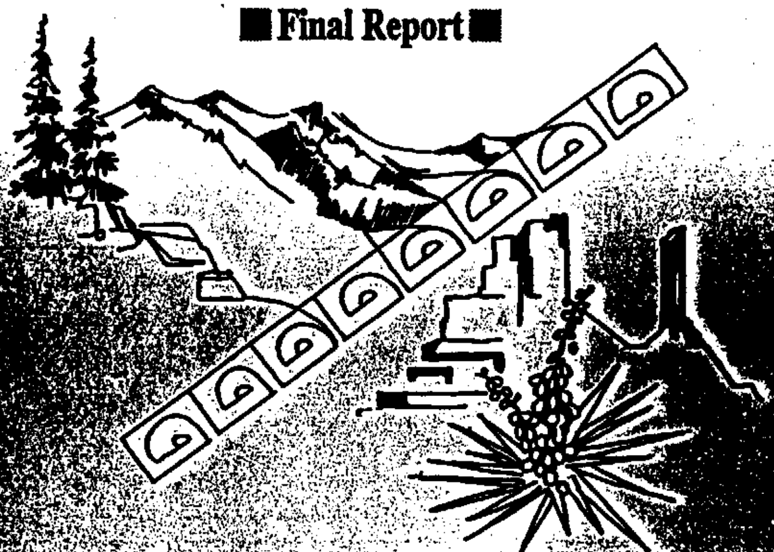
**Watershed** - The land area draining into a stream, or other body of water.

**Xerophytes** - Plants that are structurally adapted for life and growth with a limited water supply.

Arizona State Land Department

# ARIZONA STREAM NAVIGABILITY STUDY
*for the*
# SANTA CRUZ RIVER
**Gila River Confluence to the Headwaters**

**Final Report**

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*and the*
**Arizona Geological Survey**



November 1996


ACRONYMS

## LIST OF ACRONYMS

| | |
|---|---|
| Arizona Geological Survey | AZGS |
| Arizona Land Resource Information System | ALRIS |
| Arizona Navigable Stream Adjudication Commission | ANSAC |
| Arizona Revised Statutes | A.R.S. |
| Arizona State Land Department | ASLD |
| Arizona Upland | AU |
| Bureau of Land Management | BLM |
| Cubic feet per second | cfs |
| Federal Emergency Management Agency | FEMA |
| Flood Insurance Rate Map | FIRM |
| General Land Office | GLO |
| Geographic Information System | GIS |
| House Bill | HB |
| Lower Colorado River Valley | LCRV |
| Right of Way | ROW |
| Santa Cruz River | SCR |
| US Geological Survey | USGS |

1985). This increase in magnitude and number of flows in the fall and winter results from a shift in the seasonal distribution of precipitation. Webb and Betancourt (1992) explain the shifts in the seasonal distribution of precipitation in terms of fluctuations in large-scale oceanic and atmospheric processes:

> "Twentieth-century climatic variability stems from decadal trends in atmospheric circulation over the Northern Hemisphere and in the frequency of El Niño-Southern Oscillation (ENSO) phenomena in the equatorial Pacific Ocean. Before 1930 and after 1960, westerly winds on average followed a more meridional path, and ENSO conditions occurred more frequently and with greater variability in the equatorial Pacific. By contrast, the westerlies followed a more zonal flow, and ENSO conditions occurred less frequently with less variability between 1930 and 1960. Meridional circulation and the climatology associated with ENSO conditions enhance Tucson precipitation in the winter, spring, and fall and possibly reduce summer rainfall." (Webb and Betancourt, 1992, p.35-36) ..... "Winter frontal storms are more numerous and intense during certain ENSO years... the probabilities for generation and recurvature of tropical cyclones change during ENSO conditions, but the advection of moisture needed to fuel monsoonal storms is reduced. Hypothetically, ENSO conditions could reduce the number of monsoonal storms but increase the number of frontal systems and tropical cyclones that affect Arizona." (Webb and Betancourt, 1992, p. 12)

Arizona's Statehood occurred during a period characterized by relatively intense winter storm activity. Such intense storm activity, when combined with human activities and other riverine processes, resulted in significant geomorphic changes of the Santa Cruz River channel. These changes and other related hydrologic changes associated with the shift from fall-winter dominated precipitation, to summer dominated and then back to fall-winter dominated, are described in greater detail in the chapters on hydrology and geomorphology.

## IV. VEGETATION

The type and density of vegetation in the Santa Cruz River basin also directly and indirectly affects the character of the Santa Cruz River. For example, the presence of vegetation affects channel form by stabilizing the channel banks against erosion, and affects flow by withdrawing quantities of water that would otherwise contribute to either surface flow or ***subflow*** in the channel. Vegetation indirectly affects the character of the river by how it impedes runoff during precipitation events. Relationships between vegetation, hydrology and geomorphology are discussed in greater detail in the following chapters on hydrology and geomorphology. The purpose of this chapter is to give a brief survey of vegetation types present in the upper and lower Santa Cruz River basin and to provide a description of how that vegetation has changed since the time of Statehood. The Latin names of all plants mentioned in the following text are listed in Table 1.

**A. Vegetation Types**

The vegetation cover of the upper Santa Cruz River basin is dominated by semidesert grasslands at elevations between 3000 and 5500 feet, plains grasslands between 4500 and 6000 feet, evergreen woodland between 4000 and 7000 feet, and ponderosa pine and mixed-conifer forests above 7000 feet. Prominent grasses in the semidesert grasslands community are the gammas, threeawns, tobosa, curly mesquite, cotton grass, and bush muhly. The plains grasslands community, in which grasses form a mostly continuous cover, is dominated by such perennial grasses as the gramas, bluestems, plains lovegrass, threeawn, galleta, and plains bristlegrass. Historically, there have been increases in the woody shrubs such as snakeweed and acacia, and in trees such as mesquite and one-seed juniper in the grasslands area. The evergreen woodland community is composed mostly of oaks, the most prevalent being Emory oak, Arizona white oak, and Mexican blue oak. Interspersed among the oaks are alligator juniper, one-seed juniper, and Mexican pinyon. The ponderosa pine and mixed-conifer forests account for only a very small area of the total vegetation cover, occupying the upper parts of the Santa Rita, Santa Catalina, Huachuca, and Rincon mountains. This vegetation community is dominated by ponderosa pine, Douglas fir, and white fir, with some aspen, and Gambel oak.

Riparian forests line some reaches of the Santa Cruz River and its tributaries. Such forests are composed predominantly of cottonwood and willow with dense thickets of mesquite, and other important riparian trees such as Arizona sycamore, velvet ash, walnut, and saltcedar or tamarisk, an introduced tree that has invaded nearly all of southeastern Arizona's major riparian habitats below 5,000 feet.

**Table 1. Vegetation Communities in the Santa Cruz River Basin.** [Source: Bahre, 1991]

## A. Upper Santa Cruz River Basin:

*Semidesert Grasslands Community:*
- acacia/catclaw (Acacia greggii)
- burroweed (Haplopappus tenuisectus)
- bush muhly (Muhlenbergia porteri)
- cotton grass (Trichachne californica)
- curly mesquite (Hilaria belangeri)
- gammas (Bouteloua spp.)
- mesquite (Prosopis spp.)
- one-seed juniper (Juniperus monosperma)
- snakeweed (Gutierrezia sarothrae)
- threeawns (Aristida spp.)
- tobosa (Hilaria mutica)

*Ponderosa Pine and Mixed-Conifer Forests:*
- Douglas fir (Pseudotsuga menziesii)
- Gambel oak (Quercus gambelii)
- ponderosa pine (Pinus ponderosa)
- quaking aspen (Populus tremuloides)
- white fir (Abies concolor)

*Plains Grasslands Community:*
- bluestems (Andropogon spp.)
- galleta (Hilaria jamesii)
- gramas, perennial grasses (Bouteloua spp.)
- plains bristlegrass (Setaria macrostachya).
- plains lovegrass (Eragrostis intermedia)
- threeawn (Aristida spp.)

*Evergreen Woodland Community:*
- Arizona white oak (Quercus arizonica)
- Emory oak (Quercus emoryi)
- Mexican blue oak (Quercus oblongifolia)
- alligator juniper (Juniperus deppeana)
- one-seed juniper (Juniperus monosperma)
- Mexican pinyon (Pinus cembroides).

*Riparian Forests:*
- Arizona sycamore (Platanus wrightii)
- cottonwood (Populus fremontii)
- mesquite (mostly P.velutina and P. glandulosa)
- saltcedar or tamarisk (Tamarix chinensis)
- velvet ash (Fraxinus pennsylvanica)
- walnut (Juglans major)
- willow (Salix spp.)

## B. Lower Santa Cruz River Basin:

*Lower Colorado River Valley Desertscrub Community:*
- big galetta (Hilaria rigida)
- bursage (Ambrosia spp.)
- creosote bush (Larrea tridentata)
- saltbush (Atriplex canescens)

*Arizona Upland Desertscrub Community:*
- acacia/catclaw (Acacia greggii)
- brittlebush (Encelia farinosa)
- bursage (Ambrosia spp.)
- creosote bush (Larrea tridentata)
- foothill paloverde (Cercidium microphyllum)
- ironwood (Olneya tesota)
- ocotillo (Fouquieria splendens)
- saguaro (Carnegiea gigantea)
- teddy bear cholla (Opuntia bigelovii)
- [some annual and perennial grasses]

The present day vegetation cover of the lower Santa Cruz River basin is dominated by two Sonoran desertscrub communities, the lower Colorado River Valley (LCRV) and the Arizona Upland (AU) communities (Shreve, 1942 and 1951; Bahr, 1991). The LCRV community is composed of creosote bush, bursage, and saltbush, interspersed with species of bunch grasses such as big galetta. The AU community is comprised mostly of foothill paloverde, saguaro, teddy bear cholla, ocotillo, brittlebush, ironwood, catclaw, bursage, and creosote bush, and some annual and perennial grasses.

**B. Changes in Vegetation**

Human activities have modified the vegetation of the Santa Cruz River basin. Bahre (1991) described historic human impact on vegetation in southeastern Arizona. He found no evidence that the Sonoran desertscrub communities had invaded extensive areas of former grassland or that grassland distribution had changed during the historic period. However, he and other researchers found that there has been a decline in native grasses (attributed to grazing and a slight trend towards aridity) and an increase in woody ***xerophytes*** such as mesquite. The increase in woody trees and shrubs is generally attributed to a combination of overgrazing and wildfire exclusion. Agricultural clearing, wild hay cutting, clearing for urban and rural development, range management policies, and the introduction of exotics are other factors that have caused changes in the grasslands. Also, there have been changes in the cover, density and number of bursage, brittlebush, foothills paloverde, and other native desertscrub dominants that may be related to plant life cycles and/or short-term cycles linked to climatic and other environmental fluctuations.

In the evergreen woodlands, the density of oaks, brush and shrubby trees has increased and decreased in different areas since 1870. Fire suppression policies in this century and overgrazing have diminished the occurrence of wildfires, allowing brush and shrubby trees to increase and causing a decline in oak regeneration (i.e., due to browsing of oak seedlings and damage to acorns by livestock). Bahre (1991) notes other changes in the evergreen woodlands are due to clearing of native cover for expanding settlement, invasion of exotics, and an increase in oak in areas that have been protected from fire, grazing and fuelwood cutting.

Since the 1850's and 1860's, the native riparian vegetation has largely disappeared or been replaced by exotics (Bahre, 1991). The development of more efficient water pumps in the 1940's led to a boom in irrigated agriculture in southeastern Arizona. Groundwater irrigation between the 1940's and 1970's led to groundwater overdrafts that had a major impact on riparian ***phreatophytes***, killing extensive areas of mesquite and galeria forests. Rea (1983, as summarized in Bahre, 1991) noted several other causes of riparian deterioration in southern Arizona, i.e., overgrazing of arid and adjacent semiarid uplands, excessive woodcutting in watersheds and mesquite *bosques* (forests), overtrapping of beaver and loss of beaver dams, gullying of stream banks and hillsides by trampling of cattle, and cutting unprotected wagon roads.

Overall, riparian habitats in southeastern Arizona have been significantly altered or decreased by extensive groundwater pumping. However, sewage effluent discharge from two sewage treatment plants located adjacent to the Santa Cruz River have led to the establishment of riparian habitat where formerly there was no perennial flow, or the re-establishment of riparian vegetation in reaches of the river where historically there was perennial flow. Such altered reaches of the of Santa Cruz are discussed in greater detail in the following chapters.

## V. HYDROLOGY

The location and character of surface water in the Santa Cruz River Basin is intrinsically linked to the regional climate, to the level of groundwater, and to the geomorphology of the channel itself. This chapter describes several aspects of the hydrology of the Santa Cruz River basin. It begins with a brief background on the historical and present-day surface water locations. The main section of this chapter is devoted to the description of the average flow conditions (including no-flow conditions) and peak flows as recorded by the six USGS streamgages located throughout the basin. Descriptions of the effects of human activities on river flow and groundwater are interwoven with the discussion of the hydrologic changes throughout this chapter. More detailed information about the changes of the location and character of the surface flow as they relate to geomorphological changes is discussed in the next chapter.

**A. Description of Surface Flow and Groundwater**

The upper Santa Cruz River is an ***intermittent*** stream, meaning, most of the river flows for only part of the year or only during wet weather, while some short reaches of its course flow throughout the year (Bryan, 1925b); the lower Santa Cruz River has ***ephemeral*** flow that results directly from precipitation. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River near Laveen. Historically, the Santa Cruz River was perennial above Tubac. Perennial ***subflow*** maintained several marshes (***cienegas***) near Sentinel Peak in Tucson, where a subsurface dike and an impervious layer formed by the convergence of Pleistocene terraces and the bedrock at the foot of the Tucson Mountains forced the groundwater to surface. ***Cienegas*** existed about 10 miles south of Tucson above the San Xavier Mission (the *Agua de la Misión* and the *Punta de Agua,* see Figure 4) and along both the West Branch and the Santa Cruz River proper about 3 miles south of the Congress Street Crossing in Tucson (Betancourt and Turner, 1988; Halpenny, 1988). Bryan (1922a) observed another *cienega* at the confluence of the Santa Cruz and the Gila Rivers.

In 1949, during the unusually dry period that lasted from 1930 to 1950, the diversion of the Santa Cruz River's flow 19 miles upstream from the Nogales gage began for municipal supply for the city of Nogales, Sonora (USGS Gage Remarks). Because of the increased extraction as Nogales' population has grown and the expansion of irrigated agriculture along the inner valley of the river in Santa Cruz County during the period after the second World War to about 1955, the ***water table*** in the inner valley has been lowered and the ***subflow*** of the river depleted (Halpenny, 1988). The once perennial flow in Sonora, Mexico, is now captured by wells and infiltration galleries for agricultural and municipal use. Today, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley (Betancourt and Turner, 1988).

Two reaches of the upper Santa Cruz River have perennial flow and riparian forests resulting from the discharge of secondary-treated municipal effluent. Discharge of sewage effluent from the treatment plants at Ina Road and Roger Road began in 1970 and has resulted in perennial flow in the channel past the Cortaro streamgage. The second reach, south of Nogales, has had perennial baseflow since the Nogales Wastewater Treatment Plant began discharging effluent into the Santa Cruz at the mouth of Potrero Creek in 1972

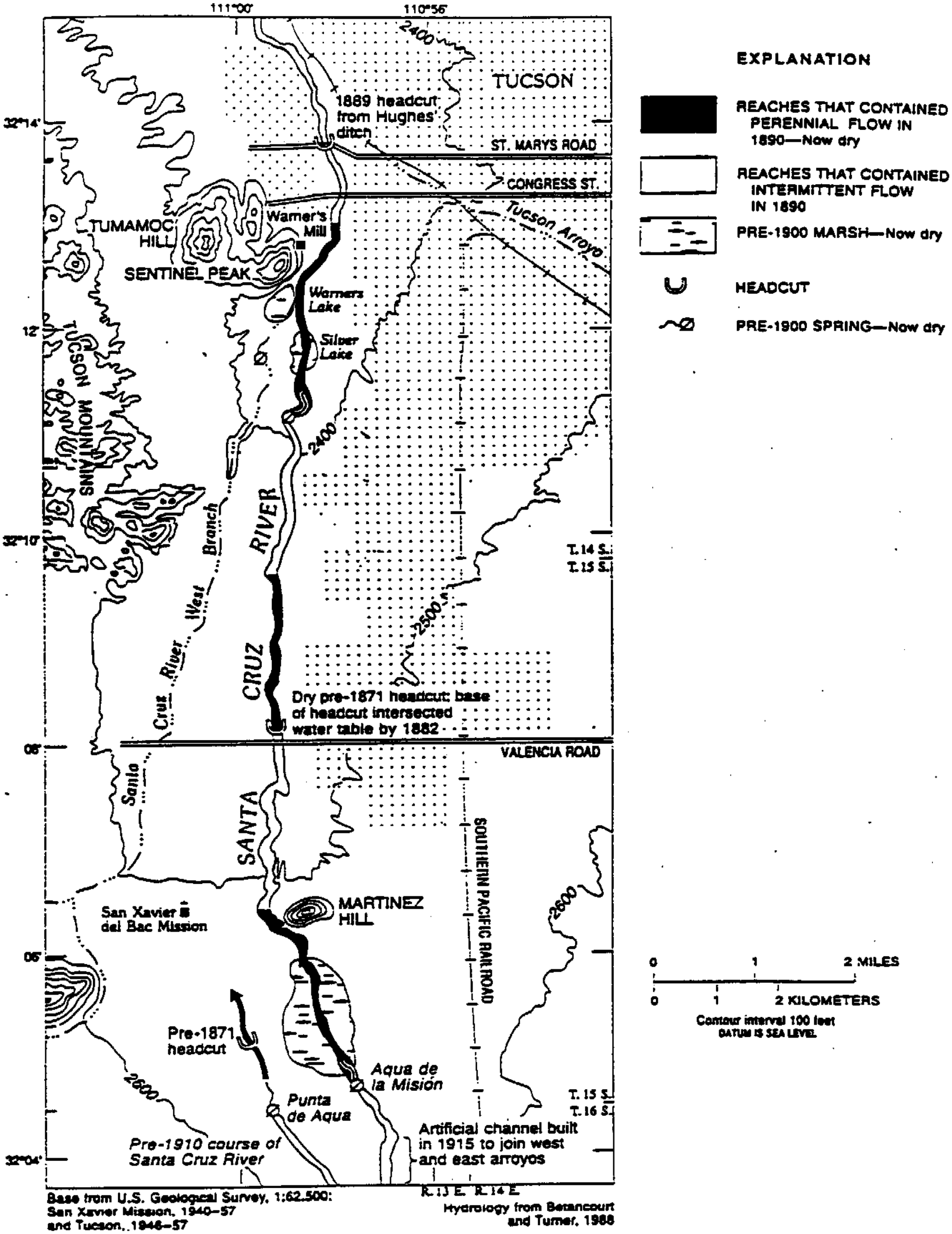



Figure 4. Santa Cruz River in 1988, perennial and intermittent reaches in 1890, and location of headcuts in relation to marshes in the late 19th century. [Source: Parker, 1995. First cited in Betancourt, 1990.]

(Brown *et al*, 1978). The flow is now perennial from the mouth of Potrero Creek to Tubac, as it was during the historical period of 1775-1872, though surface flow becomes underflow near Otero and reemerges upstream from the Rancho Santa Cruz guest ranch, just north of Josephine Canyon. (Applegate, 1981). In winter, the stream frequently flows to just south of Continental Road due to less water consumption by vegetation upstream (Betancourt and Turner, 1990; Halpenny, 1988).

**B. Streamflow Characteristics**

The goal of this section is to provide a description of the flow characteristics at the time of Statehood and to determine how the flow characteristics have changed over time. We combine information gathered from previous studies with an analysis of annual peak, daily average and monthly average discharge series. The discharge series records are from gages located near Lochiel, Nogales, Continental, Tucson, Cortaro and Laveen, and are of varying lengths and quality. Table 2 lists the period of record and contributing drainage area for each gage. We begin this section with a description of infiltration processes and the no-flow characteristics of the Santa Cruz River channel, and then focus on the characteristics of the daily, monthly and peak discharge series.

***Infiltration and No-Flow Conditions.*** The streambed of the Santa Cruz River is generally quite permeable, and water is lost to the subsurface as flood flows move downstream (Condes de la Torre, 1970). Figure 5 illustrates the reduction by channel losses of the September 12-14, 1965 flow event. Burkham (1970) analyzed two reaches of the upper Santa Cruz River in his study of streamflow depletion by ***infiltration*** in several streams in the Tucson Basin. He found that about 40.2% of the average annual inflow was depleted by infiltration along the 28.5 mile reach between the gaging station at Continental and the gaging station at Tucson. About 29.9% of the inflow was depleted along the 12.3 mile reach between the gaging station at Tucson and the station at Cortaro.

Condes de la Torre (1970) discerned several relevant hydrologic characteristics in his analysis of the time distribution of streamflow. He found by studying ***flow-duration curves*** for the period 1936 to 1963 that streamflow occurred in direct response to precipitation and that snowmelt and groundwater discharge did not contribute sufficient

Table 2. Santa Cruz River U.S. Geological Survey Streamflow Gages.

| GAGE | PERIOD OF RECORD (Monthly Flow) | DRAINAGE AREA $MI^2$ |
|---|---|---|
| 1. LOCHIEL: | Jan. 1949 to May 1990 | 82.2 |
| 2. NOGALES: | Jan. 1913 to June 1922, May 1930 to July 1990 | 533 |
| 3. CONTINENTAL: | May 1940 to Dec. 1946, Oct. 1951 to Sep.1985 Oct. 1989 to July 1989 | 1,682 |
| 4. TUCSON: | Oct. 1905 to Dec. 1907, Jan. 1913 to Sept. 1982 | 2,222 |
| 5. CORTARO: | Oct. 1939 to June 1947, July 1950 to Sept. 1984 | 3,503 |
| 6. LAVEEN: | Jan. 1940 to Sept. 1946, Dec. 1947 to Aug. 1990 | 8,581 |

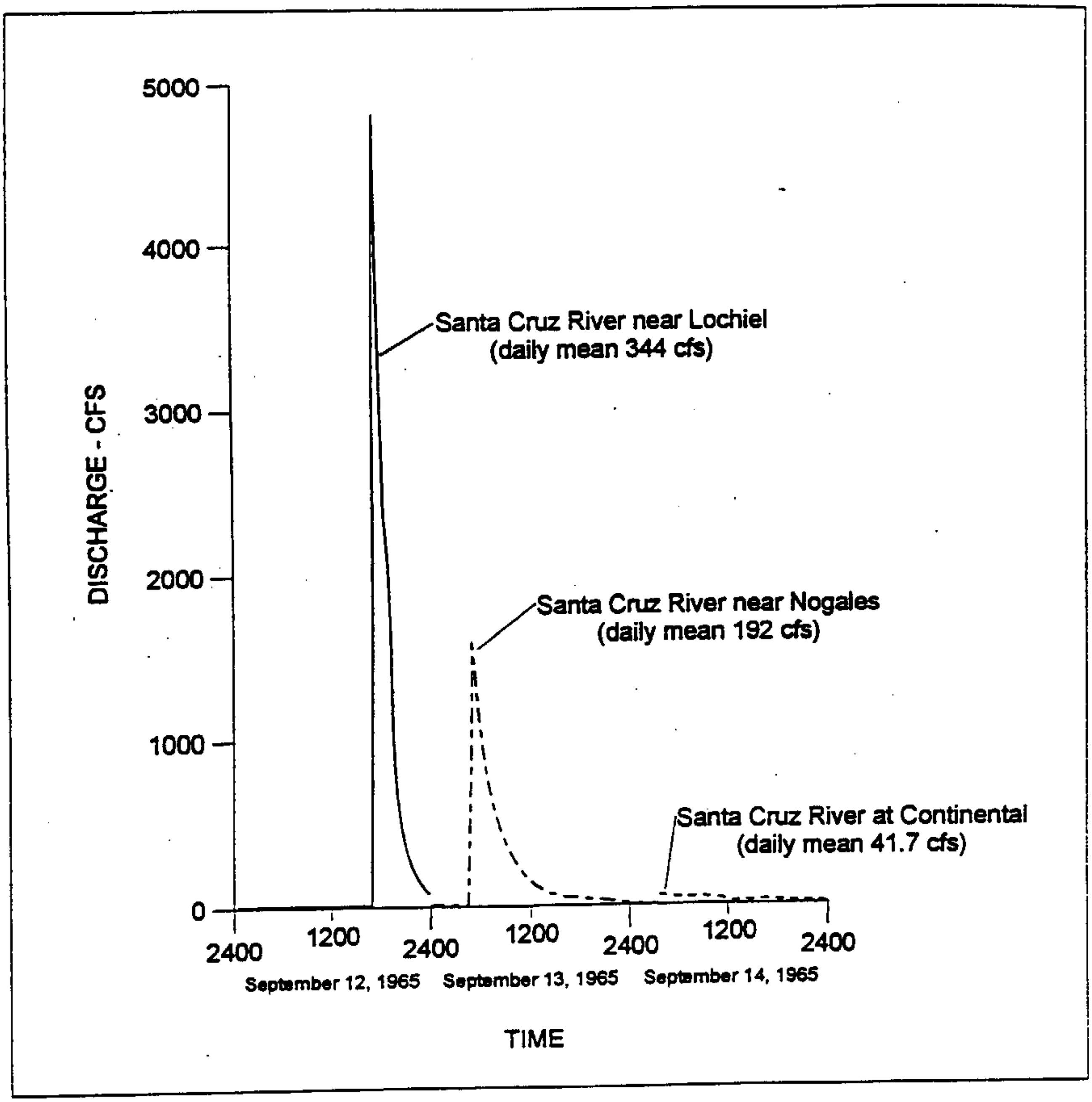



**Figure 5. Reduction of the flood peak by channel losses in the Santa Cruz River.**
[Source: Condes de la Torre, 1970.]

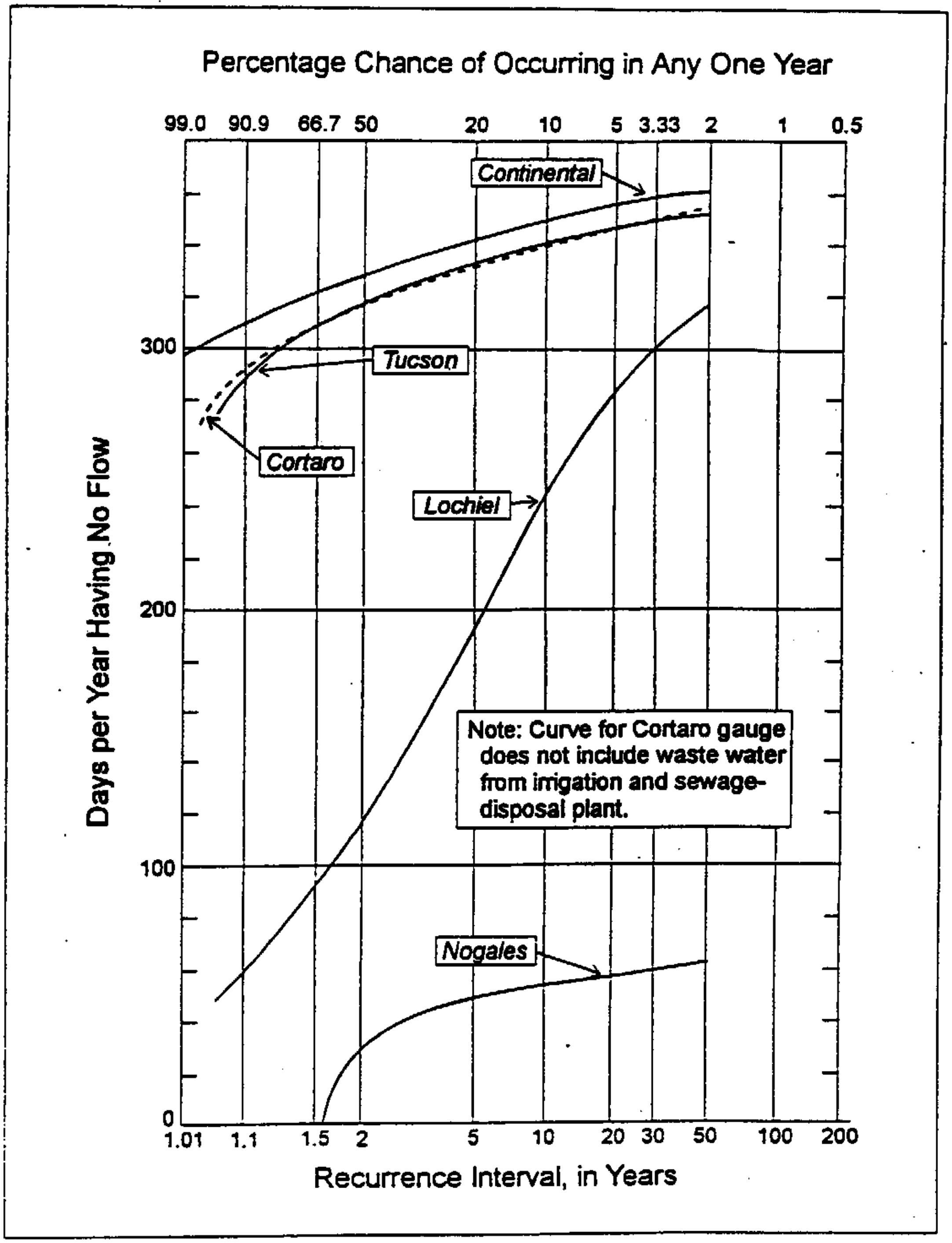



**Figure 6. Frequency of days having no flow at selected gaging stations on the Santa Cruz River.** [Source: Condes de la Torre, 1970.]

amounts of water to sustain flow at any of the gaged reaches in his study. In his analysis of low flows in the Santa Cruz River basin, he calculated the frequency of days having no flow and their return intervals for the period of record for selected gages (Figure 6). For example, in any future year there is a 50 percent chance of 30 or more days of no flow at Nogales and 328 or more days of no flow at Continental.

***Daily Average Flow Characteristics.*** Summer floods are extremely flashy and rarely last longer than a few days in both the upper and lower Santa Cruz River Basin (Figure 7). Schwalen (1942), in his study of the basin south of Rillito, found that flows in the upper part of the basin tend to be more or less continuous during the winter rainy season. Even in the reach near Tucson, flows may continue for four or five days, and during exceptionally wet winters, such as 1914-1915 and 1992-1993, flow may continue over several months. Figure 8 uses the earliest recorded gage data to provide an example of winter daily flow at Tucson and Nogales near the time of Statehood. Figure 9 illustrates the shift from the continuous winter flow to the sporadic flow of the summer season. The gage record indicates that by the time of Statehood, the Santa Cruz River at Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The winter discharge averaged about 15 cubic feet per second (cfs) except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. The flow throughout the rest of the year ranged from 0 to 80 cfs. The streamflow record at Tucson indicates a similar seasonal flow pattern: an average daily flow of about 12 cfs during the winter, and during the April to September period there were only five days with recorded flow in that reach.

The daily stream flow of the Santa Cruz River has changed markedly over time in response to climate changes and human activities. Webb and Betancourt (1992) discerned that daily discharges in summer months that were exceeded less than 2 percent of the time were much higher for 1930-59 than for 1915-29 or for 1960-1986, and that daily discharges in fall months that were exceeded less than 2 percent of the time were much less for 1930-59 than before or after. These temporal changes in daily flow characteristics reflect the changes in climate over the past century that were discussed previously.

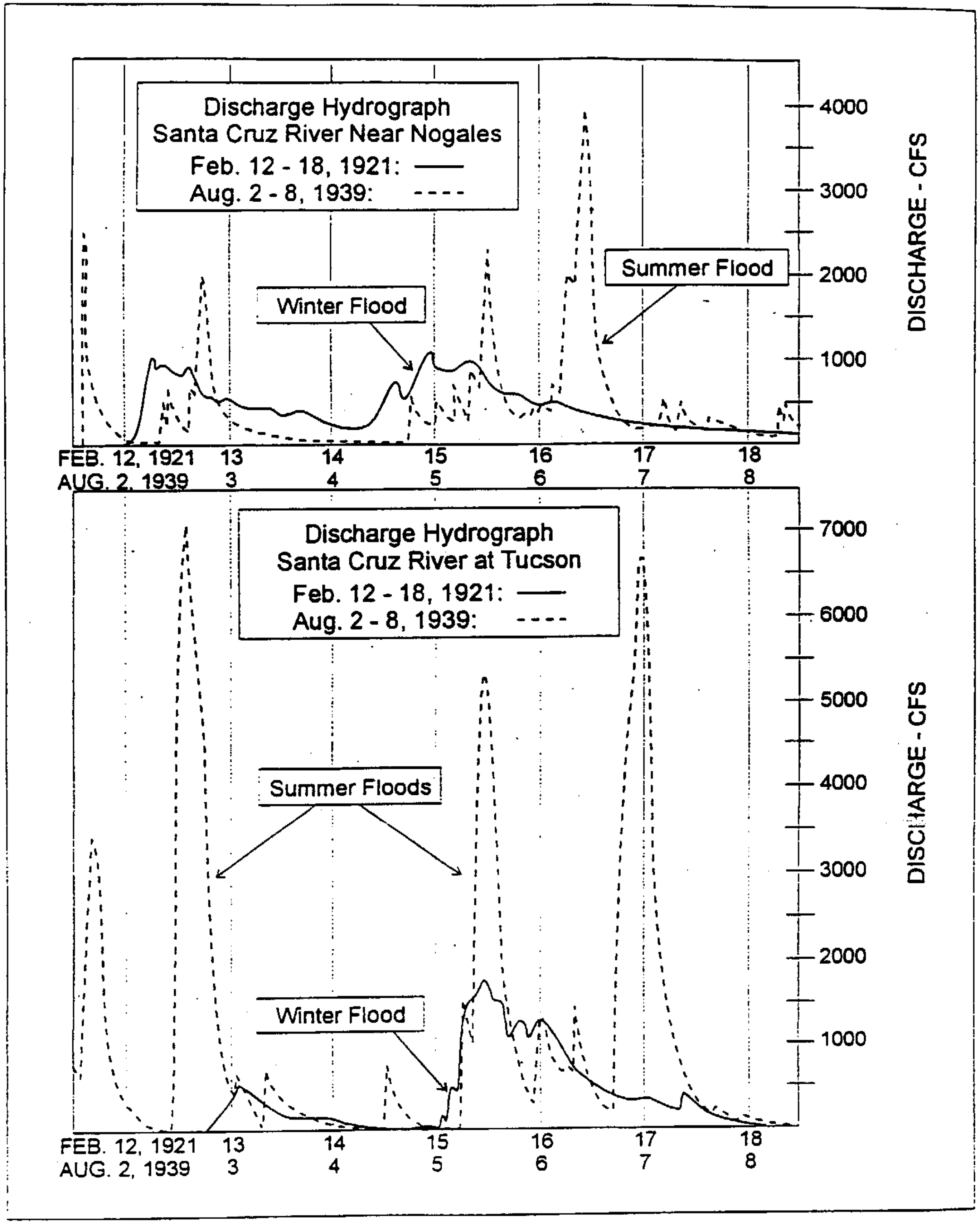
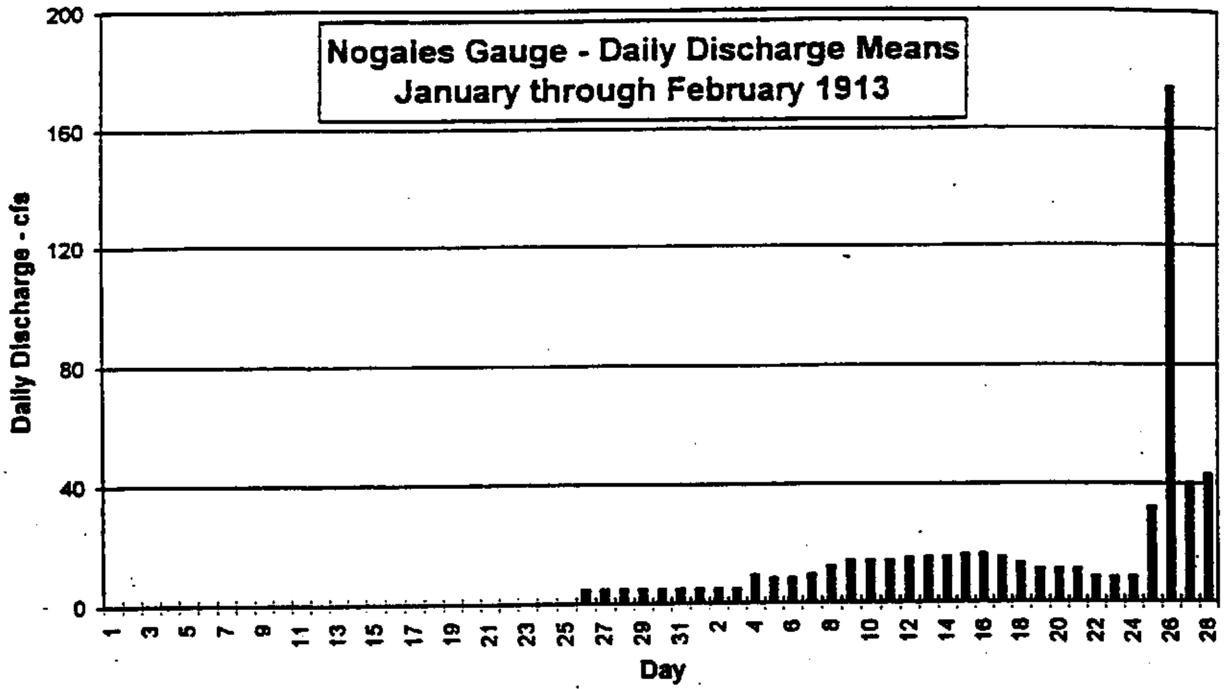



**Figure 7.** Comparative discharge hydrographs for the Santa Cruz River near Nogales and at Tucson for a summer and winter period of large flow. [Source: Schwalen, 1942.]

Figure 8. Daily discharge data for a winter period at the beginning of the centuy.

Note: the Nogales record began January 26, 1913.



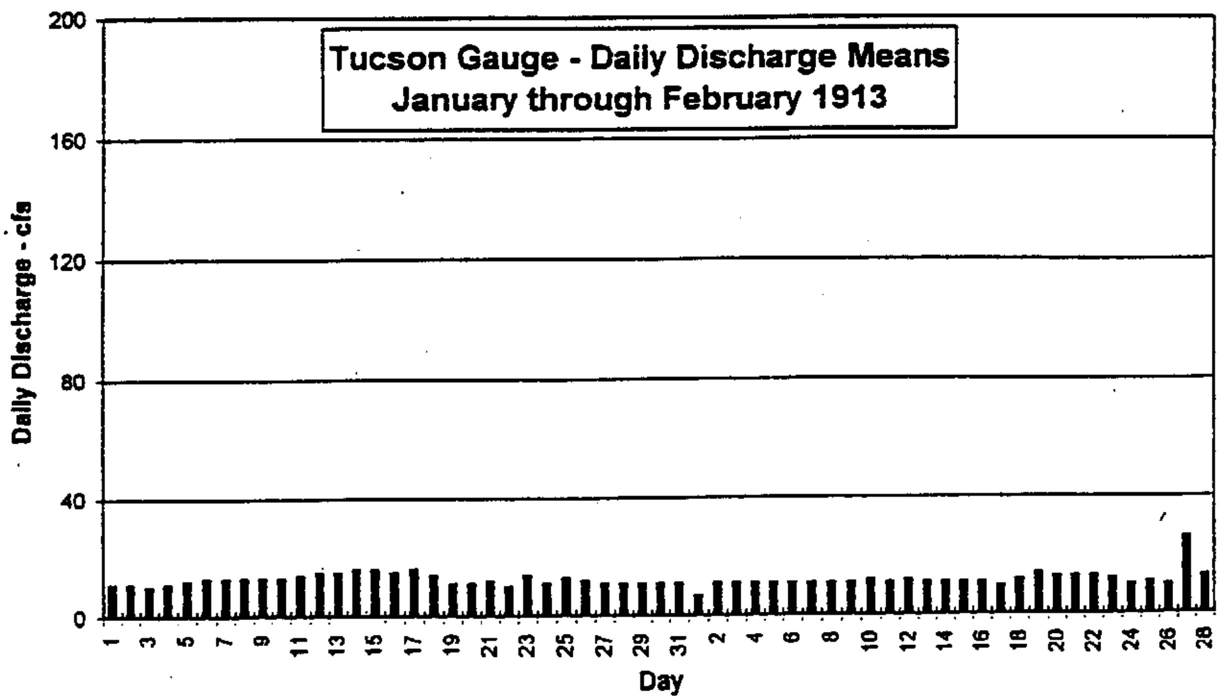



Figure 9a. Daily discharge means at the Nogales gage, March through September, 1913.
Note: days of each month are numbered from left to right, beginning with March 1 and ending with September 30.

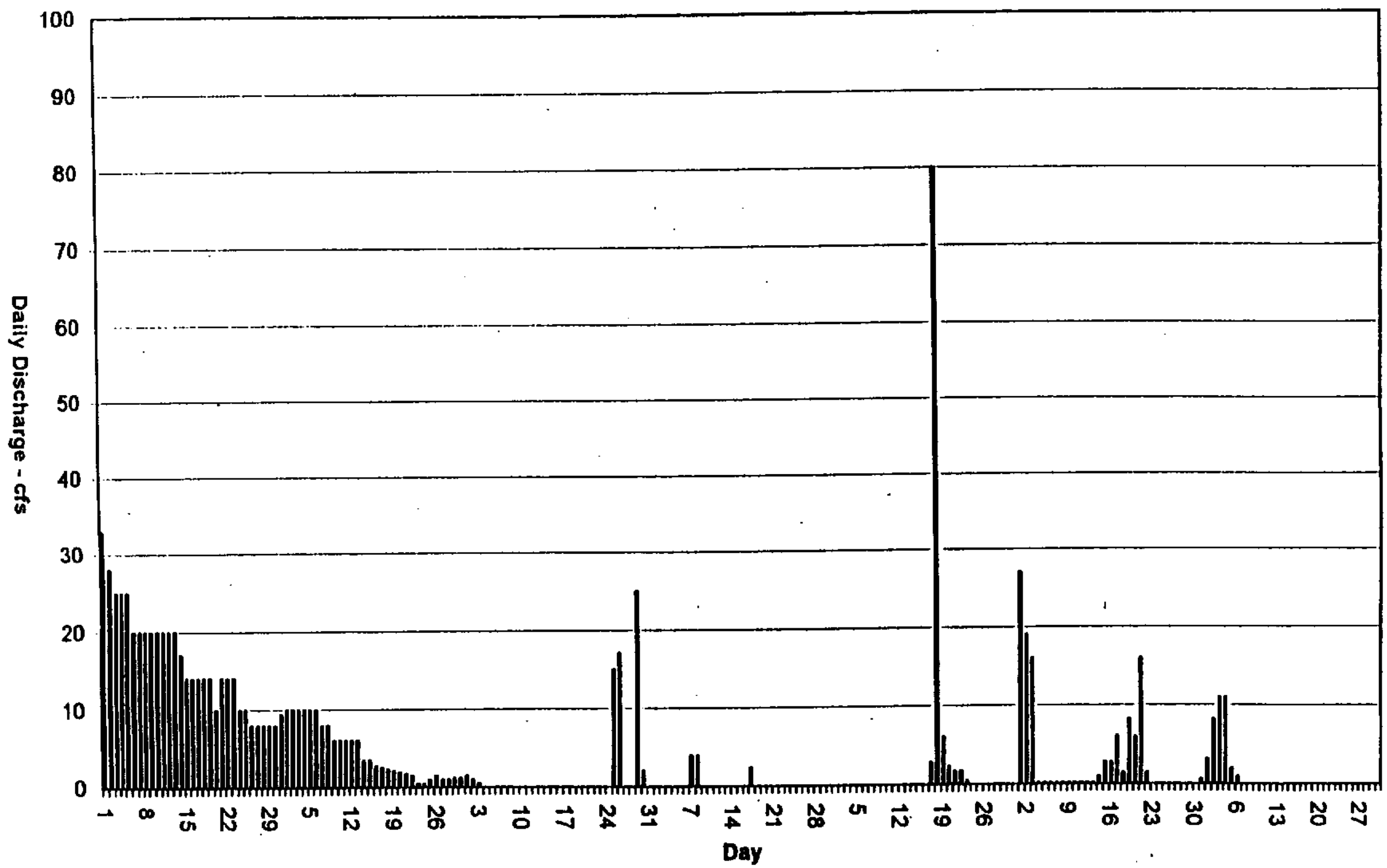


**Figure 9b. Daily discharge means at the Tucson gage, March through September, 1913.**
Note: days of each month are numbered from left to right, beginning with March 1 and ending with September 30.

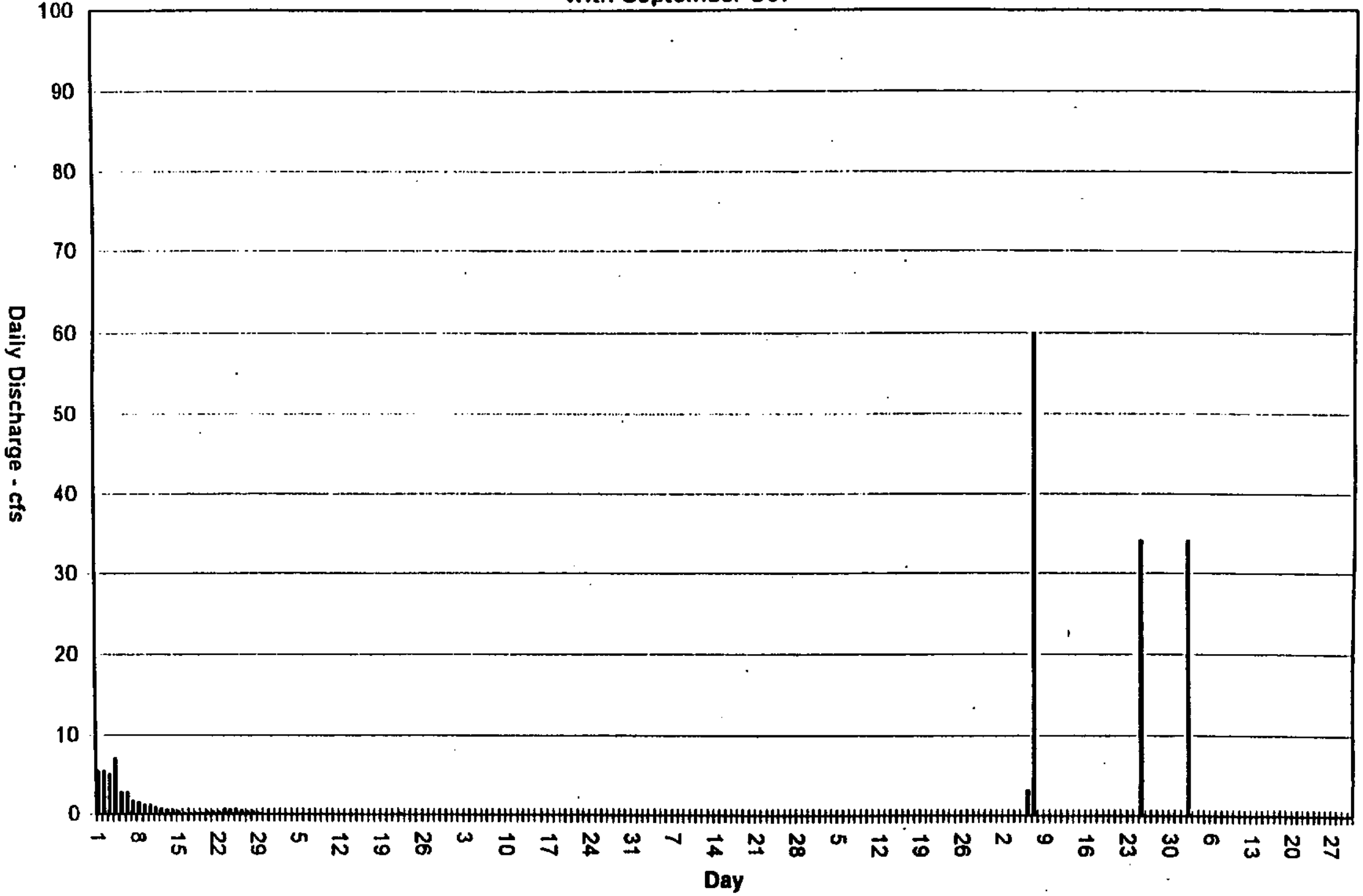
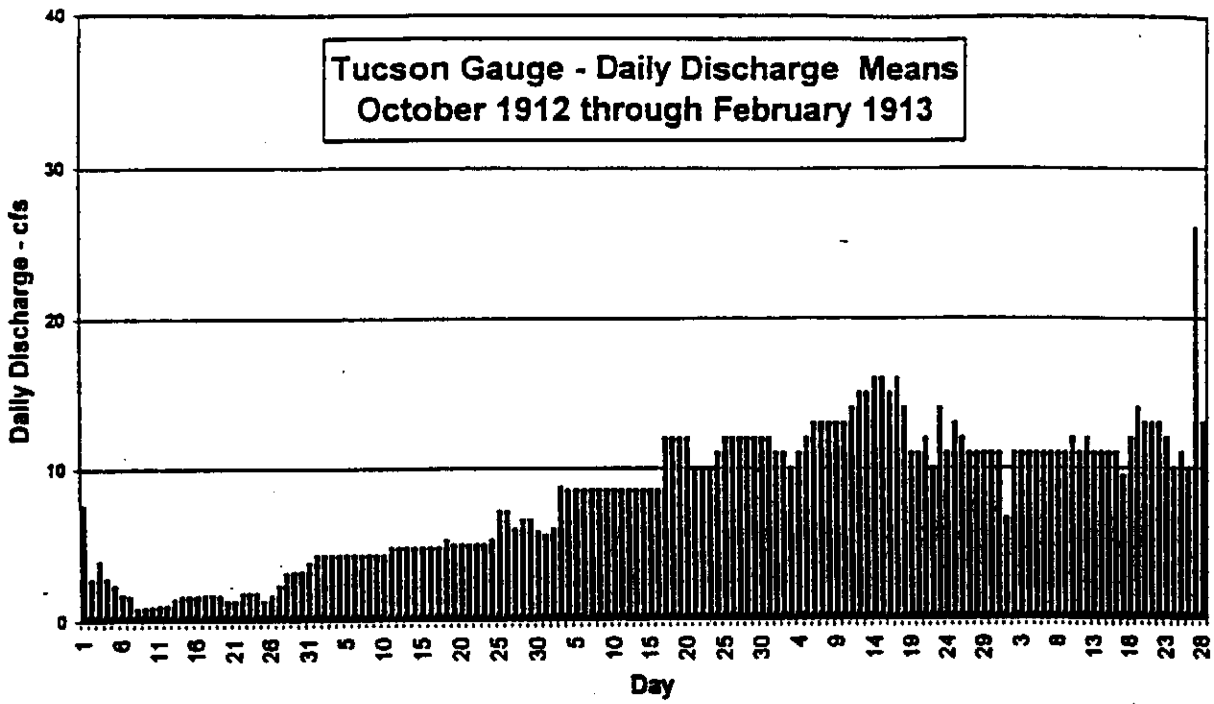
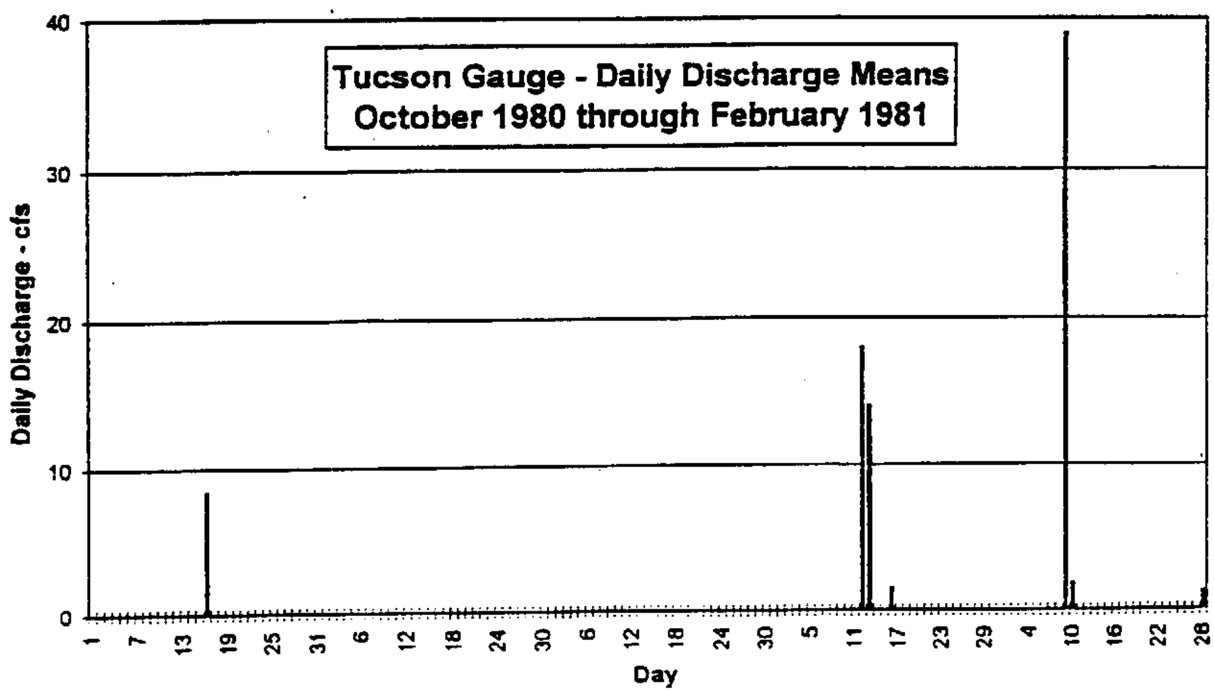


Figure 10. Comparison of daily discharge data for the fall-winter period of 1912-13 and 1980-81.



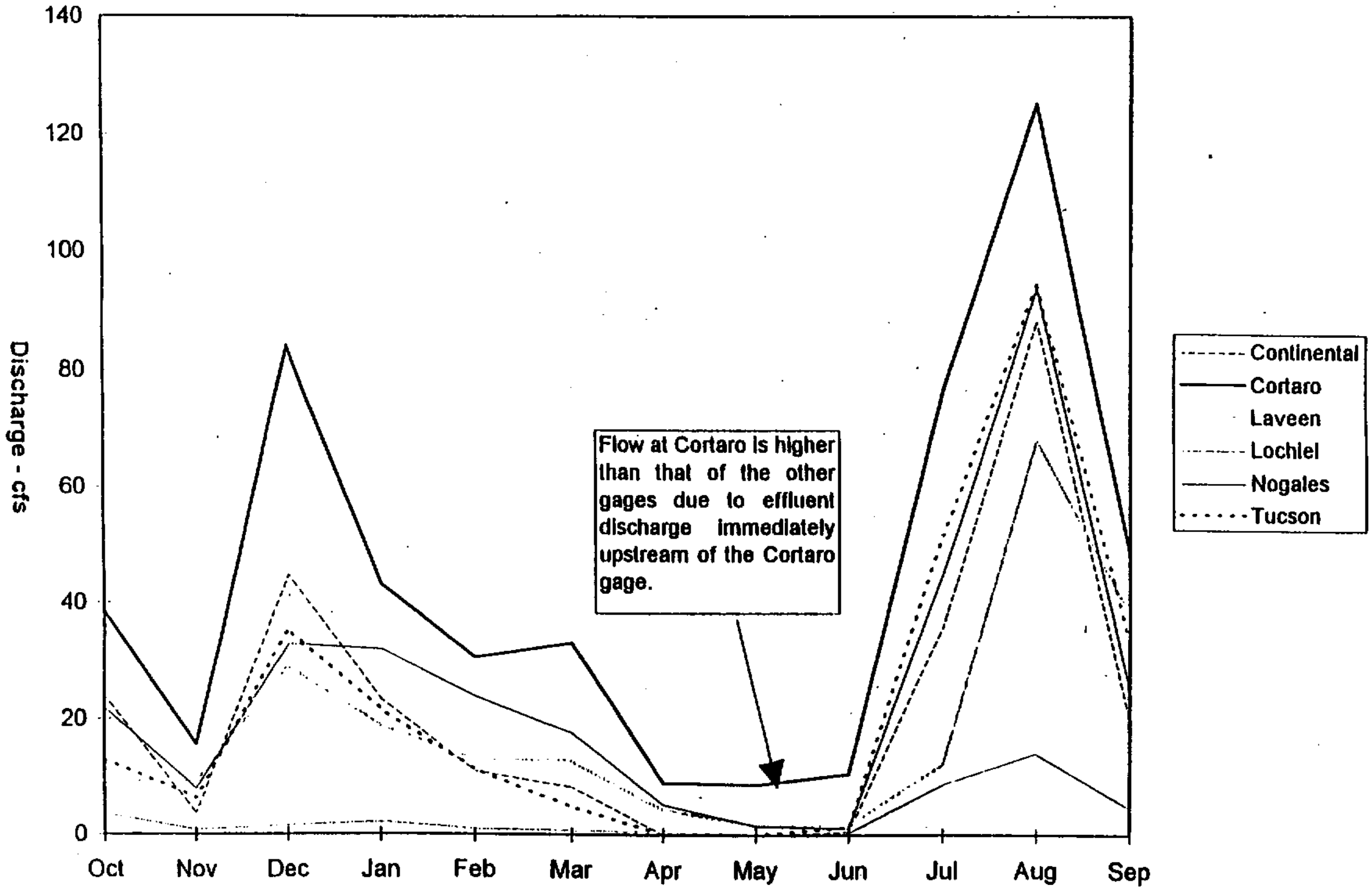
Though much of the change in the hydrologic record can be explained by changes in the climate, some have more direct links to human activities and channel changes. Figure 10 compares the daily flow at Tucson for the period nearest in time to the date of Arizona's Statehood (1912-1913) to the more recent period (1980-1981) measured by the gage before it was deactivated. Although both the 1912-1913 and 1980-1981 records were measured during periods that were dominated by fall and winter flows, the 1980-1981 record does not have the continuous flow that characterizes the 1912-1913 record, and it has much higher daily flow averages. These hydrologic changes resulted from a combination of factors: climate change, the lowering of the water table induced by groundwater pumping, and channel changes such as arroyo development and channelization that are discussed in the next chapter.

The Laveen gage, which was established in 1940 near the confluence of the Santa Cruz and Gila Rivers, apparently also had continuous baseflow until about 1956. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions and had peaks as high as 5060 cfs during wet periods. In 1960, the Santa Cruz at Laveen began to experience no-flow conditions for months at a time. In the following years, the Laveen reach continued to experience months at a time with no flow. Again, this change probably was a result of the combination of climate change, channel incision at that reach, and the dramatic increase in groundwater pumping that occurred in that region during the middle part of the century.

***Monthly Average Flow Characteristics.*** The monthly flow averages illustrated in Figure 11 reflect the seasonality of the precipitation. The peaks occur during the summer and winter seasons. The high frequency of no-flow conditions result in very low monthly averages for April, May and June. The Cortaro gage records the highest monthly averages during drought months because of the input of discharge from the sewage treatment plants upstream.

Figure 12 compares the average monthly discharge and monthly streamflow variability of the Santa Cruz River at Tucson. It shows that the year-to-year variability is less for the summer months than for the fall, winter and spring seasons. Decadal

Figure 11. Monthly flow averages at the six gages on the Santa Cruz River.



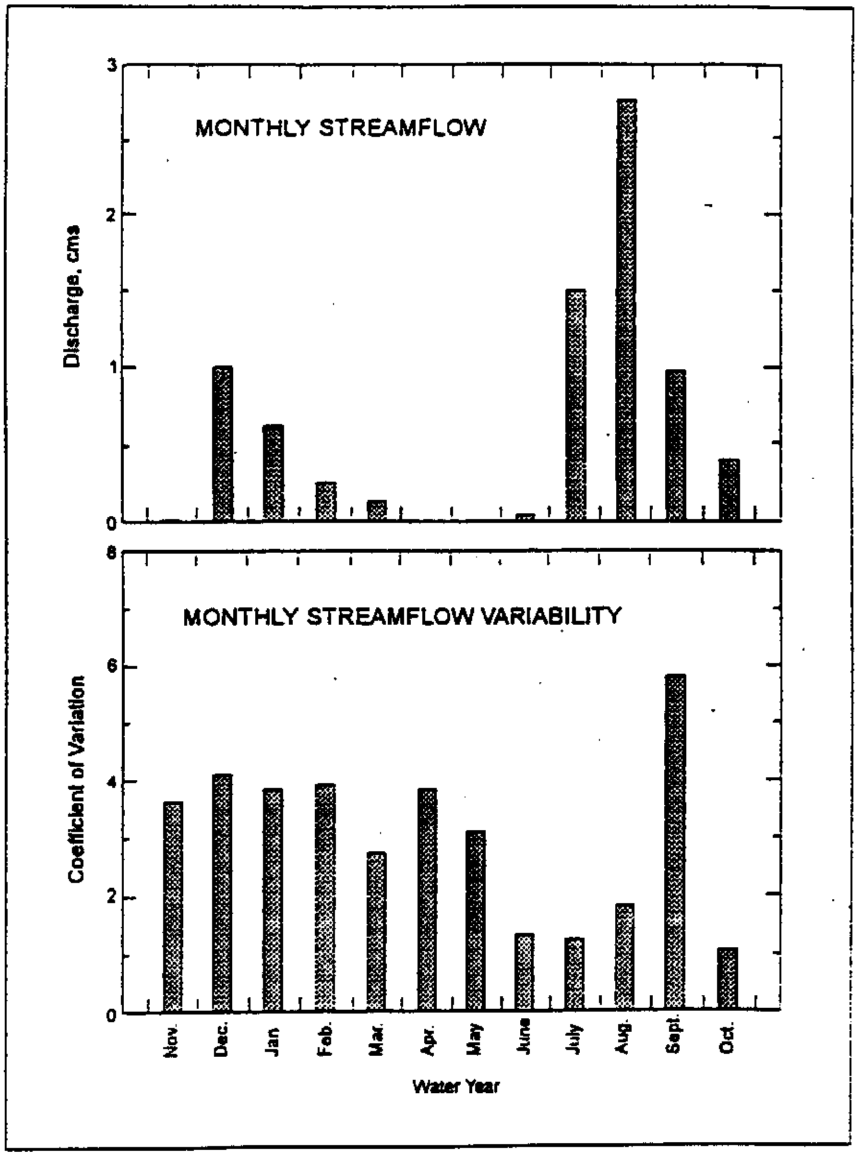



**Figure 12. Average monthly streamflow and monthly streamflow variability, Santa Cruz River at Tucson,** [Source: Webb and Betancourt, 1992.]

variability in the monthly averages reflects changes in the peak flow characteristics discussed below and are strongly related to climate change.

***Peak Flow Characteristics.*** Peak flows in the Santa Cruz River typically result from summer monsoon storms, fall tropical storms and/or cutoff lows and winter frontal storms. Hirschboeck (1985) assigned a hydroclimatic classification to each flow event occurring at selected gauging stations during the period 1950 through 1980. (See Figure 1 for locations of the streamgages.) For the gage at Tucson, 104 of the 140 flow events analyzed occurred during the monsoon season, 18 were attributed to tropical storm and/or cutoff lows, and 11 were attributed to frontal passages. Of the 119 flows analyzed at the gage near Nogales, 95 were attributed to monsoonal weather patterns, 8 to tropical storms/cutoff lows, and 10 to fronts. At Lochiel, 47 of the 56 flows studied were classified as monsoonal, 4 as tropical storms/cutoff lows, and 3 as frontal in origin.

All six gages measured their highest discharges in the latter portions of their records (Figure 13). Webb and Betancourt (1992) argued that the changes in magnitude and seasonality of annual peak flows resulted from climate change rather than channelization and land-use changes:

> "Although land use and changes in channel conveyance undoubtedly have increased flood discharges to some unknown extent, climatic effects are the only common link between the six gauging stations on the Santa Cruz River... At Lochiel, flows in the Santa Cruz River could not have been affected significantly by land use, yet peak discharges have increased since 1960... The August 1984 flood at Lochiel, the peak of record, was larger than the October 1983 flood, which indicates the apparent changes are not caused by a few isolated large floods. Changes in the hydroclimatology of the basin are reflected by a shift in the seasonality of annual peaks, which is also the most striking symptom of the underlying climatic control of flood frequency." (Webb and Betancourt, 1992, p. 23)

Although flood-frequency estimates for the Santa Cruz River are strongly influenced by the extraordinary October 1983 flood, six of the seven largest floods at Tucson occurred after 1960. Winter and fall floods account for 53 percent of annual peaks before 1930, only 3 percent from 1930 to 1959, and 39 percent after 1960. Seven of the eight largest peaks in the flood series were produced by fall or winter storms, and five of these

Figure 13a. Annual peak discharges at Lochiel, Nogales, and Continental.

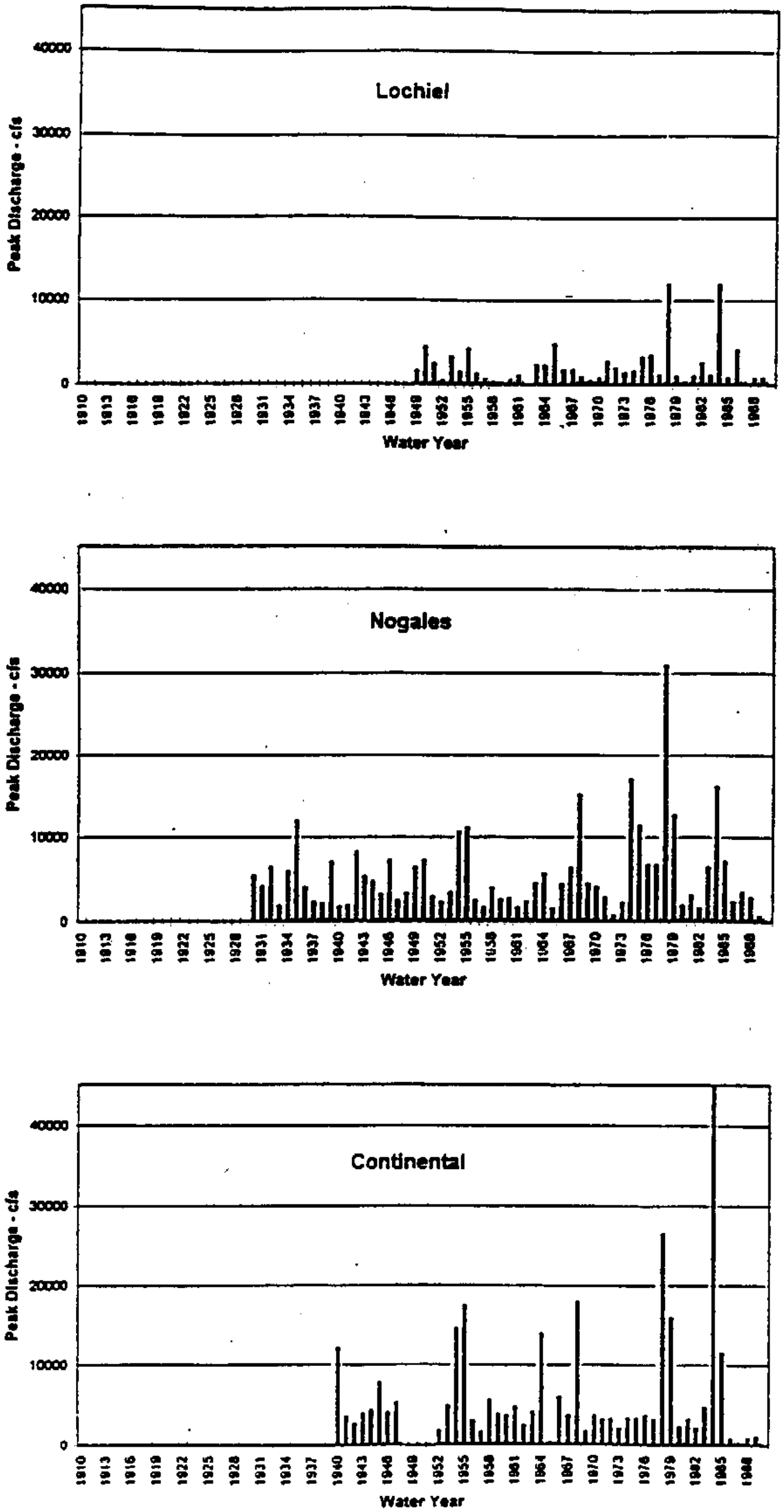
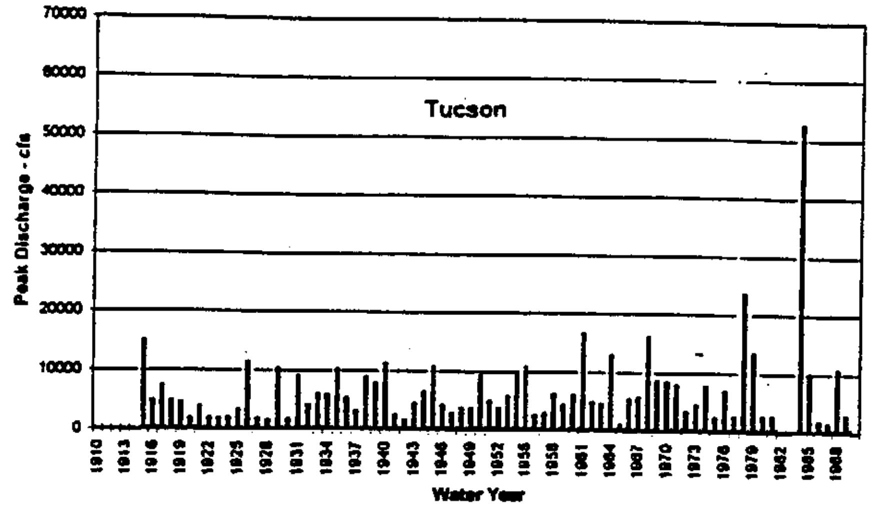
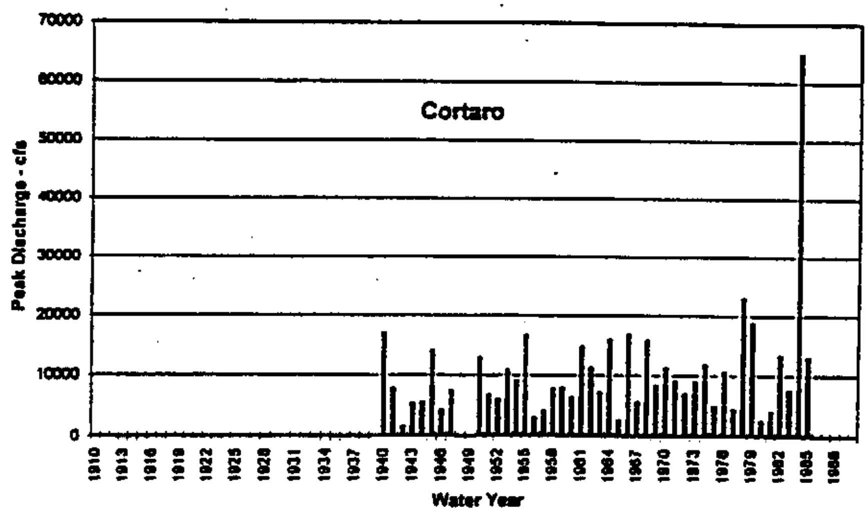
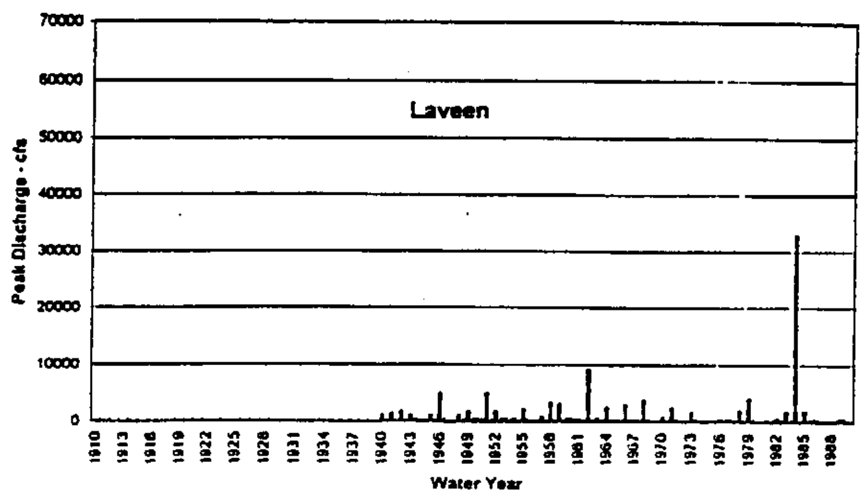


Figure 13b. Annual peak discharges at Tucson, Cortaro, and Laveen.



occurred between 1960 and 1986. Although most of the annual floods at Nogales occurred in summer, four of the six largest floods occurred in fall or winter. Webb and Betancourt (1992) concluded that these changes indicate that the seasonality of flooding is not stationary or random on the Santa Cruz River.

Rhoades (1991) determined that land-use changes in the lower Santa Cruz River basin have affected the peak flood discharges. Since 1962, the construction of flood-control channels in the washes of the lower Santa Cruz basin have resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the *attenuation* -- the downstream decrease of the flood peak -- of peak discharges. Rhoades (1991) compared the input/output volume ratios for the floods of September 1962 and October 1983, both events caused by widespread, heavy precipitation associated with tropical storms. He concluded that attenuation of peak flow was greater during the 1962 flood because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 flood was efficiently transmitted downstream by the flood-control channels.

## VI. GEOMORPHOLOGY

One of the main goals of this study is to determine the nature of channel changes along the Santa Cruz River, especially any changes in location of the channel boundaries since the time of Statehood. To do this, we focused on three objectives: 1) to gather the oldest and most recent aerial photographs and historical and current survey maps of the Santa Cruz River; 2) to compile channel configurations through time (as determined from the aerial photographs and survey maps) onto a single base map; and 3) to integrate historical accounts, previous channel change studies and channel location data.

The temporal and spatial scales of channel change along the upper and lower Santa Cruz River are dramatically different. Channel change in the upper reaches of the river have been on the order of thousands of feet, and they can be detected through the comparison of aerial photographs for one year to photographs of consecutive years. In contrast, changes in the location of the channel in the lower basin can be measured in miles, and due to the nature of the causes of the changes, the timing spans decades of years. For this reason, we developed different strategies for the mapping of channel locations in the upper and lower reaches. For the upper Santa Cruz River north of the Mexico-United States border, we compiled the channel locations discerned from the oldest survey maps (~1904-1916), the oldest aerial photographs (1936), and the most recent aerial photographs (1995) onto 1:24,000-scale base maps. For the lower Santa Cruz River, we compiled the flow paths of several of the largest flow events that occurred on the Santa Cruz River in this century onto one 1:100,000-scale base map.

The first section of this chapter provides a background of the different types of geomorphic processes that result in changes of a river's channel. Examples from along the upper Santa Cruz River are used to illustrate the different types of channel change. Because of the important role that arroyo formation and change play in defining the character of the upper Santa Cruz River, the second section is devoted to a review of the theories of arroyo development and to descriptions of arroyo formation and change along the Santa Cruz River. The third section documents the disparate courses taken by the flood flows of 1914-15 and 1983, with a focus on the effects of the Greene's Canal construction on the flood paths. Descriptions of channel location changes and arroyo development from the literature are integrated with information gathered from our study of aerial photographs and historical survey maps.

### A. Types of Channel Change

Channel patterns are a result of the interplay between local geology, precipitation and runoff, sediment influx and movement, vegetation and land-use, and the larger context of the drainage basin (Hays, 1984). Parker (1995) thoroughly reviewed mechanisms of channel and arroyo change on the Santa Cruz River in Pima County. He described three types of lateral change: meander migration, avulsion and meander cutoff, and channel widening. He described two types of vertical change: aggradation and degradation of the channel bed. He determined that the dominant mechanism in each reach depended on channel morphology, channel sediment, bank resistance, and flood magnitude, and he noted that where the channel is entrenched into an arroyo, a combination of fluvial processes and bank retreat mechanisms leads to arroyo change. Table 3 describes the various channel change mechanisms outlined in his review. Hays (1984) noted that soil types bordering the channel reaches affect the stability of channel location, and that banks

**Table 3. Channel Change Mechanisms** [Source: Parker, 1995]

| MECHANISM | DESCRIPTION |
|---|---|
| Meander migration: | Lateral shifts of centerline position associated with the inception of meanders and their subsequent downstream translation, lateral extension, or rotation of meander axis. |
| Avulsion: | An abrupt shift in channel position that occurs when overbank flow incises new channels as other channels aggrade and are abandoned. |
| Meander cutoff: | An abrupt shift in channel position that occurs at meanders and may or may not involve concurrent aggradation of the abandoned channel segment. Meander cutoff and avulsion tend to occur where channels are shallowly incised, the floodplain is active, and aggradation rates generally are high. |
| Channel widening: | Results primarily from high flows that erode weakly cohesive banks. It is different from arroyo widening because arroyo boundaries may delineate not only a channel but also a floodplain at the bottom of the arroyo. It is product of corrasion by fluvial erosion during rising flow, or mass wasting by of banks following the flow peak. |
| Vertical change: | Results from changes in stream power, sediment concentration, or resistance that occur as a result of variation in flood magnitude, sediment availability, channel morphology, or local channel gradient. "Degradation and aggradation occur over years to decades and may reflect climatic changes, adjustments to channel widening or narrowing, sediment storage and episodic transport, and natural or artificial changes in channel-hydraulic properties... Degradation and aggradation can alternate in time and space." [Parker, 1995, p.24] |

composed of coarser soils tend to be more prone to erosion than those composed of more cohesive soils containing more silts and clays.

Several human modifications have resulted in channel change on the Santa Cruz River (Hays, 1984; Betancourt and Turner, 1990; Rhoades, 1991; Parker, 1995). Nine different categories of modifications and their effects in the upper and lower Santa Cruz River basin are summarized here. The first six modifications listed have had the greatest effect on channel morphology in the Santa Cruz River basin:

1) **Bank protection and bridge construction** stabilize the position of an alluvial channel by preventing the channel from adjusting its dimensions laterally in response to increased discharge. This results in the artificial concentration of streamflow, increases in stream power, and increased peakedness of flood hydrographs. Bank protection also can remove a major sediment source by preventing bank erosion, thus lowering sediment concentrations of a given discharge and enhancing the erosiveness of streamflows. Bridge construction has locally stabilized channel positions in both the San Xavier and Cortaro reaches.

2) **Channelization** typically shortens stream length, increases stream power and decreases attenuation of flood peaks. Both channelization and bank protection initially cause degradation within and upstream from the altered reach, aggradation downstream from the altered reach, and increased erosion at unprotected sites. Continued degradation may result in a period of channel widening by producing steep banks in unprotected reaches that fail readily, while continued aggradation may result in the plugging of downstream channels and a shifting of channel position by avulsion. Channelization has been implemented in several reaches of the Santa Cruz River, most notably in the San Xavier and Tucson reaches of the upper Santa Cruz River, and throughout the lower Santa Cruz River for the purpose of flood control.

3) **Artificial diversion of drainage** diverts flow to a different route or to a reservoir for the purpose of: (a) flood control; (b) irrigation, as was the goal of the Greene's Canal project in the lower Santa Cruz River; or (c) protection from erosion, as in the San Xavier reach in the upper basin.

4) **Obstruction of regional drainage lines** alters flood patterns. The construction of roads, highways, and railroads that trend perpendicular to the courses of washes and

streams cause such transportation routes to act as barriers to flow, resulting in widespread inundation immediately upstream. Notable examples of this occur in the lower Santa Cruz River basin where Chuichu Road crosses Greene Wash near Chuichu, where Highway 84 and Interstate 8 cross the Santa Cruz Wash, Greene Wash and Santa Rosa Wash west of Casa Grande, and where the Southern Pacific Railroad crosses the Santa Rosa and Santa Cruz washes east of Maricopa (Rhoades, 1991).

5) **Artificial narrowing** (i.e. by emplacement of artificial fill along channel margins) may reduce capacity and armor the banks against erosion, producing the same effects as bank protection and channelization. The incision of the channel bottom at Tucson of 9 to 15 feet after 1946 (Aldridge and Eychaner, 1984) may have resulted from the artificial narrowing of the channel by the dumping of garbage and highway construction debris into the channel and adjacent floodplain (Betancourt and Turner, 1988).

6) **Discharge of sewage effluent into downstream reaches** leads to an increase in vegetation that results in more rapid sediment accretion and stabilization of the channel. The Tumacacori and Cortaro reaches dramatically illustrate the effects of the establishment of riparian vegetation that resulted from the perennial flow maintained by sewage effluent.

7) **Dam and reservoir construction** reduces or eliminates the threat of flooding from runoff. The Tat Momolikat Dam in the upper Santa Rosa Wash, completed in 1974, was constructed to control flows originating from the Santa Rosa basin. As footnoted later in this chapter, the dam has not succeeded in eliminating flooding along the lower Santa Rosa Wash.

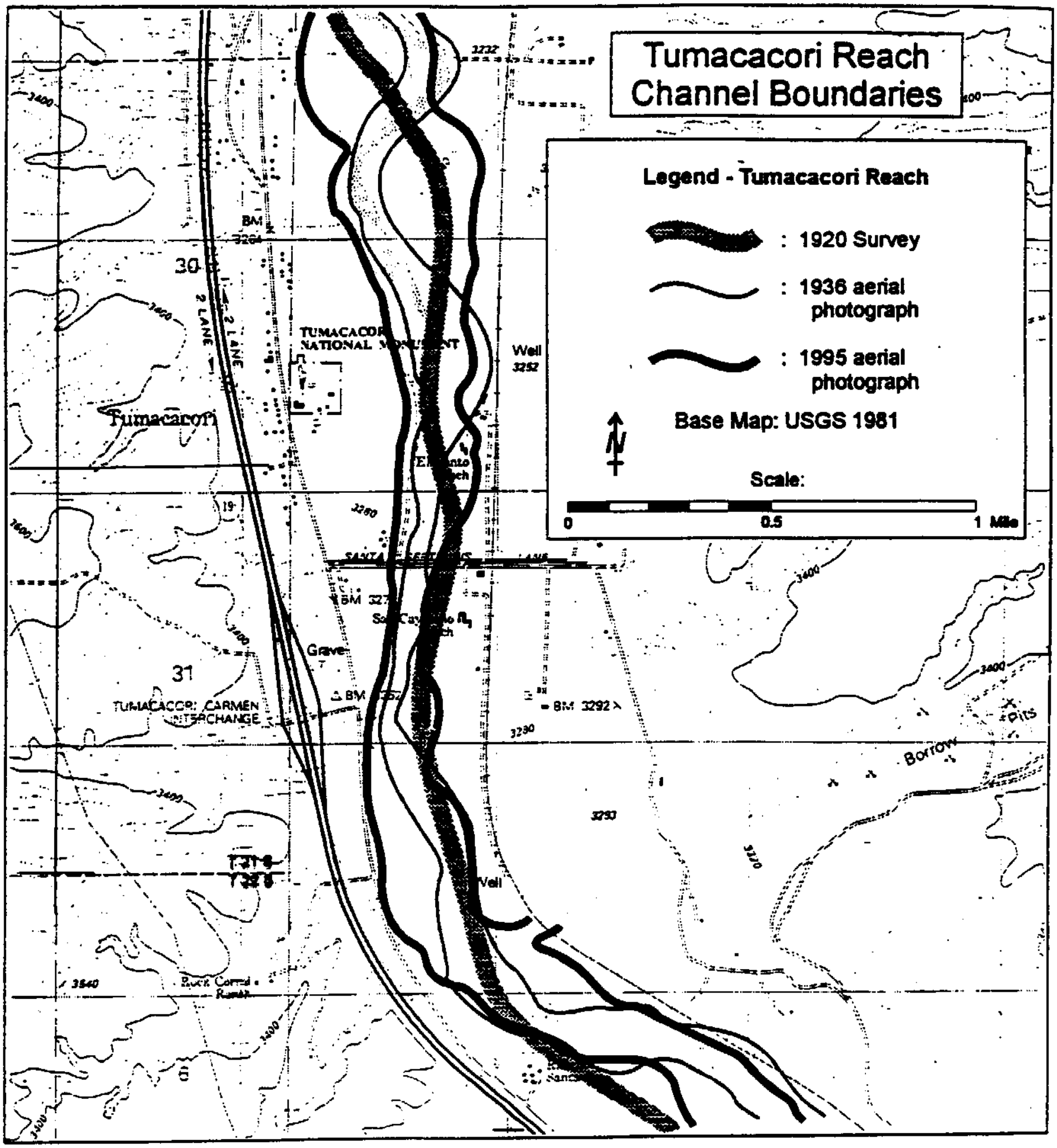
8) **Sand-and-gravel operations** within the floodplain.

9) **Channel-maintenance operations.**

The following sections provide more detailed descriptions of reaches where geomorphic processes and human activities have resulted in dramatic channel change along the Santa Cruz River.

***Tumacacori Reach***. The reach of the Santa Cruz River near the Tumacacori National Monument (Figure 14) illustrates the effects of channel widening processes. Widening is especially apparent downstream of Tumacacori. Masek and Corkhill (Masek, 1996,

Figure 14



Tumacacori Reach
Channel Boundaries
Legend - Tumacacori Reach
: 1920 Survey
: 1936 aerial photograph
: 1995 aerial photograph
Base Map: USGS 1981
N
Scale:
0
0.5
1 Mile
Tumacacori
TUMACACORI CARMEN INTERCHANGE
Grave
Well
Well
Borrow
Pits
30
31
2 LANE

personal comm.), using 1954 aerial photographs, observed that the Santa Cruz River in this region was channelized and lacked natural meanders for most of its course downstream of Sonoita Creek. By 1973, Masek and Corkhill observed that the dikes, levees and energy-dissipating structures seen in the 1954 aerial photographs had not been maintained and channel widening had occurred. The flood of October 9-10, 1977, which had a calculated peak discharge of 35,000 cfs at Santa Gertrudis Lane, resulted in several changes in the channel configuration (Applegate, 1981). The flood caused the main channel to become broader and flatter, the low flow channel to change its course in many places, and extensive bank erosion to occur. Applegate (1981) noted that the property owner on the east side built a stone wall to protect his fields, and mechanically widened and cleared the channel for about 1,000 feet of its length. By 1995, the Santa Cruz River had cut new channels, noticeably widened its meanders, eroded farmland, and allowed for the establishment of new cottonwood and willow stands (Masek, 1996, personal comm.).

The Tumacacori reach also illustrates hydraulic and channel changes caused by the re-establishment of riparian vegetation that resulted from the sewage effluent discharge from the International Sewage Treatment plant north of Nogales. Applegate (1981) studied the reach of the Santa Cruz between its confluence with Josephine Canyon and where it crosses Santa Gertrudis Lane, 45 miles south of Tucson and 15 miles north of Nogales. He analyzed large-scale aerial photography that covered the site for ten different time periods from 1965 to 1980 in order to identify channel changes. He found that the average increase in water surface elevation over the reach would have been 2.3 feet for the 10-year flood and 2.0 feet for the 100-year flood from 1967 to September 1977, due to the increased vegetation. After most of the trees were scoured out during the floods of 1977, Applegate estimated that subsequent water surface elevations would have been much lower. Such increases in water surface elevations due to the effects of the increase in vegetation greatly increase the area inundated by flow once the main channel is filled. Figure 15 illustrates the increase in area inundated by the 1967 and 1977 flow events. As can be seen by the 1995 low flow channel illustrated in Figure 16, input of discharge from the sewage treatment plant not only has resulted in re-establishment of riparian vegetation, but also has restored year-round flow to this historically perennial reach.

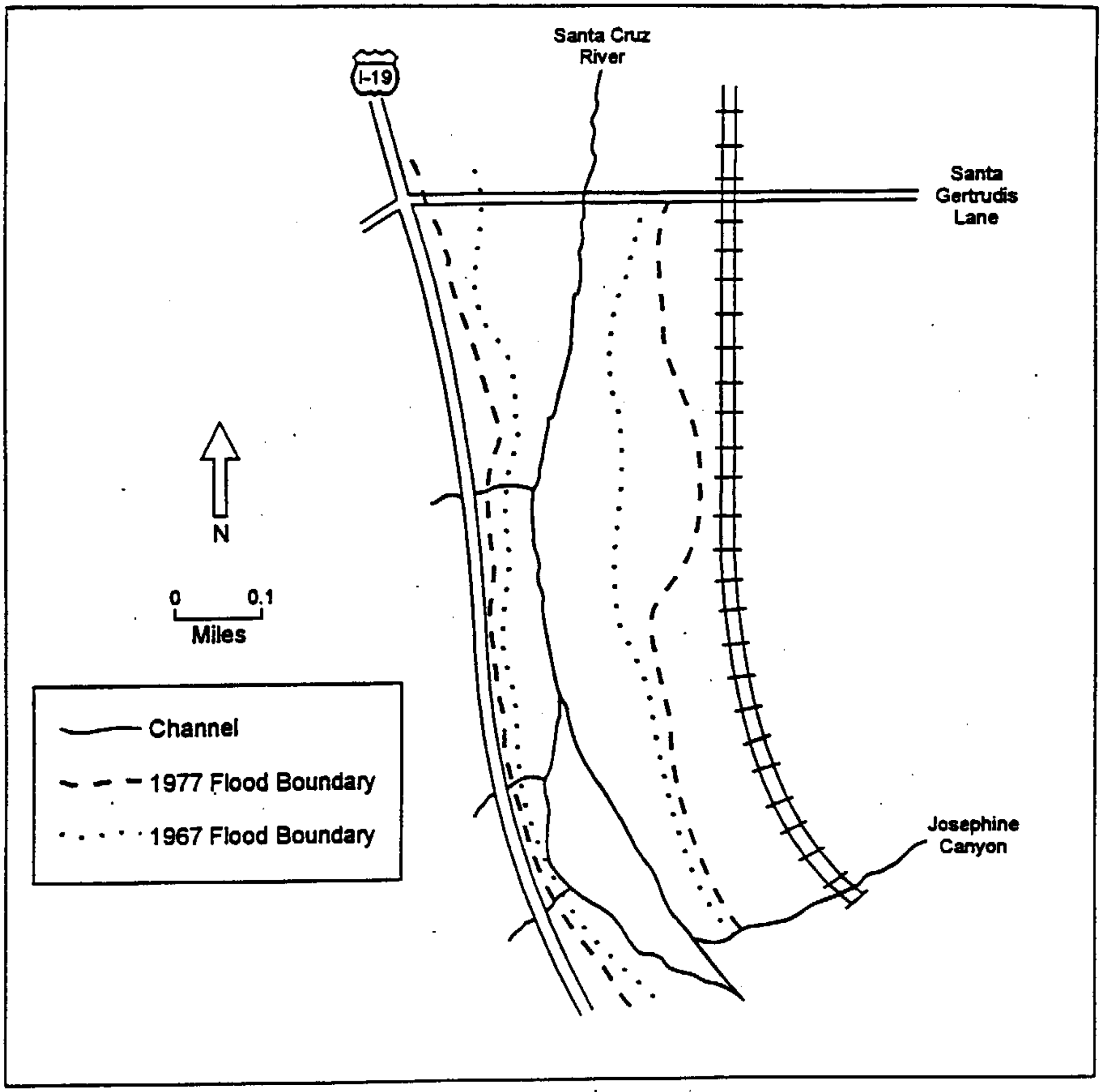
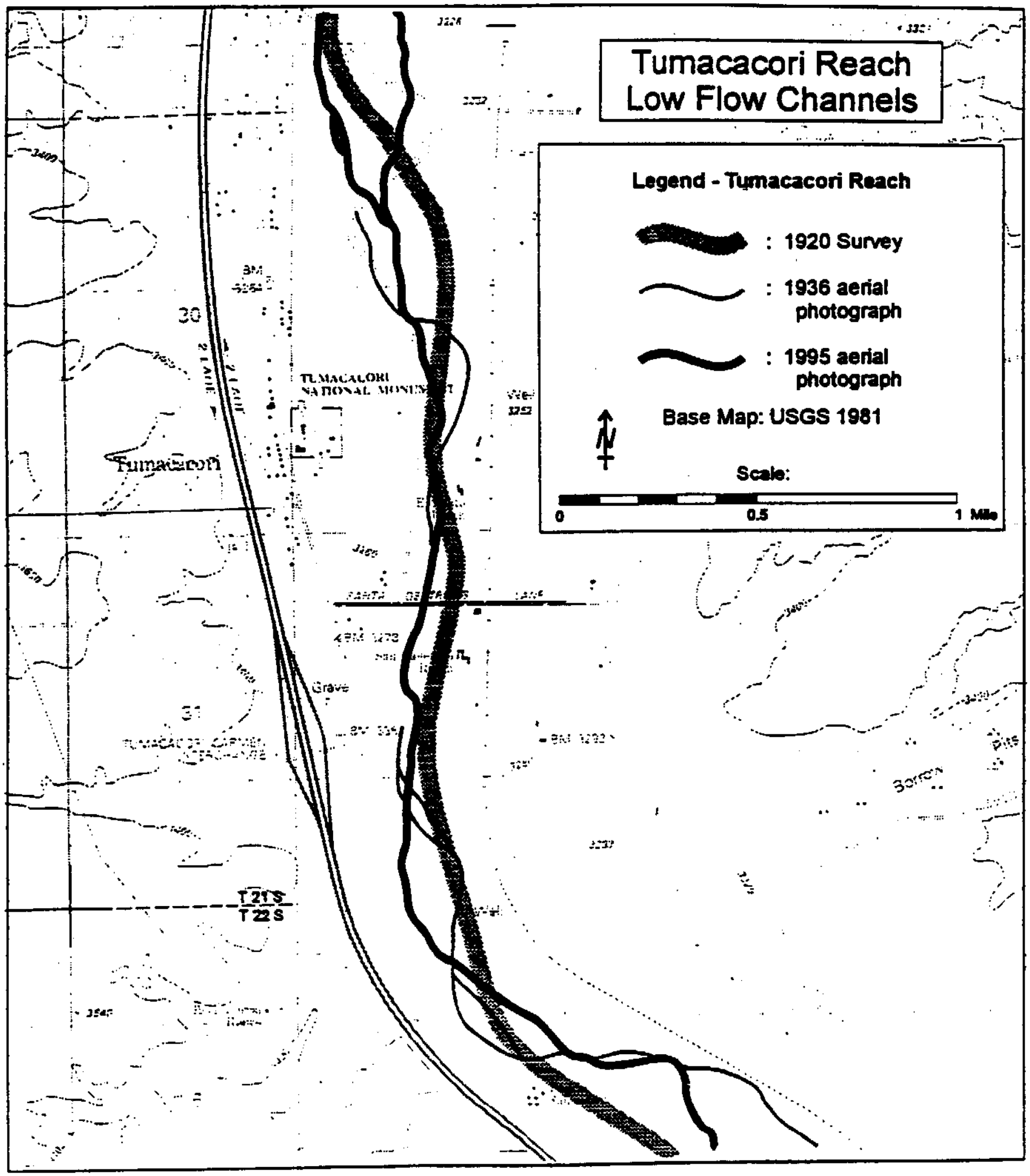



**Figure 15. Calculated 100-year flood boundaries for 1967 and September, 1977, for a portion of the Tumacacori Reach of the Santa Cruz River. [Source: Applegate, 1981]**

Figure 16


Tumacacori Reach
Low Flow Channels
Legend - Tumacacori Reach
: 1920 Survey
: 1936 aerial photograph
: 1995 aerial photograph
Base Map: USGS 1981
N
Scale:
0
0.5
1 Mile
TUMACACORI NATIONAL MONUMENT
Tumacacori
Grave
30
31
T 21 S
T 22 S

***Marana and Cortaro Reaches***. Substantial aggradation, overbank flooding, and stream avulsions have occurred at the northern end of the Tucson Basin and beyond in recent years. Parker (1995) found that the Cortaro and Marana reaches of the Santa Cruz River had the most complex record of channel change since 1936 of all the reaches he studied in Pima County. Between 1936 and 1986, the Marana reach changed from a wide, braided channel to a compound channel that was less than half the width of the channel in 1936. Before 1966 the Marana and Cortaro reaches were sparsely vegetated ephemeral channels that experienced large, frequent shifts in position. At the turn of the century, the channels of these reaches were relatively narrow (Hays, 1984); they were drastically widened by the winter floods of 1914-1915. (See Table 4 for a comparison of channel widths at different sections in 1895 and 1936.) From 1936 to 1982, a period dominated by summer rainfall, there was an overall decrease in channel width from 418 feet to 236 feet. Hays (1984) noted that though the downstream end of the study reach remained braided, much of the length of the study reach had developed into a narrow single channel pattern.

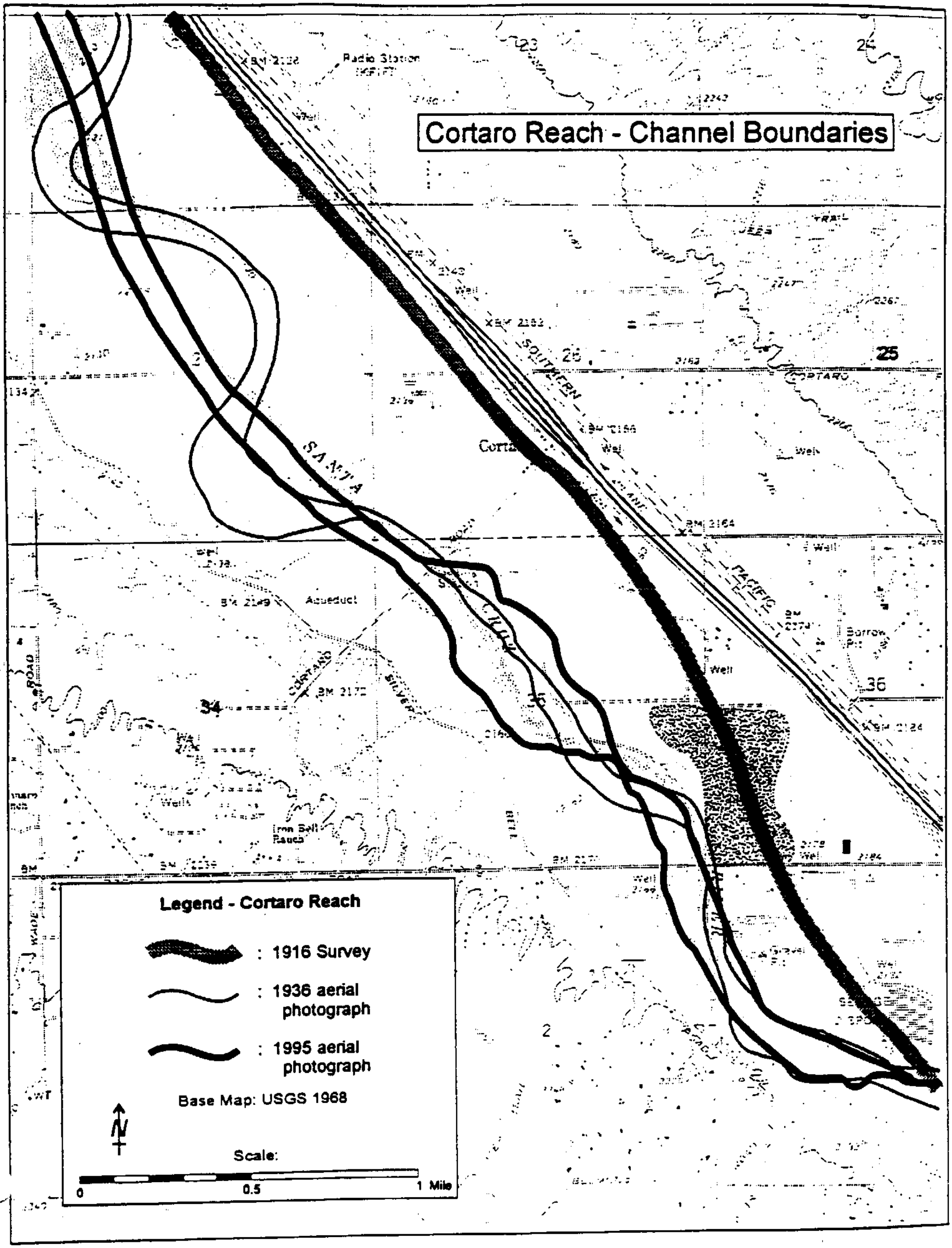
In 1970, when flow from sewage effluent discharge from Pima County's Ina Road and Roger Road treatment plants began, channel morphology became controlled by the low, steady base flows, and the channel became generally more sinuous than previously. The channel was also stabilized by vegetation growth, undergoing little change during the large 1977 flood. As a result of the peak flood of record in October, 1983, channel width widened to a mean width of 477 feet, with a range of 100 to 1300 feet. Figure 17 illustrates the boundaries of the 1916, 1936, 1968 (base map) and 1995 channels in the Cortaro reach. The change in channel boundary locations north of Cortaro Road show the meander migration that occurred between 1916 and 1968. The comparatively straight 1995 channel location indicates the meander cutoffs that resulted from the 1983 floods. The series of unconfined meanders in the Cortaro reach have been undisturbed by channelization throughout the historical period (Parker, 1995). Unconfined meanders do occur on the Marana reach, but they tend to be isolated bends in an otherwise straight channel. These meanders were obliterated between 1976 and 1986 by the flood of 1983.

Channel shifting and widening occurred in the reach near Marana due to overbank flow during fall and winter high flow events (Hays, 1984). During a high discharge, the

**Table 4. Comparison of 1895 and 1936 channel widths at selected cross sections downstream of the Cortaro reach illustrated in Figure 17.** 1895 channel widths were derived from General Land Office Surveys; 1936 data were obtained from aerial photographs. [Source: Hays, 1984.]

| Location | 1895 Width (feet) | 1936 Width (feet) | Percent Change |
|---|---|---|---|
| Between sec. 7 & 8 T.12 S, R.12 E | 99 | 400 | +300 |
| Between sec. 6 & 7 T.12 S, R.12 E | 79 | 170 | +120 |
| Between sec. 2 & 3 T.12 S, R.12 E | 50 | 350 | +610 |
| Between sec. 3 & 34 T.11 S, R.11 E | 152 | 550 | +260 |
| Between sec. 32 & 33 T.11 S, R.11 E | 462 | 670 | +150 |
| Between sec. 29 & 30 T.12 S, R.12 E | 937 | 950 | +1 |

Figure 17


Cortaro Reach - Channel Boundaries
Legend - Cortaro Reach
: 1916 Survey
: 1936 aerial photograph
: 1995 aerial photograph
Base Map: USGS 1968
N
Scale:
0
0.5
1 Mile
Radio Station
Well
Aqueduct
Borrow Pit
Gravel Pit
Iron Bell Ranch
SANTA CRUZ
SOUTHERN PACIFIC
CORTARO

flood water followed a direct route down the valley, cutting off meander bends. As the flood flow subsided, the low flow channel established itself along the cutoff routes. In contrast, meander migration occurs through bank erosion during the more typical, less extreme flow events that have occurred after several days of continuous discharge. Channel narrowing has been associated with periods dominated by summer flows that tend to be shorter in duration and smaller in volume, and have a higher sediment concentration than winter flow events (Hays, 1984; Pearthree, 1982). Hays (1984) noted that the most stable reaches of the study area were dominated by an alluvium that was more cohesive due to a higher content of silt and clay, than the coarser alluviums that characterized the least stable reaches.

**B. Arroyo Development: Theories and Examples from the Upper Santa Cruz River**

Over the last century, several theories explaining the causes for arroyo initiation in the American Southwest have been developed and refined. The following sections review these theories, describe arroyo development along the Santa Cruz River, and provide illustrations showing how the Santa Cruz River arroyos have changed since the time of Statehood. In the convention established by Bryan (1922a) and refined by Antevs (1952), we use the term "wash" where the banks of a river or stream are low and there are multiple channels, and the term "arroyo" when there is a single channel incised in unconsolidated material consisting of clay, silt, sand and some gravel, with banks more than two feet high.

***Theories.*** Antevs (1952) summarized the principal suggested causes of modern trenching given in the literature at that time as:

> "1. Overgrazing, trampling, and human activities, which reduced or destroyed the vegetative cover and made trails, ruts, and ditches, which, in turn, led to greatly accelerated and concentrated runoff, resulting in violently erosive flash floods after torrential rains.
>
> "2. Increase in moisture, which induced denser vegetation, and longer, steadier, and clearer streams with considerable erosive power in the valleys.
>
> "3. Sudden violent showers followed by unobstructed runoff, together with grazing and forest-cutting.

"4. Increasing dryness of climate, which reduced the vegetation and promoted the runoff, which, in turn, enlarged the magnitude and the erosive and transporting power of floods. (Antevs, 1952, p. 376)"

Through his analysis of ancient and modern channeling and filling in the southwestern United States, Antevs (1952) determined that natural arroyo-cutting takes place during drought periods. However, Antevs noted that the above-normal rainfall from 1905 to 1923 or 1932 did not distinctly improve or restore the plant cover and lead to filling of the trenched channels. He also noted that protection from livestock grazing and trampling did enable the vegetation on the grounds of the Desert Laboratory at Tucson to make a remarkable recovery, even during the 1928-1936 period of average rainfall conditions. Antevs therefore considers the ultimate cause of modern arroyo-cutting in the Southwest to be overgrazing since about 1875.

Cooke and Reeves (1976) made two observations of possible climatic change since 1865 that may have affected the development of arroyos in southern Arizona. They noted that the frequency of light rains was lower and the frequency of heavy rains higher at the end of the 19th century than during the 20th century. The lower frequency of light rains could have resulted in a depletion of grasses and other shallow-rooted plants, causing a reduction in surface cover. Increased runoff at that time may have resulted from the heavy rains. The second observation of climatic change made by Cooke and Reeves (1976) was that droughts are often terminated by relatively wet years. Vegetation probably was depleted during the droughts and did not have time to recover during the following wet periods. As a result, runoff and erosion were increased during the heavy rains at that time. Cooke and Reeves also noted that while the pattern of droughts followed by wet years was important in the development of arroyos, there was no evidence to prove that this pattern was peculiar to this time period.

Betancourt and Turner (1990) divided explanations for arroyo-cutting into five general categories: livestock grazing, direct and indirect manipulation of streamflow by man, climatic change, extraordinary floods, and intrinsic geomorphic factors. They noted that both erosional and depositional phases have been linked to cyclical drought. The underlying climatic interpretation of the cutting and filling cycles is the assumption that vegetative cover is the immediate factor affecting erosion, which is controlled by precipitation. Several researchers (i.e. Thornthwaite *et al*, 1942; Leopold, 1951; Martin, 1963; Cooke and Reeves, 1976; Bull, 1964; Hansen *et al*, 1977) have addressed the possible effects of changes in frequency of rainfall intensities on plant productivity and alluvial processes. Betancourt and Turner (1990), after summarizing the different hypotheses, found the different rainfall intensity hypotheses to be inconclusive for two reasons: (1) there are uncertainties in how light versus heavy rains affect vegetation across the broad range of ecological settings that experienced arroyo cutting; and (2) secular trends in rainfall intensity may not be unique to the last hundred years; such trends may characterize other times when arroyos failed to develop but we do not have adequate climatic data to define the trends precisely. They did find agreement in the literature that initial downcutting was associated with extraordinary floods. They noted that, over the past century, most channel erosion in the Southwest was accomplished by large floods during the relatively wet periods of 1884-1891, 1904-1920, and 1965-1987. Recent hydrologic analyses of dated slackwater deposits in bedrock canyons suggest that floods of the past century represent the largest events for periods of up to 2000 years (Baker, 1985). On the Escalante River in Utah, such hydrologic analyses indicated that paleofloods recorded by slackwater deposits in bedrock canyons coincide with the formation of paleoarroyos in alluvial reaches (Webb, 1985).

Betancourt and Turner's 1990 survey and synthesis of historical anecdotes establish a link between initial arroyos and human modifications of the floodplain. They also note that, while many authors considered the widespread erosion that occurred during A.D. 1100-1400 to be unrelated to human activity, prehistoric farmers during this period (i.e., Anasazi on the Colorado Plateau and Hohokom in the Sonoran Desert), may have outnumbered the rural population in the Southwest in the late 19th century, and that these prehistoric farmers harnessed streamflow to grow crops in a similar manner to the Europeans.

***Arroyo Development on the Santa Cruz River.*** The Santa Cruz River system had arroyos no more than a few miles long separated by 12- to 20 -mile-long reaches of unincised alluvium before 1880 (Betancourt and Turner, 1988). For example, the reach below the present site of Valencia Road was described in 1871 as having a channel with vertical banks 60 feet apart and up to 10 feet high (Foreman, 1871, as quoted in Betancourt and Turner, 1988). Since then, a 50-mile-long arroyo through the Tucson Basin has formed, separating relatively unincised reaches upstream and downstream on the Santa Cruz River. Bryan (1925a) and Thornber (1910) place the timing of initial development of large, continuous arroyos on the Santa Cruz River at 1885 to 1890. Thus, arroyo development along the Santa Cruz River began before the time of Statehood.

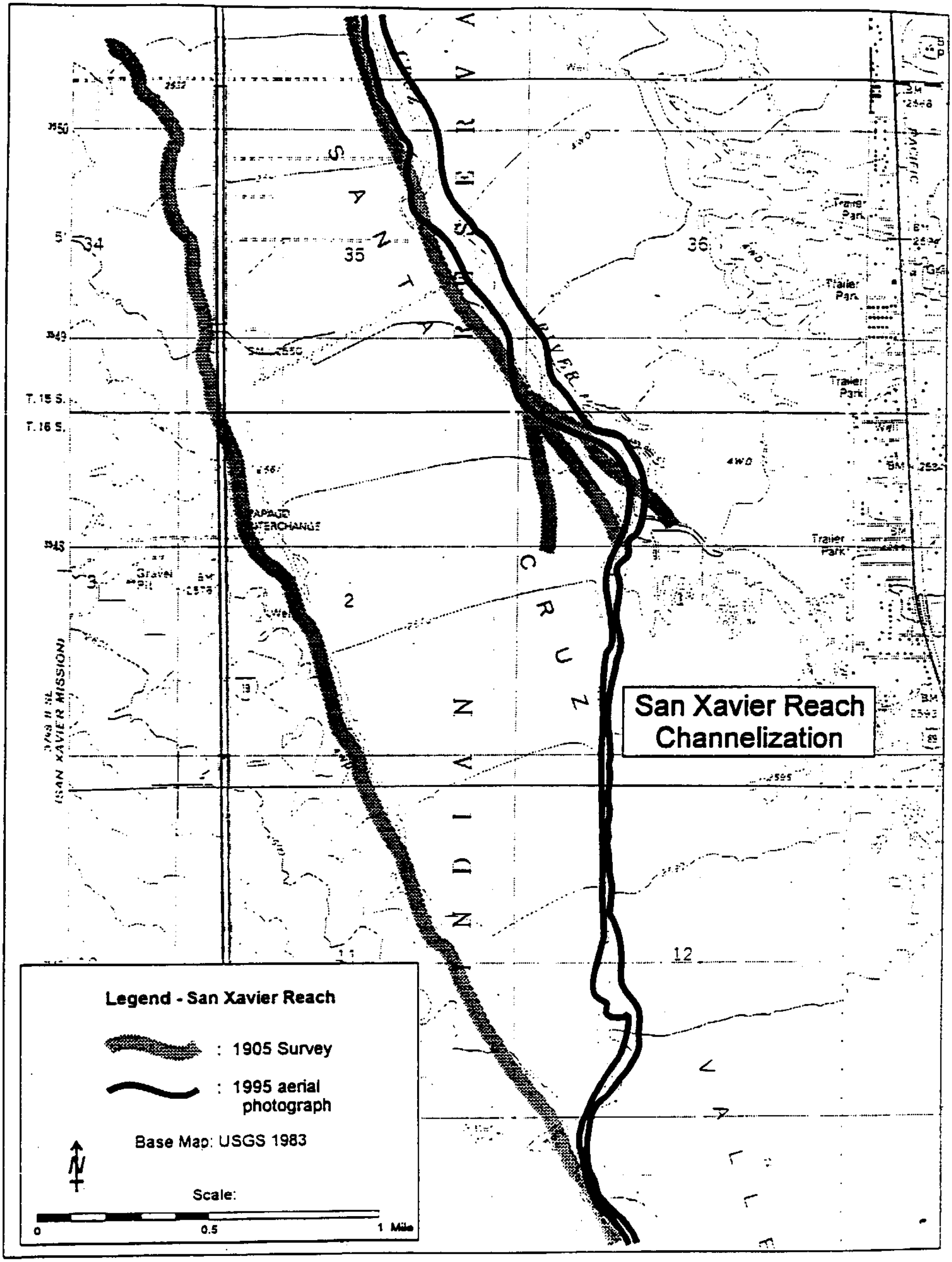
Schwalen (1942) noted that the deepest arroyo entrenchment is between Continental and Tucson, and a short stretch about a mile and one half above the town of Santa Cruz, Mexico. Betancourt and Turner (1990) noted that the short discontinuous arroyo in Mexico is the only entrenched segment of the river upstream of the Tucson Basin. The Santa Cruz River is entrenched most dramatically within the San Xavier Indian Reservation, with vertical banks up to 30 feet high and 300 feet apart where the river meanders around the base of Martinez Hill.

Cooke and Reeves (1976) note that entrenchment in the lower Santa Cruz River Valley is confined to the arroyo along Greene's Canal and to the 5 to 6 mile-long trench that extends south from the Gila River, which probably resulted from headward erosion following downcutting of the main river (Bryan, 1925b).

***San Xavier Reach.*** The chronology of channel change along the San Xavier reach of the Santa Cruz River provides examples of arroyo development and of other channel changes such as channelization that are direct results of human activities. Historically, there were two main sources of spring water in the San Xavier reach, the *Agua de la Misión* and *Acequia de la Punta de Agua*, both south of San Xavier del Bac Mission (see Figure 4). Springs at the *Agua de la Misión* were destroyed by an earthquake in 1887 and flow was forced to the surface higher up in the valley. Development of this water led to the formation of the *East-Side Barranca*, a channel 100-200 feet wide, 15-20 feet deep, and over two miles long. By 1912, a channel 60-100 feet wide, 6-20 feet deep and about two miles long developed after the construction of an infiltration gallery. This channel came to be known as the *West-Side Barranca* (Cooke and Reeves, 1976). Both the *West-* and *East-side Barrancas* were initiated by 1882 (Cooke and Reeve's, 1976) and dried up periodically, which led them to be deepened and extended artificially (Berger, 1901).

The most serious erosion on the San Xavier Indian Reservation resulted when overbank flow crossed from the west to the east side of the valley, and cascaded into the *East-Side Barranca* near the base of Martinez Hill. In 1915, the Santa Cruz River did not have an entrenched channel near the south boundary of the San Xavier Indian Reservation. However, during the 1914-1915 floods, a headcut eroded to a point south of Martinez Hill, destroying the marsh at the source of the Spring Branch. In 1915, engineers acting on behalf of the Papago Indians implemented C.R. Olberg and F.R. Schank's 1913 plan (Olberg and Schanck, 1913) to build an artificial channel that connected the Santa Cruz River channel with the head of the entrenched Spring Branch. The headcut migrated rapidly along the artificial channel and continued upstream so that by the 1930s, a continuous arroyo defined the river's course for a distance of 35 to 45 miles in the Tucson Basin (Betancourt and Turner, 1988). The channel of the Santa Cruz River still follows the route of the 1915 dike into the former course of the Spring Branch (Figure 18) and is now 18 to 24 feet deep (Betancourt and Turner, 1990).

The downstream section of the San Xavier reach, especially the portion above Martinez Hill to Valencia Road, has undergone the most extensive and continuous arroyo widening on the Santa Cruz River. The channel was incised as much as 30 feet in silt and sand of Holocene age, and about 1,200 feet of widening occurred at some places between 1936 and 1986. Mean arroyo width of the entire San Xavier reach increased from 200 feet in 1936 to 500 ft in 1986 (Parker, 1995). Meyer (1989) determined that channels in which bedload transport is significant and bed material are predominantly gravels, such as the Santa Cruz arroyos (i.e. near Nogales, Amado, and I-19), initially widen their arroyos by meandering. Figure 19 illustrates the meandering of the low flow channel within the arroyo walls in the San Xavier reach between 1972 and 1983, while Figure 20 graphs the widening that occurred. Flows undercut weakly indurated, oversteepened arroyo walls, or return flow of bank storage to the channel causes seepage erosion at the base of the walls (Parker, 1995). Figure 21 provides a dramatic time-elapsed view of arroyo widening along the reach upstream of San Xavier Road. Once arroyos widen to the point they no longer constrain flood-channel width, they become braided. The rate of arroyo wall erosion then decreases because the low flow and flood channels can shift freely within the arroyos and only rarely impinge upon the arroyo walls. The arroyos eventually become relatively stable;


San Xavier Reach
Channelization
Legend - San Xavier Reach
: 1905 Survey
: 1995 aerial photograph
Base Map: USGS 1983
Scale:
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SAN XAVIER
INDIAN
Trailer Park
T. 15 S.
T. 16 S.
34
35
36
2
12

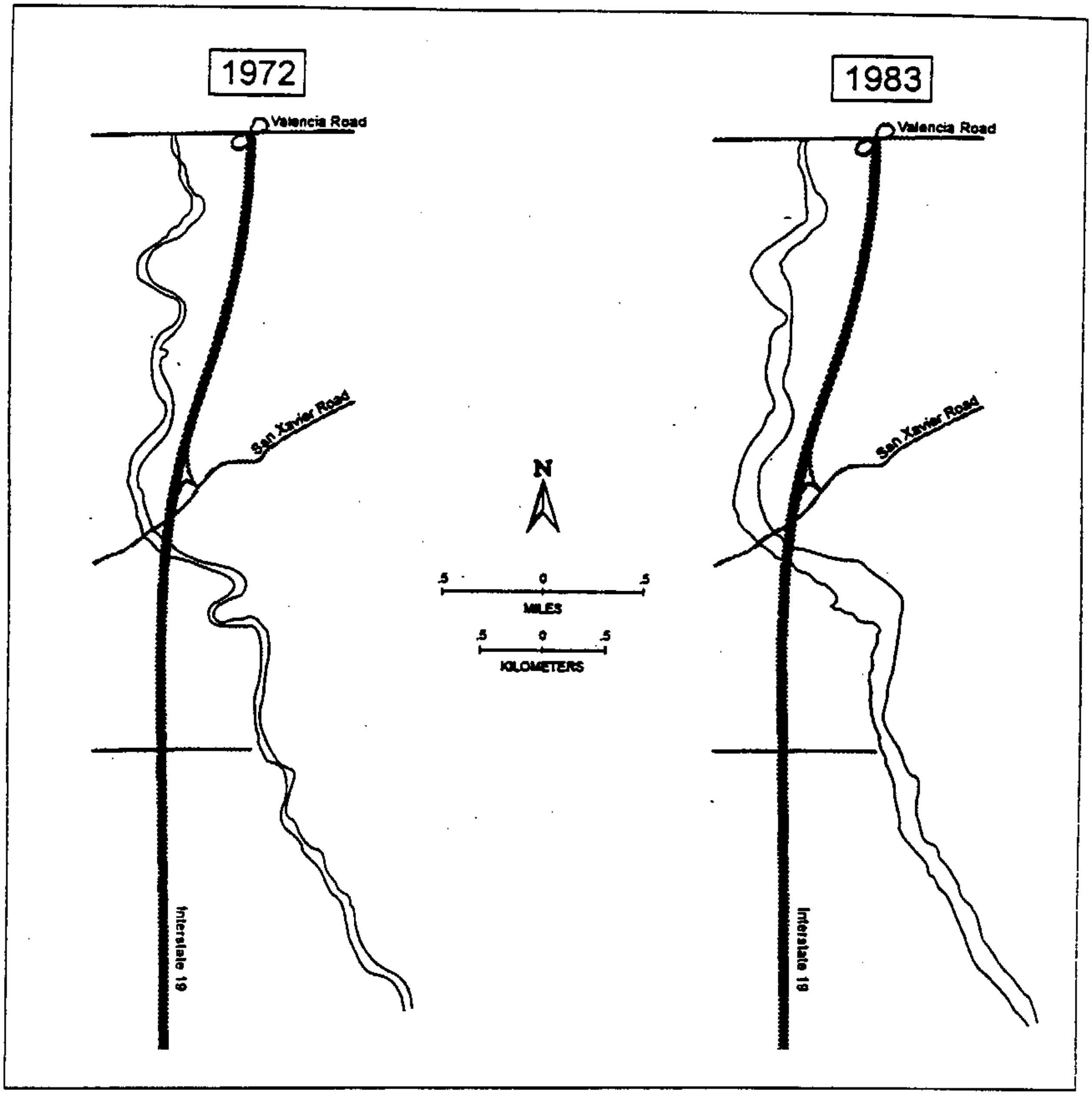


**Figure 19. Low flow channel boundaries within the Santa Cruz arroyo in the San Xavier reach.** Channel boundaries are represented by solid black lines; roads are indicated by dark grey lines. Boundary data was obtained from aerial photographs. [Source: Guber, 1988.]

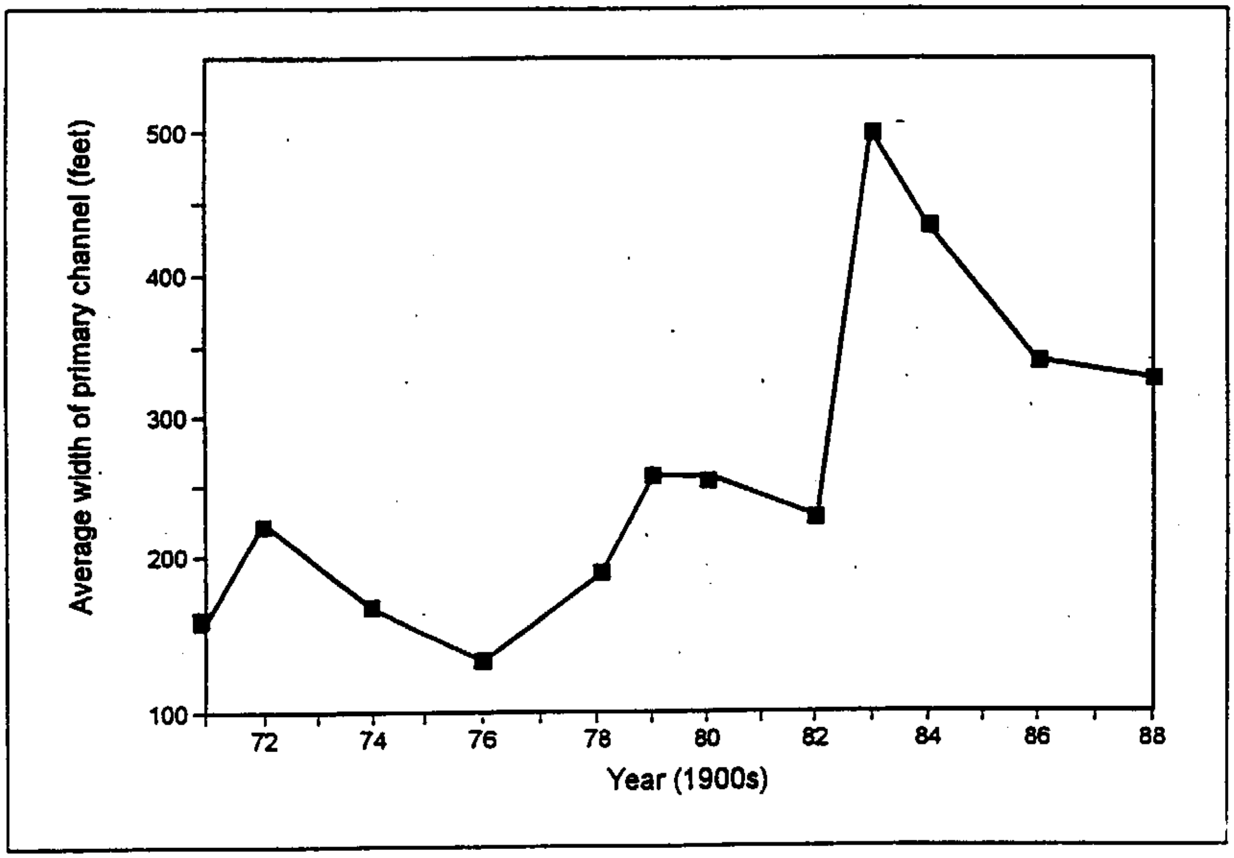


**Figure 20. Average width of the primary flow channel within the San Xavier arroyo.** Each box in the graph represents a measurement made from an aerial photograph. [Source: Guber, 1988.]

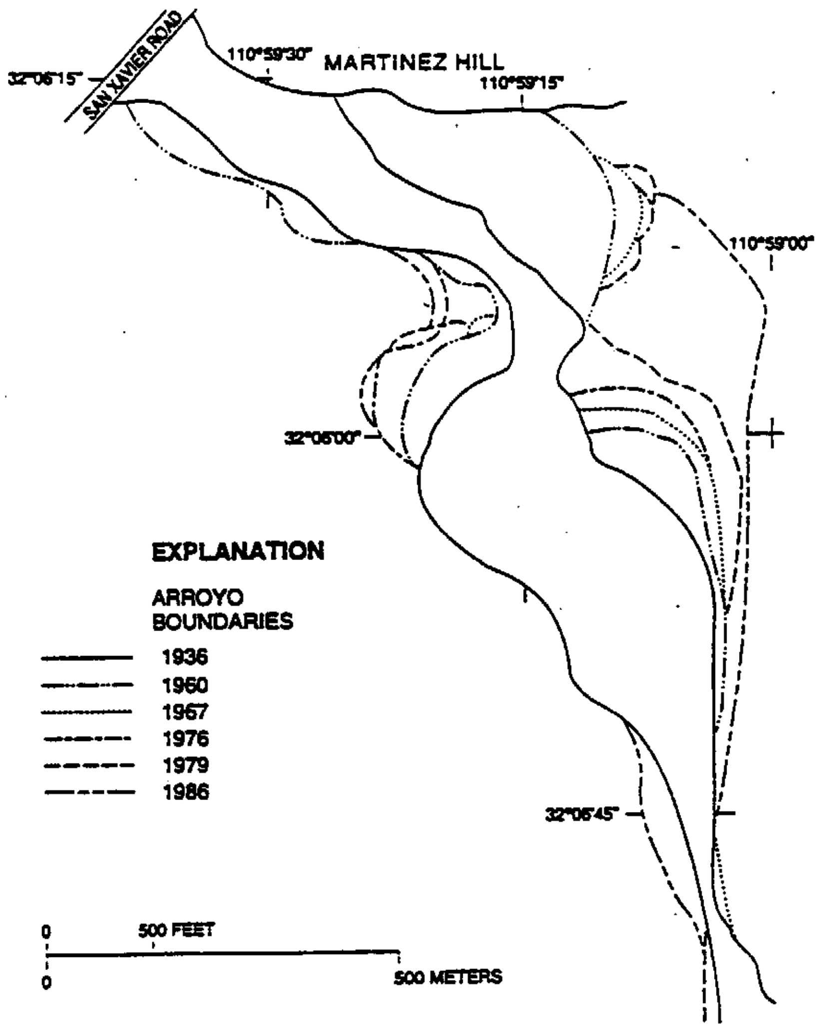


**Figure 21. Arroyo widening caused by migration of entrenched meanders in the San Xavier reach at Martinez Hill, 1936-86.** Data from U.S. Soil Conservation Service, 1936; Cooper Aerial Survey, 1960, 1967, 1979, 1986; Kucera and Associates, 1976. [Source: Parker, 1995.]

former floodplains become terraces and arroyo floors become floodplains (Meyer, 1989). Unlike channel widening, the process of arroyo widening is not readily reversed on large systems such as the Santa Cruz River (Parker, 1995).

### C. Channel Changes in the Lower Santa Cruz River Basin

Change in channel form and pattern on the lower Santa Cruz River is less understood and documented than the upstream reaches. The fluvial system of the lower Santa Cruz River is distinctly different from its upstream counterpart and such changes are more challenging to document and describe. Only during large floods does significant streamflow from the upper Santa Cruz River extend through the lower Santa Cruz River to the Gila River. This hydrological discontinuity is mirrored by a geomorphological discontinuity wherein the basic form of the river transforms from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain with only intermittent channels. Prior to human disturbance, this transition occurred in the Marana area. Due primarily to the effects of Greene's Canal (discussed in the following section), the Santa Cruz River now has a fairly well-defined channel to Chuichu area. (Refer to Figure 1 and Figure 2 for locations.)

Broad sheetflow that is characteristic of large floods on the lower Santa Cruz River is associated with deposition of abundant sediment that remains in storage for long periods of time between large floods. The widespread sedimentation during large streamflow events and the low gradient of this part of the system are conducive to large scale changes in channel position. However, the low frequency of the recurrence of large floods influences the timing of these changes such that they occur only over long time spans. The evidence for significant changes (primarily in channel position) is present in the regional geomorphology and the spatial distribution of geologically young (i.e. 1000 to 5000 years) alluvial deposits in the area. However, because of data limitations and the long time scale of the processes involved, we cannot provide an assessment of long-term channel change. In terms of channel change in the 20th century, description of the effects of Greene's Canal and documentation of the disparate courses taken by two large floods provide interesting and useful perspectives on the behavior of the Santa Cruz River in this unique environment.

***Greene's Canal.*** The modern Santa Cruz River has a relatively distinct channel from its headwaters to just upstream of Greene's Canal. Greene's Canal is a man-made feature that has dramatically influenced the evolution of the lower Santa Cruz River. In 1908 the Santa Cruz Reservoir Company developed a plan to concentrate water from the Santa Cruz River into Greene's Canal, transfer the water to a reservoir, and distribute it for the irrigation of farm land near Toltec (Cooke and Reeves, 1976). A diversion dam and canal were constructed in 1909-10 under the leadership of Colonel William C. Greene. The irrigation scheme was temporarily halted when Colonel Greene died in 1911 and then reactivated in 1913 (Sonnichsen, 1974). However, during the floods of 1914-1915, the diversion dam was destroyed and the canal was eroded to a depth of about 12 feet (Cooke and Reeves, 1976).

Greene's Canal, and headcuts migrating upstream from the canal, have continued to capture and concentrate extensive sheetflow in the upstream area during subsequent floods of this century. This unintended flow diversion had the effect of restricting the vast majority of flood runoff to the western Santa Cruz Flats. Prior to the diversion, floodwaters apparently flowed in a more northerly direction, inundating areas that are now covered by Eloy, Toltec, and Casa Grande. Following the diversion by Greene's Canal, these areas have not been affected by significant flooding from the Santa Cruz River. In 1983, a tongue of floodwater extended to the outskirts of Eloy, apparently following part of the old path. Thus, Greene's Canal has become the dominant conduit for flows from the upper Santa Cruz River. The large floods in 1914-1915, 1977, 1983, and 1993 have transformed what was once a relatively small canal into a deep, wide arroyo that bears a strong resemblance to portions of the Santa Cruz River channel upstream.

***Flood Flow Patterns in the Lower Santa Cruz River Valley.*** Greene's Canal flows west-northwest to the site of the abandoned reservoir for which the canal was originally constructed. The reservoir outlet, now Greene Wash, flows towards the north-northwest. Northwest of Casa Grande, Greene Wash is joined by the Santa Rosa Wash and the North Branch of the Santa Cruz River (refer to Figure 1). The North Branch of the Santa Cruz Wash is an east-west flowing tributary between the town of Casa Grande and the piedmont of the Sacaton mountains to the north. This drainage currently receives runoff from the southern side of the Sacaton Mountains. Flow in the Santa Rosa Wash and the Santa Cruz Wash intermingle during large runoff events because agricultural modification of the landscape has removed the effective drainage divide between the two systems[2] (Rhoades, 1991).

Detailed mapping of flow paths on the lower Santa Cruz River is possible because two of the largest flood events on the Santa Cruz river this century followed distinctly different paths and have been mapped in reasonable detail at various scales. Previous flood mapping in this area has been combined and compiled on a 1:100,000-scale base map of the lower Santa Cruz River area (Plate 1, in pocket). Lines have been drawn to indicate: 1) the spatial extent of the winter flood of the 1914-15 as discerned from Smith's 1938 and 1940 publications and the General Land Office (GLO) surveys; and, 2) the distribution of floodwaters of the 1983 flood event, as published by Roeske *et al* (1989).

Smith's mapping was transferred directly to the 1:100,000-scale base map by enlarging the original map. Smith's 1940 publication indicates only areas "overflowed by floods (not complete)." The 1938 map claims to show the 1914-1915 flood swath, thus it is possible that Smith's maps indicate areas overflowed by earlier (or subsequent) events, i.e. the 1905 flood event. The data sources for the maps by Smith are unknown. No verbal description of methods compilation, data sources, or likely evolution of the flow path depicted for the 1914-1915 map is available. Smith's mapping can only be taken as a somewhat rough depiction of inundation; however, Smith's delineation of one branch of the flow swath extending through Eloy and towards the northwest is consistent with the position of the Santa Cruz River and Santa Cruz Flats as mapped by the GLO surveyors. Lines that represent interpretations of channel positions made by various survey parties also were transferred from the original GLO plats to the 1:100,000 base map.

Roeske *et al* (1989) mapped the distribution of floodwaters from the flood of 1983 using high altitude aerial photography, field reconnaissance, and flood reports. Their rendering is probably considerably more precise than Smith's mapping. The path of the

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[2] An interesting and somewhat unfortunate consequence of the floodwaters crossing the drainage divide between the Santa Cruz Wash and the Santa Rosa Wash, combined with the effects of Greene's Canal, is that it nullifies much of the flood-control effect of the Tat Momolikat Dam on the Santa Rosa Wash (Rhoades, 1991). The dam was constructed in 1974 to protect communities in the floodplain of the lower Santa Rosa Wash. These areas are now subject to inundation by floods on the Santa Cruz River, which are historically more frequent than floods on Santa Rosa Wash.

1983 flood was first transferred from Roeske *et al*'s high altitude aerial photograph to a 1:130,000 scale aerial photograph, and then overlain on the 1:100,000-scale base map. In a few places, flow paths of the 1977 flood on the lower Santa Cruz River mapped by Aldridge *et al* (1984) were added to refine the mapping of likely flow paths of the 1983 event where imagery was not available. This addition was done under the assumption that the general flow paths were the same, although the extent of the 1983 flood was likely greater.

The effect of Greene's Canal can be seen by the comparison of the strikingly different flood paths illustrated in Plate 1. According to both the GLO surveys and Smith's map, the North Branch of the Santa Cruz River near Casa Grande was an important element of the Santa Cruz system. According to Smith (1938, 1940), the floodwaters in 1914-1915 also crossed the low divide near the southeastern corner of the Sacaton Mountain Piedmont between the North Branch and McClellan Wash, the principal drainage of the Picacho Basin. This resulted in the Santa Cruz River flowing along both the east and west sides of the Sacaton Mountains and entering the Gila River at two points separated by more than 20 miles. The very low gradient in the region explains the apparent variability of flow paths through this area. Also evident in Smith's map are broad areas of inundation associated with flow down Greene's Canal and along the western margin of the lower Santa Cruz River Valley. This flow path became the main flow route during the 1983 and 1993 floods.

The low-relief characteristic of the area and the widespread distribution of geologically recent alluvial deposits indicates that much of the area in the lower Santa Cruz River basin has conveyed flow at some point during the last few thousands of years. Only in a few areas are there relatively high standing surfaces (aside from the isolated mountains) that obviously have been free from any inundation. Since the construction of Greene's Canal and the development of the arroyo it initiated, the main flow of the Santa Cruz no longer follows its former paths down the North Branch and McClellan Wash. Instead, it follows the western route via Greene's Canal.

## VII. SUMMARY

The hydrology and geomorphology of the Santa Cruz River have experienced both subtle and dramatic changes in their character since the time of Statehood. These changes have resulted from a combination of climate change, human activities and geomorphologic processes. In this concluding chapter, the characters of the Santa Cruz River at the time of Statehood and the Santa Cruz River of the last decade are described and contrasted.

### A. Hydrology

Historically (~1890s), the Santa Cruz River was perennial from its source to Tubac. Climate change since the turn of the century, combined with the extensive groundwater pumping for irrigation and the flow diversion for municipal use that began near the International Border during the 1930 to 1950 drought period, has resulted in no flow in the channel in Sonora, Mexico, and in discontinuous flow in the channel near Nogales, Arizona. The 1913 gage record at Nogales (the earliest in that region), indicates that by the time of Statehood, the Santa Cruz River at Nogales was no longer perennial, but instead had continuous flow during the winter and occasional flow during the spring, summer and fall. The winter discharge averaged about 15 cubic feet per second (cfs) except for an increase caused by a rainfall event that ranged from 35 to 174 cfs. A survey of the daily data for the rest of the Nogales record indicated that, during unusually wet years, there were only a few days of no-flow conditions. During dry years there were entire months that passed with no flow recorded in the channel. At present, naturally occurring perennial reaches occur only in the uppermost part of the river in the San Rafael Valley. Perennial flow in the reach near Nogales results from the discharge of sewage effluent from the Nogales International Wastewater Treatment Plant that began in 1972.

The Santa Cruz River historically had several springs and marshes (*cienegas*) within its channel from Tubac to Tucson, and a marsh existed at its confluence with the Gila River near Laveen. Even in the historical record, only the very largest floods were sustained from the headwaters to the confluence with the Gila River. A review of the daily discharge record indicated that there was some semblance of baseflow with an average of about 12 cfs during the fall and winter of 1912-1913 at the Tucson gage. Such continuous flow for months at a time was not seen again in the years that followed, though there were periods of several weeks that experienced continuous or nearly continuous flow during very wet winter seasons. The Laveen gage recorded nearly year-round flow from its beginning date (1940) until June, 1956, when it began to measure zero flow for weeks at a time. During the 1940 to 1956 period, the daily flow averaged about 3 cfs during low flow conditions and had peaks as high as 5060 cfs during wet periods. By 1960, the Santa Cruz at Laveen was experiencing no-flow conditions for months at a time.

Not only have the locations of surface flows changed since the time of Statehood, but also the seasonality and magnitude of flows in the Santa Cruz River have changed in response to shifts in the hydroclimatology of the region. Though the majority of flow events occur during the summer season, the magnitude and number of annual peak discharges that occurred in the fall and winter were higher before 1930 and after 1960 than during the 1931-1959 period. For example, six of the seven largest floods at Tucson occurred after 1960, indicating that the magnitude of flood peaks has increased in the past few decades.

Human activities as well as climate change have had notable effects on the peak flows of the Santa Cruz River, especially in the lower Santa Cruz River basin. Since 1962 the construction of flood-control channels in the washes of the lower Santa Cruz River basin have resulted in the reduction of floodplain storage and infiltration losses, therefore reducing the *attenuation* (the downstream decrease of the flood peak) of peak discharges. For example, the attenuation of peak flows was greater during the 1962 floods than during the 1983 floods because water was able to spread out over the broad flow zones in the lower reaches of the Santa Rosa and Santa Cruz washes. In contrast, much of the floodwater during the 1983 floods was efficiently transmitted downstream by the flood-control channels.

**B. Geomorphology**

The geomorphology of the upper Santa Cruz River is quite different from that of the lower Santa Cruz River. The river has a well-defined, often entrenched channel in its upper reaches that contrasts strongly to the ill-defined system of braided channels that exist north of the northern end of the Tucson Mountains near Marana. Both the upper and lower reaches of the Santa Cruz River have experienced dramatic changes resulting from a combination of both natural geomorphic processes and human activities. Three types of lateral change have occurred: meander migration, avulsion and meander cutoff, and channel widening. Two types of vertical change have occurred: aggradation and degradation of the channel bed. While arroyo development is the most obvious type of channel change to occur since the 1890s in the upper Santa Cruz River, most of the initial channel incision occurred before the time of Statehood. Since 1912, various reaches of the upper Santa Cruz River have been dominated by such processes and activities as meander migration and cutoff, channel widening, arroyo widening, channelization, and the vegetational effects of sewage effluent discharge. The channel locations in different reaches have changed spatially on the order of a few feet to a few thousand feet, depending on the processes that resulted in the change, and often change could be detected from one year to the next.

The lower Santa Cruz River experienced changes of a completely different magnitude from the upper Santa Cruz River. Changes in the location of the channel in the lower basin can be measured in miles, and the timing of changes spans decades. Before the construction of Greene's Canal in 1910, the river transformed from a relatively deep, well-defined channel to a broad, flat, extensive alluvial plain at a point in the Marana area. Now that transition point occurs near Chuichu, Arizona. The construction and subsequent flood damage of Greene's Canal has resulted in dramatic geomorphic changes. Prior to and during the floods of 1914-1915, flood flow had the opportunity to follow routes down the North Branch of the Santa Cruz Wash and McClellan Wash. After the development of the arroyo in Greene's Canal, subsequent flood flows have had westerly paths *via* Greene's Canal.

## GLOSSARY

***adobe flats***: defined in Bryan (1922a) as broad flats that are formed by deposition from sheet floods and are floored with sandy clay, also called "adobe."

***aquifer***: a permeable geologic formation, group of formations, or part of a formation which stores and transmits water.

***arroyo***: a river or stream with a single, definite channel incised in unconsolidated material consisting of clay, silt sand and some gravel, with banks more than two feet high.

***basin***: an extensive depressed area into which the adjacent land drain. The Tucson Basin is the northward-trending, structural depression of about 2600 $km^2$ into which the adjacent land drains.

***cienega:*** term applied to riparian marshlands by Spanish explorers.

***ephemeral stream***: a stream or portion of stream which flows only in direct response to precipitation. It receives little or no water from springs and no long continued supply from snow or other sources. Its channel is at all times above the water table.

***flow-duration curves***: cumulative frequency curves that show the percentage of time specified discharges are equaled or exceeded in a given period.

***groundwater***: that water which infiltrates the earth's surface, percolates downward, and is stored in the saturated zone of a geologic stratum.

***infiltration***: the process whereby water passes through an interface, such as from air into soil.

***infiltration rate***: the rate at which soil can absorb water.

***intermittent stream***: a stream with reaches that flow only during wet weather or during part of the year.

***percolation***: the process whereby water passes through fine openings in porous stones.

***perennial stream***: a stream or portions of a stream that flow throughout the year.

***phreatophytes***: deep-rooted plants that obtain water from the ***water table*** or the layer of soil just above it.

***recharge***: inflow to a ***groundwater*** reservoir. ***Aquifers*** may be recharged from ***infiltration*** of water from adjacent mountains, direct penetration of precipitation on valley floors, infiltration of waters used for irrigation, water rising from depths as fault or fracture springs, and ***underflow*** from outside the basin. Water is discharged from aquifers by underflow into a downstream basin, evaporation, transpiration, spring discharge, and pumping.

***riparian***: refers to that which is related to or located or living along a watercourse whether natural, man-made, ephemeral, intermittent, or perennial.

***subflow***: see ***underflow***.

***underflow***: a term used interchangeably with ***subflow*** throughout this report to describe the groundwater underlying the surface of a stream's channel. Sykes (1939) noted that these words imply continuous forward movement of water beneath the stream-bed, which probably seldom occurs in a stream channel like that of the Santa Cruz River. Sykes instead describes the "underflow" as being a series of semi-isolated sub-surface reservoirs, which retain most of the seepage water received from local precipitation, or channel flow, and only intercommunicate when the sub-surface layers of the stream bed become supersaturated.

***wash***: a river or stream with low banks and numerous channels.

***water table***: the plane which forms the upper surface of the zone of ***groundwater*** saturation. Should the water table rise so that it intersects the ground surface, a spring results.

***xerophytes***: plants that are structurally adapted for life and growth with a limited water supply.

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## Appendix A

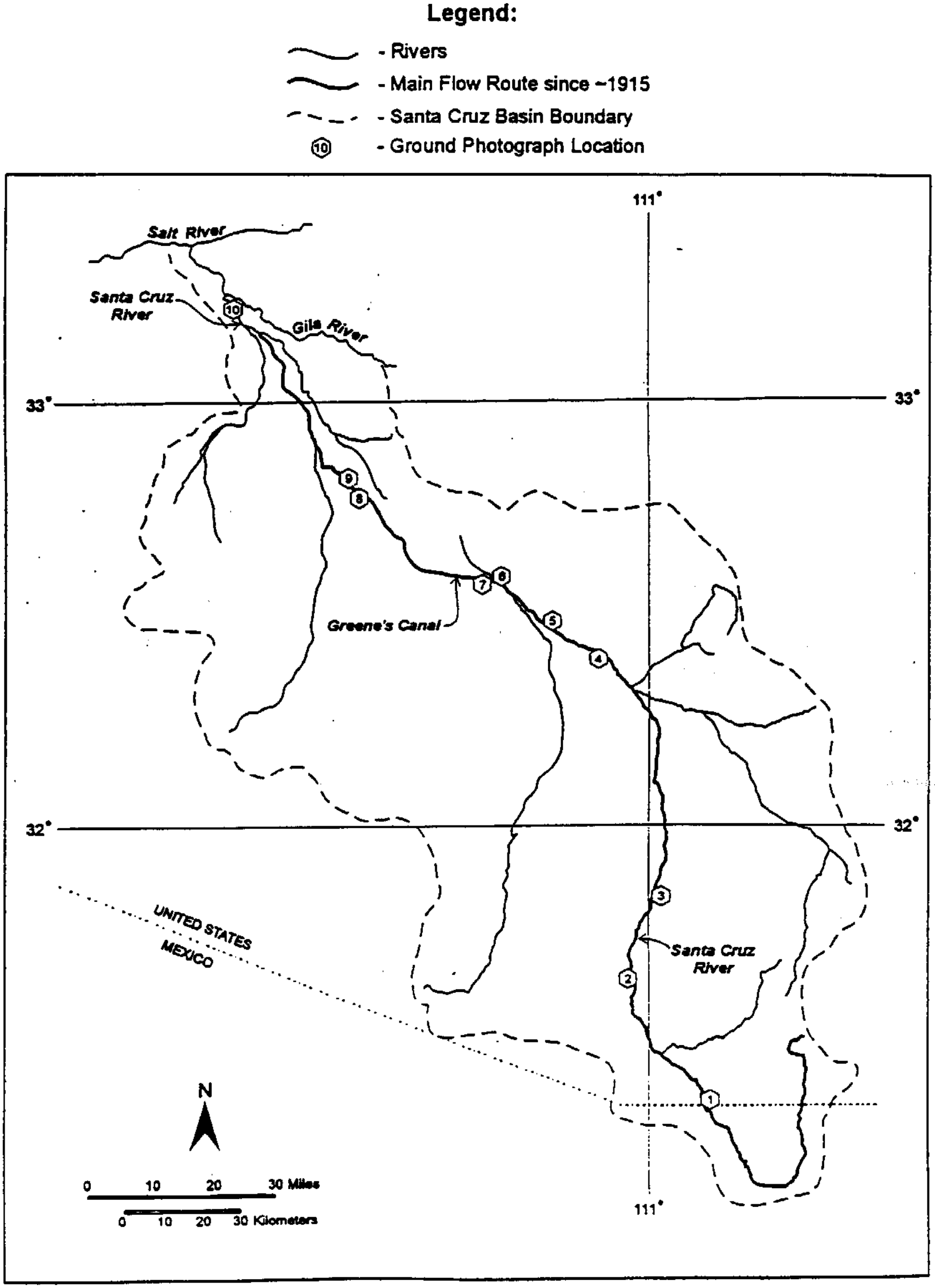
## Ground Photographs

The ground photographs provided in this appendix illustrate key differences between the different reaches of the upper and lower Santa Cruz River. Figure A-1 indicates the locations of the photographed reaches. All photographs were taken in 1996. For a review of historical photographs of the Santa Cruz River, refer to Tucson's Santa Cruz River and the Arroyo Legacy.[A-1, A-2]

[A-1] Betancourt, J.L. (1990). Tucson's Santa Cruz River and the Arroyo Legacy. The University of Arizona, Ph.D. dissertation, 239 p.

[A-2] Betancourt, J.L., and Turner, R.M. (1990). Tucson's Santa Cruz River and the Arroyo Legacy. To be submitted to the University of Arizona Press, Tucson, as a book manuscript, 239 p.

**Figure A-1. Locations of ground photographs provided in this appendix.**



1. Downstream view of the Santa Cruz River, 0.75 mi north of the international border. (9/18/96)

2. View of the Santa Cruz River from Chavez Siding Rd. crossing, ~ 2 miles north of Tubac. (9/18/96)

3 Upstream view of the Santa Cruz River from the Continental Rd. crossing. (2/19/96)

4. Downstream view of the Santa Cruz River where it curves around the base of Rillito Peak. (2/19/96)

5. Upstream view from Trico-Marana Rd. crossing of the Santa Cruz River with erosion control structures. (9/18/96)

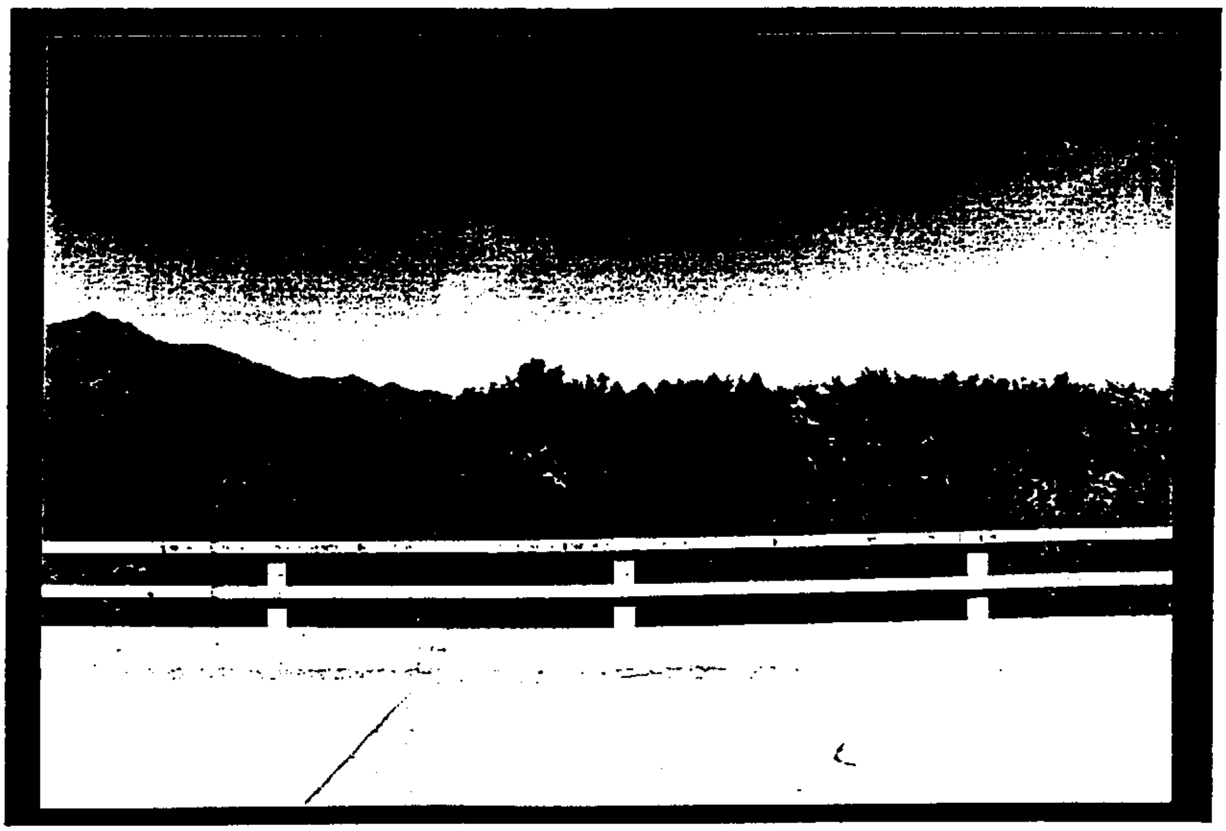
6. Downstream view of the Santa Cruz where it splits from Greene's Canal. Note, the base of the Santa Cruz channel is perched above the base of Greene's Canal. (10/7/96)

7. Southward view from the north bank of Greene's Canal, ~300 feet downstream of the Santa Cruz split. Note the termination of the man-made levee within the channel and the steepness of the southern channel bank. (10/7/96)

8. Downstream view of Greene's Wash as seen from the levee of the Santa Rosa Canal. The wash has defined banks only where it has been channeled through the canal. (10/7/96)

9. View of Greene's Wash downstream from Montegomery Rd. crossing. The wash has been channeled to form a canal and has been constrained by a levee. (10/7/96)

10. Downstream view of the vegetation-filled channel of the Santa Cruz River, as seen from the Santa Cruz Rd. crossing north of Maricopa. (9/27/96)



## Appendix B

## Mapping of Low and High Watermarks

To aid the Arizona Navigable Stream Adjudication Commission in its determination of the potential navigability of the Santa Cruz River, the ordinary low and high watermark boundaries were mapped for the Santa Cruz River and Greene's Canal/Greene Wash for all the reaches that have a defined channel. Several qualitative and quantitative procedures have been developed to delineate high and low watermark boundaries.[B-1] The ANSAC Technical Review Committee determined that a three-level approach should be utilized.[B-2] The first level is a boundary determination based on the qualitative assessment of physical evidence identified during field checks of different reaches of a given Arizona river. The second level incorporates additional physical evidence collected from the interpretation of aerial photographs and topographic maps. Field observations are used to verify the information gathered from the aerial photographs and maps. The third level, the analysis of flow duration data published by the USGS for gaged streams, is to be undertaken "where there is justifiable need and sufficient data exists."[B-2]

In accordance with the approach outlined above, information gathered from field checks, aerial photographs and topographic maps was utilized to delineate the low and high watermark boundaries in the Santa Cruz River basin. Aerial photographs of the Santa Cruz River area in Pima and Santa Cruz counties were produced by Landiscorp Aerial Surveys in March of 1995 and have a scale of ~1:24,000. Aerial photographs of the Santa Cruz Flats region in Pinal County were produced by Aerial Mapping Company, Inc., and had photograph dates ranging from September, 1994, to March, 1995, with a scale of ~1:7200. Color copies of the Santa Cruz County aerial photographs and blue-line copies of the Pinal County photographs are indexed and archived at the Arizona Geological Survey. Field checks of the aerial photographs and topographic maps were conducted in late September and early October, 1996. Photographs taken of different sites at ground level are indexed and provided in Appendix A.

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[B-1] GVSCE, 1996: Definition of Ordinary Low Watermark. Report submitted to the Arizona State Land Department, 22 July 1996.

[B-2] GVSCE, 1996: Ordinary High and Low Watermark Delineation. Memorandum submitted to the Arizona State Land Department, 9 August 1996, that sumamrizes the procedure to be used in the delineation of ordinary high and low watermarks.

The ordinary low watermark, per ARS § 37-1101, is defined as "the line on the banks of a watercourse created when the water recedes at its regularly recurring lowest stage in normal years without reference to unusual droughts."[B-1] Though this definition is fairly straightforward when used to describe rivers with a baseflow, ambiguity arises when applying such a definition to the Santa Cruz River because it is intermittent or ephemeral in the majority of its reaches. First, physical markers on the landscape left by low flows tend to be quickly erased by periodic high flows. Second, even if there were a statistical definition of the ordinary low watermark based on hydrological records, much of the Santa Cruz River is not gaged. For these reasons, low watermark boundaries were mapped only in the reaches in which there was water at the time the most recent aerial photographs were taken. The low watermark boundaries discerned from the 1994 and 1995 aerial photographs were transferred to USGS 7 1/2′ topographic quadrangles using a zoom-transfer projector and marked in blue pencil. Figure B-1 provides an index of the topographic maps that were used in this study and submitted to ANSAC. In most reaches, the low watermark boundaries were too close together to draw separately. Therefore, one line was drawn, the width of which approximately matches the width of the low flow channel. The existence of surface flow as seen in the aerial photographs was verified by field-checking and the analysis of daily synoptic weather maps and topographic maps.

The ordinary high watermark is defined as "that line on the bank established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of the soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas." (33 CFR, Part 328.(e)[B-1]). We mapped high watermark boundaries in all reaches that had any combination of: defined channel banks, channel surfaces cleared of vegetation, changes in vegetation type from riparian to terrestrial, and changes in soil type. Figure B-2 is an annotated aerial photograph of the reach of the Santa Cruz River one mile north of the USGS gage near Nogales. The channel surfaces cleared of vegetation appear as bright white or light tan in the original color photographs (white in this black and white image) and provide relatively straightforward evidence of the high watermark boundaries. The water-filled low flow

**Figure B-1. USGS topographic quadrangles included in this appendix.**

**Legend:**

- Rivers
- Main Flow Route since ~1915
- Santa Cruz Basin Boundary
- Ground Photograph Location

**30** - USGS Topographic Quadrangle. (The number refers to the name of the quadrangle listed in the box below.)

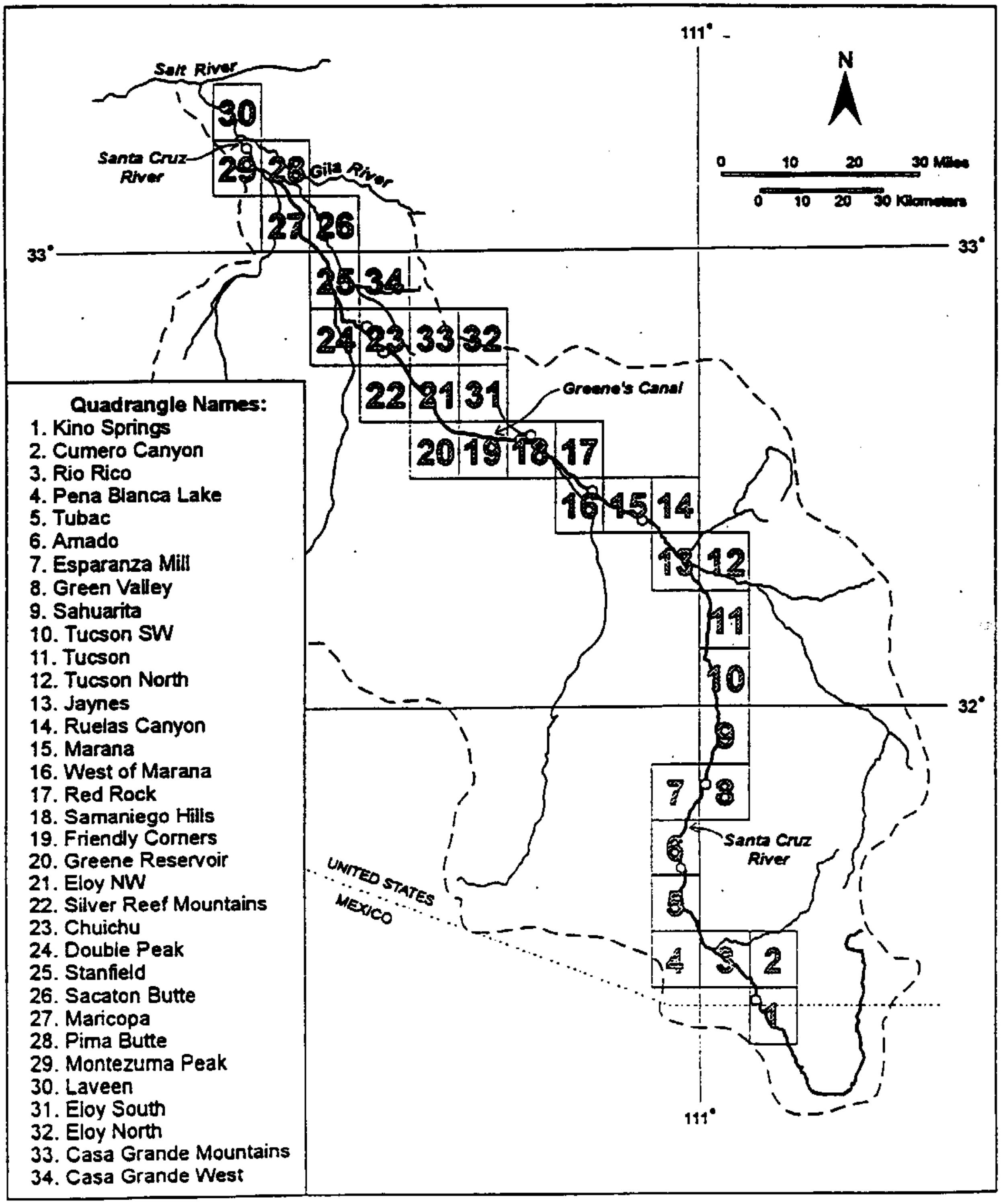
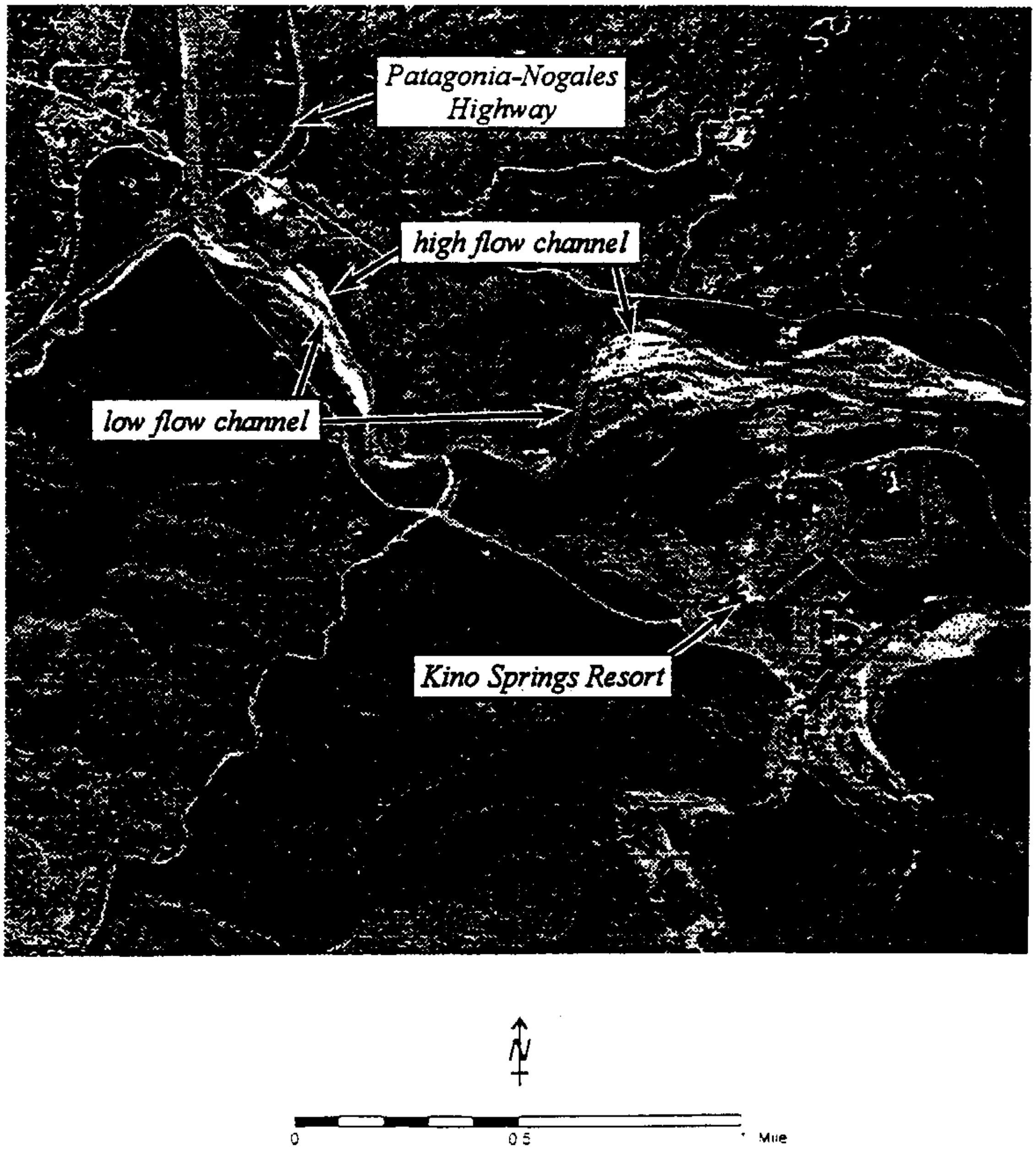


Figure B-2. Annotated aerial photograph of the Kino Springs reach of the Santa Cruz River.



channel appears as a darker tan color (darker gray in this image) and delineates the low watermark boundaries.

In some reaches, the high and low watermark boundaries are the same, as evidenced by the lack of vegetation-cleared surfaces adjacent the low flow channel. Areas where recently deposited river sediments were observed beneath riparian vegetation cover (i.e. mesquite *bosques* and large cottonwood trees) were included within the high watermark boundaries. The location of the high watermark boundaries were transferred from the aerial photographs to the USGS 7 1/2' topographic quadrangles on which the low watermark boundaries were mapped using a zoom-transfer projector and marked in green pencil. A dashed green line on the topographic maps indicates areas that were recently (i.e. during the 1983 floods) cleared of vegetation and, as of the 1995 aerial photographs, were experiencing re-vegetation. Figure B-3 shows the high and low watermark boundaries mapped near Cortaro, north of Tucson.

The review of aerial photographs and topographic maps indicated that the current locations of the high and low watermark boundaries has remained approximately the same since the 1983 floods. However, there have been notable changes in the location of the high and low flow channel boundaries since the time of Statehood. These channel changes were discussed in great detail in Chapter VI of Section 4. A more detailed narrative of the mapping of the low and high watermark boundaries is provided below. If the narrative describes features mapped on the USGS 7 1/2' topographic quadrangles, the italicized names of those quadrangles are provided in parentheses.

***Low Watermark Boundary Delineation***

Low watermark boundaries were mapped in two reaches of the Santa Cruz River: 1) from the U.S.-Mexico border to south of Green Valley; and 2) from south of Jaynes to north of Marana. Figure B-4 highlights the locations of these reaches. Most of the surface water results from the discharge of secondary-treated municipal effluent from the Nogales International Wastewater Treatment Plant, and the treatment plants at Ina Road and Roger Road just north of Tucson. Refer to Figure B-4 for the locations of the treatment plants and Chapter V and VI of Section 4 for a more detailed review of the effects of effluent in these areas.

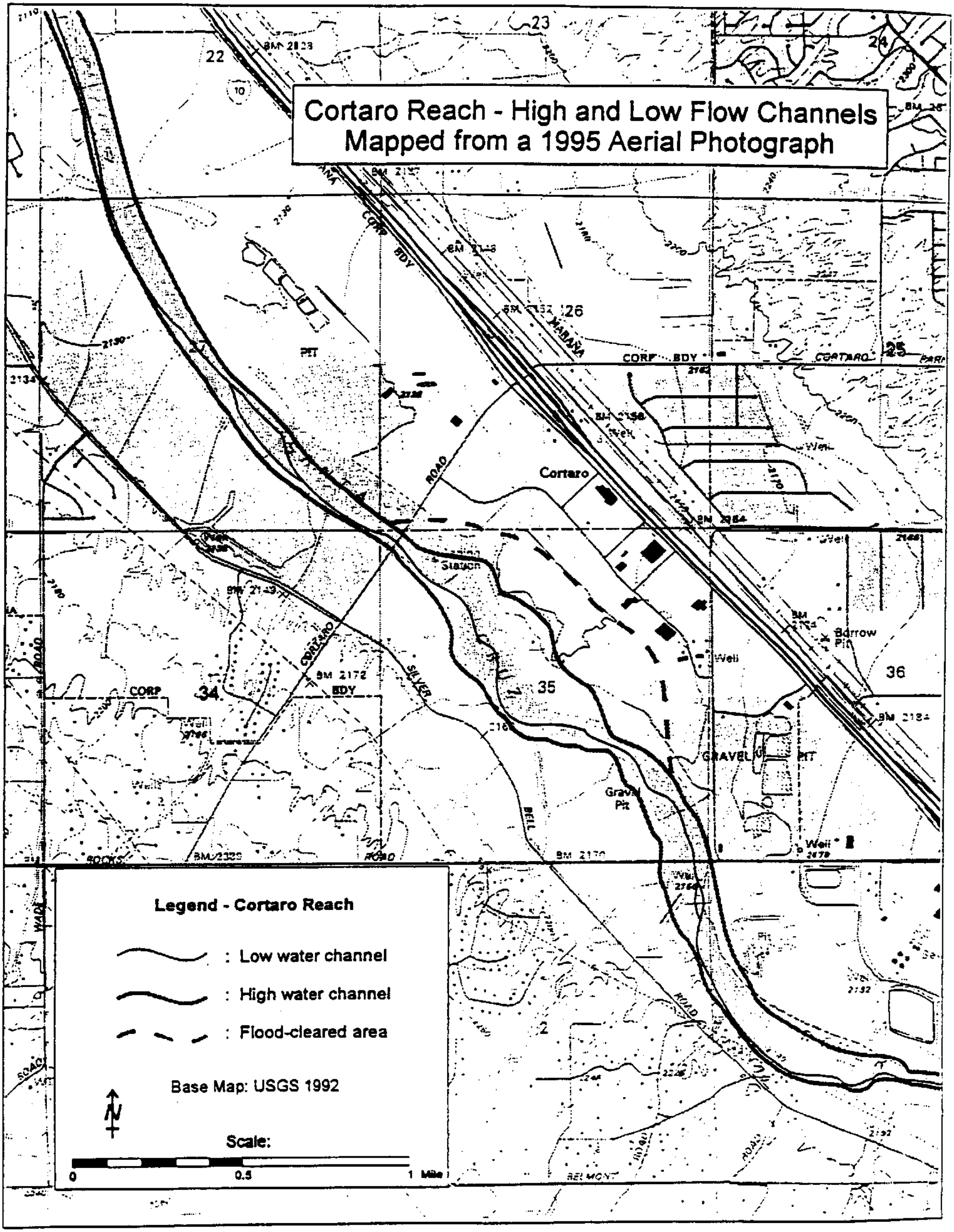
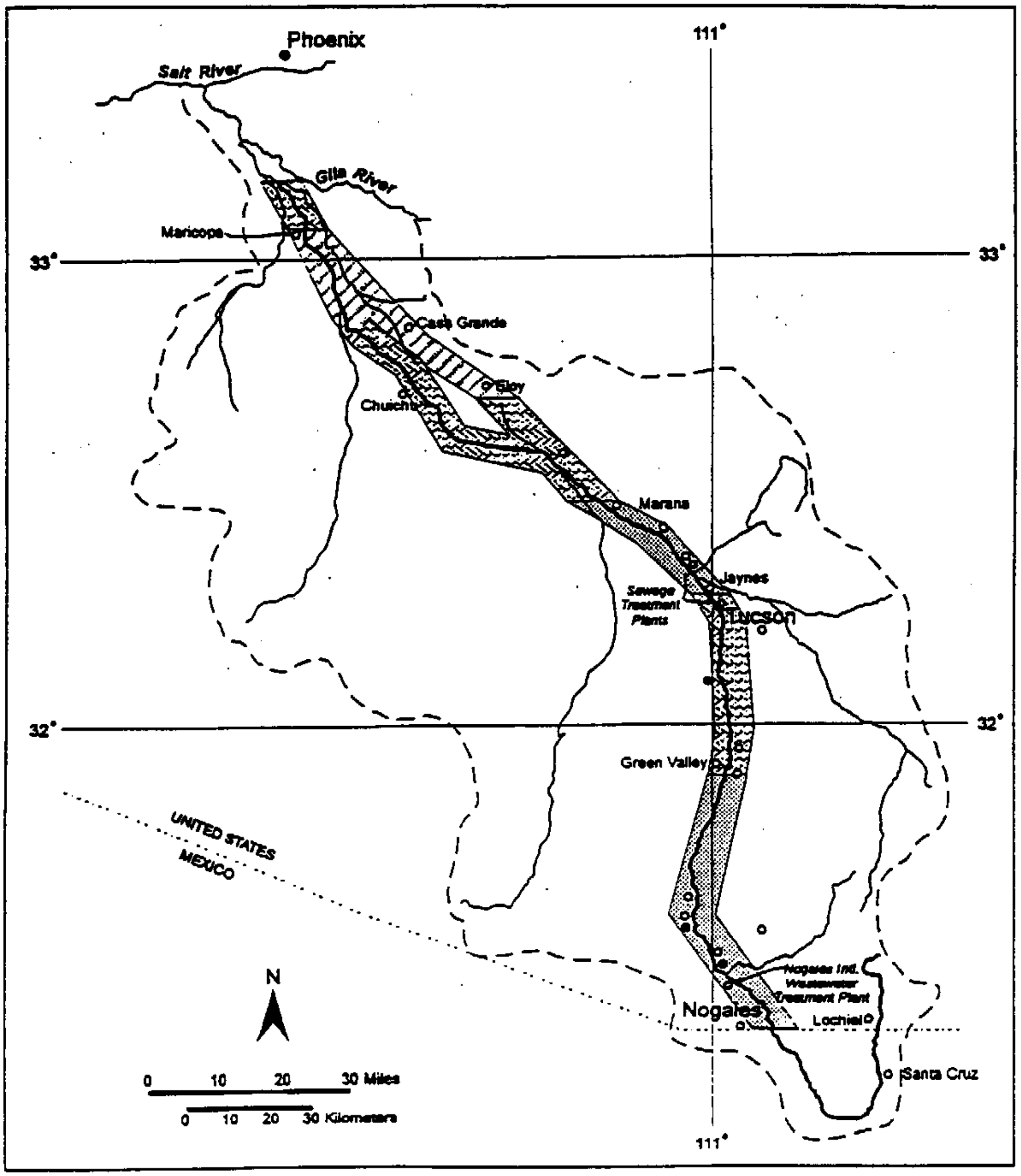

Cortaro Reach - High and Low Flow Channels
Mapped from a 1995 Aerial Photograph
Legend - Cortaro Reach
: Low water channel
: High water channel
: Flood-cleared area
Base Map: USGS 1992
N
Scale:
0
0.5
1 Mile
Cortaro
Gravel Pit
Borrow Pit
22
23
24
26
34
35
36

**Figure B-4. Santa Cruz River Basin: Mapping of ordinary high and low watermark boundaries.**

**Legend:**

- o - Populated Places
- • - Historical Sites
- ⊙ - Sewage Treatment Plants
- ~ - Rivers
- ~ - Main Flow Route since ~1915
- - - Santa Cruz Basin Boundary
- High and low watermark boundaries mapped from aerial photographs.
- High watermark boundaries only mapped from aerial photographs.
- 7 1/2' maps supplied for this region. No high or low watermarks are mapped.



The aerial photographs taken on March 27, 1995, indicated that the channel upstream from the Nogales treatment plant also contained surface water (*Kino Springs, Cumero Canyon* and *Rio Rico* quadrangles). This section of the Santa Cruz's channel is often dry due to the lowered water table and depleted subflow that has resulted from increased groundwater extraction and diversion of the river's flow in this region during the last few decades. (Refer to Chapter V-A, for more details.) A review of the daily synoptic weather maps determined that three fronts had passed over or near the upper Santa Cruz River within the ten days before the aerial photographs were taken, bringing both isolated and widespread rain showers that would have resulted in flow in the channel. Field checks in late September, 1996, a week after several intense monsoon showers, found evidence of either surface water or water just beneath the channel surface in this same reach.

We also conducted field checks to determine where the surface water terminated downstream of the treatment plants. Surface flow that had its source from the Nogales treatment plant ceased just south of Amado. Surface flow that had its source from the Ina Road and Roger Road treatment plants ceased about one mile west of downtown Marana. The surface flow in the reach downstream from the Nogales treatment plant ended south of the termination location discerned from the aerial photographs. Most likely, both the aerial photograph interpretation and field observations are valid. During the cooler winter/spring season in which the aerial photographs were taken, there would be less evaporation from the water surface and less withdrawal of water by the vegetation adjacent the channel. Hence, surface flow would continue farther downstream than during the hotter summer months.

### *High Watermark Boundary Delineation*

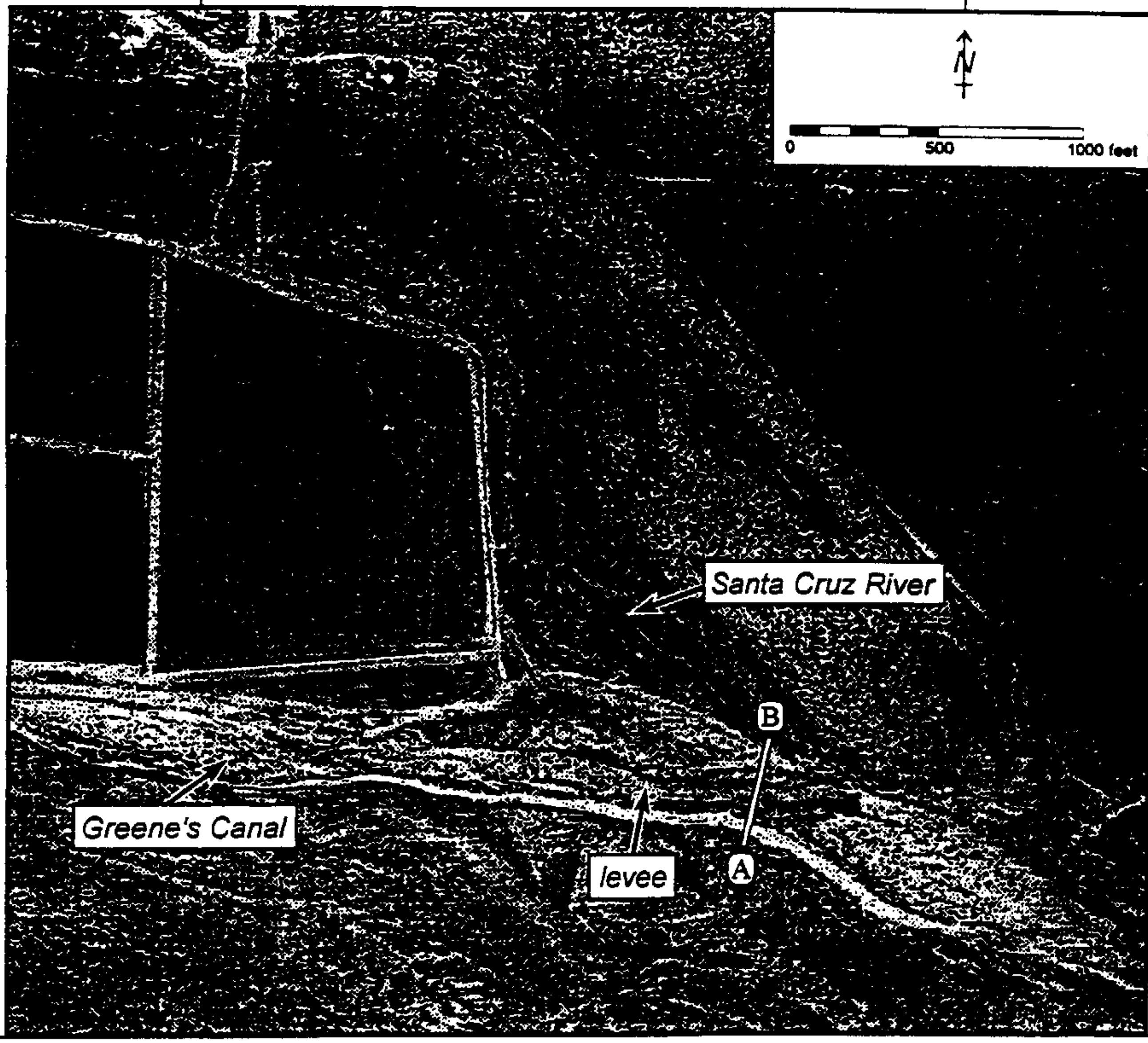
The entire upper Santa Cruz River had a well defined channel for which high watermark boundaries could be mapped from the aerial photographs in a straight-forward manner. There were a few sections of the river that had dense mesquite *bosques* in or immediately adjacent the channel. Where the *bosques* led to ambiguity in the exact watermark boundary location in the aerial photographs, field observations and an analysis of the topographic maps provided clarity.

The Santa Cruz has a well defined channel until four miles southeast of the Santa Cruz/Greene's Canal split (*Samaniego Hills Quadrangle*). A distinct channel appears again about two miles south of the Santa Cruz/Greene's Canal split. A headcut begins about one and a half miles upstream of this split and the Santa Cruz is deeply eroded with steep banks until the Greene's Canal junction. Field checks discovered two interesting channel features in this reach. First, a 1500 foot levee has been constructed within the main channel that diverts flow down Greene's Canal and away from the Santa Cruz branch. Second, a low flow channel has incised itself about five feet into the main channel where the channel's flow has been directed. Figure B-5 provides both an aerial view of this reach and a cross-sectional view of the main channel where the Santa Cruz channel splits from Greene's Canal. The aerial view illustrates how the levee has redirected flow from the Santa Cruz, as evidenced by the denser vegetation growth in the southern section of the main channel. The aerial view also shows how narrow the Santa Cruz channel becomes downstream of its split from Greene's Canal, with only a very thin portion of its channel cleared of vegetation. The cross-sectional view illustrates the vertical relationship between the Santa Cruz channel and the channel features within Greene's Canal.

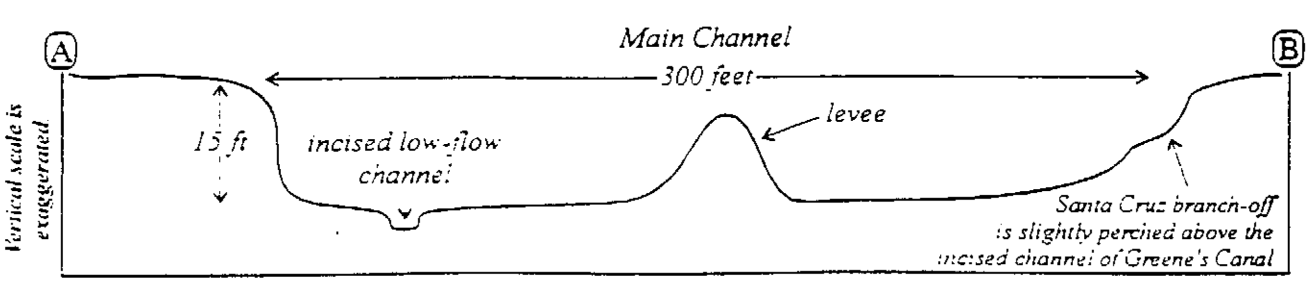
Field checks indicated that the shrubs and trees that fill the channel of the Santa Cruz immediately downstream of the split are dead. The death of the vegetation probably resulted from the Santa Cruz being cut off from the water flow in the main channel. Less than a mile downstream of the split, the narrow Santa Cruz channel is completely filled with living vegetation. This reach of the Santa Cruz receives water only from the drainage of the local fields rather than from upstream of Greene's Canal. In the aerial photographs, field checks and topographic maps, the Santa Cruz channel ends in the irrigated croplands north of the village of Friendly Corners, south of Eloy (*Friendly Corners Quadrangle*).

The Santa Cruz Wash is mapped again just north of Chuichu by USGS surveyors (*Chuichu Quadrangle*). It appears in the aerial photographs as a region of slightly denser vegetation. Field checks and aerial photographs taken during the floods of 1992-93 indicate that this was a region of extensive sheet-flow rather than channeled flow during the recent large floods; no defined channel banks were observed in the field checks. North of Interstate 8 and southwest of Casa Grande, the Santa Cruz Wash becomes completely constrained by levees. The channeled Santa Cruz Wash is routed through the croplands

Figure B-5. Annotated aerial photograph of the Greene's Canal - Santa Cruz River split.




Idealized Cross-Section of Greene's Canal - Santa Cruz Channel Split



until north of Maricopa where is spreads out into multiple braided channels that are densely vegetated.

Evidence gathered from field checks, aerial photographs and the mapping of historical floodwaters (refer to Chapter VI-C) indicates that Greene's Canal has become the main flow route during the latter part of this century. For this reason, we have mapped Greene's Canal in addition to the Santa Cruz Wash. Unlike the Santa Cruz Wash, Greene's Canal (which flows into Greene Wash) can be mapped throughout its course. From its split with the Santa Cruz Wash to its confluence with Greene Wash (*Greene Reservoir Quadrangle*), Greene's Canal is deeply incised with steep channel banks. Greene Wash has braided channels except where levees have been constructed near Chuichu (*NW Eloy* and *Chuichu* quadrangles). Field checks and the aerial photographs indicate that, like the neighboring Santa Cruz, this reach of Greene Wash is an area of sheet-flow rather than channeled flow (*Chuichu Quadrangle*). However, Greene Wash is more distinct in the landscape than the Santa Cruz in this region. For example, while breaks in the Santa Rosa Canal were created for both Greene Wash and Santa Cruz Wash, Greene Wash has a more defined, wider channel in that area and more vegetation (i.e. both shrubs and dense grass growth that was green at the time of the field checks). Three miles northwest of Chuichu, Greene Wash is constrained by levees. Less than one mile northeast of Stanfield (*Stanfield Quadrangle*), the channeled Greene Wash joins with the channeled Santa Rosa to become a second branch of the Santa Cruz Wash. This branch of the Santa Cruz also is constrained by levees and routed through the croplands until north of Maricopa where it spreads out into multiple channels. The multiple branches of the Santa Cruz join three miles southeast of the village of Santa Cruz (*Pima Butte Quadrangle*). This vegetation-filled channel continues northeast five miles to where it joins the Gila River (*Laveen Quadrangle*).

Unlike the upper Santa Cruz River, the Santa Cruz Wash in the Santa Cruz Flats region often did not meet the criteria for mapping high watermark boundaries. The following scenarios occurred:

1) Channels were completely filled with dense vegetation (i.e. no cleared surfaces were apparent in the aerial photographs); such channels were mapped on the topographic quadrangles using a green shading that filled the entire channel area rather

than two lines denoting exact watermark boundaries. If only a narrow line of vegetation denoted the location of the wash in the aerial photograph, a single green line was mapped on the topographic quadrangle.

2) Channel boundaries were completely constrained by berms and levees, or were labeled as canals; such channels were not mapped using aerial photographs, but topographic maps were compiled for such reaches and annotated.

3) Channel boundaries were not seen in the aerial photographs or from ground observations; such channels were not mapped using aerial photographs, but topographic maps were compiled for these reaches and annotated.

In several of its reaches, Greene Wash matched scenarios #1 and #2 listed above.

## Appendix C

## Stage-Discharge Rating Curves for the Santa Cruz River at Tucson and near Nogales

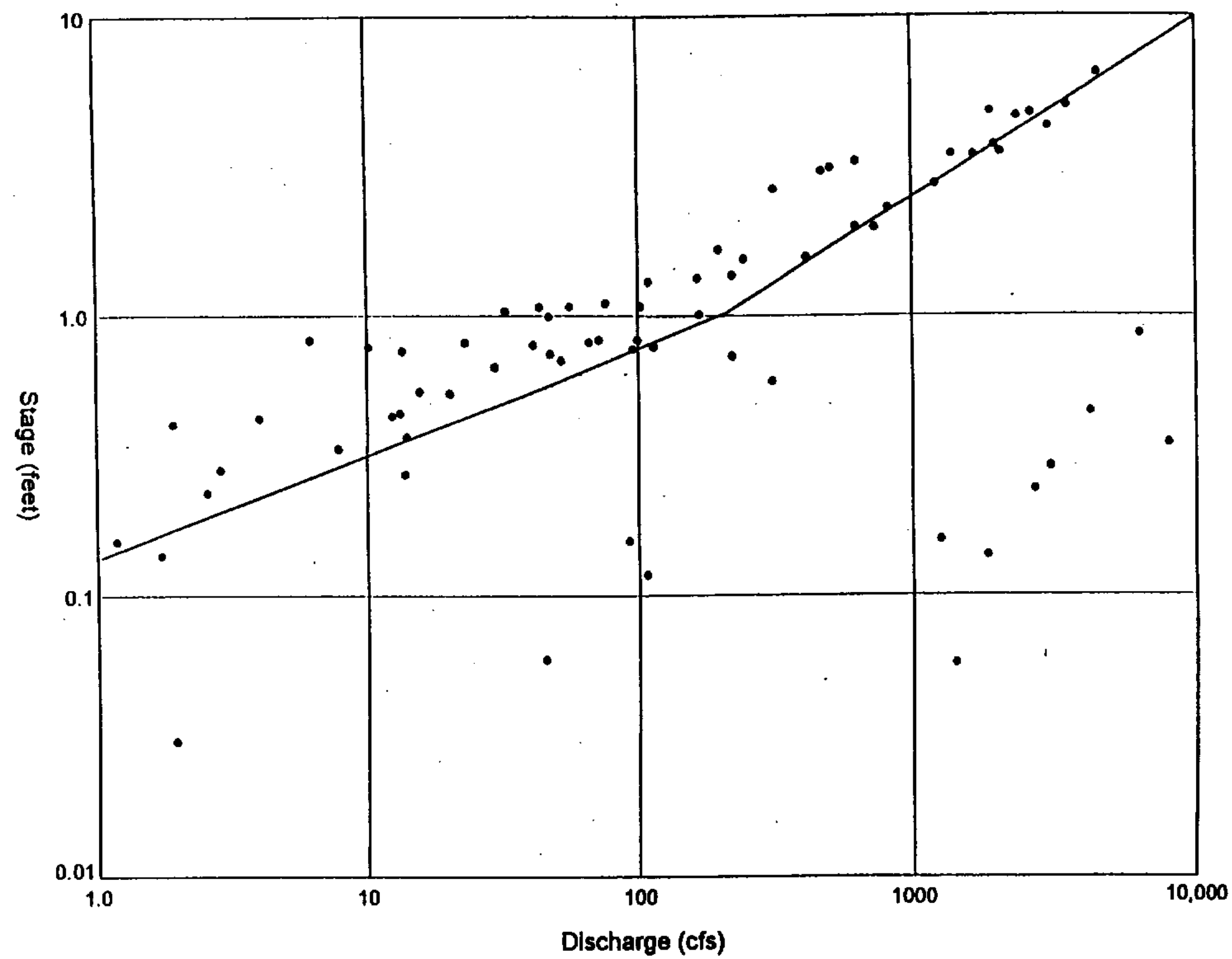
A stage-discharge rating curve is a graphical plot that shows the relationship between the monitored water level at a gaging station (the *stage*) and the corresponding flow rate (the *discharge*). The establishment of a reliable stage-discharge relationship is essential at all river gauging stations when continuous-flow data is needed from the continuous stage record.[C-1] While stage-rating curves are most often used to convert stage data to discharge values, the curves can also be used to do the reverse. Stage-discharge rating curves are provided in this appendix so that the Arizona Stream Navigability Commission may determine the water heights that correspond to the discharge values given in earlier chapters. Below is a brief background of the meaning and use of stage-discharge rating curves for the gages at Tucson and near Nogales, the gages for which the oldest and most complete data was obtainable.

The stage-discharge relationship is dependent on the nature of the channel section and the length of channel between the site of the gage and the cross-section where the discharge was measured. Channel conditions in natural rivers tend to change over time; hence, stage-discharge relationships also tend to change over time, especially after flood flows. Typically new discharge measurements are made throughout a range of stages on a regular basis by the hydrologists responsible for maintaining USGS streamflow records. The hydrologist plots the discharge measurements against the corresponding stage measurements on log-log graph paper and draws a best fit line through the points. Because the data is plotted on log-log paper, the data points tend to group in a more linear fashion that makes relationships more apparent to the hydrologist. If the data was plotted on regular arithmetic graph paper, the data points would group into a curve; hence the name "rating curve" is given to the hand-drawn line through the data points. Each time new measurements are collected, a new stage-discharge rating curve is created. That rating curve is then used until the next time new discharge measurements are made.

Figure C-1 is an example of such a stage-discharge plot using a log-log scale created for the Santa Cruz River at Tucson from data gathered during the period 1955-

[C-1] Shaw, E.M., 1988. Hydrology in Practice, Second Edition. Chapman and Hall: London, 539 p.

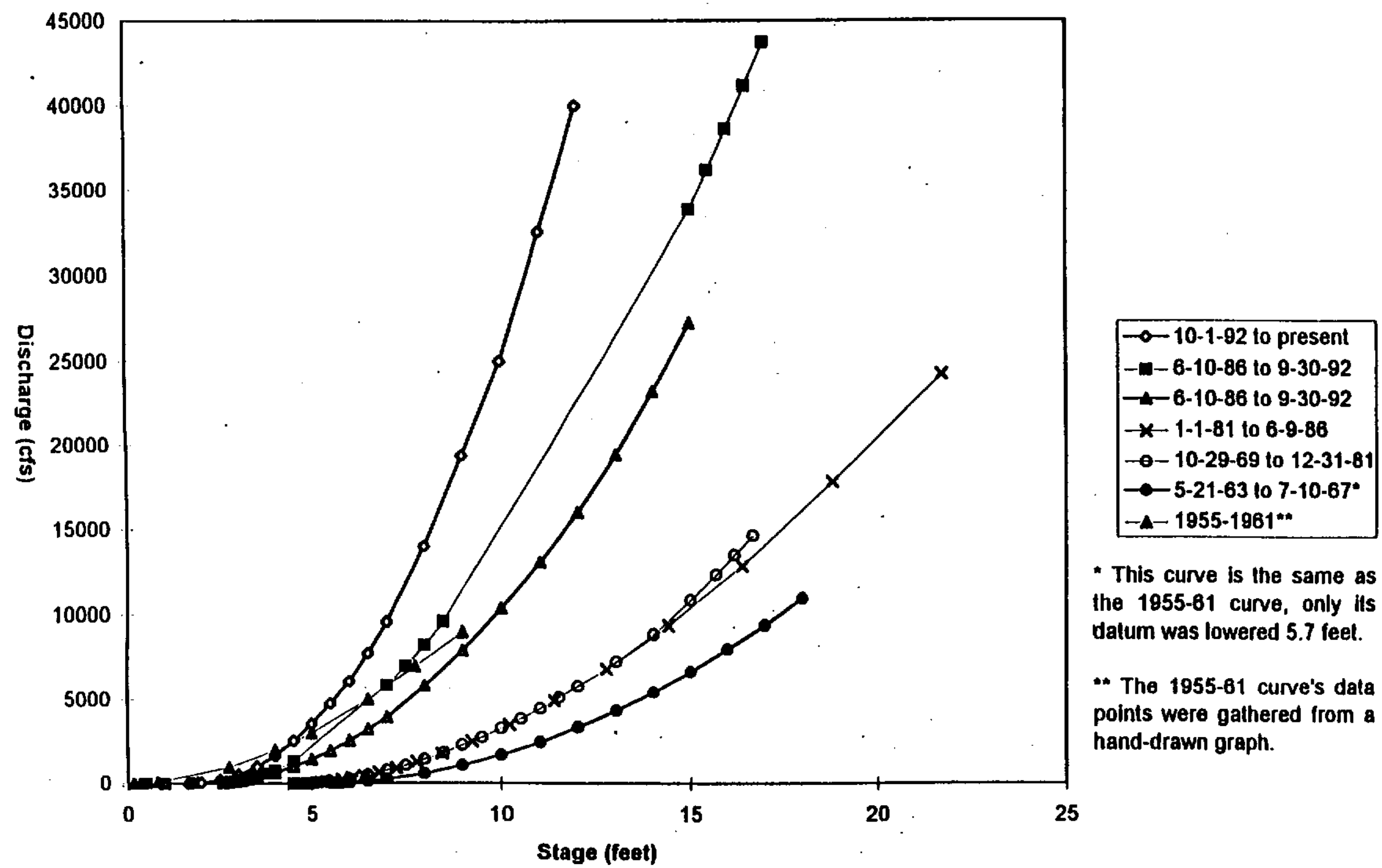
**Figure C-1. Stage-rating data for the Santa Cruz River at Tucson, Arizona.**
**Data points are plotted on a log-log scale.**
**Discharge measurements were gathered 1955-1961.**



1961. There is a great amount of scatter in the data points' location; that is, the points do not cluster close together. Such scatter often occurs in data collected from rivers with channels composed of sandy, unconsolidated materials. Rivers with bedrock channels tend to have flows that remain in a fixed location with a fixed channel geometry; therefore, their stage-discharge points plot closer together. In contrast, channels in unconsolidated materials tend to shift their locations and dimensions through such processes as channel scour and deposition and meander formation and cut-off. (Refer to the section on channel change mechanisms in Chapter VI for a more detailed review.) Channel changes may occur even as a hydrologist is taking the discharge measurements (D. Ufkes, USGS-Water Resources Division, Tucson, personal communication, 1996). The change in the slope of the line drawn through the data points in Figure C-1 at the stage height of about one foot indicates that there was a change in the channel control governing the stage-discharge relationship in this reach (i.e. there may have been a change in the slope of the river banks). In rivers where flood flows overfill the channels and spill onto flood plains, there may be another break in the slope of the line at higher discharges because the stage-discharge relationship of the within-bank flow may be very different from the stage-discharge relationship of the floodplain flow.

Once a USGS hydrologist establishes a satisfactory rating curve, a rating table is constructed from values of stage and discharge read off the line drawn through the data points. We retrieved the rating tables used for different time periods from the USGS-Water Resources Division office in Tucson for the gages at Tucson and near Nogales. We plotted the data as curves on an arithmetic scale rather than as straight lines on a log-log scale to make the graphs easier to read. Figures C-2 and C-3 illustrate how the stage-discharge relationships at these sites have changed over time. While most of the differences between the curves are a result of changes in the channel characteristics, some result from the use of different methodologies in obtaining discharge measurements. For example, the two curves in Figure C-2 plotted for the period June 10, 1986, to September 30, 1992, result from different data collection methodologies. Figures C-4 and C-5 are enlargements of the same curves in Figures C-2 and C-3 that better show the stage-discharge relationships for lower stage heights.

**Figure C-2. Stage-rating curve for the Santa Cruz River at Tucson.**
Each line represents the stage-discharge relationship for a different period.




* This curve is the same as the 1955-61 curve, only its datum was lowered 5.7 feet.

** The 1955-61 curve's data points were gathered from a hand-drawn graph.