Arizona Stream Navigability Study for the Salt River:

Granite Reef Dam to the Gila River Confluence

Draft Final Report

Prepared for the

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Preface

This report was prepared under contract to the Arizona State Land Department Drainage & Engineering Section. The report summarizes factual information relating to the navigability of the Lower Salt River as of the time of statehood. This report provides information on the portion of the Salt River located between Granite Reef Dam and the confluence with the Gila River. Information presented in this report is intended to provide data to the Arizona Navigable Stream Adjudication Commission (ANSAC) from which ANSAC will make a determination regarding the navigability of the Lower Salt River. This report does not make a recommendation or draw any conclusions regarding title navigability of the Lower Salt River.

The report consists of several related parts. First, archaeological information for the Salt River Valley relating to river uses is presented to set the long-term context of river conditions and river uses. Second, historical information from the periods prior to and including the time of statehood are discussed with respect to river uses, modes of transportation, and river conditions. Limited oral history information for the river is also presented. Third, a review of geologic influences on stream flow and river conditions is also presented. Fourth, historical and current land use information are described and presented in a GIS format. Fifth, historical and modern hydrologic data are summarized to illustrate past and potential flow conditions in the river.

The original Lower Salt River Stream Navigability Study was performed by CH2M HILL, Inc. and SWCA, Environmental Consultants, Inc. in 1993 under contract #A3-0061 for the Arizona State Land Department on behalf of ANSAC. Project staff for the original study included V. Ottosawa-Chatupron, Arizona State Land Department, Project Manager; Jon Fuller, CH2M HILL team leader, hydrologist, and geomorphologist; Dennis Gilpin, SWCA, historian; Marc Cederholm, SWCA, GIS specialist. Data summarized in this study were obtained from numerous agencies, libraries, and collections named in the appendixes of this report. Use of this document is governed by the Arizona State Land Department and the Arizona Navigable Stream Adjudication Commission. Revisions to the CH2M HILL report were completed in 1996 by JE Fuller/ Hydrology & Geomorphology, Inc. under contract #LOA 97-01, and in 2003 by JE Fuller/Hydrology & Geomorphology, Inc. under contract #AD000150-010.

Executive Summary

CH2M HILL, in cooperation with SWCA Environmental Consultants and the Arizona Geological Survey (AZGS), was retained in 1993 by the Arizona State Land Department (ASLD) to provide information to the Arizona Stream Navigability Adjudication Commission (ANSAC). ANSAC will use information provided by the project team to make a determination regarding the navigability or non-navigability of the Lower Salt River. This report provides information on the portion of the Salt River located between Granite Reef Dam and the Gila River confluence. The 1993 CH2M HILL report was later revised in 1996 and 2003 by JE Fuller/Hydrology & Geomorphology, Inc. (JEF) under contracts to ASLD.

The basic approach to this study was to develop a database of information to be used by ANSAC in making a determination of navigability or non-navigability. Because the State's definition of navigability includes both actual navigation and susceptibility to navigation, the data collection effort was directed at two areas:

- Historical Uses of the River. Data describing actual uses of the river at the time of statehood were collected to help answer the question, "Was the river used for navigation?"

- Potential Uses of the River. Data describing river conditions at the time of statehood were collected to help answer the question, "Could the river have been used for navigation?"

Specific tasks for the study included agency contact, a literature search, summary of data collected from agencies and literature, and preparation of a summary report. The objectives of the agency contact task were to inform community officials of the studies, to obtain information on historical and potential river uses, and to obtain access to data collected by agency personnel on the Lower Salt River. For the latter task, public officials from communities, towns, cities, and counties located within the study reach were contacted. The objective of the literature search was to obtain published and unpublished documentation of historical river uses and river conditions. Information collected from agency contacts was supplemented by published information from public and private collections.

The literature search focused on five subject areas: (1) Archaeology, (2) History, (3) Hydrology, (4) Hydraulics, and (5) Geomorphology. Archaeological data augment the historical record of potential river uses at statehood by providing an extended record of river conditions, use of river water, climatic variability, and cultural history along the rivers. Historical data provide information on actual river uses as of the time of statehood, but also provide information on whether river conditions could have supported certain types of navigation. SWCA historians prepared a chapter summarizing use of the river and adjacent areas in historic times, with special emphasis on the establishment, growth, and development of towns, irrigation systems, commercial activities, and developments. The hydrologic/hydraulic data are the primary source of information regarding susceptibility to navigation. These data include estimates of flow depths, width, velocity, and average flow conditions at statehood, based on the historical streamflow estimates, and available modern records for natural stream conditions at the time of statehood, as well as for existing stream conditions. Geomorphic data provide information relating to river stability, river conditions at statehood, and the nature of changes to the river since the time of statehood.

Other elements of the study included collection of land use information and ethnographic data. Land use data were compiled for the Lower Salt River and were entered in a GIS database. Land use data included existing title records from county assessor's offices, state and federal land leasing records from ASLD, the Bureau of Land Management, and the US Forest Service. Ethnographic data, or the recollections of individuals with personal knowledge of historical conditions, supplement formal historical and archaeological records. Interviews were conducted with long-time residents, professional historians, avocational historians, and professional land managers who were knowledgeable about the river.

The data collected were organized into six main subject areas: archaeology, history, ethnography, geology, hydrology, and land use. Archaeological records indicate that the prehistoric inhabitants of the Salt River Valley, known as the Hohokam culture, occupied the area along the Lower Salt River from approximately A.D. 250-1450. The Salt River Valley was one of the most densely populated areas in the prehistoric Southwest and contained the most extensive irrigation system in prehistoric North America. The Hohokam depended heavily upon the Salt River for their existence in several ways. First, fish from the river were used to supplement their food source. Second, river water was used for irrigation and direct consumption. Third, the riparian habitat fostered by the river was heavily utilized for food, fuel, and construction purposes. The irrigation system constructed by the Hohokam in the Salt River Valley extended over 315 miles. The system included at least ten separate canal systems, some as long as 16 miles. The main canals measured 10 to 20 feet wide and were 3 to 12 feet deep, with a maximum individual diversion capacity of about 240 cubic feet per second (cfs). Most of the prehistoric canal systems have been destroyed by modern development and historical agriculture. By the early 1930's fewer than 10% of the Hohokam canal system was still visible. As late as 1877, however, it was reported that Mormon settlers were still able to clean and reuse some of the prehistoric canals, indicating that river conditions had not significantly changed between the time of Hohokam occupation and the years immediately preceeding statehood.

Euroamerican colonization of the Salt River Valley began with the establishment in 1865 of Camp McDowell on the Verde River just upstream from the junction of the Verde and the Salt Rivers. Establishment of Fort McDowell not only provided protection from Apache raids, but also created a market for agricultural crops. Within two years, permanent white settlement of the Phoenix area began, with the goal of providing crops to Fort McDowell. The main commercial uses of the Salt River were for irrigation, fishing, milling of grain, and transportation. In 1867, Jack Swilling and Joseph Davis separately began developing canal systems in the Phoenix area. Commercial fishing on the Salt River, primarily by Native Americans, was reported in the newspapers between 1879 and 1909. As early as 1867, the Army began to leave a boat at McDowell Crossing on the Lower Salt River on a full-time basis. By the late nineteenth century, at least five commercial ferries were in existence on the Salt River. Sixteen accounts of attempted or successful boating or transportation of goods on the Lower Salt River were identified for the period between 1873 and 1915.

Thirteen professional historians, four avocational historians, and one long-term resident were interviewed to provide ethnographic information on the Lower Salt River. A number of interviewees could cite or recall instances of the Salt River being used for boating. One historian said that an article in the Mesa Free Press, circa 1890-91, described how wooden construction material from abandoned Fort McDowell was floated down the Verde and Salt rivers to be used in constructing canal headgates. One long-term resident recounted his father's stories of how, around 1910, he and other high school students built rafts from debris in the Salt River and floated them down the Salt River. Two historians suggested that nineteenth-century trappers might have used canoes or boats, although the primary documents indicate that the mountain men traveled through Arizona on horseback. Most of the historical data obtained from ethnographic interviews with local historians are documented sources that summarized elsewhere in this report.

Geologic data indicate that the existing geomorphology of the Salt River is substantially different from its condition at or before the time of statehood. At statehood, the Lower Salt River had a compound channel formed in deep alluvial deposits. The compound channel consisted of a low flow channel inset within a broad active floodplain. The relatively unstable low flow channel shifted periodically within the floodplain. The floodplain, which was up to several miles wide, consisted of low terraces, cutoff channels, and flood flow channels. The overall limits of the floodplain were more stable than the low flow channel, which tended to fluctuate seasonally and in response to floods. The stream bed was composed of sandy silty material, which together with perennial flow supported healthy riparian vegetative communities along the low flow channel banks. Prior to the anthropomorphic channel changes brought on by urbanization and 20th century flooding, the Salt River probably existed in its relatively stable pre-statehood conditions for many centuries.

Like its geomorphology, the hydrology of the Lower Salt River has significantly changed during the last century. The Salt River Valley has a long history of reliance on the perennial flows of the Salt River watershed. Prior to statehood, perennial streamflow rates were sufficient to support rich riparian vegetation, fish and beaver populations, and extensive prehistoric irrigation systems. During the prehistoric period the mean annual flow in the Lower Salt River averaged about 1,300 to 1,700 cfs. Stream gage records indicate that the Lower Salt River experienced perennial runoff, with average monthly flow rates ranging from a seasonal early summer low of about 300 cfs to late winter/early spring high of about 3,400 cfs. By 1912, numerous irrigation diversions upstream and within the Lower Salt River had significantly reduced flow rates, and even caused the river to cease flowing in some reaches during some years. After extensive settlement of the Salt River Valley, reliance on the river for supplying irrigation water led to depletion of water flowing in some reaches of the study reach. Currently, the Lower Salt River flows only during periods of flooding or due to the release of treated wastewater effluent.

During 1912, the year of Arizona statehood, below average runoff from the upper watershed, normal irrigation withdrawals, and filling of the newly completed Lake Roosevelt Reservoir combined to produce reaches of dry or limited flow in the Salt River in February 1912. Likely perennial reaches in 1912 were located the following areas:

- Granite Reef Dam to Tempe Canal head. Typical flows included water released as irrigation supply to downstream diversions, releases from Roosevelt Dam, flows exceeding upstream diversion capacity, and flood flows.
- Tempe Butte to Jointhead Dam (56th Street). Typical flows included ground water and underflow forced to the surface by shallow bedrock in the bed of the Salt River, flows exceeding the upstream diversion capacity, and flood flows.
- Downstream of Phoenix to the Gila River confluence. Typical flows included irrigation return flows, ground water discharge, flows exceeding upstream diversion capacity, and flood flows.

Recorded incidents of boating occurred on the Salt River prior to statehood at various times throughout the calendar year, but were generally limited to low-draft boats floated or paddled in the downstream direction, ferries, and recreational boating. Instances of boat use of the Lower Salt River included transportation of goods, floating logs and lumber, and several permanent and seasonal ferries. Hydrologic and hydraulic information indicate that the natural flow rate and pre-urbanization channel conditions would support low-draft boating throughout the year, although boating in the upstream direction would be moderately difficult. By 1912, opportunities for boating on the Lower Salt River were limited due to declining streamflow caused by diversions and impoundments, though boating during high flows and floods still occurred. Recreational boating on Lower Salt River continues to the present time during periods of high flow, on the man-made Tempe Town Lake, and in areas where treated wastewater effluent is released into the streambed, and where other stormwater impoundments occur.

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Chapter 1
Introduction

CH2M HILL, in cooperation with SWCA Environmental Consultants, was retained by the Arizona State Land Department (ASLD) to provide information to the Arizona Stream Navigability Adjudication Commission (ANSAC). ANSAC will use information provided by the project team to make a determination of navigability or non-navigability for the Lower Salt River. In this report, the following topics are presented for the Lower Salt River:

- Project Background
- Definition of Navigability
- Limit of Study
- Methodology
- Summary of Results

A glossary of technical terms used is provided at the back of this report.

Project Background

During recent years the State, and a number of private and public entities, have asserted claims of ownership on certain streambeds in Arizona. These claims are based on whether or not the streams were navigable as of the time of statehood.[1] Under the "Equal Footing Doctrine," the states received sovereign title to the beds of navigable streams upon statehood. In the past, Arizona failed to act on its claims to streambed ownership, and other parties have asserted title to certain streambed lands. In assuming ownership of lands located in or near these streambeds, many of the current record title holders have constructed projects and improvements to the land, paid property taxes, and have altered the stream ecosystems and riparian habitat.

On July 7, 1992, the Governor signed House Bill 2594 (H.B. 2594; A.R.S. 37-1101 to -1156) which established a systematic administrative procedure for gathering information and determining the extent of the State's ownership of streambeds. The main purpose of the Bill was to settle land titles by confirming State or private ownership, and to confirm State ownership in lands located in the beds of navigable streams. HB 2594 also created the Arizona Navigable Stream Adjudication Commission (ANSAC), a five-member board appointed by the Governor. ANSAC was directed to establish administrative procedures, prioritize Arizona streams to be analyzed, hold public hearings, and adjudicate navigability. The Bill also directed the ASLD to assist ANSAC in its investigatory role, and act as technical support staff for ANSAC. The original Lower Salt River navigability report was prepared on behalf of ASLD under the provisions of HB 2594.

In 1994, after ANSAC had made an initial classification that the Lower Salt River had

[1] Arizona obtained statehood on February 14, 1912.

characteristics of possible navigability as of the time of statehood, and had scheduled public hearings to receive evidence of navigability or non-navigability, the Arizona Legislature passed HB 2589. HB 2589 (ARS 37:1101-1156) revised and defined the criteria to be used to determine whether a stream was navigable or non-navigable, established an ombudsman office to represent the interests of private property owners, amended the powers of ANSAC to an advisory role, and made decisions of navigability subject to judicial review and action by the Arizona Legislature. The 1996 revision of the CH2M HILL report was prepared to reflect changes in the definition of navigability made under HB 2589.

In 1999, after the Arizona Legislature ratified ANSAC's recommendations that the Salt River and other Arizona rivers be found non-navigable, lawsuits were filed challenging the constitutionality of certain provisions in HB 2589. In response to the subsequent Arizona Court of Appeals decision, the Arizona Legislature enacted SB 1275, which removed the unconstitutional presumptions of non-navigability and limitations on information consider, and restored the applicable burden of proof in line with the so-called federal test of navigability. The 2003 revision of the original CH2M HILL report was prepared to reflect changes in the navigability statutes made under SB 1275.

Definition of Navigability

S.B. 1275 established a definition of navigability for use in the Arizona streambed program. The data collection effort for this study attempts to provide information that would enable ANSAC to determine if a given watercourse meets the criteria of the State's definition. The State's definition is:

> 'Navigable' or 'navigable watercourse' means 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.

A.R.S. 37-1128 further states that ANSAC shall review all available evidence and render a determination as to whether the particular watercourse was navigable as of February 14, 1912. If the preponderance of the evidence establishes that the watercourse was navigable, the commission shall issue its determination confirming that the watercourse was navigable. If the preponderance of the evidence fails to establish that the watercourse was navigable, the commission shall issue its determination confirming that the watercourse was non-navigable.

Limit of Study

This report presents evidence of past and existing river conditions and uses for the Lower Salt River from Granite Reef Dam to the confluence with the Gila River (Figure 1-1). This report provides factual information for the study area collected from existing data sources. Where necessary or relevant, information from outside the study limits was considered as a supplement

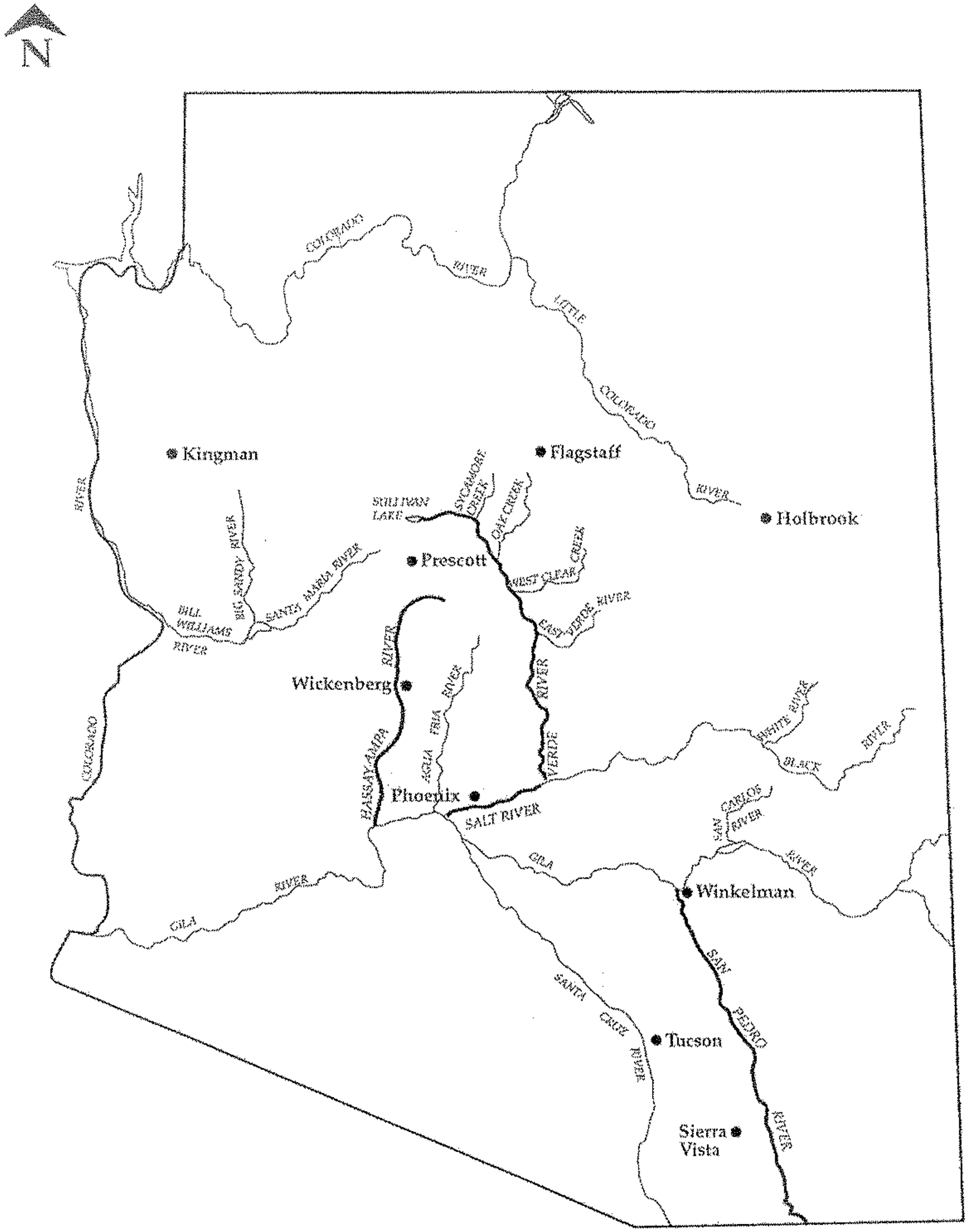

Figure 1-1
General Location Map for Arizona Stream Navigability Studies

to the existing data base. For example, streamflow records from the upper watershed, above Granite Reef Dam are presented to supplement the few stream flow records available for stations downstream of Granite Reef Dam. No new analyses or technical evaluations were completed as part of the original study or subsequent revisions of the report. Furthermore, no interpretation of the data collected was made with respect to the navigability or non-navigability of the Lower Salt River. A recommendation regarding potential navigability or non-navigability is not presented in this report, nor was it part of the scope of services for the investigation.

This report summarizes information on the Lower Salt River. The scope of services for this study included five main tasks:

- Agency Contact
- Literature Search
- Data Summaries
- Land Use
- Final Report

The objective of agency contact and the literature search was to obtain already existing information pertaining to stream navigability. These tasks included contact with various federal, state, local government and private agencies, and review of literature in public and private collections. Information obtained during the first two tasks was then reviewed and summarized to provide information on stream conditions and activities at the time of statehood. A database of public and private land use information was collected for use by ASLD and ANSAC in later phases of the streambed adjudication process.

Methodology

The basic approach to the stream navigability studies was to develop a database of information to be used by ANSAC in making determinations of navigability or non-navigability. Because the State's definition of navigability includes both actual navigation and susceptibility to navigation, the data collection effort was directed at two areas:

- Historical Uses of the River. Data describing actual uses of the river at the time of statehood were collected to help answer the question, "Was the river used for navigation?" Specific tasks included agency contact, literature search, and ethnography.

- Potential Uses of the River. Data describing river conditions at the time of statehood were collected to help answer the question, "Could the river have been used for navigation?" Specific tasks included agency contact, literature search, hydrology, hydraulics, and geomorphology.

Specific activities for each of the major tasks in the stream navigability studies are summarized below. The objective of these activities was to establish whether rivers were used for navigation, or whether sufficient data exist to indicate that navigation could have occurred.

Agency Contact

The objectives of the agency contact task were to inform community officials of the studies, to obtain information on historical and potential river uses, and to obtain access to data collected on the Lower Salt River by agency personnel. For the latter task, public officials from communities, towns, cities, and counties located along the Salt River study area were contacted. Contact consisted of an initial letter describing the stream navigability study, its potential impacts on the community, and requesting information to be used in the study. Each community official was then contacted by telephone to answer questions about the study and to provide a second opportunity to provide information for the study. In addition, officials from most local, state, and federal agencies with jurisdiction or interest in the river study areas were contacted by letter and telephone. It is noted that while the vast majority of agency personnel were very cooperative, several federal, local and quasi-governmental agencies refused or limited access to their libraries and databases.

Historians, librarians and archivists from public and private museums, libraries, and other collections were also contacted. Letters requesting summaries of information pertaining to historical stream uses or conditions were sent to each institution, with follow-up telephone contact. Other contacts included letter and telephone requests for information to clubs, professional organizations, special interest groups, and environmental groups. Finally, attorneys involved with previous litigation or investigations of stream navigability in Arizona were contacted to obtain information. In most cases, contacts led to other persons thought to have information pertinent to the study. Several hundred persons were contacted as part of this task (See Appendix A: List of Agency Contacts).

Literature Search

The objective of the literature search was to obtain published and unpublished documentation of historical river uses and river conditions. Information collected from agency contact was supplemented by published information from public and private collections. The literature search was focused on the following main categories:

- Archaeology
- History
- Hydrology
- Hydraulics
- Geomorphology

Historical literature searches were conducted to obtain information on the historical uses of the rivers and adjacent lands. Library research identified books, scholarly journals, magazine and newspaper articles, and unpublished materials that provide information on the history of the use of the rivers. City directories, Sanborne fire insurance maps, and General Land Office maps were also consulted to identify businesses located near the river. Literature searches in archaeology provided data on prehistoric and historic settlement patterns along the river, including evidence on paleoenvironment and irrigation agriculture. This research included published books and articles, as well as "gray literature" and technical reports. Hydrologic, hydraulic, and geomorphic studies relating to historic navigability of each stream reach were also collected when available from city, county, state, and federal agencies. Published journal articles, books, and reports available from public library collections were also consulted. A bibliography of documents and resources for the Lower Salt River is attached as Chapter 10.

Data Summaries

Data collected from the agency contact and literature search tasks was organized and synthesized by these subject areas: archaeology, history, ethnography, hydrology, hydraulics, geomorphology, and land use.

Archaeology. Archaeological data augment the historical record of potential river uses at statehood by providing an extended record of river conditions, use of river water, climatic variability, and cultural history along the rivers. SWCA archaeologists reviewed literature and other information collected during the literature search and agency contact tasks. An overview summarizing previous archaeological work in the area, paleoenvironment, the culture history, settlement patterns, and evidence relevant to navigability of the river was prepared, and is presented in Chapter 2.

History. Historical data provide information on actual river uses at the time of statehood, and also provide information on whether river conditions could have supported navigation (susceptibility). SWCA historians prepared a chapter summarizing use of the river and adjacent area in historic times, with special emphasis on the establishment, growth, and development of towns, irrigation systems, commercial activities, and developments. In addition, bibliographical essays were prepared, listing those institutions that have collections relating to the history of navigability and river use, and describing the relevant collections of these institutions. Historical information on the Salt River is summarized in Chapter 3 and Appendixes B, C, H and I.

Ethnography. Ethnographic data, or the recollections of individuals with personal knowledge of historical conditions, supplement formal historical and archaeological records. SWCA ethnographers conducted interviews with long-time residents, professional historians, avocational historians, and professional land managers who were knowledgeable about the Salt River. Names of potential interviewees were obtained from historical societies, public agencies, and private organizations contacted during the agency contact task. A total of 18 interviews were conducted for the Salt River and are summarized in Chapter 4.

Hydrology/Hydraulics. Hydrologic/hydraulic information is a key source of information regarding susceptibility of the Lower Salt River to navigation. These data include estimates of flow depths, width, velocity, and average flow conditions at statehood, based on the available records. CH2M HILL evaluated information collected during agency contact and literature search tasks. Literature, stream gauge records, topographic maps, aerial photographs, and other data were used to develop an estimate of natural stream flow conditions at statehood, as well as for existing stream conditions. Depth, velocity, and top width rating curves for existing and for (near) statehood channel conditions were developed from historical stream gauging records. Estimates of 2-, 5-, 10-, 50-, 100-year, and average annual flow rates were obtained from gauge data. Flow duration curves and average monthly flow rates were also summarized. Finally, technical memorandums were prepared which discuss the role of climate change on stream flow (Chapter 7, Appendix E), irrigation (Chapter 7), modern boating activities (Chapter 8, Appendix F), and recreational navigation criteria (Chapter 8, Appendix F) on stream navigability.

Geomorphology. Geomorphic data provide information on river stability, river conditions at statehood, and the nature of river changes since the time of statehood. A summary of the geology and geomorphology of the Lower Salt River was prepared. These summaries were based on literature and other information collected during agency contact and the literature search. The objectives of these summaries were to estimate channel positions at the time of statehood, assess the possibility of and mechanism for historical channel movement from its current position, provide evidence of geologic control of flow rates, and to estimate the location of the ordinary high water mark. A summary of geologic information is presented in Chapter 5.

Land Use

Land use data were compiled for the Salt River and entered in a GIS database. Land use data included existing title owner records from county assessors offices, and state and federal land leasing records from ASLD, the Bureau of Land Management, and the US Forest Service. Existing improvements, commercial activities, and present use of lands were identified from land use mapping and reports, aerial photographs, and in some cases, by field visits. Other data collected for the Salt River, such as ordinary high water mark limits, floodplain limits, and hydrologic data were also entered into the GIS. The GIS/Land Use task results are summarized in Chapter 6 and Appendix G. No revision of the land use database was made for the 1996 or 2003 revisions of the original CH2M HILL report.

Conclusion

The following chapters of this report describe historical uses of the Salt River as well as the types of activities to which the Salt River was susceptible as of the time of statehood. First, the archaeological record will be examined to provide a long-term history of river use, and to determine whether more recent river uses are unique to modern history. Second, historical data will be presented which summarize the pattern of development on and near the river, document historical boating activities on the river, and provide historical descriptions of the river conditions around the period of statehood. Third, historical documentation will be supplemented by ethnographic data which summarize some of the available oral history. Fourth, geologic impacts on river conditions, including geomorphic river changes and ground water-surface water interactions will be summarized. Fifth, a summary of the Salt River hydrology will be presented which documents typical flow conditions during the period before and at statehood. Finally, information on land use along the river corridor will be presented.

Chapter 2
Archaeology of the Salt River Valley

Introduction

For more than 1,000 years, water from the Salt River has allowed civilizations to flourish in the Salt River Valley. Early cultures exploited its reliable flow to irrigate crops and to provide drinking water, and derived sustenance from the abundant fish and wildlife living within the river corridor. The Salt River Valley was one of the most densely populated areas in the prehistoric southwest and contained the most extensive irrigation system in prehistoric North America. The prehistoric population served by the irrigation system has been estimated at between 80,000 and 200,000 (Schroeder 1940:20).

A discussion of past archaeological projects in the Salt River Valley is presented in this section to indicate the nature and amount of work done in the area. This is followed by a brief summary of prehistoric culture history of the valley, prehistoric use of the river, and environmental reconstructions of the river valley for the prehistoric time period. This summary of the archaeology of the Salt River Valley sets the context for discussion of long-term and natural stream conditions, river uses, channel geomorphology, and river channel stability.

Archaeological Projects

Most archaeological projects along the Salt River have been in the form of early reconnaissance surveys, with boundaries vaguely represented by river segments or valleys; excavations of major sites; and surveys along present day highways or road alignments (Table 2-1). Therefore, most location references, such as major sites and geographic features along the Salt River, that are pertinent to the following discussion can be found on Turney's map (Figure 2-1). Other archaeological sites in the Salt River Valley are shown in Figure 2-2.

Early archaeological explorations in the Salt River Valley described the canal systems and the large village sites; little to no effort was spent in documenting other prehistoric features. Archaeological sites were first noted by scientific observers during a military reconnaissance of newly conquered territory (Emory, 1848) and by the International Boundary Survey in the 19th century. In 1880, Adolph Bandelier noted the distribution of canals and villages along the Salt River during his archaeological reconnaissance of the Southwest. The Hemenway Southwestern Archaeological Expedition, led by Frank Hamilton Cushing, began in 1887 and concentrated survey and excavation efforts at large sites, such as Los Muertos, Las Acequias, Los Hornos, and Pueblo Grande (Cushing 1890) (Figure 2-1; Table 2-1).

Explorations of several sites in the Phoenix area, including Las Colinas, Mesa Grande, and Pueblo Viejo, were conducted by Warren King Moorehead (1906) in 1897, in 1892, and later in 1907. Jesse Walter Fewkes (1909) recorded sites along the Salt River for the Bureau of American Ethnology.

Table 2-1
Archaeological Projects Along the Salt River

Sponsor	Type of Project	Area Extent	Number of Sites	Reference
Various	Canal Mapping	Salt River Valley	315 + miles of main canals	Midvale 1968
City of Phoenix	Canal Mapping	Salt River Valley	240 to 250 miles of main canals	Turney 1929
National Science Foundation	Survey	Salt River Valley (from Granite Reef to the confluence of the Salt and Gila Rivers)	202	Ruppe 1966
Maricopa County Parks and Recreation Department	Survey and Archival	Maricopa County	352	Ayres 1965
Maricopa County Parks and Recreation Department	Reconnaissance Survey	Estrella Mt. Regional Park, Lake Pleasant Regional Park, Usery Mt. Regional Park, and White Tank Mt. Regional Park	33	Johnson 1963
Archaeological Institute of America	Reconnaissance Survey	Area within the triangle formed by the Salt and Gila Rivers and the Superstition mountains.	?	Bandelier 1884, 1892
Mary Hemenway	Hemenway Expedition (Excavation)	Numerous sites along the Salt and Gila Rivers, including Los Muertos and Los Hornos	12 +	Hodge 1893 Cushing 1890 Haury 1945
American Museum of Natural History	Thompson Expedition (Excavation)	Excavation (Pueblo Grande, La Ciudad, as well as sites on the Gila River)	?	Schmidt 1927
Bureau of American Ethnology	Reconnaissance Survey	Salt River Valley	8	Fewkes 1909
Rockefeller Foundation of NY/ University of Arizona	Excavation	Excavation (Pueblo Grande)	1	Woodbury 1960
AZ Department of Transportation	Excavation	Excavation (East Papago Freeway Corridor)	3	Howard and Huckleberry 1991
AZ Department of Transportation	Excavation	Excavation (La Ciudad/Los Solares)	2	Ackerly, Howard, and McGuire 1987 Wilcox 1987 Rice 1987 Henderson 1987
AZ Department of Transportation	Excavation	Excavation (Las Colinas)	1	Hammack and Sullivan 1981 Gregory et al. 1988

Table 2-1
Archaeological Projects Along the Salt River

Sponsor	Type of Project	Area Extent	Number of Sites	Reference
				Graybill et al. 1989 Teaque and Deaver 1989
University of AZ/ Pueblo Grande Museum	Survey and Excavation	Lower Salt River Valley	9 (excavated)	Schroeder 1940
Gila Pueblo	Survey	Phoenix Basin	?	Gladwin and Gladwin 1929
National Park Service and University of Arizona	Excavation	Excavation (Pueblo Grande)	1	Hayden 1957)
Southwestern Monument Association	Survey	South Mountains	119	Snyder 1966
Unknown (?)	Excavation	Excavation (Superstition Freeway)	1	Herskovitz 1974
AZ Department of Transportation	Excavation	Excavation (Hohokam Expressway)	4	Masse 1976
City of Phoenix	Excavation	Excavation (City of Phoenix Original Townsite)	1	Cable, Henry, and Doyel 1982, 1983, 1984 Cable et al. 1985
City of Phoenix	Excavation	Excavation (Squaw Peak Parkway)	3	Cable et al. 1984
AZ Department of Transportation	Excavation	Excavation (Los Hornos)	1	Chenault, Ahlstrom, and Motsinger 1993
City of Phoenix Sky Harbor Center	Excavation	Excavation (Pueblo Salado and Dutch Canal Ruin)	2	Greenwald 1993 Greenwald, Zyniecki, and Greenwald 1993 Greenwald, Chenault, and Greenwald 1993 Greenwald and Ballagh 1993
AZ Department of Transportation	Excavation	Excavation (La Lomita)	1	Mitchell 1990
City of Phoenix	Excavation	Excavation (Grand Canal Ruins)	1	Mitchell 1989
AZ Department of Transportation	Excavation	Excavation (La Lomita Pequena)	1	Mitchell 1988
AZ Department of Transportation	Excavation	Excavation (La Cuenca Del Sedimento)	3	Henderson 1989
City of Phoenix	Excavation	Excavation (Pueblo Viejo)	1	Zyniecki 1993

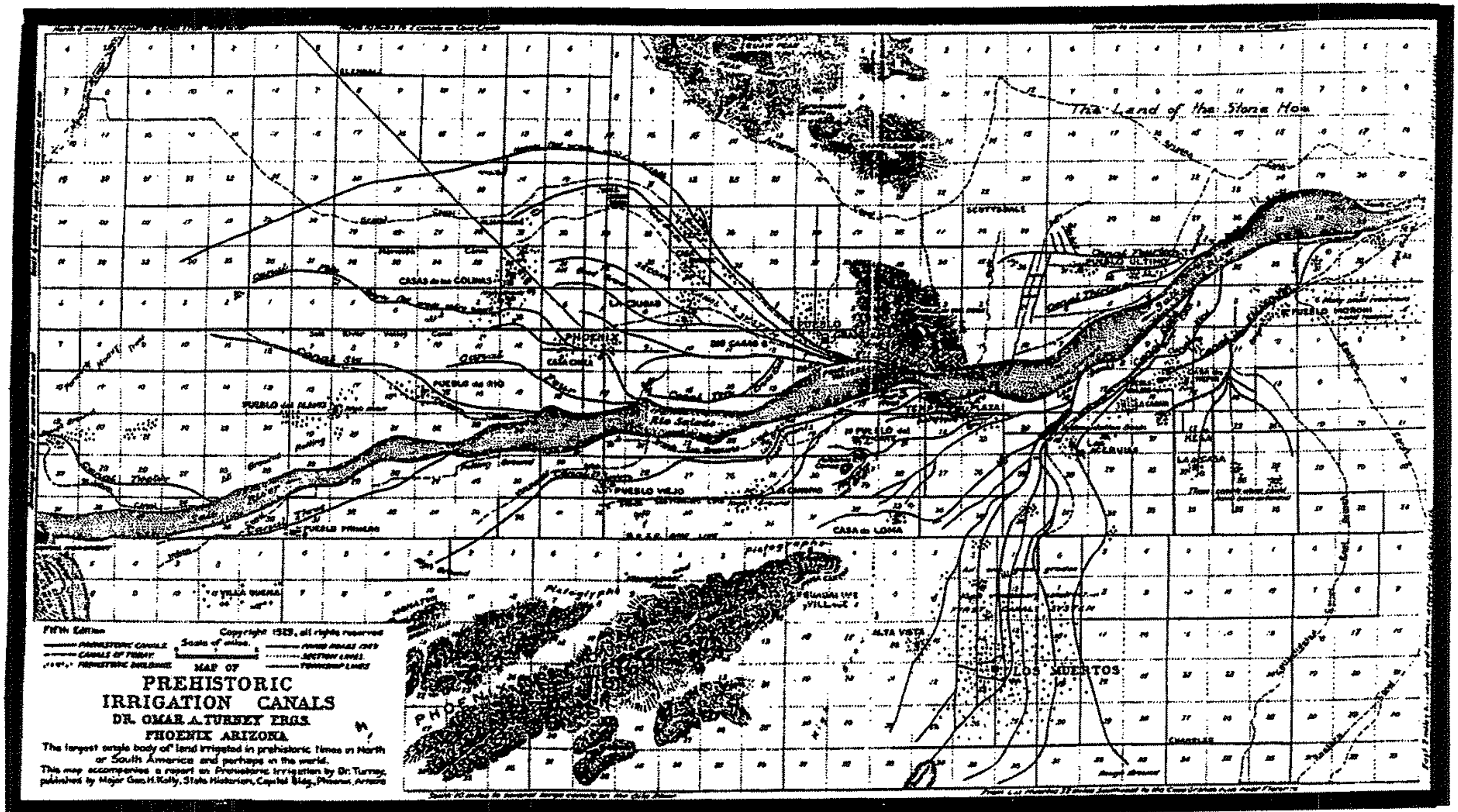

Figure 2-1. Map of prehistoric canals in the Salt River Valley (from Turney, 1929).

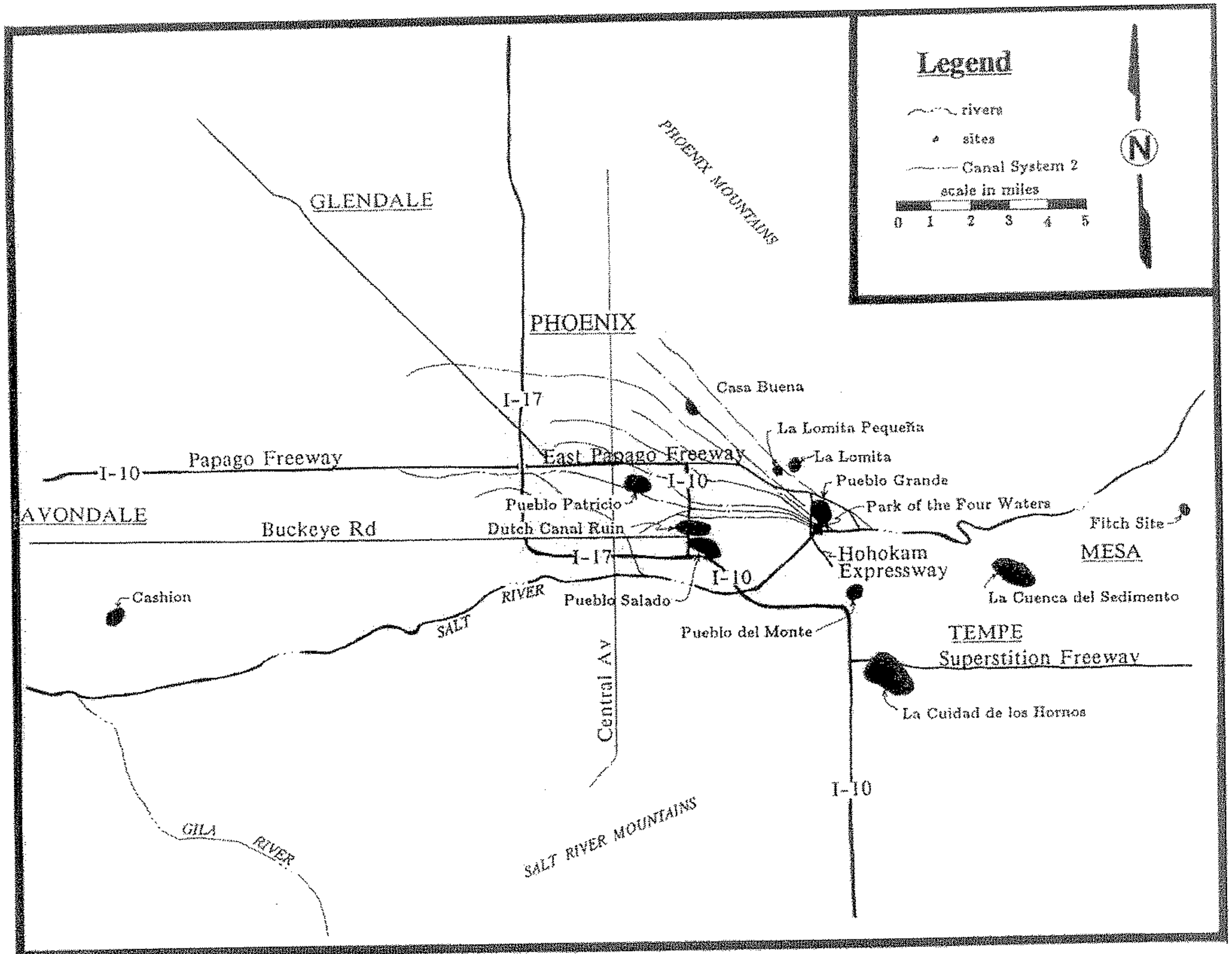

Figure 2-2 Location of Archaeological Sites in Relation to Modern Features.

Fewkes worked off of maps compiled by engineer and surveyor Herbert F. Patrick while working for canal companies in the Phoenix area. Excavations of large sites such as Pueblo Grande and La Ciudad were sponsored in the early 20th century by the following newly organized institutions: the Arizona Antiquarian Association, Arizona Archaeological and Historical Society, and the Heard Museum.

The first comprehensive study of the archaeology of the Salt River Valley was conducted by Dr. Omar A. Turney (1929), who served as a Phoenix City Engineer for many years. During his later years (he died in 1929), he studied and mapped the prehistoric irrigation systems with the help of his field assistant, Frank Midvale. In 1929, Turney published a map of all the canals in the Salt River system, which is still used by archaeologists today as a primary archival data source (Figure 2-1). Midvale's (1968) map (Figure 2-3) later documented more total miles of canals (315+) than those recorded by Turney (240 miles). Other early investigations of the prehistoric irrigation systems were conducted by Neil Judd (1930, 1931). Judd found, through aerial mapping, that fewer than 10 percent of canals recorded by Turney were still observable from the air, due to historic and modern farming practices.

Excavations were conducted at Pueblo Grande and La Ciudad, as well as at other sites, in 1925 by E.F. Schmidt during the Thompson Expedition from the American Museum of Natural History (Schmidt 1927). The goal was to establish chronological relationships by excavating trash mounds and a structural mound. With a similar goal, Gila Pueblo[1] conducted a Salt River Valley survey to document the distribution of red-on-buff pottery (Gladwin and Gladwin 1929) to establish a ceramic and cultural sequence for the area. Another survey, by A. L. Schroeder (Schroeder 1940), between 1938 and 1940, was carried out in the lower Salt River Valley to compare the chronological sequence established at Snaketown for the Gila River Valley. Schroeder also performed test excavations at some sites, including Pueblo Grande. His efforts produced important information regarding the movement and nature of populations in the Salt River Valley during the pre-Classic to Classic period transition and the changing influence of Salado traits during the late Classic period.

Between 1936 and 1940, Julian Hayden excavated various features at Pueblo Grande for the National Park Service, although the work was never fully reported. Woodbury's excavations for the University of Arizona at the Park of the Four Waters (See Appendix H), in 1959 and 1960, described two large prehistoric canals near Pueblo Grande (Woodbury 1960).

Between 1940 and 1960 there was little archaeological work done in the Salt River Valley. The only systematic survey that was conducted was done by the Arizona State University between 1963 and 1964 from Granite Reef to the confluence of the Salt and Gila rivers, in addition to portions of local drainages. The survey recorded 202 Hohokam sites along the river, with most described as representing the Sedentary (late Formative) or Classic periods (Ruppé 1966, cited in Berry and Marmeduke 1982). During the early 1960's, the Maricopa County Parks and Recreation Department sponsored studies by Ayres (1965) and Johnson (1963) to survey and consolidate records existing at that time to produce an inventory of recorded archaeological sites

[1] Gila Pueblo is private, non-profit research group.

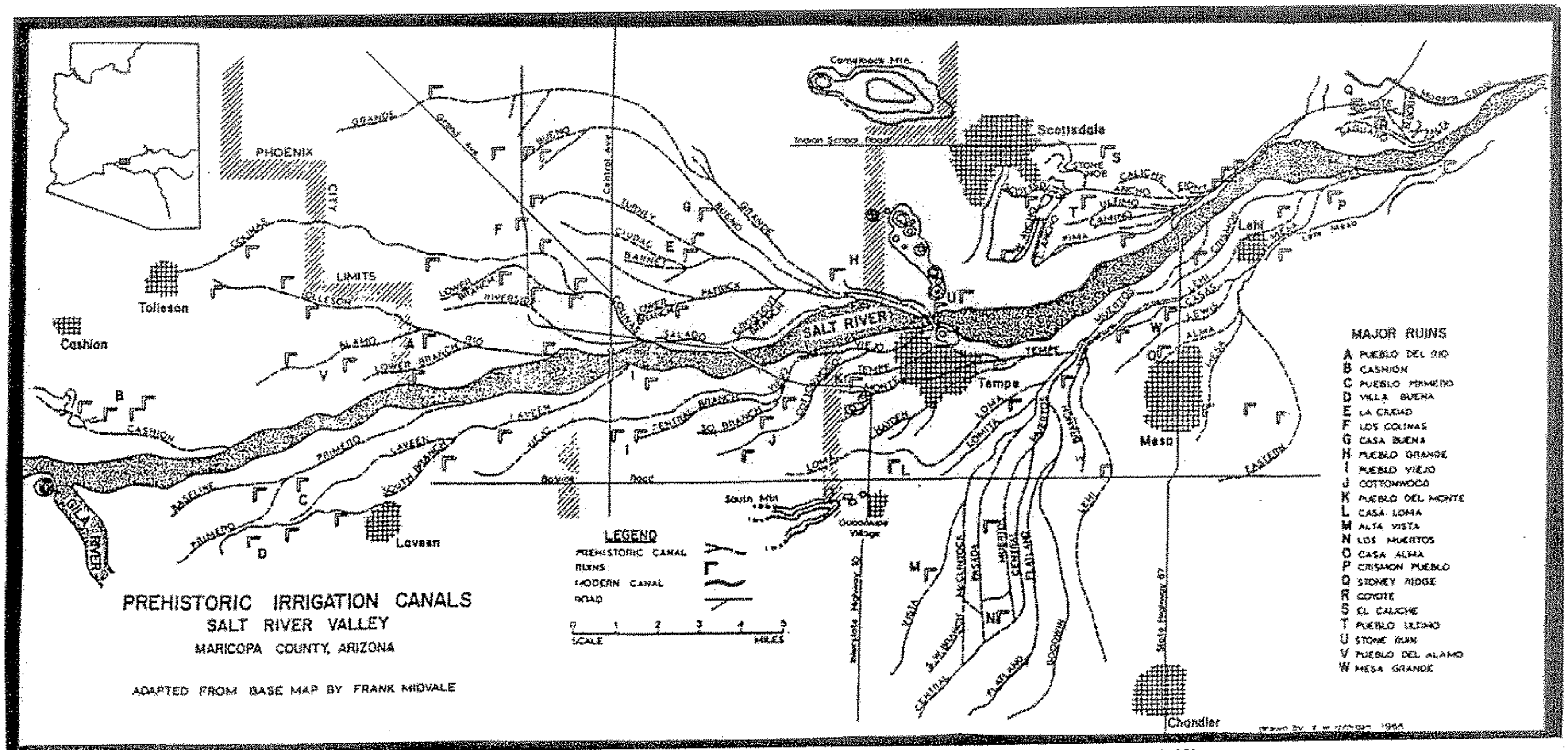

Figure 2-3. Map of prehistoric canals in the Salt River Valley (from Midvale, 1968)

within the county. In the 1965 document, Ayres estimated that as much as 90 percent of the previously recorded sites in the county no longer existed due to agriculture and construction of housing, roads, and dams. In 1983, this work was updated (Stone 1983) and, although sites were not plotted on maps, a total of 49 sites were located near the confluence of the Salt and Gila rivers; 101 sites were located in the area between approximately Phoenix and Tempe; 202 sites were situated along the Salt River between approximately Tempe and Scottsdale; and 278 sites were located around the confluence of the Salt and Verde rivers, including much of the lower Verde River area (Stone 1983:Figure 4).

During the 1960's some early Hohokam sites were excavated due to funding by the National Science Foundation. In 1964, the Red Mountain Site was excavated by Morris and Ives (Morris 1969), and three other sites along the Salt River were investigated by Ives and Opfenring (1966). The early 1960's and 1970's produced information on two Classic period Hohokam sites, the Fitch Site (Pailes 1963) and Pueblo del Monte (Weaver 1972, 1973) due to student research. Another university-sponsored study was the survey conducted by Dr. Dittert from Arizona State University on the Salt River Indian Reservation. Although the intensive survey located and identified over 200 sites, no report was ever prepared (Berry and Marmeduke 1982:86).

New laws protecting archaeological resources from damage due to federally funded construction heavily impacted the amount of archaeology that occurred along the Salt River from the 1970's on. Most of the earliest salvage work was due to the construction of new highway systems in the metropolitan Phoenix area, including the Superstition Freeway (Herskovitz 1974), the Hohokam Expressway (Masse 1 976), and the Papago Freeway (Hammack and Sullivan 1981). More extensive recording of a variety of sites, rather than just the large village sites, occurred in the 1980's and 1990's, due to federal legislation and standardized archaeological contract practices.

Excavations in the original townsite of Phoenix was accomplished by Soil Systems, Inc. in the early to mid 1980's (Cable, Henry, and Doyel 1982, 1983, 1984; Cable et al. 1985) and documented numerous features, activity areas, and use of the landscape through time. A large Pioneer period Hohokam village, Pueblo Patricio, was located in the original Phoenix townsite, as well as evidence for Formative and Classic period irrigation canals, agricultural field houses, and activity-related features. Differential prehistoric use of the floodplain versus the first terrace also was documented, with the more substantial residential occupation occurring on the terrace where there was less threat from flooding. Temporary field house occupation was evident on the floodplain in between large flood episodes (Cable and Doyel 1984).

Although most of the recent archaeological projects are relatively small in area (from 0.04 to 9+ acres for projects within the original Phoenix townsite) and usually only entail investigations of one site, the information has greatly contributed to Hohokam prehistory along the Salt River. Relationships among prehistoric communities along major canal systems, such as Canal System 2, are becoming better understood. For example, it is now believed that large communities at the heads of canal systems, such as Pueblo Grande, formed the apex of a socio-political hierarchy of communities, including Las Colinas, La Ciudad, Casa Buena, etc., that contributed to a single canal system (Gregory 1991:17). In addition, excavations at sites such as Dutch Canal Ruin and Pueblo Salado have shown that occupation occurred on the floodplain as well as on the river terraces during the Classic period, possibly as a response to decreasing available land, increasing population, high agricultural potential, and a great diversity of economic resources provided along the river by the riparian habitat (Greenwald, Zyniecki, and Greenwald 1993; Greenwald, Chenault, and Greenwald 1993; Greenwald and Ballagh 1993).

Prehistoric Culture History

Cultural elements will be described below for each temporal period in an effort to trace their development through time. To date there has been no evidence of Paleo-Indian occupation in the Salt River Valley (Table 2-2). Flooding along the river and the inundation of cultural deposits have been blamed for the lack of evidence of early man, including during the Archaic period.

The Formative era of Hohokam cultural history is divided into three distinct periods, the Pioneer period (A.D. 250-650), the Colonial period (A.D. 650-900), and the Sedentary period (A.D. 900-1100). The Classic period (A.D. 1100-1350) is divided into two phases, the Soho phase (A.D. 1100-1250) and the Civano phase (A.D. 1250-1350). Another phase, the Polvorõn (A.D. 1350-1450), has recently been recognized and is assigned to the post-Classic period of Hohokam culture history.

Table 2-2
Chronology for the Prehistory of the Salt River Valley.

Tradition	Period	Phase	Dates
Southwestern	Post-Classic	Polvoron	A.D. 1350-1450
	Classic	Civano	A.D. 1250-1350
		Soho	A.D. 1100-1250
	Sedentary	Sacaton	A.D. 900-1100
	Colonial	Santa Cruz	A.D. 750-900
		Gila Butte	A.D. 650-750
	Pioneer	Snaketown	A.D. 550-650
		Sweetwater	A.D. 450-550
		Estrella	A.D. 350-450
		Vahki	A.D. 250-350
Archaic[1]			800 B.C. to A.D. 1
Paleo-Indian[1]			10000 to 8000 B.C.

[1] No direct evidence of datable occupations for this time period.

The Pioneer Period (A.D. 250-650)

During this period, most sites were linearly arranged along major river systems, such as the Salt River, although non-riverine habitats also were exploited. Examples of sites occupied during this period include Pueblo Patricio, La Ciudad de los Hornos, La Cuenca del Sedimento, Red Mountain, and Los Hornos.

The first examples of pottery appeared, and disposal of the dead occurred as both flexed inhumations and cremations. Houses were pit structures with clay-lined hearths, well-defined entryways, and a 2-4 post roof-support configuration. They varied in size and shape from small and square to large and rectangular. Structures that were excavated in Blocks 1 and 2 of the original townsite of Phoenix ranged from 104 ft^2 to 200 ft^2 in floor area (Cable and Doyel 1984:259), and pit houses excavated at Block 24 east of the townsite ranged from 115 to 328 ft^2, with an average of 194 ft^2 (Cable et al. 1985). Oval, bent pole structures, thought to represent field houses during the late Pioneer period at Block 24-East were smaller in size, ranging between 75 and 140 ft^2, with an average of 140 m^2. Cable and Doyel (1985:258-259) postulate that the small square pit structures were used for domestic functions, and the large rectangular structures were community rooms or used for ceremonial functions. Site-wide, structures were arranged in a dispersed, or rancheria, pattern. According to Cable and Doyel (1985:266-269), a bi-seasonal settlement pattern was in place during the Pioneer period 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.

The transition from early to late Pioneer was accompanied by demographic, social, and economic changes. There was growth in the number of sites (Wilcox 1979:101) and a shift of population onto the river terraces, further from the river (Cable and Doyel 1985:269). Settlements began to aggregate into clusters, and large-scale irrigation was adopted. Wilcox and Sternberg (1983:229-230) hypothesize that a new religious system emerged at the end of the Pioneer period based on evidence of stylistic changes, new social structures (mounds and ball courts), ritual paraphernalia (unique stone items), and the new association of clay figurines with cremations.

Successful use of irrigation agriculture, supplemented by exchange and a hunting/collecting economy apparently contributed to the population increase and expansion experienced during the late Pioneer period. Inter- and intra-regional relations were apparently successful and non-hostile.

The Colonial Period (A.D. 650-900)

During the Colonial period, existing canal systems expanded, with additional branches and laterals, and new systems were built. This expansion was concurrent with settlement increases and geographical expansion. In fact, there was an estimated 50 percent increase in population during the early Colonial (Gila Butte phase) alone (Wilcox 1979:103). While the number of sites increased during the Gila Butte phase, the Santa Cruz phase (late Colonial period) marked an increase in village size, signaling the emergence of large agricultural villages. Cultural expansion into peripheral areas is diagnostic of the Colonial period in general. Ball courts, Hohokam ceramic motifs, cremation, and ritual paraphernalia are found beyond the Salt and Gila river valleys in surrounding areas and as far north and east as the Anasazi and Mogollon regions.

The Colonial period marked a dependency on agriculture and a sedentary lifestyle (Cable and Doyel 1985). New corn varieties were introduced, and the earliest remains of wild barley (*Hordeum*), thought to be encouraged or cultivated, came from the large site of La Ciudad (Gasser 1981-1982:221). Canal irrigation gained importance from the earlier period with most new sites, such as portions of Dutch Canal Ruin, La Ciudad de los Hornos, La Cuenca del Sedimento, and the site of Pueblo Viejo, located on arable land along the Salt River and major and minor washes. The ability of this specialized technology to grow and expand at such an early stage of development may be partially due to the relative stability of the average water flow in the Salt River during this time (Nials, Gregory, and Graybill 1989). Only toward the very end of the Colonial period are very high flows estimated to have occurred, probably washing out flood gates and damaging canals. The presence of ball courts, and a growing list of traits representing social integration, also contributed to an increase in the use of canal systems. House size decreased, following a general trend in a reduction of floor space. At La Ciudad de los Hornos, the average floor area (28-262 ft^2 range) of pit structures during the Colonial period was 99 ft^2, compared to 160 (68-338 ft^2 range) during the Pioneer period (Motsinger 1993:Table 18.1). Similarly, structures at La Cuenca del Sedimento averaged 154 ft^2 during the Pioneer period and 107 ft^2 during the Colonial period (Henderson 1989: Table 12.2). Field houses decreased in size as well; Colonial period field houses at La Cuenca del Sedimento ranged from 39 to 67 ft^2, averaging 48 ft^2, and those occupied during the early Pioneer period ranged from 49 to 66, with an average of 60 ft^2.

Evidence of interaction within the Hohokam region is supplied by the distribution of marine shell remains. Shell trade grew during the Colonial period with increasingly elaborate workmanship and design, similar to that found on stone projectile points and other items.

The Sedentary Period (A.D. 900-1100)

Most of this time period, in general, was characterized by stability. Hohokam material culture was at its peak aesthetically, and the ball court, cremation, and ritual paraphernalia phenomena continued. The ball court system expanded to its greatest spatial extent, with peripheral and far peripheral areas part of the ball court network (for example, Flagstaff and Safford Valley areas). Population increased, and well-defined boundaries of social, and possibly political, interaction existed, evident in the variability of ceramic type distribution among the Salt and Gila river valleys and the Tucson basin (Crown 1985). Wilcox (1981:209) records the development of house cluster courtyards during the Sedentary period. Courtyards are common areas among a group of houses whose entryways share similar access. The average house size at Los Hornos was 138 ft^2 (122-149 ft^2 range) (Motsinger 1993:Table 18.1); at La Lomita the average size was 142 ft^2 (53-207 ft^2 range) (Merewether and Mitchell 1990:19); and at La Lomita Pequeña, it was 169 ft^2 (107-227 ft^2 range) (Mitchell 1988).

Canal systems expanded along the Salt River. New canal systems in the lower Salt River Valley, however, were built on less optimal farmland than were previous canals (Wilcox 1981:209). A hierarchy of settlements formed along canal systems, composed of a primary village(s) and secondary settlements. Non-irrigation agricultural techniques became more widespread with the expansion of settlement onto land less accessible for canal irrigation. The exploitation of diverse wild plant and animal resources continued with an increasing reliance on agave (Huntington 1986:268; Gasser 1987).

The end of the Sedentary period marks an important transition in Hohokam prehistory. Peripheral settlements were abandoned or exhibited less influence from the core area, such as the Salt River Valley. Sites along the Salt River, such as La Lomita, Cashion, and La Lomita Pequeña, were abandoned, although some new sites such as Grand Canal Ruins were founded. Only small ball courts remained along the river; Hohokam ritual paraphernalia also disappear at this time.

Dramatic changes occurred during the Sedentary/Classic transition and transformed a regional system based on a ceremonial exchange system into a network of local systems.

The Classic Period (A.D. 1100-1350)

Platform mounds became common during the early Classic period (Soho phase), each spaced approximately every three miles east-west along the river valley. Platform mounds are thought to be either ceremonial structures (Gregory 1982), redistribution centers (Teague 1985), or residence locales (Doyel 1977:190-191) perhaps for an elite group or leader of rank (Doyel 1980:35). Another symbol of social differentiation during this time period was the dual burial practices of cremation and inhumation. Gila polychrome ceramics, which emerged after the Soho phase, were often associated more with inhumations than with cremations.

While local systems emerged and social/political alliances were being made, the water flow in the Salt River was erratic (Nials, Gregory, and Graybill 1989). Major floods, as well as lower-than-normal flows, occurred. Canals probably required a large labor force to keep them repaired and functional. Surprisingly, irrigation agriculture increased during the Classic period despite these setbacks. Perhaps the greatest factor in the success of the canal systems was the structure of the local socio-political units in the Salt River Valley. Wilcox (1987) describes these as macro-canal systems. They are spatially equivalent (generally) to hydrographic zones and encompass 14-15 platform mound settlements with one very large platform mound site at the head of each major canal system (i.e. Pueblo Grande). These local systems controlled water flow and probably other important resources within their area.

On the intrasite level, house construction changed to rectangular surface adobe structures. Household clusters were defined by contiguous rooms or compound walls; courtyard groups, which may have contained one or more households, occurred as a group of contiguous rooms sharing a common courtyard. At Pueblo Salado, 25 adobe rooms with intact dimensions were excavated, yielding a range of 74 to 194 ft^2 in floor area, with a mean of 117 ft^2 (Greenwald, Chenault, and Greenwald 1993). Great houses, such as Pueblo Grande (Wilcox 1991:268), were built, and platform mounds often exhibited multiple stages of construction. New sites include Pueblo Salado, with many other sites such as La Ciudad and Las Colinas continuing to grow in population during this time.

Specialization at the household or community level is a hallmark of the Classic period. Gasser and Miksicek (1983) present evidence of specialization of cultigens at two sites on the same canal system. Excavations at La Ciudad produced very large quantities of *Hordeum* while those at Las Colinas recovered large amounts of cotton. Intensive agave cultivation also takes off at this time (Fish, Fish, and Madsen 1985; Fish et al. 1985). Amaranths and other weedy taxa possibly were domesticated by the Classic period (Gasser 1981-82:221). Often found around fallow, abandoned, or untended fields, these types of plants were encouraged to grow. They often make up a substantial portion of archaeobotanical remains from agricultural sites, sometimes in frequencies that suggest they were a primary resource, or diet staple.

Four agricultural strategies, employed in earlier periods, were in use during the Classic period. Canal irrigation, dry farming, diversion farming, and floodwater farming were all used in an effort to maximize floodplain use for agriculture while also exploiting other ecosystems, such as the creosote plain and mountain bajadas.

Post-Classic Period (A.D. 1350ff)

After the Classic period, many changes again took place along the Salt River. Population decreased and a dispersed, rather than nucleated, settlement pattern appeared. Adobe architecture was discontinued, replaced by semi-subterranean structures, and mound construction stopped. The mean floor size of pit structures was between 131 ft^2 and 141 ft^2. During this time, most Hohokam sites were abandoned; however, some continued to be occupied or were re-established, including Dutch Canal Ruin and Pueblo Salado. Existing irrigation systems may have been used and minimally maintained, but new canals were not built.

Prehistoric Use of the Salt River

Prehistoric inhabitants of southern Arizona focused their settlement along the river systems due to the dry desert conditions. The Salt River Valley was densely settled, and the water control system was the largest irrigation network in the country that was built and used prehistorically. Fish found in the river were used to supplement food sources, and the riparian habitat fostered by the river was heavily used for food, fuel, construction, and probably many other uses (Greenwald and Greenwald 1993). Fish remains found during excavations at Pueblo Grande include bonytail chub, roundtail chub, Colorado squawfish, razorback sucker, Gila coarse-scaled sucker, flannelmouth sucker, and Gila mountain sucker (James 1992). Mesquite, cottonwood, and a large variety of riparian floral and faunal resources provided more variety in the prehistoric diet than any other area of the Sonoran desert (Greenwald and Greenwald 1993; Stein 1979:81). Use of irrigation expanded this diverse environment beyond the river's edge and systematically provided a water supply for crops necessary to the diet of an expanding Hohokam population. In the late 19th century, Cushing speculated that the Hohokam also used their canals for floating balsa[2] rafts (David Wilcox, personal communication, 1993).

Halseth (1932:168) grouped the prehistoric irrigation system into ten different systems, each with a separate intake. The largest system probably was one south of the Salt River that included the Classic period villages of Los Muertos, Alta Vista, Casa Loma, and Pueblo del Monte. The entire Salt River system extended over 315 miles (Midvale 1968:29), with some canals from 10 to 16 miles in length (Halseth 1932:168). Turney (1929:40) estimated that approximately 140,000 acres were under irrigation, supporting a population of at least 120,000, based on his understanding of irrigation capacity at the time of his writing. Main canals on the south side of the Salt River totaled 135 miles and supplied approximately 42,200 acres of irrigable land; 95 miles of main canals on the north side supplied 56,560 acres (Turney 1929). Less visible evidence remained of canal laterals and branches, although their presence is known through the

[2] Balsa is buoyant, lightweight type of wood.

archaeological record, and they become more complex and abundant through time. Referring to the prehistoric irrigation system near Tempe, Masse (1981:412) described the system's structure:

The main canal is divided into a myriad of branches (distribution canals), each serving various field locations. Lateral canals, the smallest visible component of the irrigation system, are usually sandwiched between, and run perpendicular to, the distribution canals. The laterals are spaced somewhat regularly from one to another, usually by about 45 to 60 meters. The distribution canals are parallel to and the laterals usually perpendicular to the direction of the slope. This system appears amenable to the type of irrigation termed wild flooding [Israelsen and Hansen 1962:297-299].

Most canals were approximately 10-20 feet in width and from 3 to 12 feet in depth. Based on the Pueblo Grande canals, Masse (1981:409) classified canal shapes into two types, trapezoidal (flat-bottomed) and parabolic, with trapezoidal cross sections occurring most often in the smaller canals.

The heads of prehistoric canals have been noted to be above the present bed of the Salt River. Patrick (1903:4) noted that they were 8-15 feet above the bed, and Schroeder (1943:380) described them as 6-16 feet above the riverbed. Schroeder believes that the difference in levels was due to lateral cutting of the river, removing all traces of the original heads rather than a change in the level of the river. He cites evidence from 1870 and 1877 of Mormons at Mesa who cleaned out and reused some of the prehistoric canals and constructed stone and brush diversion dams to divert water into the canals (McClintock 1921:213-214, cited in Schroeder 1943:383). Because the canals were only repaired, with no mention of modification to deepen their beds, Schroeder determined that the Salt River was at a level similar to that in the 1870's.

Masse (1981:413) calculated the volume of water that may have run through the Pueblo Grande canals by multiplying the velocity derived from the Manning equation by the flow cross section in square meters. Flow reconstruction for the canals was based on the 1889 average daily flow of the Salt River that was measured near its confluence with the Verde River (Masse 1981: Table 2). Assuming that the prehistoric volume of the Salt River was comparable to that recorded in 1889, individual canal discharge rates ranged from 2 to 240 cubic feet per second (cfs), with a mean of 60 cfs.

Environmental Reconstructions

Archaeological research also provides information on the prehistoric natural environment. This research includes paleoclimatic and hydrologic studies of the lower Colorado Plateau applicable to southern and central Arizona (Dean et al. 1985; Euler et al. 1979); paleobotanical and paleofaunal studies of the Salt River Valley and used by the prehistoric inhabitants; and the annual stream flow of the Salt River for the years A.D. 740 to 1370.

Euler et al. (1979) produced a paleoenvironmental record for the American Southwest by plotting geoclimatic and bioclimatic indicators for the Colorado Plateau. Indicators consisted of data from tree-rings, pollen records, and alluvial sediments. These data were analyzed within a temporal

Table 2-3

Environmental Reconstructions Applicable to the Salt River Valley.

A.D.	Effective Moisture*	Depositional and Erosional Cycles*	Dendroclimatic Variability*	Salt River Geomorphic Processes**
1500				
		Degradation	Frequent Oscillations	
1400				Marked lateral erosion and channel widening (A.D. 1356-1370)
1300				Stable Conditions; trend toward island-braided channel (infrequent high-magnitude flows); some channel avulsion probable; deepening of channel (A.D. 1197-1355)
	Low	Aggradation		
1200			Infrequent Oscillations	
		Degradation		Trend toward bar-braided channel (infrequent high-magnitude flows); some channel avulsion possible (A.D. 1052-1196)
1100				
1000		Aggradation		Trend away from bar-braided channel toward island-braided conditions; channel narrowing (A.D. 900-1051)
	High			
900				
			Frequent Oscillations	Establishment of bar-braided channel; channel widening and bank erosion (A.D. 798-899)
800	Low	Degradation		
				Channel Stabilization (A.D. 740-797)
700				
	High	Aggradation	Infrequent Oscillations	
600				

*From Masse 1991, after Dean et al. 1985 and Euler et al. 1979.
**From Gregory 1991, after Nials, Gregory, and Graybill 1989.

framework, and fluctuations through time were noted (Table 2-3). Dean et al. (1985) used similar data to produce a model of interaction between the cultural system (prehistoric populations) and the natural system (environment), and identified periods of stress. In general, low water tables and channel entrenchment, or degradation, would have an adverse effect on agriculture; on the other hand, high effective moisture and aggradation, or surface stability, would be favorable to the development of irrigation systems, as well as other agricultural technologies. Variability in the dendroclimatic record might have produced some short-term responses prehistorically to accommodate unusually high or low precipitation, such as relocation of agricultural fields or the expansion of irrigation systems (Dean et al. 1985:542-543).

Table 2-4
Statistical Description of Actual and Reconstructed Salt River Flow
July-June, October-April, and Estimated Summer Flow
(from Graybill 1989)

Statistic	A.D. 1914-1979			A.D. 1800-1979	A.D. 740-1370
	Actual	Reconstructed		Reconstructed	Reconstructed
		GRCMN	AZNOF	GRCMN	GRCMN & AZNOF
Jul-Jun					
mean	626.42	554.63	556.83	568.24	537.91
s.d.	497.34	291.66	318.57	339.56	237.25
Oct-Apr					
mean	458.63	399.21	393.29	408.10	376.82
s.d.	413.13	243.89	261.04	289.78	192.60
Statistic	Actual		Estimated	Estimated	Estimated
Summer[1]					
mean	167.79		160.41	160.14	161.09
s.d.	103.56		49.65	53.87	45.93

Note: Summer flow in thousands of acre-feet
Note: Flow of Salt River above Roosevelt, does not include Verde River Flows
[1] Actual summer flow includes the values for July, August, and September plus those of May and June of the succeeding year. Estimated summer flow is the simple remainder resulting from subtraction of the October-April reconstructed values from the July-June reconstructed values.

The geomorphic data provided in Table 2-4 for the annual discharge of the Salt River was reconstructed from a series of tree-rings from the Salt and Verde drainages for the period A.D. 740-1370 (Graybill 1989). The tree-ring series were calibrated with gaged records of the Salt River flow (A.D. 1914-1979) and Verde River flow (A.D. 1895-1979). It was found that the average flow from A.D. 740-1370 was somewhat less than modern average flows, due to a larger number of extremely high flow events after A.D. 1800. The statistics for Salt River reconstructed flows are presented in Table 2-4. Tree-ring series used in the reconstructions are referred to as AZNOF, those taken from archaeological sites within the geographic quadrangles of Arizona N and O, as well as from the Flagstaff area, and as GRCMN, tree-rings that were used from archaeological sites near the Grasshopper Ruin and from data published elsewhere (Dean and Robinson 1978:19-20) as the Central Mountain North Chronology. According to reconstruction statistics, the summer flows were less variable than the winter flows and were more predictable in terms of average amount of flow.

Prehistorically, the floodplain and terraces of the Salt River contained a wide variety of plant and animal species. Desertification and reduction in this habitat (Crosswhite 1981:67; Hastings and Turner 1965; Rea 1983) in recent times have decreased species diversity and changed some types of flora and fauna that characterize the Sonoran Desert landscape. Man's influence over only the past 100 years has created changes along the river in the amount of groundwater, erosion, and depletion of native vegetation. The riparian forest is mostly gone or replaced by feral salt cedar, and weedy species proliferate. The water table, previously a few feet below the surface, now averages hundreds of feet underground (Rea 1983:3). The archaeological and historical records document the change in riparian and desert scrub communities from historic to modern times. Yet, the natural resources used prehistorically by the Hohokam remained relatively constant. Archaeological data, such as pollen, macrobotanical, and faunal remains, indicate that there were no radical differences in the natural environment, and thus climate, prehistorically. Therefore, Graybill and Gregory (1989) contend that the flow of the Salt River, instead, was "...the single most important source of variation in the effective environment of canal-dependent Hohokam communities" (Graybill and Gregory 1989:3).

Conclusions

Archaeological records indicate that the prehistoric inhabitants of the Salt River Valley, known as the Hohokam culture, occupied the area from approximately A.D. 250-1450. Hohokam use of the Lower Salt River included the following characteristics:

- The Salt River Valley was one of the most densely populated areas in the prehistoric Southwest and contained the most extensive irrigation system in prehistoric North America.
- The entire Salt River irrigation system constructed by the Hohokam extended over 315 miles. The system included at least ten separate canal systems, some as long as 16 miles. Most canals measured 10 to 20 feet wide and were 3 to 12 feet deep, with a maximum diversion capacity in an individual canal of about 240 cfs.
- Most of these extensive canals have been destroyed by modern development and farming practices; by the early 1930's, fewer than 10% of the system was visible. As late as 1877, however, it was reported that Mormon settlers were able to clean and reuse some of the prehistoric canals.
- The Hohokam depended heavily upon the Salt River for their existence. Fish found in the river were used to supplement their food sources, the water was used for irrigation and direct consumption, and the riparian habitat fostered by the river was heavily utilized for food, fuel, and construction purposes.
- Paleoenvironmental information indicate that the prehistoric climate and hence, stream flow rates, were probably not very different from conditions found by early Euroamerican explorers and settlers.

The archaeological record does not, of course, provide any data that indicates that the Salt River was used for as a navigable waterway as of the time of statehood, as defined by A.R.S. 37-1100. However, some archaeologists have speculated that the Hohokam used light boats on their canals, and have concluded that the Hohokam harvested fish from the river, and relied on the constant and predictable flow of the river to support one of the largest, most complex, irrigation-based societies in prehistoric North America.

Chapter 3
History of the Salt River

Introduction

The modern historical record of the Salt River begins in the 1700's, although detailed documentation of river uses and conditions begins in the 1860's. Historical uses of the Salt River include irrigation, boating, floating logs, ferries, diversions for irrigation and mills, water supply, wastewater discharge, fishing, open space, and recreation. This chapter describes these river uses, and provides an historical overview of the region, summarizes historical descriptions of the river by early residents and explorers, describes historical modes of transportation in the region, and lists recorded accounts of boating on the Salt River.

Historical Overview/Chronology[1]

The Salt River was largely bypassed by exploration and development throughout the Spanish, Mexican, and United States Territorial periods, until the 1860's. The early Spanish explorers and missionaries mention the Salt River, but they did not missionize or colonize the Salt River Valley, and seem to have had only passing familiarity with it. Likewise, a series of trapping expeditions in the 1820's by U.S. citizens resulted in only brief descriptions of the river. During the Mexican War, the United States military traveled along the Gila and along what is now the international border between the United States and Mexico, but not along the Salt River. The forty-niners, on their way to the gold fields of California, mostly followed the military trails that bypassed the Salt River Valley. The surveys of the Boundary Commission mapped much of southern Arizona, but were conducted south of the Salt River.[2] Surveys for railroads and wagon roads passed to the north of the Salt River, along the Mogollon Rim, or to the south, along the present international border.

In 1865, Camp (later Fort) McDowell was established on the Verde River approximately eight miles above the confluence of the Verde and the Salt Rivers. The primary transportation route to the post ran from Yuma up the Gila River to Maricopa Wells, then to the Salt River and up the Verde River. As early as 1867, the United States Army kept a boat at the lower crossing of the Salt River so that this transportation route could be kept open when the Salt River flooded. The presence of the fort and the military transportation route encouraged white settlement along the Salt River, and in 1867, the Phoenix area began to be settled. Figures 3-1 to 3-4 show the locations of historical sites in the Salt River study area. Table 3-1 provides a chronology of significant historical events along the Salt River.

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[1] NOTE: In this chapter the spelling and grammar of quotations from historical documents have been left as written in the original document.

[2] Except Bartlett, who traveled along the Salt River from the Gila River to the present-day location of Mesa.

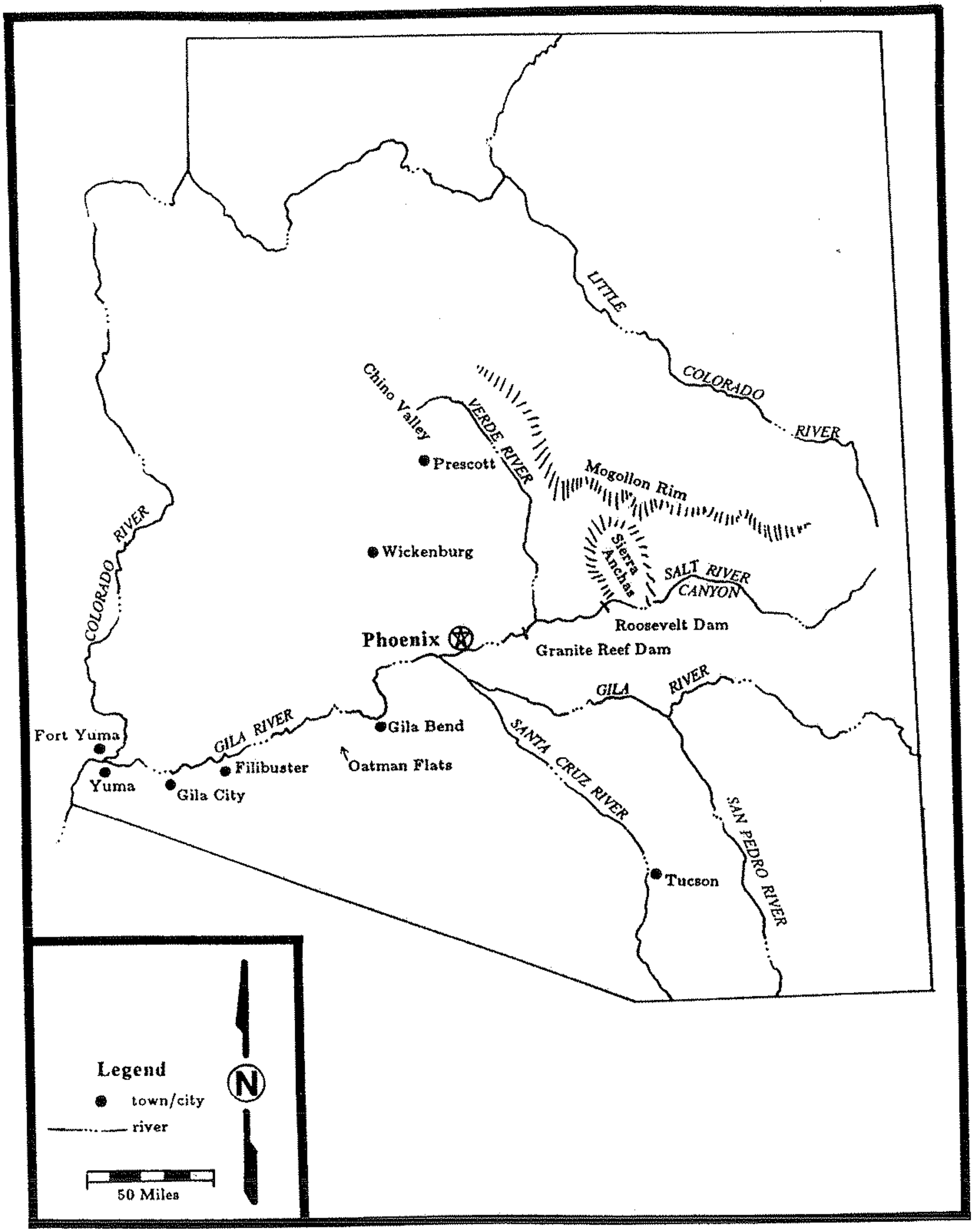

Figure 3-1. Salt River Regional Map Showing Localities of Historical Significance

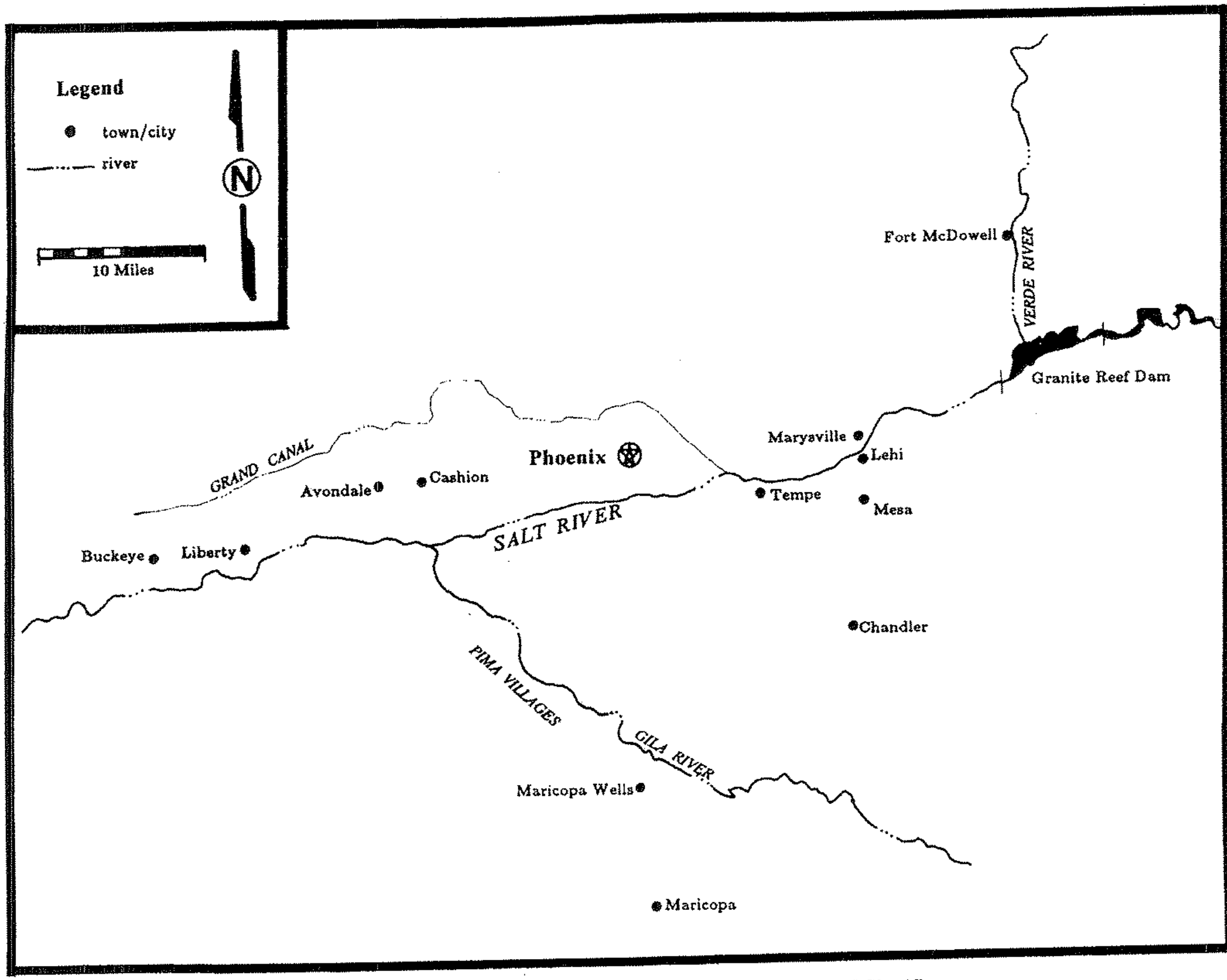

Figure 3-2. Salt River Reach Map Showing Localities of Historical Significance.

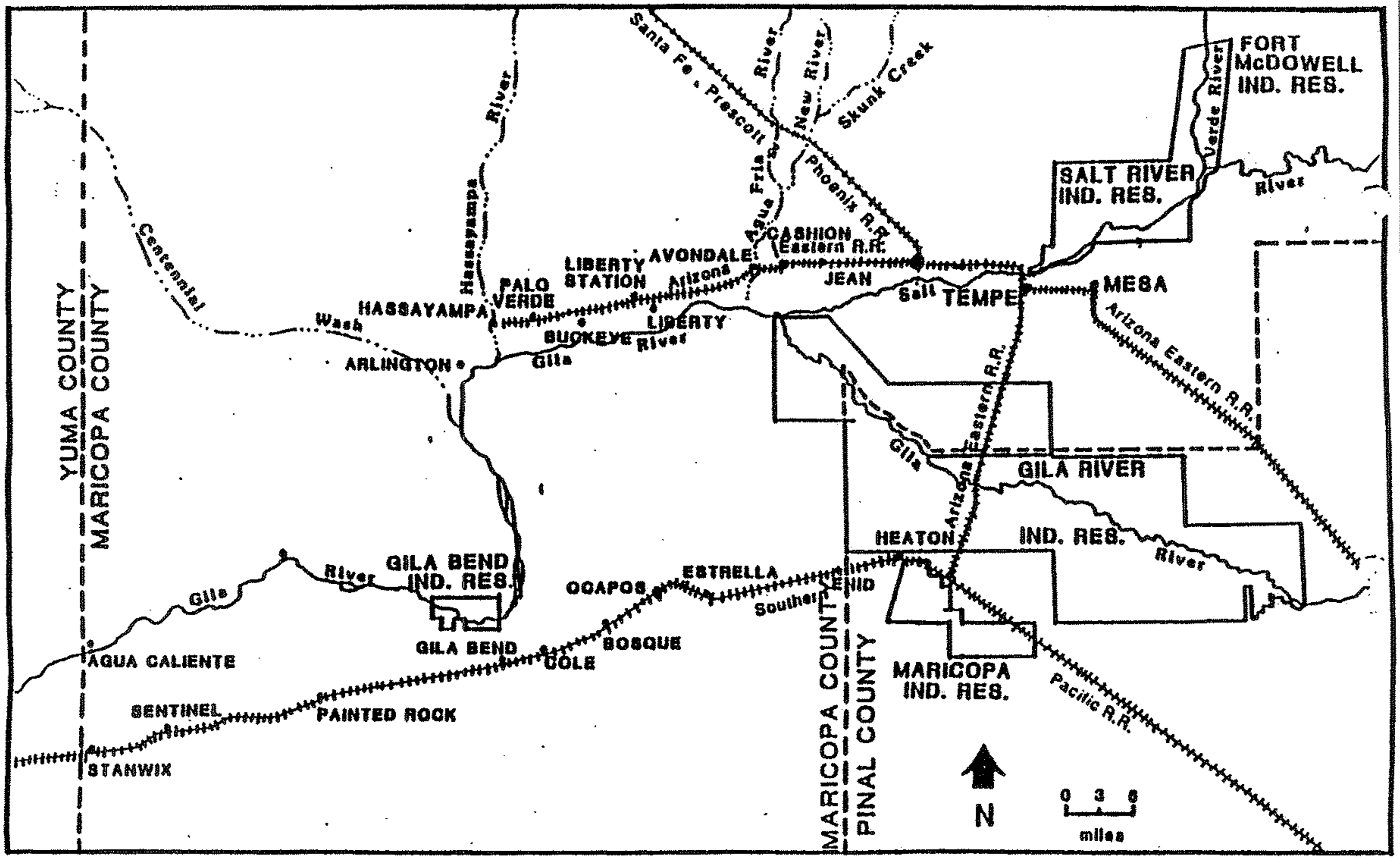

Figure 3-3. Regional Towns and Railroads in Salt and Gila River Area, circa 1900 (from Lacy et al, 1987:Figure 2)

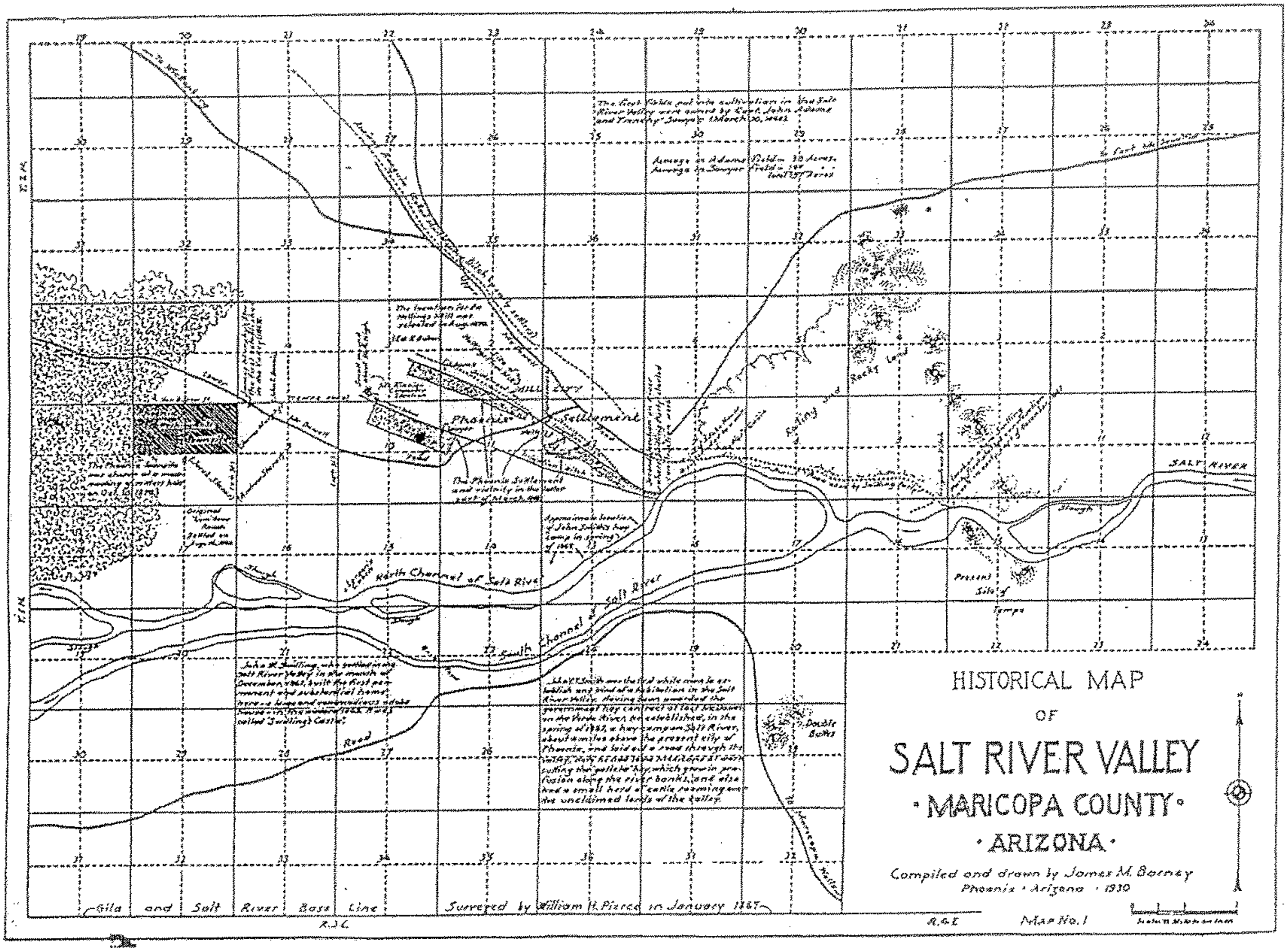

Figure 3-4. Historical Map of the Salt River Valley, Maricopa County, Arizona (from Cable and Doyel, 1985:Figure 5).

Table 3-1
Chronology of the Salt River Valley

1527	Cabeza de Vaca first European to stand on Arizona soil (Wallace W. Elliot & Co. 1884:26).
1539	Marcos de Niza explores Arizona (Wallace W. Elliot & Co. 1884:26).
1540	Francisco Vazquez de Coronado explores the Southwest (Wallace W. Elliot & Co.1884:26). Referred to by the Spanish as the River of Rafts--Coronado and his men had to build rafts to cross it in 1540 (Byrkit, 1984:323).
1698	Salt River--Fr. Eusebio Kino called it the Rio Salado, also saying he had named it for the Evangelist Matthew (Granger 1984:541).
1826	Report of attack by Indians near the confluence of the Gila and the Salt. Mention of beavers abounding on river--Salt, especially in the stretch from the Gila to the Verde (Flint 1930:139). Fur trappers traveled along the river--Sylvester and James O. Pattie and Ewing Young and friends. (Ayres & Stone 1984:7; Hill & Goff 1970:113; Walker & Bufkin 1986:17).
1829	Young and his party, including Kit Carson, again traveled and trapped the Verde and the Salt (Walker & Bufkin 1986:17).
1846	Description: Salt River joins the Gila River near Phoenix. It passes through an area in which it picks up salts that give its waters a brackish taste (Granger 1984:541).
1847	U. S. Army under General Kearny enters the New Mexico-Arizona area (Wallace W. Elliot & Co. 1884:26).
1852	John R. Bartlett of the United States Boundary Commission conducted a reconnaissance of the Salt River from its confluence with the Gila as far upstream as present-day Mesa (Bartlett 1854).
1862	Passage of U.S. Homestead Act
1863	Arizona Territory created by President Lincoln (Mawn 1979:4). The Howell Code adopted by the First Arizona Territorial Legislature. This water law code stated that: The regulations of acequías [canals] which have been worked according to the laws and customs of Sonora and the usages of the people of Arizona, shall remain as they were made and used up to this day (Bashford, *Compiled Laws of Arizona*, 1864-1871 cited in Lewis 1963:7). This meant that the laws regarding water and irrigation which had been in use in New Mexico Territory were to be continued in Arizona Territory. In Mexican law the right to the use of water from a stream went with the land. The common law doctrine of riparian rights to the waters of a non-navigable stream was unknown to the Mexican farmers and was not adopted into the water code of Arizona territory (Lewis 1963:7).
1864	The Bill of Rights, enacted by the Territorial Legislature, provided that "All streams, lakes, and ponds of water capable of being used for the purpose of navigation or irrigation are hereby declared to be public property; and no individual or corporation shall have the right to appropriate them exclusively to his own private use, except under such equitable regulations and restrictions as the legislature shall provide for the purpose (*Revised Statutes of Arizona* 1913, Water and Water Rights, p. 1727, cited in Pollard 1945:58-9).
1865	Camp (later Fort) McDowell established (Reed 1977).
1867	John Y. T. Smith set up hay camp at site of present-day Phoenix (Ayres & Stone 1984:7). Salt River--4 miles upstream from Phoenix--first settler (before Phoenix was established) was John Y.T. Smith--an officer of the California Column and trader at Ft. McDowell (McClintock 1916:565). Jack Swilling organized the Swilling Irrigation and Canal Company organized at Wickenburg in December. Swilling and his groups moved into the Salt River area and started

Table 3-1 Chronology of the Salt River Valley	
	building ditches (Farish 1915, Vol. 6:71-3; Lewis 1963; Trimble 1977:362; Adams 1930:396; Granger 1985:191). John W. Swilling built irrigation system in Phoenix area (Ayres & Stone 1984:7). Jack Swilling built Swilling Ditch also known as the Salt River Valley Canal (Walker and Bufkin 1986:59).
1868	Pumpkinville (later to become Phoenix) established on the Salt at the place where Swilling began building canals (Byrkit 1984:323). Swilling Ditch and Irrigation Company, later to be called the Salt River Canal was formed (Smith 1972:9-10).
1870	Charles T. Hayden moved to Phoenix established the first ferry in the Phoenix area across the Salt (Farish 1915, Vol. 6:103-4). Hayden's Ferry was used only when high water impeded fording the river. It was carried downstream several times during flooding (Hayden 1972:37). 1800 acres under cultivation in the Salt River Valley. Hayden Milling and Farming Ditch Company organized, staking claim to 10,000 miners' inches of water from the Salt River, and a couple of sections of land (Peplow 1979:35). Tempe Canal construction began which eventually served approximately 25,000 acres (Pollard 1945:50).
1870-3	Irrigation and farming occurred along the Salt in the vicinity of present-day Phoenix (Farish 1915, Vol. 6:137-57).
1870-88	More than 400,000 acres brought under cultivation in the Salt River Valley (Pollard 1945:50).
1871	"From near the northwestern base of the Butte a cable was suspended across the channel and a ferry boat made of heavy lumber was built which could accommodate a wagon and a team of horses." This was Hayden's Ferry (Hayden 1972:36). Maricopa County created (Peplow 1979:23). San Francisco Canal built (Pollard 1945:50).
1871	Mill City re-established.
1872	Nine irrigation ditches supplying water to about 8100 acres of land in the Salt River Valley (Peplow 1979:22).
1876	King S. Woosley operated a salt mine in the salt draws (Granger 1984:541).
1877	Desert Land Act passed. This act encouraged the entry of farmers onto remaining unoccupied sections of land in the vicinity of Phoenix. The Act allowed for 160 acre homesteads to expand to an additional 640 acres, for a total of 800 acres (Mawn 1979:45). Oscar Cluff established a Mormon settlement at Carrizo Creek called Forest Dale--18 families moved there--in 1881 the Apaches drove them out (Byrkit 1984:323). Irrigation on the Salt River (Hodge 1877:43). Utah Canal built (Pollard 1945:50).
1877-8	Irrigation along the Salt by Mormon settlers (Bancroft 1889:532).
1878	Mesa founded by Mormons (U. S. Federal Management Administration [FEMA] 1979:2).
1879	Military maps show extensive salt works in the Salt Banks (Granger 1984:541). Grande and Mesa Canals built (Pollard 1945:50).
1879	Hayden's ferry adopts name "Tempe."
1880s	A local Phoenician describes the Salt River: "...fishing in the Salt River was quite good where an abundance of fish could be caught, including that prince of Arizona waters the Colorado Salmon. The fish could be as long as 5 feet and weigh as much as 40 pounds. Occasionally, someone would use "great powder" to kill fish in the river causing great outrage by local sportsmen against such opprobrious practice (*Phoenix Herald* 1880 and 1882; *Phoenix Gazette* 1883 cited in Simkins 1989:351).
1881	Phoenix incorporated (Mawn 1979:38; Simkins 1989:196). Description of Hayden's Ferry: "When the Salt River was at a high stage, travelers depended on Hayden's Ferry to transport

Table 3-1 Chronology of the Salt River Valley	
	their teams and wagons across the swollen river. The wooden ferry boat ran from the northwest base of the butte to the north bank of the river by cable on poles. By lowering the boat's rear end, the current would swing it across the stream. Several times floods washed out the cable supports on the north side of the river and took the ferry boat downstream. Hayden had only to send a team of horses downstream to haul the boat back because it would only float a few miles before landing on a sandbar (*Phoenix Herald* 1881 and 1882 cited in Simkins 1989:39).
1883	Arizona Canal built (Pollard 1945:50). Mesa incorporated (FEMA 1979:2).
1884	Salt--"capable of irrigating vast stretches of land" (Hamilton 1884:361). Description of Salt River: The Salt River rises in the eastern part of the Territory, in the White Mountains, its head-waters being the White and Black Rivers. It has numerous large branches, coming in mostly from the north, draining the country far to the north, including the Tonto Basin, the Sierra Ancha, White, San Francisco and other mountains. Arivaypai is the principal southern tributary. On this stream is a deep cañon with wild scenery. Its course is west and southwest, and it unites the Gila below Phoenix some twenty miles. The river was named the Rio Salado by the early Spanish and Jesuit explorers, on account of its waters being highly impregnated with salt, which is easily noticed at low water. This is caused by a heavy salt formation, through which the river passes about one hundred miles above Phoenix. At low water it is a clear beautiful stream, having an average width of 200 feet for a distance of 100 miles above its junction with the Gila, and a depth of two feet or more. Its length is about two hundred miles and it flows through the largest body of agricultural land in the Territory after it leaves the cañon (Wallace W. Elliot & Co. 1884:90). Mesa incorporated (Simkins 1989:196).
1885	Buckeye canal laid out by G. L. Spain and M. M. Jackson to supply water to agricultural land in western Maricopa County. Buckeye Canal Company formed by M. E. Clanton and others (Parkman 1987:ii and 2).
1886	Indian threat in Arizona subdued with surrender of Geronimo.
1888	Buckeye Irrigation Company formed. It included the Buckeye Canal Company (Parkman 1987:2). Highland Canal built (Pollard 1945:50).
1889	Birth of the Salt River irrigation project (McClintock 1916:431). Arizona Cross Cut Canal built (Pollard 1945:50).
1889	Territorial capital moves to Phoenix.
1890	Salt River floods area destroying crops, and water-logging bottom lands. The Maricopa and Phoenix Railroad loses 300 feet of the Tempe Bridge (*Phoenix Herald* 1890 cited in Mawn 1979:137).
1891	Major Salt River flood (Granger 1985:191; Parkman 1987:ii). Salt River floods southern Phoenix, leaving section to develop into an area for social and economically disadvantaged groups such as Hispanic, Chinese, black and prostitutes, as upper income residents left area (*Arizona Gazette* 1890; *Phoenix Herald* 1891 and 1897 cited in Mawn 1979:139). Greatest flood on record in Tempe area (FEMA 1980:4).
1892	Consolidated Canal built (Pollard 1945:50).
1894	Tempe becomes a municipality (Simkins 1989:196).
1895-1903	Arizona Dam in operation until it was partially destroyed by flooding. Replaced by the Granite Reef Dam (Ayres & Stone 1984:58).
1897-1907	Severe drought descends upon the watersheds of the Salt and Verde Rivers (Zarbin 1986:37).

Table 3-1 Chronology of the Salt River Valley	
1898-1904	Salt River Valley characterized by extreme drought (Smith 1972:10).
1900	Salt River Valley Water Users Association established. It was set up as a central organization to represent individual water users in their dealings with the federal government (Lewis 1963). Water production lowest on record (Smith 1972:10).
1902	National Irrigation Act adopted as law (Lewis 1963; Smith 1972:1).
1903	Roosevelt Dam construction begins (Lewis 1963). Salt River Project was created to serve a community of twenty thousand. Tonto Basin Dam site approved (Smith 1972:1,12). Salt River Valley Water Users Association founded. It is one of two organizations later to form the Salt River Project (Zarbin 1986:1)
1905	Federal engineers and crews of Apaches, not 20 years removed from Geronimo's warrior bands, with a scattering of Hispanics and of Anglo hoboes began construction of the Roosevelt Dam. After construction was over, Apaches, Mexicans and hoboes went elsewhere looking for jobs (Worster 1985:172). Flooding on the Salt and Verde Rivers damaging the Arizona Dam (Zarbin 1986:1).
YEAR OMITTED	Federal government purchases and incorporates most of the canals in the Valley in an integrated irrigation project (Smith 1972:13).
1906-8	As part of an integrated irrigation project construction on the Granite Reef Dam begins on the Salt (Smith 1972:13; FEMA 1980:10; Salt River Project 1966:33; Ayres & Stone 1984:8).
1908	Granite Reef Dam completed for irrigation purposes (Granger 1985:183).
1910	The Kent Decision and Decree issued, which defined the irrigation status of every parcel of land in the Salt River Valley (Pollard 1945:63; Zarbin 1986:113).
1911	Roosevelt Dam completed; modern age of irrigation in Valley begins (Lewis 1963; FEMA 1980:10).
1923	Salt River Valley Water Users Association and the Tempe Canal Company merge (Lewis 1963).

Historic Indian Use of the Salt River Valley

According to Gifford (1936, as cited by Cable and Doyel 1986:3), the Salt River Valley was largely uninhabited during the first half of the nineteenth century. Instead, it served as a buffer zone between the Southeastern Yavapai, Tonto Apache, and San Carlos Apaches, who lived in the mountains to the north, and the Pima and Maricopa, who lived along the Gila River. The Pima Village at the junction of the Salt and Gila rivers was a landmark mentioned by numerous explorers, military men, and travelers.

Spanish Exploration

Byrkit (1984:223) suggests that the Salt River was the river Coronado crossed using rafts, but most reconstructions of Coronado's route place this crossing to the east of the study area.[3] The

[3] For a review of the routes of the Coronado Expedition, see National Park Service, 1991.

Salt River lay to the north of the area missionized and colonized by the Spanish. The main transportation route used by the Spanish to connect southern Arizona and California was along the Gila River, but even this route bypassed the junction of the Salt and the Gila by running straight between Maricopa Wells and Gila Bend (Rea 1983:21, as cited by Cable and Doyel 1986:3). Padre Luís Velarde mentioned the Salt River in 1716 (Wyllys 1931:116); Father Jacobo Sedelmayr described it in 1748 (Dunne 1955:24); and Father Ignaz Pfefferkorn described it in 1763 (Hammond 1949:29, as cited by Cable and Doyel 1986:3).

American Trappers

In 1826, trappers James Ohio Pattie, Ewing Young, and others traveled up the Salt, trapping beaver along the way. At the Verde River (which they called the San Francisco River), the party split, and Ewing Young went up the Verde, while Pattie continued up the Salt. Young followed the Verde to its headwaters, and then returned to the Salt River (Byrkit 1978:34; Davis 1982; Flint 1930). Young returned to the Verde with 40 other trappers (including Kit Carson) in 1829, following the Salt River to the Verde, and then traveling up the Verde to the Chino Valley (Byrkit 1978:35, 46; Pierson 1957:325-326).

United States Military Exploration

Prior to the founding of Fort McDowell in 1865, United States military exploration through southern Arizona largely bypassed the Salt River, traveling instead along the present international border and the Gila River. In 1849, Lt. Beckwith traveled from Santa Fe to Zuni to the Gila, then down the Salt River to the Colorado via the Gila River (Foreman 1937). In July of 1852, John R. Bartlett of the United States Boundary Commission conducted a reconnaissance of the Salt River from its confluence with the Gila as far upstream as present-day Mesa (Bartlett 1854).

Permanent White Settlement

In 1865, Camp McDowell was established on the Verde River eight miles above its confluence with the Salt River. The soldiers cleared 150 acres of bottom land for cultivation and irrigated it with Verde River water brought by an acequia from four miles upriver. At first, the farm was worked by employees of the Quartermaster Department but later was leased to private citizens who produced grain for the quartermaster and cavalry animals (Surgeon General 1870:459-460). Recognizing a market for agricultural produce at Fort McDowell and in the gold fields around Wickenburg and Prescott, Jack Swilling and others formed the Swilling Irrigation and Canal Company in Wickenburg in 1867. Later that year, the Swilling group attempted to clear out an old Hohokam canal on the north side of the Salt River opposite Tempe Butte, but they encountered too much rock. The following spring, though, they completed the Swilling Ditch with its headgate in Section 7, Township 1N, Range 4E (Figure 3-5). At roughly the same time, Joseph Davis built a canal with its headgate in the same section. A community grew up around these canals and was named Phoenix. In 1870, a formal townsite for Phoenix was established in Section 8, Township 1N, Range 3E, and the old community of Phoenix became known as Mill

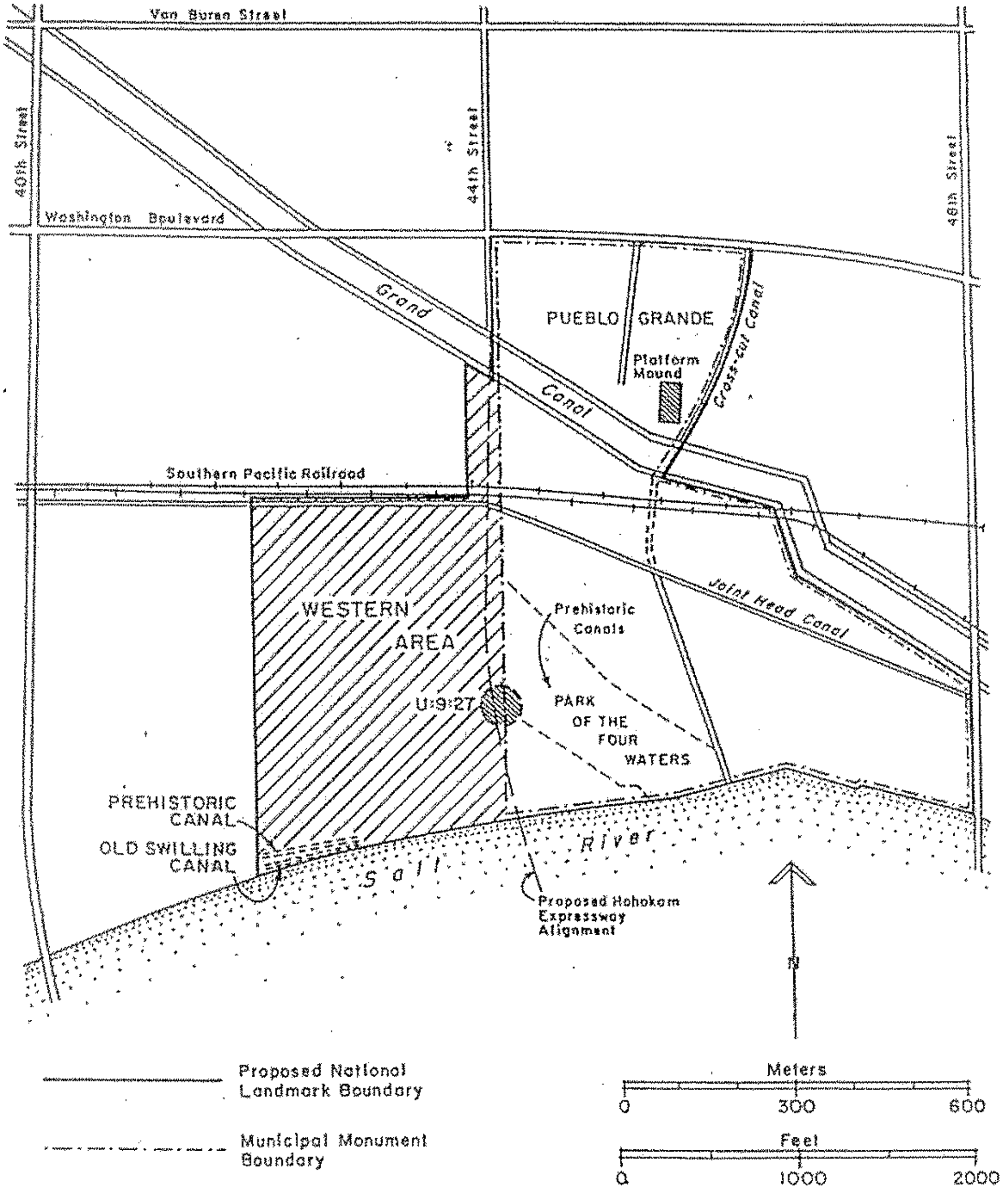

Figure 3-5. Location of Swilling's Ditch in Relation to Modern Features (from Cable and Doyel, 1986:figure 3).

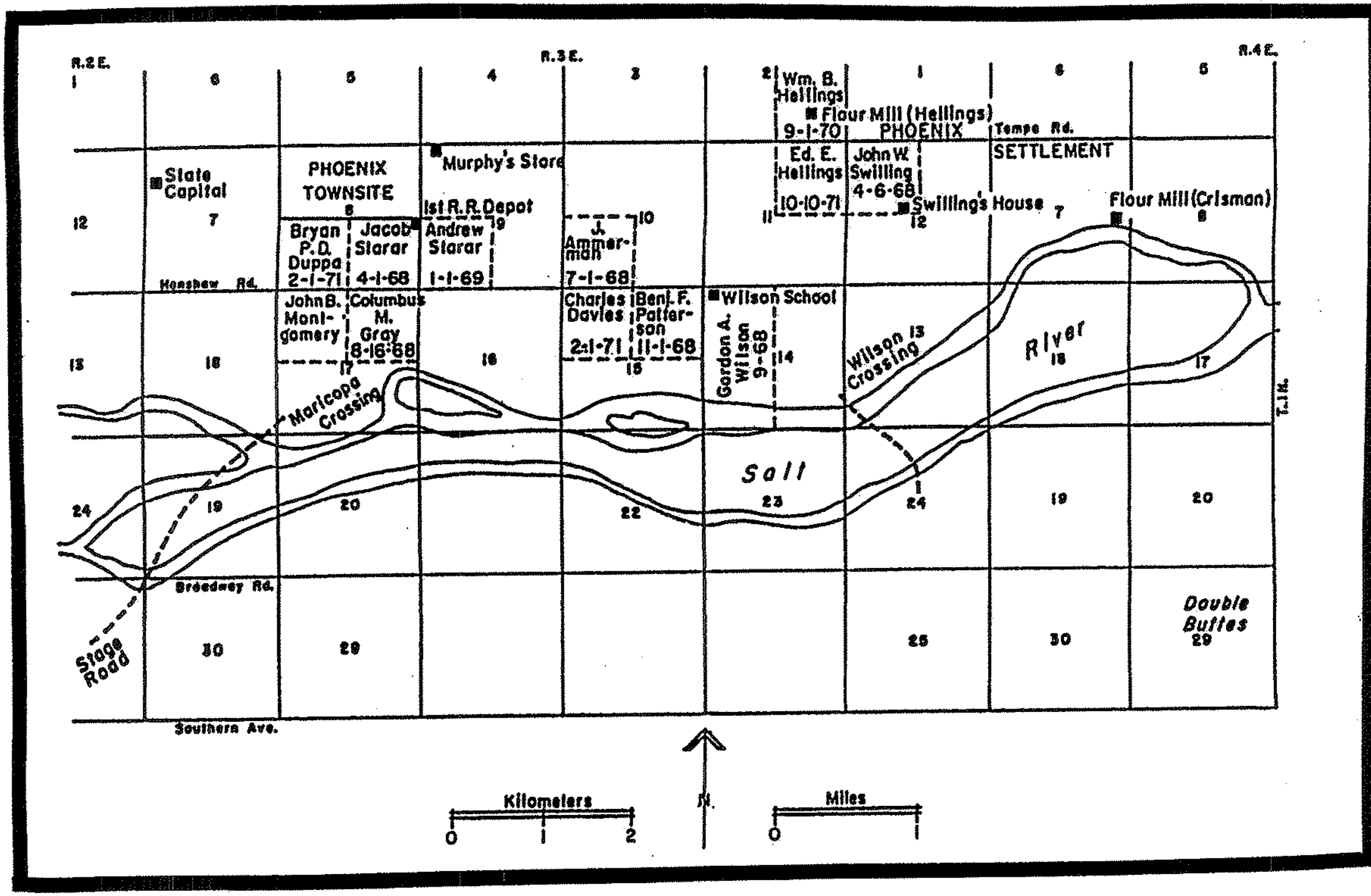

Figure 3-6. Map of Early Phoenix Settlement, 1868 (from Cable and Doyel, 1986: figure 5).

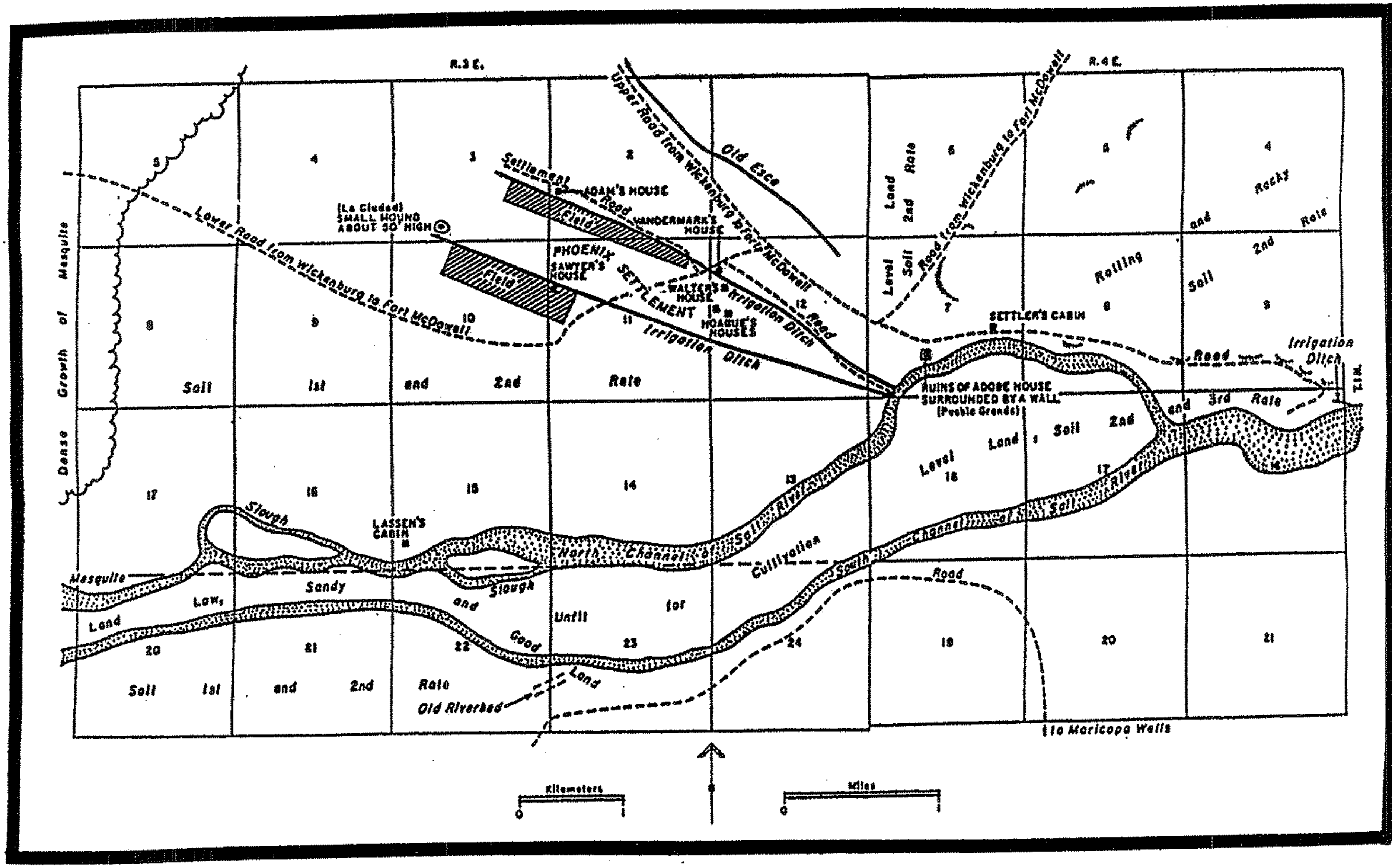

Figure 3-7. Map of Phoenix Homestead Entries in the Phoenix Settlement (Derived from Barney, 1933; and Cable and Doye, 1986: figure 7).

City (Cable and Doyel 1986:7-10). Figures 3-6 and 3-7 show location of the early Phoenix settlement and homesteads.

Lacy et al. (1987:5-6) summarize the history of communities along the Salt River. These include Lehi (established as a Mormon agricultural settlement in 1877), Mesa (a Mormon agricultural settlement established in 1878), Tempe (established in 1868 as Butte City, then called Hayden's Ferry, this agricultural settlement was also one of the principal crossings of the Salt), Phoenix (established in 1868 as Mill City), Cashion (established on the railroad in 1900), Avondale (a stage and, later, railroad stop founded in 1896), Liberty (a stage stop founded in 1895 as Altamont), and Buckeye (an agricultural community and, later, railroad stop founded in 1888).

From 1905 to 1910, Roosevelt Dam was constructed. The Granite Reef Diversion Dam was constructed in 1908 to replace the numerous brush dams at canal head gates along the Salt (Lacy et al. 1987:19). These dams greatly altered the flows of the Lower Salt River. Additional information on dam construction and flow rates is provided in Chapter 7.

Historical Descriptions of the Salt River

Padre Luís Velarde's 1716 description of the Pimería Alta states that the major rivers of the region were the Gila and the Colorado but also mentions "two others, called the Salado and the Verde, the first because it is salty, and the latter perhaps because it runs among greenish shapes or rocks" (Wyllys 1931:116).

In 1744, Father Jacobo Sedelmayr (Dunne 1955:24) described the confluence of the Salt and Gila rivers as follows:

> *A very pleasant country surrounds this fork of the rivers. Here the eye is regaled with creeks, marshes, fields of reed grass and an abundant growth of alders and cottonwood.*[4]

James Ohio Pattie called the Salt River the Black River. Describing the Salt River at its confluence with the Verde on February 1, 1826, Pattie said, "It affords as much water at this point as the Helay.... We found it to abound with beavers. It is a most beautiful stream, bounded on each side with high and rich bottoms" (Pattie 1833:91, as cited by Davis 1982).

In July of 1852, John R. Bartlett, head of the United States Boundary Commission, traveled up the Salt River from its confluence with the Gila to the site of present-day Mesa (Cable and Doyel 1986:4). Bartlett (1854, 2:240-241) described the Salt River 12 miles above its mouth as follows:

> *The bottom, which we crossed diagonally, is from three to four miles wide. The river we found to be from eighty to one hundred and twenty feet wide, from two to three feet deep, and both rapid and clear. ... The water is perfectly sweet, and neither brackish nor salty, as would be inferred from the name. We saw from the*

[4] Spelling from original document.

banks many fish in its clear waters, and caught several of the same species as those taken in the Gila. The margin of the river on both sides, for a width of three hundred feet, consists of sand and gravel, brought down by freshets when the stream overflows its banks; and from the appearance of the drift-wood lodged in the trees and bushes, it must at times be much swollen, and run with great rapidity. ... [A] long the immediate margin of the stream large cotton-wood trees grow.

Bartlett noted that the bottom lands of the Salt River were one to four miles wide, supported shrubs and mesquite trees, and potentially could be irrigated. Bartlett's party also observed "the remains of several Indian wigwams, some of which seemed to have been but recently occupied," which their guide said "were used by his people and the Pimos when they came here to fish" (Bartlett 1854:209-265, as cited by Cable and Doyel 1986:3).

Writing in 1867, the physician and naturalist Elliot Coues described beaver as still being "very abundant" along the Rio Salado and San Francisco (Verde) rivers (Coues 1867, as cited by Davis 1982:169).

According to Randall (1993), W.F. Ingalls, who conducted a cadastral survey of the area in 1868, described the Salt River Valley around present-day Tempe as "low and inclined to be swampy; with timber cottonwoods along banks." Describing the river on December 15, he wrote:

Salt River is at this season of the year at least a large stream...nor do I think it ever entirely dry. It has moreover a very heavy fall of I should think 12 to 15 feet to the mile which makes it especially valuable for irrigating. I consider this valley from 6 to 10 miles wide...as some of the best agricultural land I have yet seen in the Territory and should recommend that it be subdivided at an early day.

Hiram Hodge (1877:38), author of a guidebook to Arizona, said of the Salt, "At low water it is a clear, beautiful stream, having an average width of two hundred feet for a distance of one hundred miles above its junction with the Gila, and a depth of two feet or more."

According to Randall (1993), the first recorded flood on the Salt River occurred in February 1890. Presumably this refers to the first flood that was measured, since Bartlett (1854, 2:240-241) noted the propensity of the river to flood in 1852, and General James Rusling (1877:381-383) witnessed a flood in 1867 (described more fully below). Lacy et al. (1987:24) found citations for floods on the Salt or Gila in 1833, 1862, 1869, 1880, 1883, 1884, 1889, 1891, 1895, and 1896. The 1890 flood reported by Randall occurred somewhat later than the time other streams in southern Arizona began to flash flood and cut arroyos. Other major floods on the Salt River during the period surrounding statehood occurred in 1891-2, 1905, 1909, 1911, and 1916 (Lacy et al. 1987:24).

According to Behan (1988:7), historian James H. McClintock provided a summary description of the Salt River in a 1901 promotional pamphlet on the Phoenix area. McClintock stated,

For the greater part of the year the Salt River is a river only in name. Yet it is one of the most considerable of the flood streams in the nation. It has an average *volume ten times that of the Gila* (McClintock 1901:25, as cited by Behan 1988:7).

A number of newspaper articles dating from about 1879 to 1908 describe fish in the Salt River, and in fact, commercial fishing, primarily by Native Americans, was practiced during this period. This use of the river is described more fully below.

Historical Uses of the River

The primary use of the Salt River in historic times was for irrigation. Several flour mills were also powered by water. The river also supported recreational and commercial fishing. In addition, ferries operated on the Salt, and boating also occurred. McClintock (1901:29) also mentions hydroelectric plants in operation or under construction on canals at Chandler, Tempe, and Phoenix.

Farming

The development of irrigation along the Salt River has been exhaustively documented (Anonymous n.d.; Cable and Doyel 1986; Lewis 1963; Myres 1961; Parkman 1961; Peplow 1979; Pollard 1945; SRP 1966; Smith 1972; Worster 1985; Zarbin 1984, 1986) and will not be repeated here. Perhaps the best overviews are Lewis (1963) and Pollard (1945). Cable and Doyel (1986) provide a detailed account of the establishment of Swilling's Ditch, the first historic canal in the Salt River Valley. The history of the Salt River Project is recounted in Anonymous (n.d.), SRP (1966), Smith (1972), and Zarbin (1984, 1986).

Agricultural development of the Salt River Valley began in 1867. In 1870, the Surgeon General reported that, "Another system of acequias which, in former times, irrigated the country near the mouth of this river [the Verde], has recently been cleared out in part, and a thriving settlement, named Phoenix, established by American and Mexican settlers" (Surgeon General 1870:459).

In 1877, Hodge (1877:43) described the agricultural potential of the Salt River Valley, writing, "The largest tract of agricultural land which can now be cultivated in Arizona, is that on Salt River, in Maricopa County, in and around Phoenix for a distance of from twenty to fifty miles. The amount of such land in this rich valley is approximately one million acres." A map derived from the 1900 census data shows that virtually the entire valley was irrigated, or was mapped as irrigable.

The Helling's mill, located on the Swilling Canal, was established in 1871 and was steam powered, with the water for the steam presumably coming from the canal. Hayden's Mill at Tempe was powered by Salt River water, and the Crismon (Mormon) Mill, located on the upper Grand Canal, was also water powered (Behan 1988:14, 17).

Fishing

A number of newspaper articles dating from about 1879 to 1908 describe fish in the Salt River. In 1881, "Two of the Herald boys went fishing yesterday and in a few hours they caught over a hundred pounds of fish" (*Phoenix Herald*, July 18, 1881), and in 1882, "A lucky disciple of Izaak Walton succeeded in hauling a five pound fish from the Salt River this forenoon. It was a Colorado River salmon" (*Arizona Gazette*, March 7, 1882). Articles in the *Phoenix Herald* (May 7, 1879) and the *Arizona Gazette* (December 17, 1881) mention fish being supplied for market, and the *Phoenix Herald* (June 24, 1880) stated, "The restaurants occasionally furnish their boarders with excellent fish caught in Salt River." It is unclear whether boats were used for fishing, or whether fishing was conducted exclusively from the banks of the river.

The use of giant powder to harvest fish was a concern as early as 1879 (*Phoenix Herald*, May 7, 1879), and in 1881, a bill prohibiting the use of giant powder and other explosives in killing fish was passed in the Territorial Legislature and signed by the governor (*Arizona Gazette*, January 21, 1881, February 4, 1881). Despite this legislation, the use of explosives continued, and Indians were blamed. In 1882, the *Arizona Gazette* (November 13, 1882) reported, "The Indians have been supplying this city with fish, most abundantly, for several weeks past. However, we understand that they obtain their fish by illegal methods--the use of giant powder." In 1885, "A complaint was today filed with the district attorney accusing three Indians with using giant powder for the purpose of killing fish" (*Arizona Gazette*, June 30, 1885). The diversion of river water for irrigation also left dead fish in the river, dry river bed, and fields where they were collected by small boys and Indians (*Phoenix Herald*, June 20, 1888; *Arizona Gazette*, July 7, 1892, and June 13, 1908).

Regional Transportation

Cable and Doyel (1986:7) report that when the Swilling company set out from Wickenburg in 1867 to begin construction on the first historic irrigation canal in the Salt River Valley, they traveled overland with an eight-mule team carrying the provisions and tools. A stage station was built near Swilling's house in 1870 (Cable and Doyel 1986:9).

In 1870, mail to Fort McDowell went by way of Maricopa Wells (Surgeon General 1870:459). Reed (1977:131) describes this route in more detail. It ran from Drum Barracks to Fort Yuma, up the south bank of the Gila (with camps at Gila City, Filibuster, Stanwix, Oatman's Flat, and Gila Bend), then went 45 miles across the desert to Maricopa Wells, then across another 35 miles of desert to the Salt River crossing at Maryville (across the Salt River from present-day community of Lehi), then 15 miles through McDowell Canyon to the fort. Reporting on Fort McDowell in 1870, the Surgeon General stated that "the floods of the Gila and Salt River have cut the post off from communication with the outside world for three and four weeks at a time (Surgeon General 1870:459).

Reed (1977) mentions instances in which pack trains of mules passed through the Salt River Valley on their way to Fort McDowell. "On January 19, 1871, a pack train belonging to W.B. Hellings and Company, loaded with grain for Camp McDowell, was attacked fifteen miles south of the upper Salt River crossing" (Reed 1977:56).

Stagecoach lines also operated in the Salt River Valley. The Wells Fargo line was perhaps the most prominent, operating a route along the north side of the Salt (Lacy et al. 1987:6). Writing of Tempe in 1893, George Finch (1932:18, 20) said, *In those days the horse and buggy was the only resource of transportation, so from a feed-yard I had developed a through livery line, including the transfer outfit. ... The biggest problem we had was crossing the river which was past fording most of the time. People would get stuck in the quick sand. I had to respond with a team of horses and pull them out.*

Finch (1932:22-23) also mentions crossing the river with horses. Finch eventually purchased and operated a ferry across the Salt River, but when it came to navigation, he deferred to the Colorado. "All the freight at that time was evidently ferried up the Colorado river, at a point above Yuma. So the Colorado river was navigable and Arizona had a sea-port" (Finch 1932:20).

The Maricopa and Phoenix Railroad was completed to Phoenix in 1887 (Hayden 1972:37). The construction of railroad bridges (and later, highway bridges) across the Salt River limited the need for ferries across the river, although the Haws & Finch ferry continued to operate until as late as 1898 (*Arizona Republican*, February 1, 1898).

Historical Accounts of Boating on the Salt River

Historical accounts of boating on the Salt River primarily describe two activities: ferries and downstream boating. The need for ferries along the Salt River was apparent at least as early as 1867 and in the late nineteenth century at least five ferry crossings were in operation. Downstream boating is also well documented with 16 accounts of successful or unsuccessful attempts to boat or to transport goods down the Salt River between about 1873 and 1910. In addition, photographs of boating the Salt River provide further evidence that boating was not uncommon. Tables 3-2 and 3-3 summarize published accounts of boating and ferries on the Salt River. Newspaper accounts of boating, ferries, and fish in the Salt River are also summarized in Appendix B. Sources of historical information are discussed in Appendix C.

The sixteen historical accounts of boating on the Salt River between about 1873 and 1915 are summarized in Table 3-2. More detailed descriptions of these events are provided in the following paragraphs.

On May 3, 1873, the *Weekly Arizona Miner* reported, "Salt River is navigable for small craft as, last week, L. Vandemark and Wm. Kilgore brought five tons of wheat in a flat boat from Hayden Ferry down the river to the mouth of Swilling canal and thence down the canal to Helling & Co.'s mill."

Table 3-2
Accounts of Salt River Boating

1873	Two men transported a flat boat loaded with five tons of wheat down the Salt River from Hayden's Ferry to the Swilling Canal, then down the canal to Hellings and Co.'s mill (*Weekly Arizona Miner*, May 3, 1873).
1873	Charles Hayden attempted to float logs down the Salt River and to establish a lumber mill in Tempe, but could not get the logs through the canyons upstream (*Weekly Arizona Miner*, June 14, 21, 28, 1873; Robinson and Bonham n.d., as cited by Lacy et. al., give an incorrect date of 1875).
1881	Two men (Cotton and Bingham) reported to be planning to travel in an 18-foot, flat-bottom skiff from Phoenix to Yuma by way of Salt and Gila rivers (*Arizona Gazette*, February 17, 1881).
1881	Buckey O'Neill and two others tried to boat from Phoenix to Yuma on the *Yuma or Bust*, a boat 20 feet long and 5 feet wide (*Phoenix Gazette*, November 30 and December 3, 1881; McCroskey 1988).
1883	Jim Meadows and three other men floated the Salt River between Livingstone (near the present-day Roosevelt Dam) and Tempe *(Arizona Republican*, October 4, 1909).
1883	North Willcox and Dr. G.E. Andrews, U.S.A., floated a canvas skiff from McDowell to Barnum's pier on the Salt River Valley Canal (*Arizona Gazette*, February 14, 1883). Report states that the "Salt River is a navigable stream and should be included in the Rivers and Harbors appropriation."
1885	In another attempt to see if logs could be floated down the Salt, William Bunch and four other men (listed variously as John Meaders, John Meadows, Lew Robinson, and James Logan) successfully boated the Salt River in a 18'x5' boat from 4 miles above Tonto Creek confluence to Phoenix (*Arizona Gazette*, June 3, 5, 6, 8, 1885).
1888	Major E.J. Spaulding (commandant at Fort McDowell) and Capt. Charles A.J. Hatfield, intending to canoe from Fort McDowell on the Verde River to Phoenix, hunting along the way, made it as far as the Mesa Dam on the Salt River, where Major Spaulding was killed when his gun discharged while lifting the canoe over the Mesa Dam (*Phoenix Herald*, December 12, 1888; Reed 1977:140).
1889	A ferry boat owned by Vol Gentry and W. Cox, "which had been used for years on the Salt River at the Maricopa crossing was floated down the river with the purpose of taking her to the Gila Bend crossing." Forty miles below Phoenix, the boat struck a snag and was cut in two (*Tombstone Daily Prospector*, January 24, 1889).
1890?	According to Scott Soliday, research historian at the Tempe Historical Museum, an article in the *Mesa Free Press* of 1890 or 1891 describes how, after Fort McDowell was abandoned, A.J. Chandler had logs or sawn timber from the fort floated down the Verde and then used in the head gates of the Consolidated Canal (Scott Soliday, personal communication to Douglas Mitchell, 8/12/93). (This article has not been located.)
1895	Amos Adams and G.W. Evans boated from the San Francisco River to Clifton, then down the Gila to Sacaton. They then hauled the boat overland to Phoenix, and then boated down the Salt and Gila Rivers to Yuma (*Phoenix Herald*, February 18, 25, 1895).
1905	Engineers from the Reclamation Service of the Department of the Interior, appraising the property of the Arizona Water Company, traveled by boat from below the Arizona Dam to the head of the Consolidated canal (*Arizona Republican*, December 9, 1905).
1905	Jacob Shively built a boat at the Chamberlain Lumber Company in Phoenix, intending to float it to Yuma (*Arizona Republic*, March 30, 1905).
1905	Boat used to rescue people from the flooded Salt River (*Arizona Republic*, February 5, 1905).

Table 3-2 Accounts of Salt River Boating	
1910	Two men took a rowboat trip from Roosevelt Dam on the Salt River to Granite Reef Dam, and then to Mesa via the South Canal (*Arizona Republican*, June 28, 1910).
1915	Boat used to rescue people from the flooded Salt River (*Arizona Gazette*, January 30, 1915).

Later that year, Charles Hayden attempted to float logs down the Salt River and to establish a lumber mill in Tempe, but he could not get the logs through the canyons upstream (*Weekly Arizona Miner*, June 14, 21, 28). The *Weekly Arizona Miner* (June 28, 1873) described the outcome as follows:

> *The Hayden party, left up Salt River to come down in a canoe and drive some logs with them, have returned, and pronounce the scheme a failure. With much toil and difficulty, on account of rapids and boulders in the river, they descended a long way, when, having lost their arms, ammunition and provisions, excepting flour, they arrived in a canon so narrow as not to admit of the passage of a log, and were compelled to abandon their boat and foot it. Mr. Hayden is still sanguine of getting sufficient timber on this side of the canons.*[5]

In 1881, the *Arizona Gazette* (February 17, 1881) announced that

> *Messrs. Cotton and Bingham will leave to-morrow for Yuma by way of the Salt and Gila rivers. They have constructed for the trip, an 18-foot skiff, flat-bottom, which will draw very little water, while at the same time it has the appearance of being very strong and durable, and able to stand a pretty severe beating.*

In late November and early December of 1881, Buckey O'Neill and two others tried to boat from Phoenix to Yuma on the *Yuma or Bust*, a boat 20 feet long and 5 feet wide (*Phoenix Gazette*, November 30 and December 3, 1881; McCroskey 1988:16). According the *Phoenix Gazette* (November 30, 1881), "The 'Yuma or Bust' party which left Phoenix recently for the purpose of exploring the Salt and Gila rivers were seen yesterday, only twelve miles from here, all wading in mud and water up to their knees, pulling the boat, and apparently as happy(?) as mudturtles." On December 3, the *Gazette* reported the return of the navigators.

> *The officers of the "Yuma or Bust" returned on to-day's stage. They report having arrived safely at Yuma six days out from this port. We have advices however, that the boat reached Gila Bend and "busted." The liquor having given out three days before, the crew subsisted on bacon straight, enduring great hardships, being compelled to wade in the water the greater portion of the time and push the craft ahead of them. The Yuma papers may enlighten us as to which account is correct, unless they have been bought off.*

A successful boat trip from Livingston to Tempe by Jim Meadows and three other men was described in the *Arizona Republican* on October 4, 1909.

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5 This account describes an attempt at boating outside the Lower Salt River study reach.

In 1883 Jim made the first attempt, with success attending him, to navigate the waters of the Salt River between Livingstone and Tempe, accompanied by two white men and a negro. In passing through the first box canyon the negro was scared stiff. In passing through the second box they got hung upon the rocks and had to roll more rocks into the water to raise the water high enough to float the boat clear.

At least two newspaper accounts describe soldiers boating down the Verde River from Fort McDowell to Phoenix. They are as follows:

Arizona Gazette, February 14, 1883:

The Salt River is a navigable stream and should be included in the river and harbor appropriation. North Willcox and Dr. G.E. Andrews, U.S.A., of McDowell, landed at Barnum's pier, on the Salt River Valley Canal, at three o'clock yesterday afternoon, direct from McDowell, having accomplished the voyage from that point to this port, in a canvas skiff. The running time proper was about eighteen hours, and the trip would have been thoroughly pleasant, had rain not fell upon them, during the night in which they camped out. The jolly mariners are now enjoying a good time among their friends in this city.

Phoenix Herald, December 12, 1888:

The death of Major E.J. Spaulding, which occurred on Monday at the Mesa dam on Salt River is to be deeply regretted for a good man, a thorough and brave officer, has come to his too early grave. While coming down to Phoenix with Capt. Hatfield in a canoe and shooting as they came, they were about to lift their boat over the Mesa dam, when the major attempted to remove his gun from the boat, and in doing so it was discharged, killing him almost instantly. He was Commandant at Ft. McDowell, Major of the 4th Cavalry and an officer highly esteemed by his superiors and men under him.

Reed (1977:140) also mentions the death of Major Spaulding, and cites both the *Phoenix Herald* and the Post Return for December 1888. Reed (1977:140) makes it clear that Major Spaulding "left the garrison with Captain Charles A.P. Hatfield bound for Phoenix in a canoe."

In 1885, William Burch, John Meaders, John Meadows, Lew Robinson, and James Logan successfully boated the Salt from four miles above the Tonto Creek confluence to Phoenix. The men described their voyage in a series of articles in the *Arizona Gazette* (June 3, 5, 6, 8, 1885). The June 3 article stated the following:

A party of five men, including William Burch, John Meadows and Lew Robinson, started in a boat from near Eddy's ranch, yesterday morning, to explore Salt river canyon, said to be about 60 miles long and through which a boat was never known to pass. The rapids with numerous projecting boulders make the trip a hazardous one, but the party have a staunch craft, 18 feet long by five feet wide, and are confident of accomplishing the passage of the canyon without any *mishaps. The object of the trip is to ascertain if logs could be floated through the canyon. If practical, Mr. Burch intends erecting a saw mill at the foot of the Sierra Anchas and floating the logs down the river to Phoenix.*

The June 5 article stated the following:

Yesterday James Logan, Wm. Burch, John Meaders and Wm. Robinson, composing the party of daring adventurers arrived in this city, having landed their craft at Tempe and coming into this city in six days after launching their boat. They report having enjoyed a most exciting and interesting trip. Through the box canon of the Salt river the banks frequently towered above them over 1,000 feet, and on one occasion they were wrecked, losing provisions, fire arms, etc. The object of the trip was to determine whether saw logs could be rafted to the lower Salt river, and the undisputed conclusion is that such work can be successfully carried on. In fact Mr. Burch, who is a sawpull man on the upper Salt river has partially contracted for the delivery at Tempe of over one thousand railroad ties. If experience should demonstrate that saw logs can be successfully floated from the timber regions to this portion of the Salt river, then the benefits derived from this exploration cannot be over-estimated.

The June 6 article was an interview with John Meaders, describing the adventures of the voyage.

Timber exists in the Four Peak range in large quantities. Game and fish are most plentiful, the party having killed one mountain sheep and several deer, while they caught large quantities of Salt river trout--called by some white salmon. These fish closely resemble the lake trout of California but are not so game. Several of these fish, weighing eight and ten pounds, were caught by the explorers, but in previous instances fish of this species weighing forty pounds have been caught. The boat on one occasion shot under a cave, but a few feet high, and where its inmates commenced to fear that the end had come; here the fish were so thick that the boat floated on their backs.

They expected every minute to strike a waterfall and have their boat dashed to pieces, as they feared when they shot the cave. On one occasion their boat upset and much of their supplies were lost. In case of losing their vessel in the canon but one recourse would be left, that of swimming down the stream to a break in one bank or another and that might not be encountered for a distance of twenty miles.

The stream was described as being six to twenty feet deep, with no driftwood or other debris in it. The success of the voyage demonstrated to the *Gazette* that "it will open to this valley the timber belt of the Sierra Anchas which is undoubtedly the best and most extensive in the territory."

On June 8, the *Gazette* reported that, according to Postmaster Mowry, a trip through the canyons of the Salt River (this one on foot, during a period of low water) had been made eight to ten years before by Frank Middleton and his brother in-law, George Shute (*Phoenix Gazette*, June 8, 1885).

As mentioned above, the ferry boat owned by Vol Gentry and W. Cox and used at Maricopa Crossing was floated down the Salt in 1889 in an attempt to move it to Gila Bend. The boat made it forty miles downstream before hitting a snag and being cut in two. The *Tombstone Daily Prospector* (January 24, 1889) described it thus:

> *Boating in Arizona. It does one so much good to read of boating in Arizona that we produce the following account of a wreck on the Gila from the Arizonan: On the 9th inst. the large ferry boat which had been used for years on the Salt River at the Maricopa crossing was floated down the river with the purpose of taking her to the Gila Bend crossing. Five men were manning her and everything was going on smooth until they reached a point about forty miles below Phoenix, when the boat came in contact with a willow snag just in the middle of the river. The current of the river being about at the rate of fifteen miles per hour the five men lost control of her and she struck the snag. She was cut in two parts as if she had come across a buzz saw. She is a total loss. Her owners, Messrs. Vol Gentry and W. Cox, valued her at about $1,000.*

According to Scott Soliday, research historian at the Tempe Historical Museum, an article in the *Mesa Free Press* of 1890 or 1891 describes how, after Fort McDowell was abandoned, A.J. Chandler had logs or sawn timber from the fort floated down the Verde and then used in the head gates of the Consolidated Canal (Scott Soliday, personal communication to Douglas Mitchell, 8/12/93). (This article has not been located.)

In 1895, Amos Adams and G.W. Evans boated from the San Francisco River to Clifton, then down the Gila to Sacaton. They then hauled their boat overland to Phoenix, and then boated down the Salt and Gila rivers to Yuma (*Phoenix Herald*, February 18, 25, 1895).

Floods struck the Salt and Gila rivers in 1905, and a boat had to be used to rescue the Tilzer family, which lived on an island in the Salt at the foot of Seventh Street. John Tilzer "had already brought his four boys to the bank and was returning for his wife when his boat struck a barbed wire fence" and capsized. Tilzer was drowned, and another boat was sent to rescue Mrs. Tilzer. It was the third time the Tilzer family had been removed from the island (*Arizona Republic*, February 5, 1905).

In March of 1905, Jacob Shively built a boat at the Chamberlain Lumber Company in Phoenix, intending to float it to Yuma (*Arizona Republic*, March 24, 1905). On March 29, it was reported that Shively and his boat had been sighted at Arlington and Buckeye and were headed for the Wolfley dam (*Arizona Republican*, March 29, 1905).

In December of 1905, Engineers from the Reclamation Service of the Department of the Interior, appraising the property of the Arizona Water Company, traveled by boat from below the Arizona Dam to the head of the Consolidated canal. According to the *Arizona Republican* (December 9, 1905), *they started down the river in a boat toward the head of the Consolidated canal. They found the Salt river a poor stream for navigation, however, and in the voyage of a mile they were shipwrecked twice, though without loss of life or property. In the first incident the boat went on a rock in a rapid and the next time stuck on a sandbar. On one occasion it threatened to turn over, but was righted with a little difficulty. They finally made a landing a little above the Consolidated head and after a walk of perhaps a mile met Dr. Chandler, who drove them to Mesa....*

In 1910, Roy Thorpe and James Crawford took a rowboat trip from Roosevelt Dam to Mesa. They boated the Salt River until they arrived at Granite Reef, after which they floated the South Canal and the Mesa Canal. According to the *Arizona Republican* (June 28, 1910),

The row boat which was used throughout the journey was in a very dilapidated condition at the end of the trip. Before the start was made three bottoms had been placed in the craft and one of these had been worn through by the constant friction with the boulders and sands found in shallow waters. Many times the men were compelled to lift their craft from the water and carry it over obstacles and at other times had to haul it along the stands. ... The men are well pleased with their adventure, but have no serious intention of attempting to go into competition with the stage company, nor did they attempt to break any speed regulations.

When boats were needed upstream, they had to be hauled by wagon. In 1884, J.P. Moffit had to borrow a boat from one of the ferries. As described by the *Arizona Gazette* (December 19, 1884), "...there was only one boat available and that was the one at the ferry at the Broadway crossing. J.P. Moffit finally managed to secure this skiff and putting on a wagon took it up the river,...."

When the Salt River flooded in 1915, boats were used to rescue numerous residents of the flooded Salt River bottom lands. At one point, a boat had to be hauled from the state insane asylum to rescue a woman from a rooftop (*Arizona Gazette*, January 30, 1915).

Behan (1988:18, Figures 2 and 3) contains two photographs that illustrate recreational boating on the Salt River, although neither one is identified as to location. Behan's Figure 2, which was taken from Seargeant (1960: between pp. 94 and 95), shows a boy in a canoe. According to Behan's (1988a) notes, Seargeant describes swimming in the Salt before the construction of the dams. Numerous other anecdotal (cf Halpenny, 1987) and photographic records (cf McLaughlin, 1970) of swimming in the Salt River around the time of statehood are available, although some data suggest that downstream of Central Avenue the river was considered too polluted for safe swimming. The Barry Goldwater Collection in the Arizona Historical Foundation contains a photograph from about 1900 that shows four people on a boat on a river, possibly the Salt River, with a dog on shore watching them.

Ferries

At least six ferries operated on the Salt River between Granite Reef Dam and the Gila River between 1860 and 1915 (Table 3-3). During the early years of Phoenix settlement, these ferries were viewed as "absolutely necessary" to maintain communication. In later years, the number of ferries diminished as flow in the river was impounded in reservoirs, diverted to canals, and as bridges over the Salt River were constructed.

At least as early as 1867, the United States Army maintained a boat at the lower crossing of the Salt River for use when the Salt was flooded. Behan (1988:18) mentions that General Irwin McDowell acquired canvas pontoons to use in crossing the Salt River on the route to Camp McDowell. Citing correspondence between Smart and Loosely for March 21, 1867, Reed (1977:32) states,

> *Heavy rains caused flooding in the Salt and Gila rivers, cutting off communication with the outside world. A boat, built for such emergencies, at the lower crossing of the Salt was carried away by the rising waters.*

Table 3-3
Chronology of Historic Salt River Ferries

1867	The United States Army maintained a boat at the lower crossing of the Salt River for use when the Salt was flooded (Reed 1977:32).
1867	General James Rusling had to borrow a boat from a German settler on the Gila to get across the Gila and Salt Rivers (Rusling 1877:381-383).
1874-1909	Hayden's Ferry, Tempe, established in 1874 and used at least until 1909 (Lacy et al. 1987:9) is the best known of the ferries across the Salt River.
1884-1909	Salt and Gila Ferry Company operates downstream of Phoenix (*Arizona Gazette*, April 21, 1884; McCroskey 1988).
<1898	Haws and Finch Ferry, operates three miles above Maricopa Dam (*Arizona Republican*, February 1, 1898; Finch 1932).
<1889	Maricopa Crossing, owned by Vol Gentry and William Cox (*Tombstone Prospector*, January 24, 1889).
1868-1874	Marysville Ferry on the Fort McDowell-Maricopa Road (McCroskey, 1988).
<1884	Shureman and Singletary ferry, above the bridge at Tempe (*Tempe News*, 1893). In 1884, mail bound for Maricopa was lost when the skiff that was transporting it was washed downstream by the current and struck a larger ferry boat (*Arizona Gazette*, April 14, 1884).

That same March (1867), General James F. Rusling, who was inspecting military posts in the West, was halted at Maricopa Wells by flooding on the Gila and Salt. "They were both, swollen and turbid; nobody had forded them for a month; and they were still at freshet height, and rising--without bridge or ferry" (Rusling 1877:381). Rusling was able to borrow a rowboat from a German settler on the Gila, and used it to cross the Gila, then hauled it to the Salt River and used it again. He had to disassemble his ambulances to get them across the rivers, and it took two days to get everything across the Salt River (Rusling 1877:381-384). Rusling described the crossing of the Salt River at McDowell Crossing as follows:

> *We found it at least three times the size of the Gila, and with its waters even more swollen and turbulent. Nevertheless, it was perceptibly falling, and Louis predicted a much better state of things the next morning. This proved to be true; so, early on the 27th, we began to ferry over again as at the Gila. But it was a tedious and delicate operation. The river, as I have said, was three or four times as wide, and the swollen flood so swift, that the boat usually landed a quarter of a mile below where it went in. Then we had to drag and pole it along the opposite bank, half a mile or so above, whence we could row it diagonally across to the place of starting again. ... It took us two days to cross the Salado thus, and I need scarcely say, they were long and anxious ones...* (Rusling 1877:383).

In 1868, the *Arizona Miner* wrote "Some encouragement should be given to the enterprising citizens who have established ferries on the Gila and Salt River Rivers; such ferries being an absolute necessity to communication between the lower and upper country during several months in each year and the travel not yet being sufficient to support them" (*Arizona Miner*, December 12, 1868). As late as 1883, the Arizona Legislature was considering an act to regulate ferries, and the *Phoenix Herald* (February 26, 1883) reported that "Monihon's Ferry Privilege Act is meeting with great opposition from your county."

On February 27, 1874, the *Arizona Miner* reported "Via Western Union and U.S. Military Lines--Phoenix, February 25--A new ferryboat has been built at Hayden's crossing, so that in the future the river will cause no delay to passenger mail" (*Arizona Miner*, February 27, 1874). This story was repeated in *The Citizen* the following day. Hayden's Ferry, at Tempe, was in operation from 1874 to 1887 and was perhaps the most famous ferry in the state. In 1884, Fireman (1969:202) provides a description of the travails of Hayden's Ferry,

> *[the] ferry was pulled loose from its mooring and lost downstream three times. Each time it was towed back to the crossing and new cable and ropes were strung across the river to restore traffic. Once a smaller boat owned by Hayden was pirated by boat-thieves. Since they were not caught, history fails to tell whether in pioneer Arizona the penalty for piracy was the same as for horse thieves. The boat was found at Gila Bend, which shows that the Salt and Gila were running strong. At another time he had that boat hauled by wagon to the Gila River on the road to Maricopa Wells when the Gila was in flood and its ferries had washed away.*

Hayden's Ferry was in operation as late as 1909 (Lacy et al. 1987:9).
Probably most of the ferries that operated on the Salt River were short-lived, expedient ventures that were mentioned in the papers only when they first went into service. In 1881, the *Phoenix Herald* (August 16, 1881) reported that "George H.N. Luhrs is building a large skiff for the stage company, to be used in transferring passengers and mails across the storm waters of the Salt."

The year 1884 was significant in the establishment of ferries. In February, the *Phoenix Gazette* chronicled the rising waters of the Salt. "This river this morning was reported as being four feet higher than it was yesterday, and it was deemed unsafe to ferry passengers, nothing but the mail being carried across by the boat. The warm weather is melting the snow and a further rise is anticipated" (*Arizona Gazette*, February 19, 1884). The floods encouraged a flurry of boat building. On the same day that the *Gazette* wrote of the rising waters, the *Phoenix Herald* (February 19, 1884) said, "A raft is being constructed on the Salt River to ferry across goods, as there is little prospect of the river's being fordable for some time." A.J. McDonald's shop in Phoenix constructed at least two ferry boats, one for the Salt and Gila Ferry Company, and another for a Mr. Trumbull. On March 5, 1884, the *Arizona Gazette* reported, "The river rose nearly four feet last night, and has not yet reached its flood. In this connection[6] it will be good news to our business men to know that the new freight-boat, the dimensions of which are 11x28 feet, will be completed and ready for business to-morrow."

The Salt and Gila Ferry Company, incorporated in 1884 (McCroskey 1988), began running ferries on the Salt and Gila that year and continued to operate ferries until 1909. It was, after Hayden's Ferry, perhaps the longest lasting ferry on the Salt. On April 8, 1884, the *Phoenix Herald* reported, "Mr. A.J. McDonald is building a large ferry boat for the Gila and Salt River Ferry Company to be put on the Salt River below town. It will be of the same dimensions as the one sent to the Gila, viz: 16 by 48 feet. It will be worked on an inch and a quarter steel wire cable and be a permanent arrangement." On April 21, 1884, the *Arizona Gazette* said, "The new boat of the Gila and Salt river ferry company was launched on the turbulent waters of the Rio Salinas yesterday. It struck the water wrong [illegible] up but will be righted and will soon be ready for business. It is the largest boat ever put on the river, and will no doubt be able to meet the wants of the [illegible]." On May 9, 1884, the *Phoenix Herald* said, "The new ferry boat has got at work on the Salt River at last and is making up for its long delay and many mishaps by giving entire satisfaction, as it works splendidly. It carries over the largest freight wagon, loaded and with team, with perfect ease, and gives no trouble in its management."

The Ferry and Bridge Company began planning a series of ferries in 1884, as mentioned in the *Phoenix Herald* (March 17, 1884):

> *The Ferry and Bridge Company held a meeting on Saturday evening at the courthouse. Mssrs. Coats, Ryder, and C. Goldman were appointed a committee on construction of boats, etc. Messrs. F. Fowler, P. Miner, and J.M. Gregory were made a committee on the location of ferries....*

A number of other ferries were in operation in 1884. Two newspaper accounts of that year describe two of them.

> *Jesse Bryant and H.H. Hufstetter have a good and safe ferry running on the Salt River between Phoenix and Maricopa, and it will be promptly attended to both day and night* (*Phoenix Herald*, March 24, 1884).

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[6] NOTE: Spelling and grammar retained from the original document.

Mr. Trumbull has had a boat built at Mr. J. McDonald's shop, and took it down to the river this morning, where he will use it in crossing over some 60,000 pounds of freight that lies on the other side, but is now badly wanted on this side. Mr. Trumbull is to receive 12-1/2 cents per 100 for bringing the freight over, and doubtless plenty more will follow, if he is successful in the attempt (*Phoenix Herald*, February 19, 1884).

Apparently only two ferries (presumably Hayden's Ferry at Tempe and the ferry of the Gila and Salt River Ferry Company south of Phoenix) were regularly in service in 1886, when the *Arizona Gazette* (March 26, 1886) wrote, "Both ferries are running on the Salt river although the stream is very high." In 1889, a ferry boat owned by Vol Gentry and W. Cox, "which had been used for years on the Salt River at the Maricopa crossing was floated down the river with the purpose of taking her to the Gila Bend crossing." Forty miles below Phoenix, the boat struck a snag and was cut in two (*Tombstone Daily Prospector*, January 24, 1889). In 1893, however, ferries on the Salt River were apparently numerous enough that even the newspapers had trouble keeping track of them. In the *Arizona Gazette* (March 25, 1893), this correction appeared:

It was stated in this morning's issue of the Gazette that the ferry boat belonging to C.J. Ulmer had broken loose from its moorings and floated down stream. It was the ferry boat belonging to Mr. Bryan that had broken loose near Gray's crossing. Mr. Bryan has commenced the construction of another ferry boat similar to the one lost.

The Haws and Finch Ferry, located three miles above Maricopa Dam, was in operation as early as 1884 (*Arizona Gazette*, April 21, 1884; McCroskey 1988). George Robert Finch described the ferry in his reminiscences (Finch 1932:24).

The demand for transportation was so great that I purchased a ferry-boat which was being conducted by the Fogal brothers the only means of crossing the river. It was afterwards known as Finch's ferry. Sometimes it appeared as if it was a profitable business and I would be ahead five hundred dollars. Then the river would come down and wash the boat away and it would cost me all I had made to bring it back. ... One time I had to hire men to tow it back from Maricopa dam, a distance of three miles. ... The boat would easily transport three single buggies or a tally ho and four horses.

This ferry was in operation as late as 1898, when the *Arizona Republican* (February 1, 1898) reported, "The river is going down. The Haws & Finch ferry was in readiness and would be running now had the river stayed up."

Summary

The Salt River was on the fringe of historical development of Arizona until about 1865, when Camp (later Fort) McDowell was established on the Verde River eight miles above the Verde's confluence of the Salt River. The Spanish were familiar with the Salt River, but did not missionize or colonize the valley. In the 1820s, fur trappers from the United States worked the Salt River taking beaver throughout its length. During the Mexican War, military expeditions passed south of the Salt River, and the forty-niners generally followed the military trails, thereby leaving few descriptions of the Salt River. The establishment of Camp McDowell in 1865 not only provided protection from Apache raids, but also created a market for crops. Within two years, permanent white settlement of the Phoenix area began. The main commercial uses of the salt were for irrigation, fishing, milling of grain, and transportation.

Historical accounts of boating on the Salt River describe both ferries and downstream boating. The need for ferries along the Salt River was apparent at least as early as 1867, and in the late nineteenth century at least five ferry crossings were in operation. Downstream boating is also well documented with 16 accounts of successful or unsuccessful attempts to boat or transport goods down the Salt River between about 1873 and 1910. Construction of Roosevelt Dam between 1903 and 1911 and Granite Reef Diversion Dam in 1908, in addition to other historical changes in the Salt River hydrology, probably changed stream flow rates and curtailed many or most commercial boating, fishing, and ferrying activities.

Chapter 4
Salt River Oral History

Oral history for the Lower Salt River was obtained primarily by writing and calling historical societies, federal and state agencies, and private organizations with interests in the river and eliciting information about the history of the river, sources of information about the river, and names of individuals who might be knowledgeable about the river. The list of historical societies, museums, and historians was derived from records of the Arizona State Land Department, the Arizona Historical Society (which has a list of member institutions), guidebooks to Arizona museums (for example Fischer and Fischer 1993), and personal knowledge and contacts. On April 9, 1993, Dennis Gilpin of SWCA met with Mary Lu Moore, historian with the Arizona Attorney General's Office, to describe the proposed study and to interview Ms. Moore about potential contacts.

Once a list of contacts had been compiled, letters describing the project (Appendix C) were sent to each of them. A few individuals and organizations sent written responses to the initial mailing, but most were contacted by telephone after the initial mailing went out. During each contact and interview, each organization or individual was questioned about who might be able to provide additional information on the history of each river. A list of key topics and questions for interviews was developed to serve as a guide and checklist for the interviews. As the body of documentation on the history of the Lower Salt River accumulated, the emphasis on oral history lessened.

In general, individuals who were questioned during the initial and subsequent contacts might be characterized as falling into one of four groups: (1) professional land managers; (2) professional historians, archaeologists, and museum curators; (3) avocational historians; and (4) long-time residents along the rivers. For the Lower Salt River, 13 professional historians, 4 avocational historians, and 1 long-time resident were interviewed.

Professional historians contacted about the Salt River included Todd Bostwick (Pueblo Grande Museum), Don Bufkin (Arizona Historical Society), Suzanne Dewberry (National Archives), Adelaide Elm (Arizona Historical Society, Central Arizona Division), Thelma Holveck (Scottsdale Historical Society), Ken Kimsey (Prescott National Forest), Maryann Laughard (Arizona Historical Society, Central Arizona Division), Tray Mead (Mesa Southwest Museum), Mary Lu Moore (Arizona State Attorney General's Office), Scott Soliday (Tempe Historical Museum), David Tatum (Arizona Historical Society, Central Arizona Division), Angie Vandereedt (National Archives), and Al Wiatr (Chandler Museum). Avocational historians included Joann Hanley (Scottsdale Historical Society), Elizabeth Heagren (Gilbert Historical Society), Lee Thompson (Gilbert Historical Society), and Bill Soderman (Phoenix Museum of History). One individual, Earl Zarbin, might be characterized as belonging to any of these groups. Mr. Zarbin, a retired newspaperman, has spent a lifetime compiling information on, and writing about, water issues in Arizona. Mr. Zarbin sent two letters (Appendix B) providing references to boating, ferries, and fish along the Salt River. Curtis Jennings, former chairman of ANSAC, also provided an account of rafting on the Salt.

Typical questions and key topics of discussion for interviews included:

- Do you know of any use of the river for transportation or commerce? Recreational boating? Ferries? Floating logs?
- Was irrigation practiced along the river? What areas were irrigated? How reliable was the stream flow, both seasonally and year to year? Describe typical irrigation practices.
- What were the principal means of transportation in the area? Railroads? Stage and liveries? Highways?
- Were/are there fish in the river? What species?
- How has the river changed historically?
- Do your have or know of any photographs, diaries, letters, or journals that would describe or illustrate use of the river?
- Do you know anyone else we should contact?

Historians (avocational and professional) were divided about whether boating occurred or could have occurred along the Salt at the time of statehood. For example, Bill Soderman felt that the Salt River would not have had enough water in it at the time of statehood because no water flowed over the spillway of Roosevelt Dam between the floods of 1905 and 1914. Earl Zarbin was able to supply numerous published references to boating, ferries, and fish on the Salt River for the years prior to and including the time of statehood. Don Bufkin cited Hayden's Ferry and moving lumber down the Salt as examples of using the Salt for transportation or commerce. One of the professional historians (Soliday) mentioned seeing a reference to an article in the *Mesa Free Press* of 1890 or 1891, which said that Mr. A.J. Chandler took logs or sawn lumber from the dismantled Fort McDowell and floated them down the Verde to use in constructing head gates on the Consolidated Canal. This article has not been relocated, and Mr. Soliday's recollection is currently the best source on this event.

Mr. Tray Mead said that there are reports of recreational boating and fishing on the Salt. Mr. Curtis Jennings stated that his father and friends, as high school students in Phoenix circa 1910, used to build rafts with debris along the Salt, float downstream, and take the train home. One professional historian (Tatum) mentioned beaver dams on the Salt and Gila, and two (Kimsey and Mead) suggested that nineteenth-century fur trappers might have used canoes or boats. (In fact, the nineteenth-century mountain men who worked Arizona's rivers traveled by horseback.) One historian (Tatum) recalled references to converting wagons to boats. (This actually occurred on the Gila in 1846, when the Mormon Battalion [Cooke 1848, 1938, 1964] did it, and again in 1849, when forty-niner H.M.T. Powell [1931] did it, but no references to this manner of boating were found for the Salt.) Most of the information provided by the professional historians was also in documentary form and was found and cited in the history chapter.

The ethnographic and oral history information collected for the Salt River adds little to the database of historical records of Salt River navigability or non-navigability. Certainly, the accuracy of the some the oral history information can be questioned, with some oral accounts directly contradicted by the written history for the Lower Salt River. With respect to the federal test of navigability and legal criteria considered by some courts, the following conclusions can be made:

- Comments by Don Bufkin could be interpreted to mean that lumber was floated on the Lower Salt River more frequently than the written record implies.
- Comments by Bill Soderman indicate that the time of statehood was one of unusually low flow in the Lower Salt River because Roosevelt Reservoir was filling, effectively cutting off about half of the upstream water supply to the Phoenix area.
- Use of the Lower Salt River for navigation was not common enough to (or was so common that it didn't) attract the attention of local historians, although other elements of local history are very well documented.

Chapter 5
Salt River Geology

Introduction

This section describes the regional geology and fluvial geomorphology of the Lower Salt River. The objectives of this section are to:

- Describe potential geologic impacts on stream flow
- Describe channel changes, if any, that occurred since statehood
- Provide a geologic context for discussion of historical stream conditions
- Locate the ordinary high water mark for existing stream conditions

Resources used to support this summary of the Salt River geology included regional ground water investigations, summaries of regional geologic history, aerial photographs, and topographic maps.

Stream Reaches

The Lower Salt River was considered as a single stream reach for the analysis of stream geology. Although a natural dividing point exists at Tempe Butte, the river is an alluvial stream throughout, with similar geomorphic, hydrologic, and hydraulic characteristics. The study reach extends from the confluence of the Salt and Gila Rivers to Granite Reef Dam, a distance of approximately 37 miles (Figure 5-1).

Physiography

The Lower Salt River study area is located entirely within Maricopa County, although the Salt River watershed drains about 15,000 square miles of central and eastern Arizona (Figure 5-2). The watershed ranges in elevation from 12,643 feet at Humphrey's Peak north of Flagstaff (11,590 ft. at Mt. Baldy near Greer) to 930 feet at the Salt-Gila confluence. The upper Salt River watershed is bounded by the Mogollon Rim to the north, the Mazatzal Mountains to the west, the Superstition Mountains and the Gila River watershed to the south, and the White Mountains to the east. The Verde River portion of the upper watershed is bounded by the Mogollon Rim and San Francisco Peaks to the north, the Juniper, Bradshaw, and New River Mountains to the west, and the Mazatzal Mountains to the east. Major perennial tributaries to the upper watershed include the White, Black, and Verde Rivers, and Tonto Creek.

Within the study reach, the Salt River is formed almost entirely in alluvial fill eroded from the surrounding mountain ranges. The study area extends from a gap between the Goldfield and McDowell Mountains, through the southern extension of the Phoenix Mountains at Tempe Butte, to Monument Hill, the northernmost extension of the Sierra Estrella at the Gila River confluence.

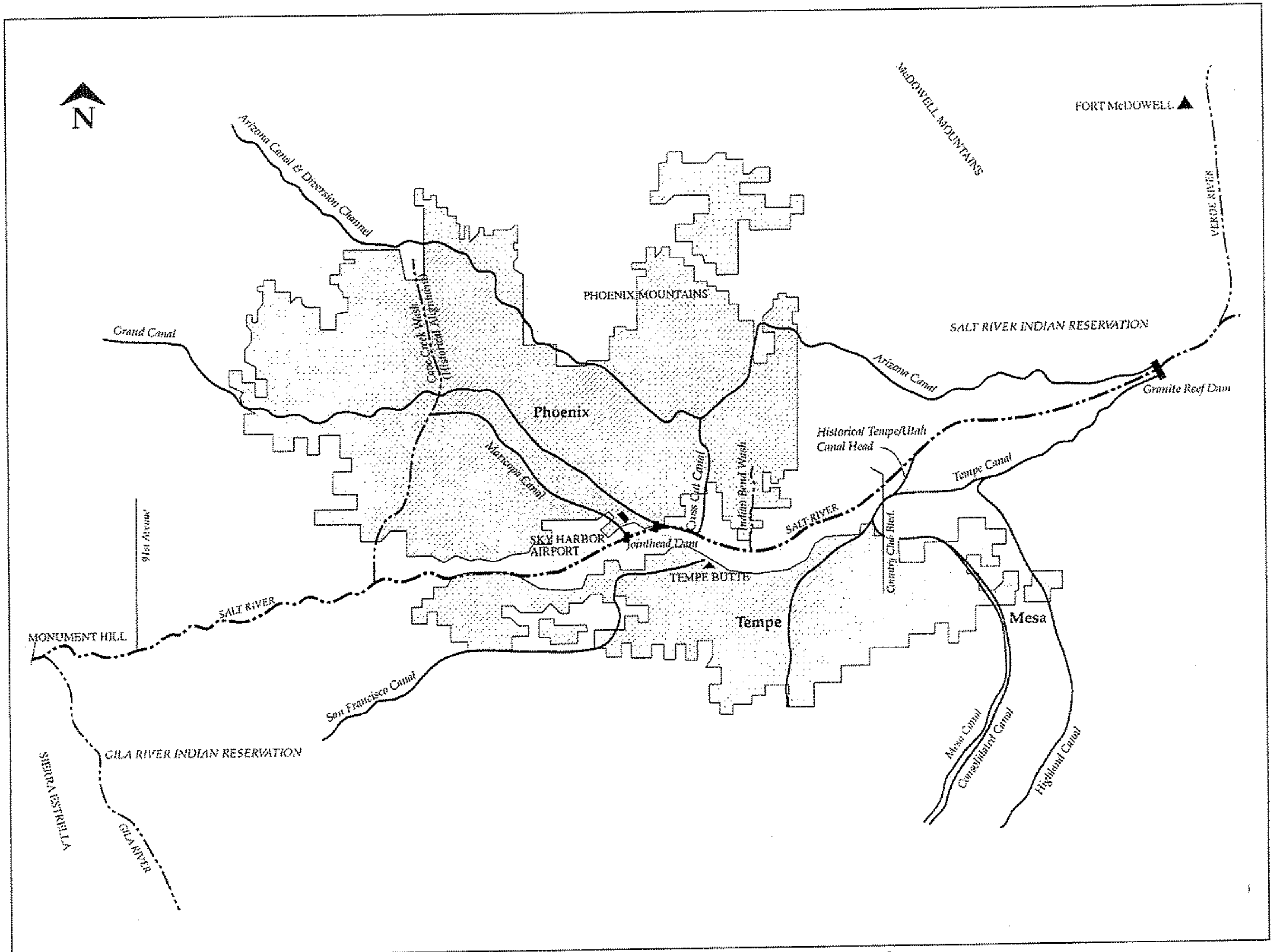

Figure 5-1. Salt River Geologic Site Map for Study Reach

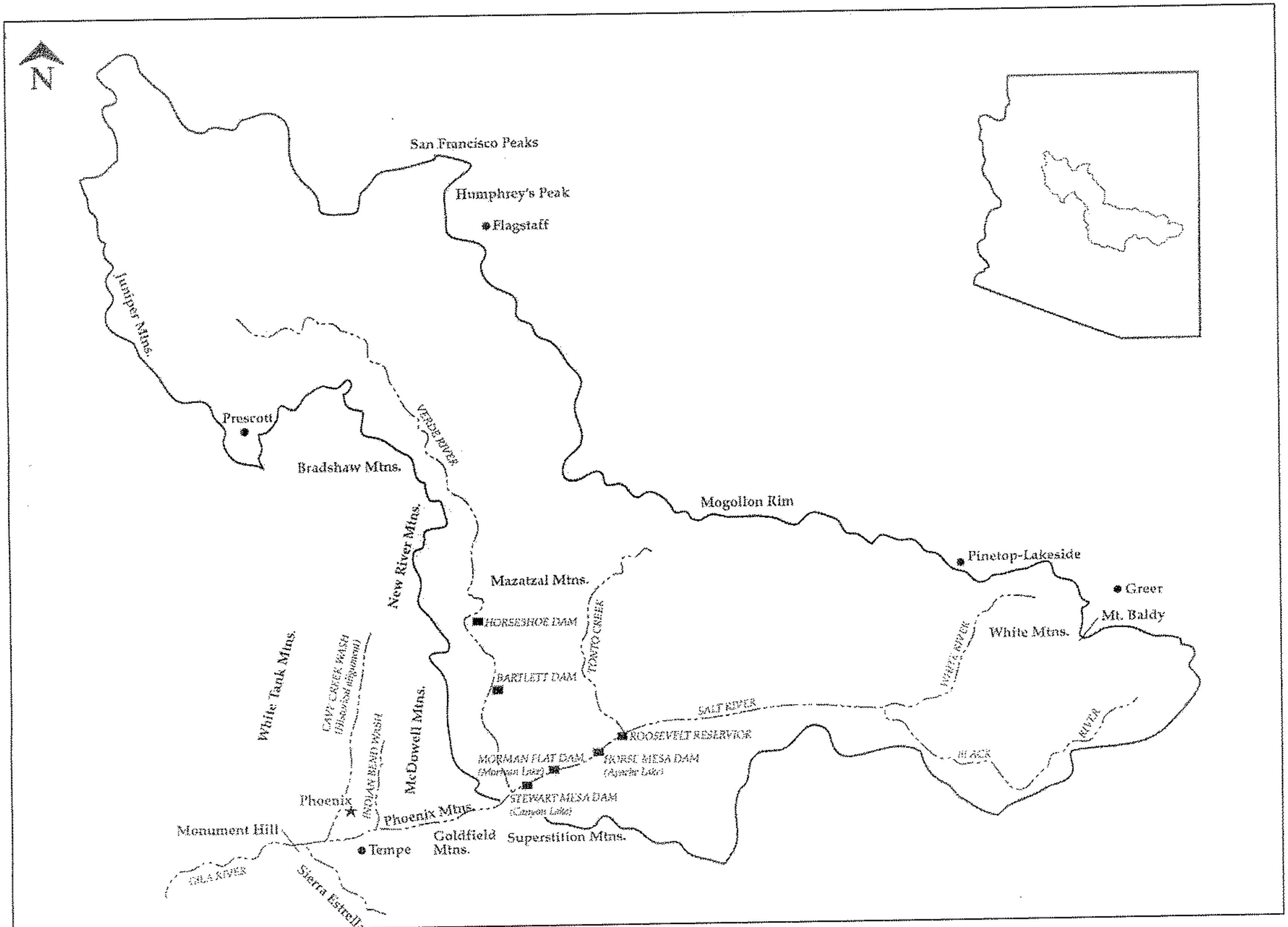

Figure 5-2. Salt River Geologic Site Map for Region

The maximum elevation within the study reach is about 1,290 feet at Granite Reef Dam. Within the study reach, only two sizable watercourses, both ephemeral, joined the Salt River: Indian Bend Wash and Cave Creek. Today, most of the runoff from Cave Creek is now diverted to the New River via the Arizona Canal Diversion Channel (ACDC) and discharges to the Gila River downstream of the study reach.

The study area experiences a hot, dry climate typical of the lower Sonoran Desert. Mean precipitation and temperature does not vary significantly within the study limits, although within the watershed, climate varies with elevation (Table 5-1). Precipitation occurs during two major seasons: in late summer as intense, localize orographic thunderstorms; and in winter as large-scale cyclonic storms which originate over the Pacific Ocean (Sellers and Hill, 1974). Winter storms tend to produces the largest (peak and volume) flows on the Salt River, with over 90 percent of the largest storms occurring in winter months. Furthermore, all years with peak flows during summer months have had below average annual discharge volumes (Fuller, 1987).

Table 5-1
Climate Data for the Salt River Watershed.

Average Annual Statistic	**Buckeye 1941-1970 elev.=870 ft.**	**Granite Reef 1938-1967 elev.=1,325 ft.**	**Show Low 1933-1955 elev.=6,382 ft**	**St. Johns 1902-1957 elev.=5,725 ft.**
Precipitation (in)	7.1	8.9	18.4	11.4
Max. Temperature	87	86	65	70
Min. Temperature	52	54	36	35

Vegetation in the study area is dominated by Sonoran Desert Scrub-Lower Colorado River Subdivision communities which include grasses, low shrubs, and saguaro cacti (Graf, 1981). Since the 1940's the dominant riparian vegetation species has been tamarix, although previously the low flow channel of the river was lined by cottonwood, seepwillow, and mesquite trees (Graf, 1981; Randall, 1993). The upper watershed extends through several climatic-vegetation zones, including areas on the highest peaks above the tree line.

Historically, sources of runoff included discharge from springs and snowmelt in the upper watershed, storm water runoff, and ground water discharge. Reservoir impoundments, canal diversions, and ground water withdrawal over the past 80 years has effectively eliminated low-flow runoff within the study reach. Today, the Lower Salt River flows only in response to local storm water inflows, runoff which passes the irrigation diversions at Granite Reef Dam during periods of high flow, and effluent discharge from the 91st Avenue sewage treatment plant downstream of Phoenix.

Flow duration statistics that reflect flow conditions at statehood are unavailable for the Salt River within the study area. Stream flow diversions began decades before stream flow measurements were initiated, making interpretation of existing measurements difficult. Long-term stream flow records are available only for the reaches upstream of Granite Reef Dam. Estimates of flow in the study area are based on indirect data such as climatic reconstructions using tree-ring records (cf. Smith and Stockton, 1981), short-term records made prior to statehood (cf Davis, 1897), reconstruction of pre-development flows derived from modern gage records (cf Thomsen and Porcello, 1991), accounts of early explorers (cf Bartlett, 1854), or extrapolations based on irrigation capacity (cf Kent, 1911). Some of these flow data are summarized in Tables 5-2 and 5-3. As with other Southwestern streams, average annual flow rates are skewed due to high flood flow volumes relative to "typical" flow rates. The flow duration statistics shown in Tables 5-2 and 5-3 indicate the flow rate which is exceeded by percent of time[1].

Table 5-2
Flow Statistics, Salt River Sites Upstream of Reservoirs[a] (cfs).

Month	Salt River above Roosevelt 1914-1989	Verde nr. Tangle Creek 1946-1989
Average Annual Flow	896	559
90% Flow Rate	157	120
50% Flow Rate	343	238
10% Flow Rate	2,040	917

[a] Roosevelt and Tangle Ck. gages located upstream of Salt-Verde confluence, and do not include numerous tributaries.

Table 5-3
Some Estimates of Average Annual Flow, Salt River at Granite Reef Dam(cfs)

Average Annual Flow	50% Flow Rate	Source/Methodology
1,265	n.a.	Smith and Stockton, 1981; Tree-ring records
1,689	1,230	Thomsen and Porcello, 1991; Modern Gage Records
2,844	n.a.	Powell, 1893; Short-Term Records

The flow estimates summarized in Tables 5-2 and 5-3 were made for the Salt River at (or near) Granite Reef Dam. Natural flow rates within the lower reaches of the study area probably varied depending on ground water levels, local inflows, and evapotranspiration along the stream bed. Historical and hydrologic data indicate that the Salt River was perennial throughout the study area prior to, and during early occupation by, Anglo settlement.

[1] For example a 10% flow rate of 200 cfs indicates that a stream exceeds 200 cfs only 10% of the time; 90% of the time the flow rate is less than 200 cfs.

Geologic Setting

Arizona is comprised of two great geologic regions: the Colorado Plateau Province, and the Basin and Range Province; with a transition zone, or Central Mountain Province, dividing them (Figure 5-3). The upper Salt River drains the Central Mountain Region, and flows across the northern portion of the Basin and Range Province. The study reach is located mostly with alluvial basins of the Basin and Range Province.

The Central Mountain Region is characterized by mountains of Precambrian igneous, metamorphic rocks, capped by remnants of Quaternary and Late Tertiary volcanics. Regional uplift of the entire state, including the Central Mountains, is thought to have occurred during the Laramide Orogeny in late Cretaceous/early Tertiary time (65 Ma[2]). The mountains of the transition zone generally experienced longer periods of erosion, resulting in generally lower elevations than mountains of the two other provinces (Nations and Stump, 1981). Central Mountain Region ranges within the Salt River basin include the White, Bradshaw, Superstition, and Mazatzal Mountains. These ranges consist primarily of Precambrian metamorphic and igneous rock with some more recent volcanics.

West of the Central Mountain Region, at the upstream end of the study area, the river enters the Basin and Range Province. The Basin and Range Disturbance (8-15 Ma) was the most recent tectonic event to affect Arizona (Nations and Stump, 1981). This event consisted of tensional stress resulting in steep, normal block faulting which formed a series of northwest-southeast trending mountain blocks. Uplift of mountain blocks was accompanied by down dropping of basin areas and by filling of these intermountain basins with alluvium eroded from the mountains. Basin and Range mountains in the study area include the Phoenix, McDowell, and White Tanks Mountains, as well as the Sierra Estrella. The McDowell, White Tanks, and Sierra Estrella are metamorphic core complexes consisting of Precambrian granitic gneiss capped by Cretaceous-aged granites and crystalline rocks.

Bedrock from the Phoenix Mountains near Tempe most directly impacts the study area. This bedrock consists of Precambrian granites and metarhyolite unconformably overlain by Tertiary-aged fanglomerates and arkose units (Schulten, 1979). Portions of this bedrock rise represent the remains of a pediment surface, uplifted by movement on a normal fault located west of the Tempe Butte. The fault is considered inactive (Péwé, 1978). Bedrock is not present in the Salt River channel in the remainder of the study reach.

[2] My = 1,000,000 years; 1 Ma = 1 My before present; 1 ky = 1,000 years; 1 ka = 1 ky before present (North American Commission on Stratigraphic Nomenclature, 1983).

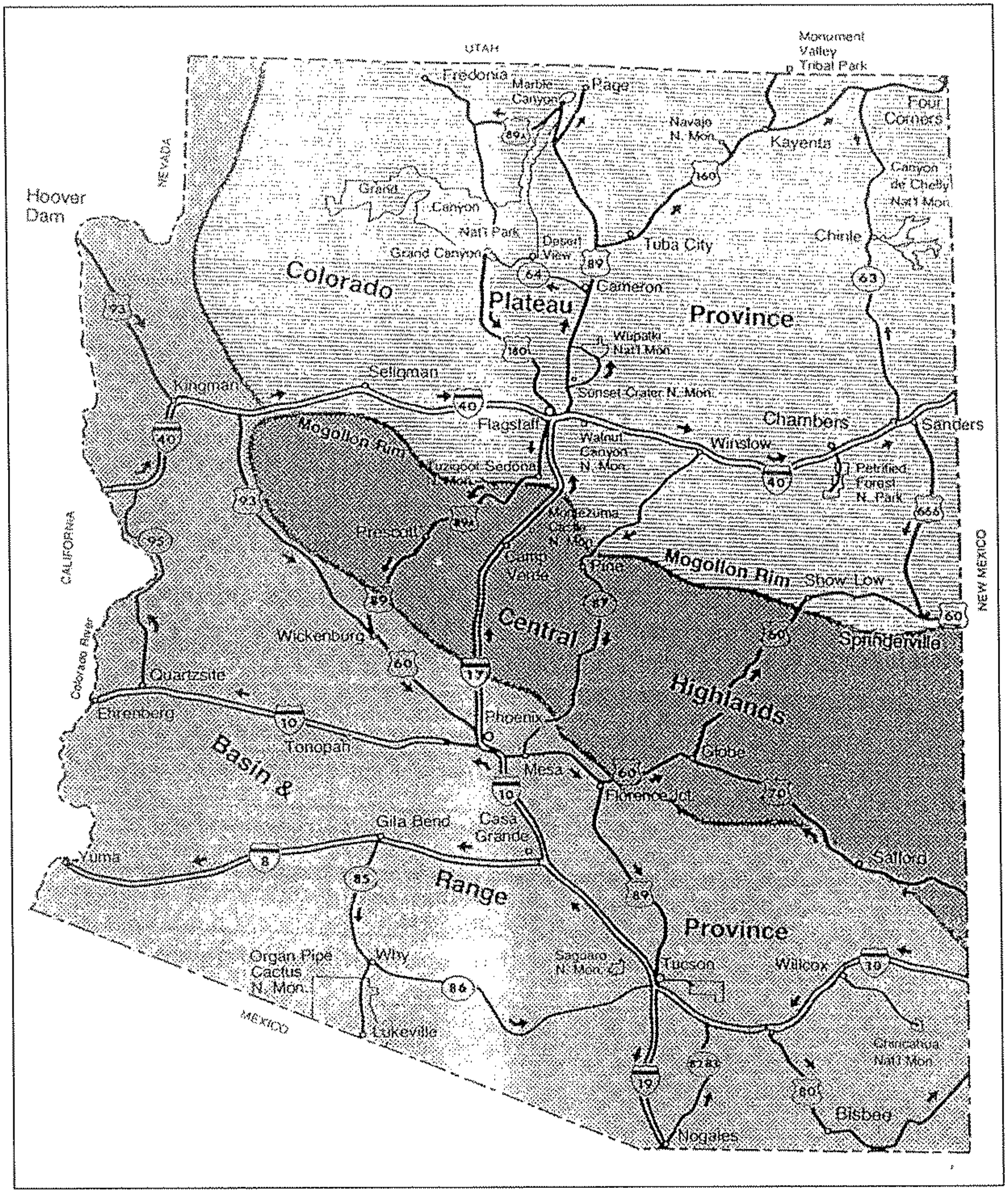

Figure 5-3. Physiographic Provinces of Arizona (from Chronic, 1983:pg. XIV).

Late Cenozoic Geology

The Phoenix Basin has experienced downdropping and slow filling for the past 2-3 Ma in response to tectonic forces (Péwé, 1978). Alluvial fill under most of the Salt River and Phoenix basin extends to great depth, in places extending well below sea level. Four sets of paired terraces have been mapped along the Salt River upstream Tempe Butte (Péwé, 1978; 1987). These terraces converge near Tempe and presumably are buried beneath valley fill downstream of Tempe. Sedimentary analysis of the material comprising the terraces indicate that the flow regime of the Salt River did not significantly vary (Kokalis, 1971) since emplacement of the terraces. Although these terraces have not been definitively dated, the upper terraces, the Mesa and Sawik Terraces, are probably early Pleistocene- or Pliocene-aged and may correlate to geologic surfaces near Arlington locally buried by basalt flows dated at 2-7 Ma. Disappearance of the terraces between Tempe Butte and the Hassayampa River confluence on the Gila River indicates that this portion of the Phoenix Basin has downdropped. In addition, these upper terraces may be absent because, at one time, the Salt River may have flowed south of Tempe Butte joining the Gila River south of South Mountain (Lee, 1905; Péwé, 1987). Regional aggradation of the Salt River over the past few million years led to relocation of the river through the bedrock gap at Tempe, rather than south to the Gila River. Lee (1905) notes the presence of lacustrine deposits along this former southerly flow path, and places them in late Tertiary time. Except for the lowest Terrace, (the Lehi Terrace) which bounds the modern floodplain, these terraces did not impact historical stream conditions in the Salt River. The Lehi Terrace forms the boundary of the modern geologic floodplain and is coincident in many places upstream of Tempe Butte with the ordinary high water mark.

Geologic Impacts on Stream flow

The bedrock geology of the region has minimal impact on stream flow conditions in the Salt River study reach. Bedrock crops out only near Tempe Butte. In the past, shallow bedrock at Tempe Butte forced groundwater to the surface, sustaining river flow in the reach immediately downstream. Even within this bedrock reach, enough alluvial material was present to support swampy conditions and a healthy riparian community during the late 1800's.

Other geologic impacts on stream flow are related to the character of alluvial fill beneath the streambed, and the elevation of the water table relative to the stream bed elevation. Upstream of Tempe Butte, the water table elevation prior to statehood was below the stream bed, and the Salt River typically lost runoff into the alluvium (cf Lee, 1905). Downstream of Tempe Butte the water table intersected the stream bed resulting in ground water discharge into the stream, particularly after extensive irrigation of the Salt River Valley had raised the water table (cf Lee, 1905; Lippincott, 1919). Currently, groundwater withdrawal and urbanization of areas formerly occupied by irrigated farms has lowered the water table in most parts of the Valley, and made the Salt River a losing stream throughout the study reach.

Channel Geomorphology

Historical and Pre-Historic River Conditions. The early explorers and residents of the Phoenix Valley record a Salt River much different than exists today, although some similarities remain. Early explorers describe a perennial stream averaging up to 200 feet wide and two to three feet deep, with abundant beaver and fish populations, and dense riparian vegetation along the stream banks(cf Pattie, 1833; Bartlett, 1852; Hodge, 1877). Early maps and photographs depict channel conditions similar to those described by early settlers. Historical and archaeological data regarding stream conditions around the time of statehood are summarized in Chapters 2 and 3 of this report.

Although detailed information are generally lacking, natural channel conditions probably included a perennial low-flow channel located within a broader low floodplain. The banks of the low flow channel were lined by riparian vegetation, while less dense vegetation or swampy areas were found in the low floodplain. Channel widths reported by early surveyors (Ingalls, 1868 cited in Graf, 1981) averaged 690 feet between Country Club Avenue and 91st Avenue. The fact that early residents were able to clear out ancient Hohokam canals for modern use (Halseth, 1947; Schroeder, 1943), indicates that these channel conditions probably persisted for several centuries prior to 1900. The channel conditions described between 1850 to 1910 most likely represent the natural (equilibrium) geomorphic condition of the Lower Salt River.

Statehood Conditions. As of the time of statehood, the geomorphology of the Salt River had been impacted by Anglo settlement, as well as by a period of severe flooding that occurred between 1890 and 1916. In addition, at least eleven canals headed in the Lower Salt River, diverting most of the low flow runoff away from the river. Roads crossed the stream at fords in at least 31 places in the study reach. Photographs and newspaper accounts indicate that the riparian areas and fish populations still existed, although beaver had been eliminated, and the low floodplain may have been less vegetated. Roosevelt Reservoir was constructed between 1905 and 1911, resulting in somewhat reduced flow rates and flooding, particularly during the period up to 1915 while the reservoir was filling. Severe floods in 1833, 1862, 1869, 1874, 1880, 1893, 1905, and the flood of record in 1891 (Fuller, 1987) undoubtedly adversely impacted channel conditions. Channel widening (bank erosion) downstream of Tempe Butte during one of these floods left one ancient Hohokam canal well above the river bottom (Schroeder, 1943; Patrick, 1903).

In 1912, the Salt River had an easily identified low flow channel, or thalweg, defined by frequent (if not perennial) flow and trees growing along the banks. The low flow channel tended to shift somewhat or dramatically within the floodplain in response to flood magnitude (Graf, 1981). The stream pattern was straight (sinuosity < 1.1) with some minor braiding of the low flow channel. The low flow channel had an average width of 360 feet, significantly narrowed from pre-settlement conditions[3]. Narrowing probably occurred in response to reduced low flow discharges brought on by irrigation diversions. Bed materials were dominantly sands and silts, with some cobble riffles (Graf, 1981). The channel and floodplain slope averaged about 0.2

[3] The 200 feet width reported by the early explorers was most likely the width of the water surface, as opposed to the width of the low flow channel discussed in this paragraph.

percent in the reach. The high flow channel that occupied the low floodplain of the Salt River was relatively straight and stable, in places vegetated by brush and grass.

Existing Conditions. In its current condition, the Salt River is an ephemeral stream whose natural geomorphology is nearly obscured by urbanization. Channel bed degradation which occurred during floods since the 1970's has lowered the bed by more than 20 feet in places. Channel lowering (degradation) has caused the stream bed to armor itself with cobbles and boulders, with the finer sand and silt channel sediment material washed away by floods. Much of the reach has been channelized. Modern development in the historical geologic floodplain includes 17 bridge crossings, soil cement and rip-rap bank stabilization, landfills, sand and gravel mining, agricultural areas, Tempe Town Lake, the Rio Salado restoration area, the Tres Rios artificial wetlands demonstration project, portions of Phoenix Sky Harbor Airport, and other commercial and industrial development. Development impacts on Salt River stream flow include construction of five major reservoirs that harvest runoff upstream of the study area, diversion of the entire natural low flow into an extensive canal system, and lowering of water tables adjacent to the river bed. Other changes in the geomorphology of the Lower Salt River since the time of statehood include straightening of the low flow and floodplain channel, loss of riparian habitat, slight increase in channel slope, reduction of sediment supply, and discharge of treated sewage effluent.

Ordinary High Water Mark

The concept of the ordinary high water mark is not rigorously defined. In practice, the ordinary high water mark is identified by a marked change in vegetation or soil characteristics from the channel bottom characteristics. Occasionally, this change is accompanied by a break in slope from the flat bottom channel or shallow floodplain to a steep or vertical bank caused by the erosive action of flowing water on the bank. At one time, certain review agencies recommended using the limits of the 20-year flood to map the ordinary high water mark. The 20-year floodplain limit is generally not used in Arizona at the present time, and was not used for this study.

For the stream navigability studies, A.R.S. 37:1101 defines the ordinary high water mark as:

> Ordinary high watermark" means the line on the banks of a watercourse established by 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 or the presence of litter and debris, or by other appropriate means that consider the characteristics of the surrounding areas. Ordinary high watermark does not mean the line reached by unusual floods.

For the Salt River, historical changes to the river in the study reach and gaps in the database for the river preclude use of the identifying characteristics defined in the State statutes to accurately delineate the ordinary high water mark for the river as of the time of statehood. Therefore, an alternative approach based on interpretation of historical topographic maps (USRS, 1907) and work by Graf (1981) were used to identify and delineate the ordinary high water mark for the study reach as of the time of statehood. The following guidelines were used in delineating the circa 1912 ordinary high water mark.

- Work by Graf (1981) indicates that the low flow channel of the Salt River has migrated over the past 130 years. Current practice by the U.S. Army Corps of Engineers (Corps), the federal agency primarily responsible for delineating the ordinary high water mark, is that the ordinary high water mark moves with the river. Therefore, the ordinary high water mark for conditions as of the time of statehood should be delineated on maps drawn close to date of statehood.

- On wide braided stream systems, the Corps typically delineates the outer limit of the widest channel braid as the ordinary high water mark. Sand and gravel bars inundated by annual floods typically are considered as located within the ordinary high water mark.

- Insufficient hydrologic data are available for the time of statehood from which to define the magnitude of the annual flood. However, according to information presented elsewhere in this report, annual flooding rates probably exceeded 20,000 cfs (cf Powell, 1893; Table 7-16, this report) prior to completion of the reservoir system on the Salt and Verde Rivers.

- Man-made structures can sometimes be used to identify topographic features that may be analogous to ordinary high water mark locations. For example, canals and roads typically follow slight topographic rises along the floodplain margin to maintain a constant grade and avoid frequent flood inundation.

Maps of the ordinary high water mark as of the time of statehood are attached, and have been entered in the GIS database (See Appendix G). In general, the ordinary high water line for statehood conditions follows the boundary of the stippled zone along the channel on the 1907 topographic map (USRS, 1907). Stippling is a map symbol generally used to identify a stream bed.

The ordinary high water mark for the existing channel was delineated based on interpretation of 1991 aerial photographs and field data. Maps of the existing ordinary high water marks were distributed by ASLD at a series of public meetings held in December 1993. In general, the existing (1993) ordinary high water marks followed the limits of the active channel and floodplain as defined by natural and man-made features. Man made features included flood control structures such as engineered bank protection, bridge abutments, sand and gravel operations, and other protected encroachments into the floodplain. Natural features used to delineate the existing ordinary high water mark included vegetation, surficial soil characteristics, and topography.

Ordinary Low Water Mark

HB 2589 limited the state's claim to navigable watercourses to the land between the ordinary low water mark. The current legislation, SB 1275, does not reference the ordinary low water mark. The ordinary low water mark was defined in HB 2589 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.

In practice, the ordinary low water mark may be difficult to identify on Arizona rivers, but is generally identified in conjunction with delineation of the high water mark, or is defined on the basis of site-specific or hydrologic characteristics. Unlike high water marks, low water marks are more ephemeral and may be erased by subsequent high flows. Case histories for application of a low water mark standard in Arizona are lacking.

Delineation of the ordinary low water mark was not within the scope of the original investigation for the Lower Salt River. However, the following general statements can be made in regard to delineation of the ordinary low water mark for the Lower Salt River:

- For existing conditions, most of the study reach is normally dry. Therefore, when dry, the ordinary low water mark definition cannot be applied. Stated another way, there is no land area between the ordinary low water mark for the portions of the study reach that are normally dry.
- For existing conditions, the reach downstream of 91st Avenue to the Gila River confluence is perennial (or nearly so) due to discharge of treated sewage effluent. The ordinary low water mark in this reach could readily be delineated using the normal water surface boundary.
- For conditions as of the time of statehood, portions of the riverbed reportedly dried up during certain seasons. However, several reaches may have retained perennial flow (See Chapter 7) due to discharge of springs and irrigation return flows, release of appropriated waters to downstream diversions, and shallow bedrock that forced ground water to the surface. Additional investigations may be required to identify the limits of ordinary low water at statehood for these reaches.

Regardless of whether the ordinary low water mark were delineated for existing (1996) conditions or for conditions as of the time of statehood (1912), it is likely that portions of the Lower Salt River were not dry in their ordinary and natural condition, as defined by HB 2589. These reaches would require additional study and data collection to identify the ordinary low water mark.

Summary

Review of the geology of the Salt River indicates that the channel geomorphology is substantially changed from its condition at or before statehood. At statehood, the stream was formed in deep alluvial deposits which allowed the main stream to shift within a more stable low floodplain. The stream bed was composed of sandy silty material, which together with perennial flow supported healthy riparian vegetative communities along the banks. Prior to the changes brought on by urbanization and 19th century flooding, the Salt River probably existed in its relatively stable pre-statehood conditions for several centuries. Today, the Salt River's geomorphology reflects changes such as channelization, bed armoring, and bed degradation brought on by urbanization of the Salt River Valley, and upstream impoundment and diversion of stream flow, as well as effluent discharge to the stream. The ordinary high watermark for the Lower Salt

River as of the time of statehood was delineated using historical maps and geomorphic interpretation of landform boundaries, and is significantly different than the location of the ordinary high watermark for current stream conditions.

Chapter 6

Salt River Land Use

Introduction

This chapter summarizes land uses along the Salt River study reach between Granite Reef Dam and the Gila River Confluence, as they relate to the ASLD Stream Navigability Study. Specific data collected for this study included:

- Land Ownership
- Land Leases
- Existing Uses
- Existing Improvements
- Wildlife and Recreation Classifications

Land use data were collected by the CH2M HILL/SWCA team for the original Lower Salt River Navigability Study and have not been updated since that report was completed in 1993. Land use data should be updated and verified pending a determination by ANSAC for the Lower Salt River.

Data Sources

The primary data source for Salt River land ownership, land use, and improvements was a Geographical Information System (GIS) developed and maintained by the Flood Control District of Maricopa County (FCDMC).[1, 2] In addition, leasing data was collected from ASLD (mining and other uses), BLM (agriculture and mining), and the U.S. Forest Service (grazing). Wildlife, riparian, and recreational classifications were obtained from Arizona State Parks and the U.S. Fish and Wildlife Service.

Methodology

The primary work product for the land use assessment is a GIS for the Salt River study reach. Geographical Information Systems combine the spatial characteristics of digital mapping with the resource information library capabilities of a database. Through a GIS, information such as land

[1] FCDMC was revising and updating the Salt River GIS at the time the draft report was prepared (1993), but had not yet made the revised GIS public. Information presented in this chapter is based on the unrevised GIS provided by the FCDMC at the time of the original report in 1993.

[2] The existing FCDMC GIS does not include information for a short reach between Granite Reef Dam and Country Club Drive. The north half of this reach is within the Salt River Pima Maricopa Indian Community, title for the south half is currently held by various public and private parties.

ownership (title), biological and hydrologic characteristics, land use, or other descriptive information can be tied to specific parcels or river reaches. The Salt River GIS developed for this study was adapted from the existing FCDMC GIS. Technical details regarding creation of the GIS are summarized in Appendix G. The remainder of this chapter summarizes information represented graphically in the GIS.

Land ownership information for the Salt River GIS was received from the FCDMC as ArcInfo export files and was converted into a GIS coverage, after removing parcel polygons for Gila River areas. Land use information was also obtained from the FCDMC. Land use codes in the GIS are based on standard State of Arizona property used codes, and were recorded and entered with ownership information using a dBASE conversion program. The standard table, developed in conjunction with ASLD staff is provided in Appendix G. No riparian information was available for the reach from Arizona Game and Fish or other agencies contacted.

Plots of GIS information for the Salt River are also included in Appendix G. The Salt River GIS plots included in Appendix G include:

- Land Ownership
- Ordinary High Water Mark
- Land Use

Land Use and Ownership

Land ownership, or current title, information was obtained from the FCDMC GIS, as was land use data. A summary of Salt River land ownership and use information based on this GIS data are shown in Tables 6-1 and 6-2. The largest percentage of land in the reach is privately held. Uses include vacant land, industrial use, public easements and right of way, commercial, agricultural, and residential. According to data available from public agencies, none of the reach is protected or designated for wildlife, riparian, or natural uses. Two Indian communities also claim portions of the reach.

Table 6-1
Salt River Land Ownership.

Owner	Acres
Private	6,012
Unknown	4,610
State	720
Gila River Indian Community	119
Bureau of Land Management	96

Table 6-2
Salt River Land Use.

Land Use	Acres
Unclassified	4,731
Misc. Undeveloped	2,341
Misc. Industrial	1,426
Municipal/County	1,212
Agricultural	673
Misc. Commercial	508
Mineral/Mining	307
Residential	188
Misc. Developed	84
Parks/Recreation/Drainage	57
Retail/Wholesale/Warehouse	30

Chapter 7
Salt River Hydrology

Introduction

The hydrology of the Salt River between Granite Reef Dam and the Gila River has been significantly altered since the mid 1800's. Therefore, the ordinary and natural hydrologic condition of the Salt River depends on which human impacts to the river are considered non-natural. HB 2589 mandated that the affects of "dams, diversions, and other human uses that existed...at the time of statehood" were part of the ordinary and natural condition of the watercourse. SB 1275, the current governing legislation lacks such a provision. To address hydrologic conditions in whatever river condition is considered "ordinary and natural," this chapter summarizes information describing the hydrology of the Salt River for three conditions:

- **Pre-Settlement**. Flow conditions prior to Anglo settlement in the area.
- **Statehood.** Flow conditions in 1912, considering human impacts on flow.
- **Existing.** Current flow conditions along the urbanized Salt River.

For stream conditions during each of these time periods, estimates of monthly and annual flow rates, anecdotal information regarding the appearance and character of the stream, and flood data will be summarized. Hydraulic rating curves relating discharge to stream depth, width, and velocity will also be presented.

Stream Reaches

The Lower Salt River study reach extends from the confluence of the Salt and Gila Rivers to Granite Reef Dam, a distance of approximately 37 miles (Figure 7-1). For the purposes of hydrology, the Salt River was considered as a single stream reach. Although a natural dividing point exists at Tempe Butte, the river is an alluvial stream throughout, with similar geomorphic, hydrologic, and hydraulic characteristics, at least during prehistoric times. At the time of statehood, canal diversions had affected the flow of the river sufficiently to justify consideration of subreaches between the major canal heads at Granite Reef Dam, the Tempe Canal, and Jointhead Dam. However, beginning in late 1912, canal diversions were primarily located at Granite Reef Dam, at the upstream end of the study reach.

Data Sources

There are few stream gauge records for stations within the study reach for the period before or around statehood. Therefore, some discharge information for the Lower Salt River was obtained from USGS stream gauge records located upstream of the study reach (cf USGS, 1902ff; 1991), miscellaneous engineering reports (cf Hancock, 1912), canal diversion records (cf Kent, 1910), Flood Insurance Studies (FEMA, 1991), and other reports describing the hydrology of the Salt River. Key data sources are referenced in the bibliography.

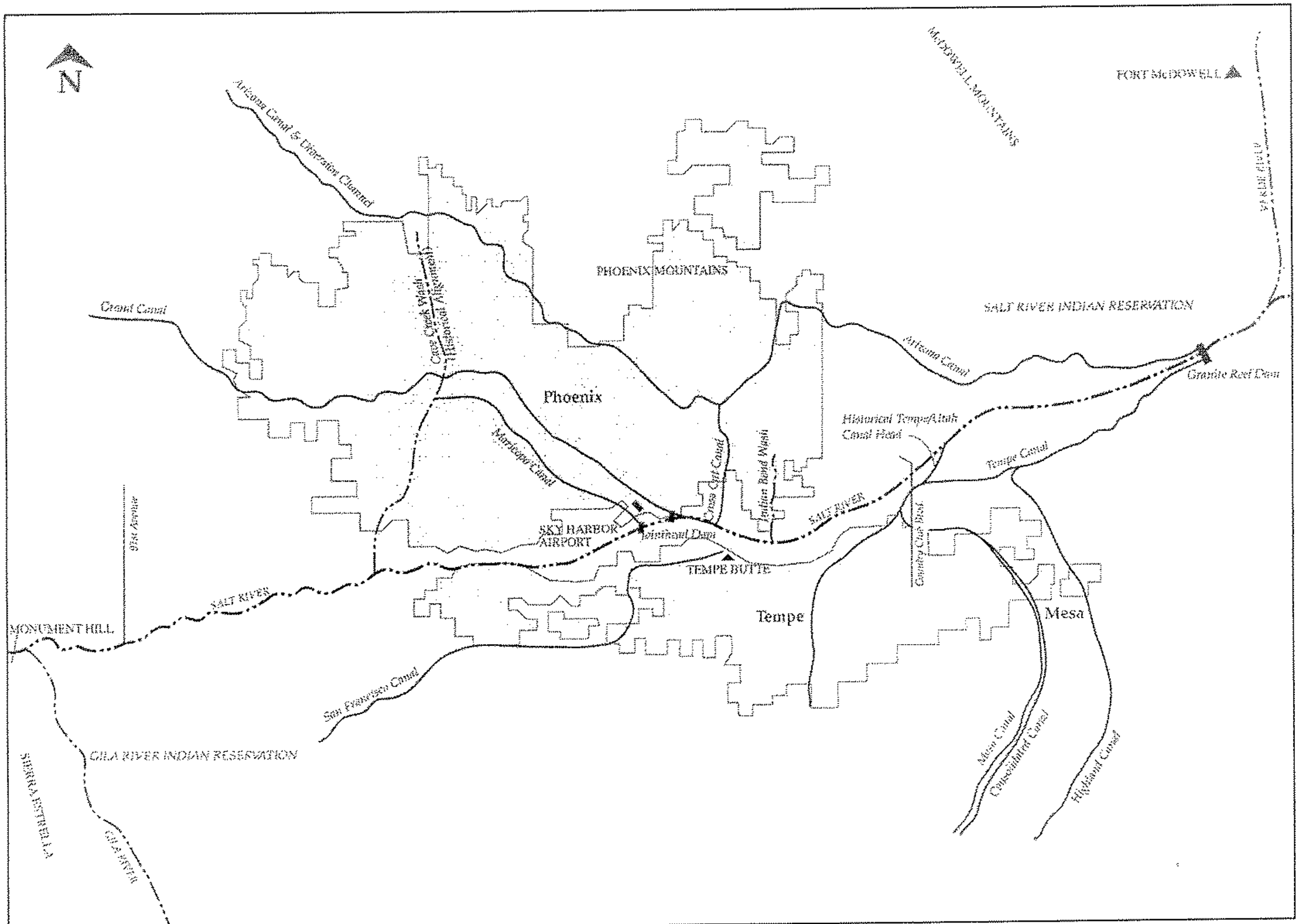

Figure 7-1. Salt River Hydrologic Site Map for Study Reach

Hydrologic Setting

The Lower Salt River study area is located entirely within Maricopa County, although the Salt River watershed drains about 15,000 square miles of central and eastern Arizona (Figure 7-2). The watershed ranges in elevation about 12,600 feet at Humphrey's Peak north of Flagstaff (11,590 ft. at Mt. Baldy near Greer) to about 930 feet at the Salt-Gila confluence. The upper Salt River watershed is bounded by the Mogollon Rim to the north, the Mazatzal Mountains to the west, the Superstition Mountains and the Gila River watershed to the south, and the White Mountains to the east. The Verde River portion of the upper watershed is bounded by the Mogollon Rim and San Francisco Peaks to the north, the Juniper, Bradshaw, and New River Mountains to the west, and the Mazatzal Mountains to the east. Major perennial tributaries to the upper watershed above the study reach include the White, Black, and Verde Rivers, and Tonto Creek.

Within the study reach, the Salt River is formed almost entirely in alluvial fill eroded from the surrounding mountain ranges. The study area extends from a gap between the Usery and McDowell Mountains, through the southern extension of the Phoenix Mountains at Tempe Butte, to Monument Hill, the northernmost extension of the Sierra Estrella at the Gila River confluence. The maximum elevation within the study reach is about 1,290 feet at Granite Reef Dam. Historically only two sizable drainages, both ephemeral, joined the Salt River downstream of Granite Reef Dam: Indian Bend Wash and Cave Creek. Most of the runoff from Cave Creek is currently diverted to the New River via the Arizona Canal Diversion Channel (ACDC), and eventually flows into the Gila River downstream of the study reach. The portion of Cave Creek downstream of the ACDC has been effectively obliterated by urbanization. Flows from Indian Bend Wash are both retained in and supplemented by structures and parks with the Indian Bend Wash multiple use flood control corridor.

The study area has a hot, dry climate typical of the lower Sonoran Desert. Mean precipitation and temperature do not vary significantly within the study limits, although within the watershed, climate varies with elevation (Table 7-1). Precipitation occurs during two major seasons (Table 7-2): in late summer as intense, localized orographic thunderstorms; and in winter as large-scale cyclonic storms which originate over the Pacific Ocean (Sellers and Hill, 1974). Winter storms tend to produces the largest (peak and volume) flows on the Salt River, with over 90 percent of the largest storms occurring in winter months. Furthermore, all years with peak flows during summer months have had below average annual discharge volumes (Fuller, 1987).

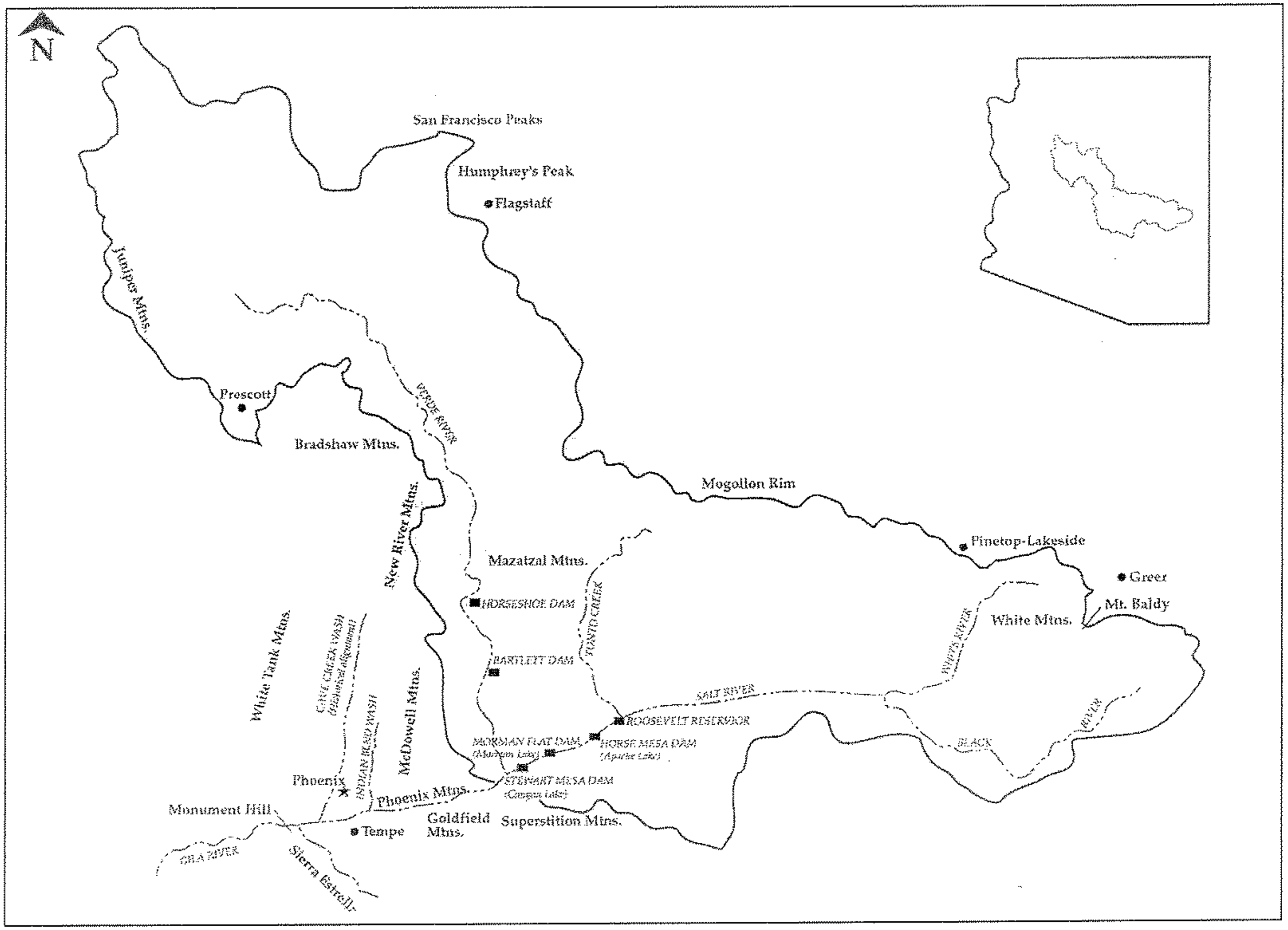

Figure 7-2. Salt River Watershed Map

Table 7-1 Climate Data for Salt River Watershed Stations at Varying Elevations				
Average Annual Statistic	**Buckeye 1941-1970 elev.=870 ft.**	**Granite Reef 1938-1967 elev.=1,325 ft.**	**Show Low 1933-1955 elev.=6,382 ft**	**St. Johns 1902-1957 elev.=5,725 ft.**
Precipitation (in)	7.1	8.9	18.4	11.4
Max. Temperature	87	86	65	70
Min. Temperature	52	54	36	35

Table 7-2 Seasonal Climate Variation in the Salt River Watershed Precipitation (Inches) and Temperature (°F)				
Month	**Buckeye 1941-1970 elev.=870 ft.**	**Granite Reef 1938-1967 elev.=1,325 ft.**	**Show Low 1933-1955 elev.=6,382 ft.**	**St. Johns 1902-1957 elev.=5,725 ft.**
January	0.7	1.0	1.3	0.7*
February	0.7	0.8	1.4	0.7*
March	0.7	0.9	1.6	0.8*
April	0.3	0.4	0.6	0.5*
May	0.1	0.1	0.7	0.5*
June	0.1	0.1	0.4	0.6
July	0.8	0.8	2.5	2.1
August	1.3	1.5	2.5	2.1
September	0.7	0.8	1.6	1.3*
October	0.4	0.5	1.7	1.0*
November	0.5	.7	1.4	0.4*
December	0.8	1.3	2.3	0.7*
Annual	7.1	8.9	18.1	11.4
* indicates precipitation may occur as snow				
Aver. Max & Min Temperature	87 52	86 54	65 35	70 35

The study area is dominated by Sonoran Desert Scrub-Lower Colorado River Plant communities, which include grasses, low shrubs, and saguaro cacti (Graf, 1981). Since the 1940's the dominant riparian vegetation species is tamarix, although the low flow channel of the river was once lined by cottonwood, seepwillow, and mesquite trees (Graf, 1981; Davis, 1982; Randall, 1993). The upper watershed extends through several climatic-vegetation zones, including areas above the tree line on the highest peaks.

Historically, sources of runoff included discharge from springs, snowmelt in the upper watershed, storm water runoff, and ground water discharge. Reservoir impoundments, canal diversions, and ground water withdrawal over the past 50 years have effectively eliminated most low-flow runoff within the study area. Existing flows include only storm water inflows, runoff which exceeds upstream reservoir storage capacity and Granite Reef diversion requirements, and effluent discharge from wastewater treatment plants. Sustained flows through the entire study reach still occur during periods of above average runoff when reservoirs fill to capacity.

Pre-Statehood Hydrology

There are four primary sources of information on the hydrology of the Salt River prior to its alteration by Anglo settlers. These include direct measurements, reconstruction of flow from upstream gauge records, reconstruction of flow by indirect methods such as tree ring data, and historical and anecdotal accounts of flow. Pre-statehood hydrologic records are most indicative of the natural flow conditions of the Salt River prior to human impacts on the river.

Direct measurement. Direct measurement includes gauging of river flow at controlled or measured stream sections. The Lower Salt River was not systematically gauged within the study reach for any duration of time prior to statehood. The river was gauged immediately upstream of the study reach at three stations between 1885 and 1912 (Table 7-3). The Salt River and Verde River near McDowell gauges were located just upstream of the Salt-Verde confluence. Prior to its current location, the Salt River at Granite Reef Dam station was located downstream of the Salt-Verde confluence at Arizona Dam until that dam's failure in 1905. None of these stations recorded sufficiently complete data for a statistically significant period of time to generate average flow statistics. However, the gauge records do indicate that flow was perennial at the upstream limit of the study area, with the minimum annual recorded flow during the time period as about 658 cfs in 1899.[1]

Referring to the Salt River near Phoenix, the annual summary of stream flow measurements for 1899 (USGS, 1900: 321) states that "during ordinary seasons all of the water of Salt River is diverted, and at the present time there is a shortage in the summer months." The 1899 Annual Summary also records instantaneous measurements made from June 12-15, 1899 in the main channel of the Salt River and at each canal head between the Salt River-McDowell station and the Gila River confluence, as summarized in Table 7-4. The data shown in Table 7-4 substantiate

[1] Combined flow of Salt and Verde Rivers from McDowell gauge records.

anecdotal and other evidence that portions of the Salt River were dry as early as 1899, at least during certain seasons. The month of June is typically one of the months of lowest average monthly flow. It is likely that similar flow measurements that document flow conditions for the Lower Salt River and its canals were made by canal companies, the Salt River Valley Water Users Association, or other parties. However, if such measurements exist, they were not made available during the course of this study.

Table 7-3
Salt River Pre-Statehood Gauges

Gauge Name	Period of Record	Minimum Average Monthly Flow (cfs)	Minimum Average Annual Flow (cfs)
Salt River nr. McDowell	1895 - 1911	64 (June, 1904)	342 (1904)
Verde River nr. McDowell	1888 - 1932	52 (June, 1892)	175 (1900)
Salt River @ Arizona Dam	1888 - 1896	331 (October, 1889)	2,656 (1889)

Notes: Gauges were not operated continuously for entire period listed; Sites were moved.

Other less systematic stream flow measurements were also taken during the period prior to statehood. Powell (1892) estimated the annual low flow of Salt River (below the Verde River confluence, above Arizona Dam) at 800-900 cfs, though he revised his low flow estimate (1893) to an average minimum flow of 500 cfs. He reports an instantaneous low discharge of 417 in August, 1889, and a high variable mean monthly discharge ranging from 940 cfs to 9400 cfs. Davis (1897), however, reports that the minimum instantaneous discharge between August 1888 and February 1891 (above Arizona Dam) was 300 cfs, and that the average monthly flow was 3,074 cfs.

Davis and Powell were likely reporting flow conditions near the Salt-Verde confluence. Within the study reach, irrigation diversion began to reduce low flows as early as the 1870's. Lee (1905, as cited in Lacy et al, 1987) reports a discharge at Jointhead Dam of 35 cfs, with a "normally dry" streambed upstream and downstream of the Tempe Butte reach. Lacy (1987) reports a "normal" flow of 60 cfs at Jointhead Dam. Further, downstream irrigation return flow and ground water discharge cause stream flow to resume west of Phoenix (Lee, 1905; Kent, 1910). This renewed flow ranged from about 15 cfs near where flow emerged to about 138 to 150 cfs near the Gila River confluence (Lacy et al, 1987; Lee, 1905).

Flow Reconstruction From Gauge Records. Several investigators have attempted to reconstruct average flow conditions in the Salt River study reach using stream gauge records from stations located upstream of the Salt-Verde confluence (Table 7-5). Thomsen and Porcello (1991) determined an average annual flow rate of 1690 cfs, with a median discharge (50% rate on the flow duration curve) of 1230 cfs.[2] The Salt River Valley Water Users Association (1957) used

[2] If upstream gauge records are extended with tree-ring data estimates: Average annual = 1730 cfs; Median flow = 1310 cfs (Thomsen and Porcello, 1991).

gauge records from 1889 to 1953 to estimate a mean annual discharge of 1773 cfs. Consideration of only the period from 1889 to 1912 would yield a mean annual discharge of 1,876 cfs, with a range from 402 to 7,183 cfs. Daily flow measurements taken at the Verde River near McDowell gauge between 1904 and 1924 indicate that the "expected daily flow" for that period was 968 cfs (Atshul, 1987). In no case was the natural minimum monthly or annual flow rate zero.

Table 7-4
Discharge Measurements in the Salt River and Canals Near Phoenix in June 1899 (USGS, 1900:322)

Date	Watercourse	Description	Discharge (cfs)
June 12	Salt River	@ McDowell	197
June 12	Verde River	@ McDowell	140
June 13	Arizona Canal	Below waste station	185
June 13	Arizona Waste	At river	88
June 13	Salt River	Opposite Arizona waste gate	18.7
June 13	Highland Canal	Opposite Arizona wast gate	31.7
June 13	Mesa Consolidated Canal	Below waste gate	67.7
June 13	Small Flume	Mesa waste gate	1.8
June 13	Mesa Consolidated Waste	Near gate	15.3
June 13	Salt River	Mesa Consolidated waste gate	5.8
June 13	Tempe Canal	Ford near head	70.6
June 13	Salt River	Opposite Tempe Canal head	0.0
June 13	Salt River	Railroad bridge	59.8
June 15	Salt River	South of Phoenix	0.0
June 15	St. Johns Canal	At head	7.8
June 15	Salt River	Below head of St. Johns canal	23.9
June 15	Buckeye Canal	At head	102.3

Table 7-5 Salt River at Granite Reef Dam Flow Statistics Derived from Upstream Gauge Records		
Reference	**Average Annual Flow**	**Median Flow**
Thomsen and Porcello (1991)	1,690	1,230
Salt River Water Users (1957)	1,773	n.a.
Smith and Stockton (1981)	1,265	n.a.
Note: 1,265 cfs is sum of Stockton and Smith's estimates for Salt and Verde. Does not include drainage area between Verde above Tangle Creek and Salt River above Roosevelt.		

Indirect Estimates. Indirect estimates of the natural, pre-development flow conditions in the Lower Salt River have been made from long-term tree-ring[3] chronologies from the upper Salt and Verde River watersheds (Smith and Stockton, 1981; Fritts, 1980), from measurements of pre-statehood channel widths, and from canal diversion records. Tree ring records dating to 780 A.D. (Graybill, 1989) indicate that the average annual flow rate derived from the modern (1900-present) gauge record is slightly above the long-term mean annual flow rate based on tree ring studies. Tree ring records from 1580 to 1989 were used to estimate average annual flows of 796 and 469 cfs for the Salt and Verde Rivers, respectively (Table 7-5). Modern stream gauge records indicate average annual flow rates of 896 and 559 cfs (USGS, 1991; Table 7-13) at these stations. Therefore, USGS gauge records for upstream stations are an acceptable source of stream flow data for at least the upstream end of the study reach, not considering the affects of man-made alterations of the channel.

Comparison of gauge records from 1895 and 1905 (prior to work on Roosevelt Dam) at the Salt River Roosevelt gauge (site of long-term records) and the Salt River McDowell gauge (site nearest study area, located just above the Verde confluence) reveal similar flow rates. Use of stream flow data from the Salt River near Roosevelt station would tend to *underestimate* the natural flow rate into the reach (Table 7-6).

Table 7-6 Comparison of February Stream flow Records on Salt River, 1895-1905	
Salt River @ McDowell	**Salt River @ Roosevelt**
1,801 cfs	1,390 cfs

[3] Tree ring studies assume the thickness of the individual annual rings are related to discharge. Wet year (high average annual flow) give rise to thicker rings. Individual tree rings can be readily matched to specific years. Smith and Stockton's data was calibrated using recent gauge data and recent tree ring records.

The Kent Decree (1910) documents irrigation diversions from the Salt River within the study reach for the period from 1896 to 1909. By 1896 the major canal diversions had been constructed. No significant changes in diversion techniques or rates occurred between 1909 and February 1912. Therefore, these irrigation records can be used to help estimate irrigation withdrawals from the Salt River for both the period prior to and surrounding statehood. Since diversion rates were tied to water rights it is unlikely that significant changes occurred between the date of the Kent Decree in 1910 and the date of statehood in 1912. From the irrigation diversion rates reported in the Kent Decree, and from stream flow data summarized in Table 7-5, average flow rates in the study reach can be estimated, as shown in Table 7-7. However, note that the data summarized in Table 7-7 may not include diversions through canal heads for purposes other than irrigation (e.g., domestic or municipal water supply).

Table 7-7
Estimated Pre-Statehood Salt River Average Flow Rate
Accounting for Appropriated Irrigation Diversions

Reach	Average Flow Rate (cfs)	Minimum Flow Rate (cfs)
Average Inflow @ Granite Reef	1,576	398
Granite Reef Dam to Tempe Canal	1,146	147
Tempe Canal to Jointhead Dam	981	55
Jointhead Dam to Gila River	893	0

Note: Minimum inflow from 1895-1909; flow less than appropriation are proportioned after Kent Decree. Does not include irrigation return flow or groundwater discharge into stream. Based on information in the Kent Decree.

The names and construction dates of key irrigation canals in the study reach are shown in Table 7-8. These canals head in three general locations: at Granite Reef Dam, at the Tempe/Utah Canal head, and at Jointhead Dam downstream of Tempe Butte. Other smaller ditches also diverted flow from the Salt River, and are shown in Figure 7-1. After 1912, the canal heads were moved to Granite Reef Dam and the canals were fed by means of cross cut canals from the Consolidated or Grand Canals.

Irrigation diversions apparently removed all of the flow from the Lower Salt River during some months in the period leading up to statehood. However, comparison of irrigation data in Table 7-7 and average monthly and annual flow rates in Tables 7-5 and 7-14 indicates that there were probably many months of continuous flow, particularly since ferrying operations persisted until as late as 1909.

Graf (1981) used early section line survey notes, maps, and photographs to estimate stream conditions for the pre-statehood period. He reports an average low-flow channel width of the Salt River between Country Club Avenue and 91st Avenue in 1868 of 690 feet. Graf's report does not explicitly state how the low flow width was defined or determined, or whether the low flow channel necessarily had flow from bank to bank for any specified period of time. It is not likely that Graf's channel width is the top width of the water surface, but rather a distance between low flow channel banks.

Table 7-8 Key Salt River Irrigation Canals, 1912 (Kent, 1910)		
Canal Name	**Construction Date**	**Location of Head**
Swilling Ditch (Salt River Canal)	1867	Jointhead Dam
Maricopa Canal	ca. 1870	Jointhead Dam
Grand Canal	1878	3 mi. upstream Jointhead 1891: head at Granite Reef Dam
Arizona Canal	1883	Arizona Dam/Granite Reef Dam
Tempe Canal	1870	9 mi. upstream Jointhead
Broadway Canal	1870	4 mi. upstream Jointhead
San Francisco Canal	ca 1880	Tempe Canal
Utah Canal	1877	5 mi. upstream Tempe Canal
Mesa Canal	1878	2 mi. upstream Utah Canal
Highland Canal	1888	3 mi. upstream Mesa Canal
Consolidated Canal	1891	Arizona Dam/Granite Reef Dam

Historical Accounts. The historical record of the Salt River extends back to the first beaver trapping expeditions of the 1820's. These historical records, as well as archaeological records are summarized in more detail in Chapters 2 and 3 of this report. For the purposes of hydrology, it is noted that of the numerous early expeditions along the Salt River study reach, all traveled by foot, horse, or wagon. However, early accounts of the river each describe abundant waterfowl, fish, water, riparian vegetation, and grassy bottom land (Davis, 1982).

Bartlett (1852, cited in Davis, 1982) describes the river as clear and sweet, averaging 80 to 120 feet wide, and two to three feet deep. Bartlett's description occurred several weeks after observing that the Gila River was completely dry, possibly due to Indian irrigation diversions. Not one of the early explorers describes a dry riverbed in the Lower Salt River study reach, at any time of year.

Historical accounts reported later in the period prior to statehood frequently describe dry river conditions, usually in conjunction with descriptions of irrigation diversions. Diversion rates recorded by Kent (1910) indicate that enough water was appropriated to completely divert the river during low flow months. Lee (1905) reports that the Salt River loses flow into the ground from Granite Reef for at least 10 miles downstream, until the bedrock rise at Tempe Butte brings stream flow to the surface to a point three miles downstream of Tempe Butte.

However, not all of the study reach was dry during this period since springs and irrigation return flow provided some Salt River discharge. Lacy et al (1987) report that although in 1900 the entire river flow was diverted at the Utah Canal, 60 cfs was "usual" at Jointhead Dam several miles downstream. The entire river flow was again diverted at Jointhead, but after a dry reach for an unspecified distance, the average flow at the Buckeye Canal head was 150 cfs. Ferrance (1990) states that flow occurred in Salt River channel until November, 1912 when all flow except high flow spills, was diverted into canals. Finally, Schuyler (1903, as cited in Lacy et al, 1987) states that the water table was so close to the surface that springs discharged along river banks and that farmers drained their land with shallow ditches.

Summary. Prior to Anglo development in the Salt River Valley, the Salt River was a perennial stream, with an average annual discharge of over 1,000 cfs. Monthly fluctuations no doubt occurred in response to seasonal precipitation and snowmelt runoff, similar to those which presently occur in the upper watershed. Stream flow rates were sufficient to support rich riparian vegetation, fish and beaver populations, and extensive prehistoric irrigation systems. By the late 1890's, irrigation diversions significantly reduced flow rates, causing the river to cease flowing in some reaches during some years. For this latter period, up to the time of statehood, Salt River stream flows were limited to discharges which exceeded irrigation requirements.

Statehood Hydrology

The hydrology of the Salt River for the year of 1912 is not significantly different than for the 10 years immediately preceding statehood. Data are available from which to estimate flow conditions in the Lower Salt River for the entire year and for the month of February, 1912. The record is not sufficiently detailed to be able to describe stream hydrology and hydraulics for the study reach on the day of statehood. In addition, some accounts of stream conditions appear to conflict.

Stream flow Data: 1912. Climatic data summarized later in this Chapter and in Appendix E indicates that the year of statehood occurred during one of the wettest periods in the past 1,000 years (Smith and Stockton, 1981). However, the year of 1912 itself had below average annual runoff of 1,176 cfs[4] (Arizona State Planning Board, 1936; See Table 7-5), and fell during the period that Roosevelt Reservoir was filling. Roosevelt Reservoir reportedly did not release flow through the spillway from 1910 to 1915. The U.S. Reclamation Service/Salt River Project (1913) computed the average annual diversion from the Salt River in 1912 (calendar year), excluding the Tempe and Utah canals, at 1,040 cfs. Therefore, the natural stream flow input into the study reach was at least 1,040 cfs. As shown in Table 7-8, nearly all of the flow of the Salt River was diverted to canals in 1912.

4 The BUREC (1924) estimated the average annual flow rate for 1912 at 1,378 cfs. The BUREC rate may have included release of 460 cfs from water stored in Roosevelt Reservoir required to meet downstream requirements.

Instantaneous flow measurements were also taken elsewhere along the Salt River study area. Hancock (1912) analyzed flow requirements between Jointhead Dam and the Marmonier Canal (a.k.a. French Ditch) in July of 1912, a distance of about 4.5 miles. Flow records from the upper watershed indicate that July is one of the drier months on the Salt River (Table 7-14). Hancock reported that flow seepage past Jointhead Dam caused surface water flow for about 2.5 miles, wet sand and pools for the next 0.5 miles, with a dry river bed for the next 2 miles. At the time of measurement, flow past Jointhead Dam was about 88 cfs, creating a stream averaging 60 feet wide. Hancock reports that water flowed over Jointhead Dam 209 days between July 1, 1911 and July 1, 1912. BUREC (1924) estimated that for the period of 1913 to 1923, even when the entire river flow was diverted at Granite Reef Dam, return flow would provide a minimum discharge of 84 cfs during any given month.

Table 7-9
Salt River Annual Flow Estimates for 1912

Source	Average Inflow to Reach	Average Diversion Rate
US Reclamation/SRP (1914)	-	1,040 cfs
BUREC (1924)	1,378 cfs	-
Ariz. State Board (1936)	1,176 cfs	-

Halpenny (1966) reports that the Salt River was perennial throughout the study area in 1912, with the possible exception of the reach between Jointhead Dam and 19th Avenue[5]. He then notes that because the Central Avenue bridge was built between 1912 and 1916, it is likely that the river was permanent there, until the 1920's when more extensive groundwater pumping began. Graf (1981) reports an average low-flow channel width of the Salt River between Country Club Avenue and 91st Avenue in 1914-1915 of 220 feet, a width reduction of several hundred feet from the average width estimate for 1868.

Stream flow Data: February, 1912. The month of statehood was unusually dry. Statistics developed by the Arizona State Planning Board (1936) estimate a monthly combined natural average flow rate of 398 cfs[6] of the Salt and Verde Rivers a rate well below the mean flow for the year (1176 cfs) and the long-term average for February.[7] By comparison, February flows from 1911 and 1913 were 4155 and 1237 cfs, respectively. The State Board estimates were made in part from the Roosevelt station, and did not account for release of water stored in

[5] The reach reported to be perennial by Hancock (1916).

[6] Salt River above Roosevelt = 233 cfs; Verde at McDowell = 165 cfs.

[7] February Average Monthly flow rates: Salt River above Roosevelt (1914-1989) = 1,360 cfs; Verde McDowell (1899-1932) = 1,990 cfs. Minimum average February flow rates are 168 cfs and 417 cfs for the Salt and Verde Rivers, respectively, for the same period of record.

Roosevelt Reservoir. Lippencott (1919) reports that average monthly discharge for February, 1912 was 532 cfs on the Salt River, with the annual discharge only 62 percent of normal. In other documentation, the U.S. Reclamation Service/Salt River Project (1916) reports the average "natural" monthly flow of the Salt and Verde Rivers for February 1912 as 532 cfs, with a six year average of 3,396 cfs for the month February. The U.S. Reclamation Service/Salt River Project (1913; 1914) reported that 963 cfs[8] was diverted from the Salt River in the study reach in February 1912, excluding diversions to the Tempe and Utah Canals. BUREC (1924) estimates that 96 cfs was available for diversion at Jointhead Dam in February 1912.

Table 7-10 shows that more flow was diverted from the Salt River in the study area than was supplied from natural stream flow. By February 1912, at least two sources of supplemental water supply were available: ground water pumpage (Kent, 1910), and reservoir releases. Ground water pumping was already in use during periods of low flow, although this practice diminished somewhat after Roosevelt Reservoir neared capacity in 1914. Given the water appropriation and canal use patterns documented in the Kent Decree, an inflow of 520 cfs to Granite Reef Dam would result in flow of about 192 cfs from Granite Reef to the Tempe Canal head, and about 72 cfs between Tempe Canal and Jointhead Dam. Downstream of Jointhead Dam the river was probably dry except for return flow and ground water discharge, which may have yielded as much as 150 cfs (Lacy et al, 1987).

Table 7-10
Salt River Flow Estimates for February, 1912

Source	Average Inflow to Reach	Average Diversion Rate
US Reclamation/SRP (1914)	-	963 cfs
Lippincott (1919) SRP (1916)	532 cfs	-
Ariz. State Board (1936)	398 cfs	-

Stream flow Data: February 14, 1912. No measurements were reported for the day of statehood, February 14, 1912. The USGS (1914) reported a measurement for the Verde River at McDowell gauge, located just upstream of the Salt-Verde confluence, of 269 cfs on February 16, 1912. No daily measurements of the Salt River are available from published USGS records. Arizona Republican for February 1, 1912 reported "normal discharge" of 99 cfs at Jointhead Dam and 520 cfs at Granite Reef Dam (Lacy et al, 1987). Anecdotal accounts of flow at the Tempe bridge construction site indicate only minor flow was present in the stream bed on the day of statehood (Braselton, 1993).

Summary. Unusually low stream flow supplied from the upper watershed and normal irrigation

[8] 616 cfs is listed in the 1913 report, but apparently is a typographic error. Value reported as 35,420 acre-feet in 1913 report, as 55,420 acre-feet in 1914 report. Annual value reported in 1913 is 20,000 acre-feet greater than sum of monthly values. Therefore, it is assumed that 55,420 is correct value.

and other diversions combined to produce reaches of dry or limited flow in the Salt River in February 1912. Likely flowing reaches were located between Granite Reef Dam and the Tempe Canal head (required spill over the dam), between Tempe Butte and Jointhead Dam (bedrock forces ground water to surface), and downstream of Phoenix to the Gila River confluence (irrigation return flow and springs). However, conflicting data regarding the exact flow rates and stream conditions during the month were found.

Post-Statehood Hydrology

Since statehood, flow has become less frequent in the Salt River due to construction of five major reservoirs, ground water withdrawal, and increased water use. These changes affected stream hydraulics, riparian conditions, biotic habitat, recreation along the river, in addition to flow frequency and flow volume.

Reservoirs. Between 1900 and 1945, seven dams were constructed on the main stems of the Salt River system (Table 7-15). These dams have the capacity to store over 2 million acre feet of water.[9] In addition, an uncounted number of stock ponds, mining ponds, and other impoundments have been built within the upper watershed that also diminish natural runoff. The major reservoirs, while maintaining water supply at constant rates, have helped reduce flood discharges (Aldridge, 1980) and eliminate most stream flow downstream of Granite Reef Dam. For one period between May 19, 1941 and April 20, 1965, no releases were made from the system, and the Lower Salt River did not flow except in response to local runoff within the Valley (City of Phoenix, 1978). Evaporation losses alone on the six major reservoirs decrease pre-development flow rates by 180 cfs (Thomsen and Porcello, 1991).

Table 7-11
Summary of Reservoir Construction in the Salt River Watershed

River	Dam	Date	Capacity (AF)
Salt	Granite Reef	1908	0
	Roosevelt	1910	1,336,734
	Mormon Flat	1925	57,852
	Horse Mesa	1927	245,138
	Stewart Mtn.	1930	69,765
Verde	Bartlett	1939	178,186
	Horseshoe	1945	131,427

9 Storage estimate does not include flood storage and increased capacity added to Roosevelt Reservoir after 1993.

Ground Water Withdrawal. Ground water fluctuations have contributed to both increases and decreases in Salt River stream flows. In 1905, Lee reported groundwater elevations of 10 to 70 feet below the surface along the Salt River. The Arizona State Planning Board (1936) documented a rise, then decline in ground water levels between 1903 and 1930 (Table 7-12). Ground water rise corresponded to increased application of irrigation water on farmland in the Valley. Ground water decline corresponds to later periods when subsurface water was pumped to supplement irrigation supply and municipal/domestic water supplies.

Table 7-12
Groundwater Level in Salt River Valley, 1903-1930[a]

Year	Depth (ft.) to Water Table	Volume (AF) of Groundwater Pumped	Acres with Water Table < 20 ft.
1903	48	0	0
1908	36	0	0
1912	26	0	0
1916	21	0	42,000
1920	15	14,000	84,000
1930	32	508,000	2,000

[a] Source of data: Arizona State Planning Board (1936).

Lippencott (1919) noted that in 1919, ground water levels were so high from irrigation that the entire river flowed, due to springs discharging from the banks. He reports that 40 percent more water was used in June, 1899 for irrigation in the Salt River Valley than was flowing in the river at Granite Reef Dam. About 338 cfs of return flow was available from the Salt River at the Gila confluence. The Arizona Water Court Commission reported that for the period from 1929 to 1952, the Salt River above the Gila River confluence had no periods of zero flow, although a steady decline in flow with time was observed. Decrease in flow is probably related to increased groundwater withdrawal, and possibly to generally drier climatic conditions in this period. The Kent Decree did not allot irrigation water for the reach and canals downstream of Jointhead Dam because of the high rate of return flow in the river.

Hydraulic Characteristics. Graf (1981) analyzed potential slope changes in the Salt River between 1868 and 1980 and found only minor long-term adjustment in slope of the low flow channel, in spite of significant channel bed degradation since the 1970's. All other conditions equal, the slope changes would result in only a 4% percent increase in velocity. He also found no trend in stream width over the same time period. Graf also noted that the stream low flow channel narrowed between 1868 and 1914 within the study area. Other hydraulic changes include armoring of the channel bed with cobbles and boulders, whereas once the stream bed was composed of silty sand and fine gravel, a substrate more conducive to plant growth.

Hydrology. Long-duration stream gauge records are available for stations located upstream of the Salt and Verde River Reservoirs. Although, these stations record stream flow for a somewhat smaller drainage area than the study reach, they are the best available data not impacted by reservoirs and major irrigation diversions. Flow duration statistics for these stations are summarized in Table 7-13. Tree-ring data suggest that period of modern gauging may be slightly "drier" than the period around statehood (cf Stockton and Smith, 1981; Graybill, 1989).

Table 7-13
Salt River Flow Duration Statistics (cfs)

Station	Aver. Annual	10% Flow	50% Flow	90% Flow
Salt River-Roosevelt	896	157	343	2,040
Verde River-Tangle Creek	559	120	238	917
Combined Flow	1,455	277	581	2,957
Reconstructed Flow	1,690	n.a.	1,230	n.a.

Note: Combined flow by addition of tributary stations. Reconstructed flow from Thomsen and Porcello (1991) for location downstream of Granite Reef Dam.

Table 7-14
Monthly Average Flow Rates (cfs)

Month	Salt River-Roosevelt	Verde River-Tangle Creek	Combined Flow
January	982	655	1,637
February	1,360	1,060	2,420
March	1,960	1,460	3,420
April	2,040	878	2,918
May	1,050	219	1,269
June	367	134	501
July	341	181	522
August	599	334	933
September	460	271	731
October	461	353	814
November	380	383	763
December	786	803	1,589
Annual	896	559	1,445

The monthly flow statistics for the long-term stations located upstream of the reservoirs (Table 7-14) show that runoff directly follows precipitation patterns. Peak flow rates typically occur in February and March following snowmelt. Annual low flows typically occur during June and July, prior to monsoon rainfall. There are no data indicating that the monthly distribution of runoff at or prior to statehood differs from that measured by modern stream gauge records.

Recent flows and floods on the Salt River in the winters of 1978, 1979, 1980, 1983, 1992 and 1993 have shown that the watershed can still generate sustained flows within the study area. In these years, flows over Granite Reef Dam flowed to the Gila River for several months between January and May, prompting opportunistic recreational boating.

Summary. While urbanization has changed the hydrology of the Salt River between Granite Reef Dam and the Gila River, stream gauge records from stations located upstream of the major reservoirs provide useful hydrologic data regarding the natural flow rates in the study area. Hydrologic data from these upstream stations indicate the study reach was once provided with perennial runoff ranging from a monthly combined low flow of about 500 cfs to a monthly combined high flow of about 3,400 cfs. Flow statistics from these upstream stations also support mean flow estimates made for the pre-statehood period.

Table 7-15
Salt River Monthly Minimum and Maximum Flow Rates (cfs)

Month	Salt River-Roosevelt		Verde River-Tangle Creek	
	Minimum	Maximum	Minimum	Maximum
January	161	16,000	224	2,710
February	168	9,070	220	11,000
March	220	10,400	194	10,400
April	212	6,280	155	5,640
May	127	5,930	113	1,320
June	79	1,370	83	316
July	78	3,280	76	430
August	151	3,610	127	1,180
September	78	1,850	99	1,460
October	86	4,830	155	4,190
November	122	2,150	192	1,380
December	127	6,330	227	4,640
Annual	236	3,250	189	1,710

Climatic Variation

Climate change is measured by monitoring weather characteristics such as daily, monthly, seasonal, or annual temperature, precipitation, or relative humidity. Although weather records for the period prior to Arizona statehood in 1912 are not as extensive as for the period since statehood, sufficient data exist to give indications of pre-statehood climatic and stream flow conditions. Stream gauge data area available for the Salt River dating to 1888. Archaeologic and historical records of flow in the Salt River extend the data base back several centuries.

The BUREC began direct measurement of stream flow on the Salt-Verde River systems in late 1888 at the Arizona Dam irrigation diversion, and has since been continued to the present time by the USGS at several upstream locations. Smith and Stockton (1981) and Graybill (1989) used tree-ring records to extend gauge records to 740 A.D.; Dean et al (1985), and Euler et al (1979) used tree-rings, pollen data, and alluvial sedimentation patterns to estimate periods of increased/decreased moisture to 600 A.D. Tree-ring records may be used to estimate annual flow volume. Smith and Stockton's interpretation of the tree-ring record indicates the following:

- The period from 1905-1920 (Arizona statehood) was the wettest period since 1580 in both the Salt and Verde River watersheds.
- The period from 1900 to 1979 (Salt River gauge record) had an average annual flow volume slightly greater than the 400 year mean annual volume.
- The period from 1940-1977 on the Salt River, and from 1932-1977 on the Verde River had below average annual runoff. This period corresponds to the majority of the gauge record of most Arizona stream gauges.
- Base flow in the Verde River portion of the watershed is controlled by springs, rather than climatic factors. Low precipitation does not generally affect discharge from springs. Irrigation diversion impact Verde River stream flows.

Graybill's data also indicate that average flow from 740 -1370 A.D. was somewhat less than twentieth century average flows on the Salt River. However, summer low flows were found to have more predictable average flows during that period. Dean's and Euler's paleoenvironmental studies determined that there were no radical differences in the prehistoric Arizona climate compared to the modern climate. Other tree-ring studies by Stockton (1975) elsewhere on the Colorado Plateau also found that the early 1900's was an unusually "wet" period.

In regional climatic studies, Sellers (1960) recorded a decreasing, but not statistically significant, trend in total annual precipitation averaging about 0.03 inch/year. Thomsen and Eychaner (1991) statistical analysis of 109 years of rainfall records from the Tucson Basin indicated no trend in precipitation. Peterson (1950) demonstrated that total annual precipitation was above average between 1881 and 1884, a period of extensive channel change in southeastern Arizona. In northern Arizona, Hereford (1984) notes a period of lower than average runoff and precipitation and above average temperature in the 1940's and 1950's when compared to records for the rest of the twentieth century. This drought period affected most of the Rocky Mountain states. Hereford also concludes that beginning in 1900, precipitation abruptly increased until about 1910, at which time a progressive decline began that lasted until 1956. Since 1956, average temperatures have cooled somewhat, and discharges increased somewhat. Regional analyses of archaeological data have concluded that there were no radical differences in climate that would have affected stream flow (Graybill and Gregory, 1989).

Analysis of national climatic data by Diaz and Quayle (1980) indicates that in the southwest, the period between 1920 and 1954 had warmer winters, cooler summers and less precipitation than the period from 1895 to 1920. These data generally support the observations of Hereford (1984) and Stockton (1975) cited above, and suggest that climatic conditions may have favored higher runoff rates around the period of Arizona statehood.

The effects of climatic variations on potential stream navigability and channel conditions are complex, and cannot always be clearly distinguished from stream changes initiated by man. However, some basic conclusions can be drawn from the studies cited above.
First, Arizona's climate at statehood was not drastically different from existing or pre-statehood conditions. The same basic climatic patterns applied. Summers were warm and relatively dry with intense, late summer monsoonal rainfall. Winters were cool, with less intense Pacific frontal storms bringing snow to higher elevations and rain to lower elevations. However, subtle differences in rainfall and temperature patterns around the time of statehood may have resulted in higher average stream flow. These differences included the following:

- Generally higher precipitation and stream flow volumes
- More frequent intense monsoonal rainfall
- Cooler average temperatures, with warmer summers and cooler winters

Therefore, the period surrounding statehood was probably subject to higher than average stream flow, indicating that streams may have been more likely to have been navigable at statehood, than during other, less "wet" periods of Arizona history.[10] It is noted that some of Arizona's largest floods, in terms of both volume and peak flow rate, occurred in the twenty years prior to statehood.

Second, stream gauge records must be used cautiously to adequately predict the natural, long-term average discharge rates. Tree-ring records indicate that the average annual flow rates on the Salt and Verde Rivers between 1900 and 1980 are just slightly above the average annual flow rates for the past 400 years. Gauge records from 1905 to 1920 may predict average flow conditions well above long-term average rates, but may accurately reflect conditions at statehood. Gauge records with the majority of years of record in the 1940's and 1950's may predict average flow conditions below the long-term average, and well below the wetter conditions at statehood.

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[10] Human impacts such as reservoir construction, ground water withdrawal, etc., have tended to lessen average stream discharge rates obscuring climatic affects on some Arizona streams.

Of course, stream gauge data must also be filtered to account for human impacts on stream flow, such as reservoirs, irrigation diversions, and groundwater withdrawal. *In general, use of the existing stream gauge database will probably result in prediction of flow rates less than those that existed at statehood.*

For the Salt River, climatic changes are almost completely obscured by human impacts on the stream system. These human impacts include construction of reservoirs, irrigation diversions, groundwater withdrawal, channelization, mineral extraction from the river bed, and addition of urban storm waters. Climatic conditions may have contributed to somewhat higher low flow channel stability due to sustained, higher (low) flows. Conversely, extreme floods which occurred in the three decades prior to statehood may have adversely affected channel conditions.

Floods

Construction and operation of the Salt-Verde Reservoir system has had significant impacts on flood peaks in the study area. Aldridge (198?) estimated, for instance, that the 123,000 cfs peak of the March 2, 1978 flood would have been about 260,000 cfs without storage of flood waters in reservoirs and canals. No flood recurrence interval estimates are available for floods that occurred during the period prior to statehood. Gauge records from the pre-statehood period are not detailed enough to develop statistically significant estimates. However, accounts of floods in the study reach were recorded in newspapers and by early residents and explorers. Bartlett (1854) describes seeing flood debris 15 to 20 feet above the channel bottom. Powell (1893) reports that floods of 10,000 to 20,000 cfs occur annually (Compare to data in Table 7-16).

Table 7-16
Floods Greater Than 20,000 cfs, 1888-1939 (mean daily cfs)

Date	Discharge	Date	Discharge
1888	41,315	Jan. 20, 1916	83,475
Mar. 17, 1889	33,794	Apr. 18, 1917	27,668
Feb. 22, 1890	143,288	Mar. 9, 1918	45,375
Feb., 1891	285,000	Nov. 28, 1919	101,867
March, 1893	351,514	Feb. 23, 1920	108,600
Jan. 18, 1895	82,994	Sept. 17, 1925	20,000
Jan., 1897	35,109	Apr. 6, 1926	32,000
Apr. 2, 1903	21,500	Feb. 17, 1927	70,000
Nov. 27, 1905	199,500	Apr. 5, 1929	26,000
Mar. 14, 1906	67,000	Feb. 14, 1931	34,000
Mar. 6, 1907	50,770	Feb. 9, 1932	53,000
Dec. 16, 1908	63,000	Feb. 7, 1937	63,000
Jan. 2, 1910	294,000	Mar. 4, 1938	95,000

Note: After 1939, Bartlett Dam was closed, completing flow regulation on both branches of the Salt River system.

Flood Frequency Estimates. Flood discharge rates at various key concentration points are listed in Table 7-17. Flow rates obtained from Flood Insurance Studies (FIS, 1991; 1992) are based on rainfall runoff modeling and are significantly larger than flow rates determined by the USGS (1991) using stream flow records. The flood frequency data summarized in Table 7-17 were determined considering the impacts of reservoirs and diversions on flood peaks. For comparison, a discharge-area regression equation developed by the USGS (1978) was applied for the basin characteristics at Granite Reef Dam. This equation, developed from regional stream gauge records, predicts flood peaks for various recurrence intervals using the drainage area, mean basin elevation, and annual precipitation. The flood frequency data shown in Table 7-17 generally support early claims that floods of about 20,000 cfs occur annually (cf Powell, 1893).

Table 7-17 Summary of Salt River Discharges, Existing Conditions (cfs)							
Location	**Area (mi^2)**	**Flood Recurrence Interval**					
		2-Year	**5-Year**	**10-Year**	**50-Year**	**100-Year**	**500-Year**
Verde-Tangle Creek[a]	5,589	16,000	39,400	61,300	128,000	164,000	-
Salt-Roosevelt[a]	4,306	13,800	36,000	60,000	150,000	208,000	-
Granite Reef Dam[b]	12,250	-	-	68,000[c]	175,000[c]	245,000	-
Tempe Bridge[b]	12,831	-	-	93,000	160,000	215,000	330,000
Gila River[b]	12,962	-	-	85,000	145,000	185,000	310,000
USGS Eq'n[d]-Granite Reef	12,250	21,300	54,000	87,900	197,000	257,000	442,000

[a] Source: USGS, 1991; upstream of reservoirs
[b] Source: FEMA, 1991; accounts for reservoir attenuation
[c] Source: Newton, 1957 cited in Halpenny, 1966
[d] Source: Roeske, 1978
Note: Estimates pre-date modification of Roosevelt Dam for additional flood storage.

Hydraulic Rating Curves

Rating curves relate stream discharge to stream width, velocity, and depth. Rating curves were developed for representative locations within the Lower Salt River. Six sections were selected (one per Township-Range) which represented local low flow channel and floodplain characteristics such as floodplain width, sinuosity, and slope. Channel cross section data was obtained from a pre-statehood 5-foot contour interval topographic map (USRS, 1907) drawn from survey data from 1902. Visual comparison of this map with topographic data from a 1914 map indicated that the 1902 channel survey information was probably representative of conditions at statehood. Channel changes which have occurred since statehood, preclude use of more recent detailed channel survey data or hydraulic modeling. Hydraulic characteristics were estimated from the topographic map, historical photographs, and historical descriptions of channel and floodplain conditions. A composite Mannings' roughness coefficient of 0.045 was selected to represent gravelly sand beds, with possible dune and ripple bed forms, and channel bank and floodplain vegetation. Topographic data were interpolated to generate sections of non-linear geometry (more parabolic in shape, rather than flat). Channel slope was also estimated from topographic contours along the low flow channel. A range of discharges from 20 cfs to 2,000 cfs was modeled using HEC-2.

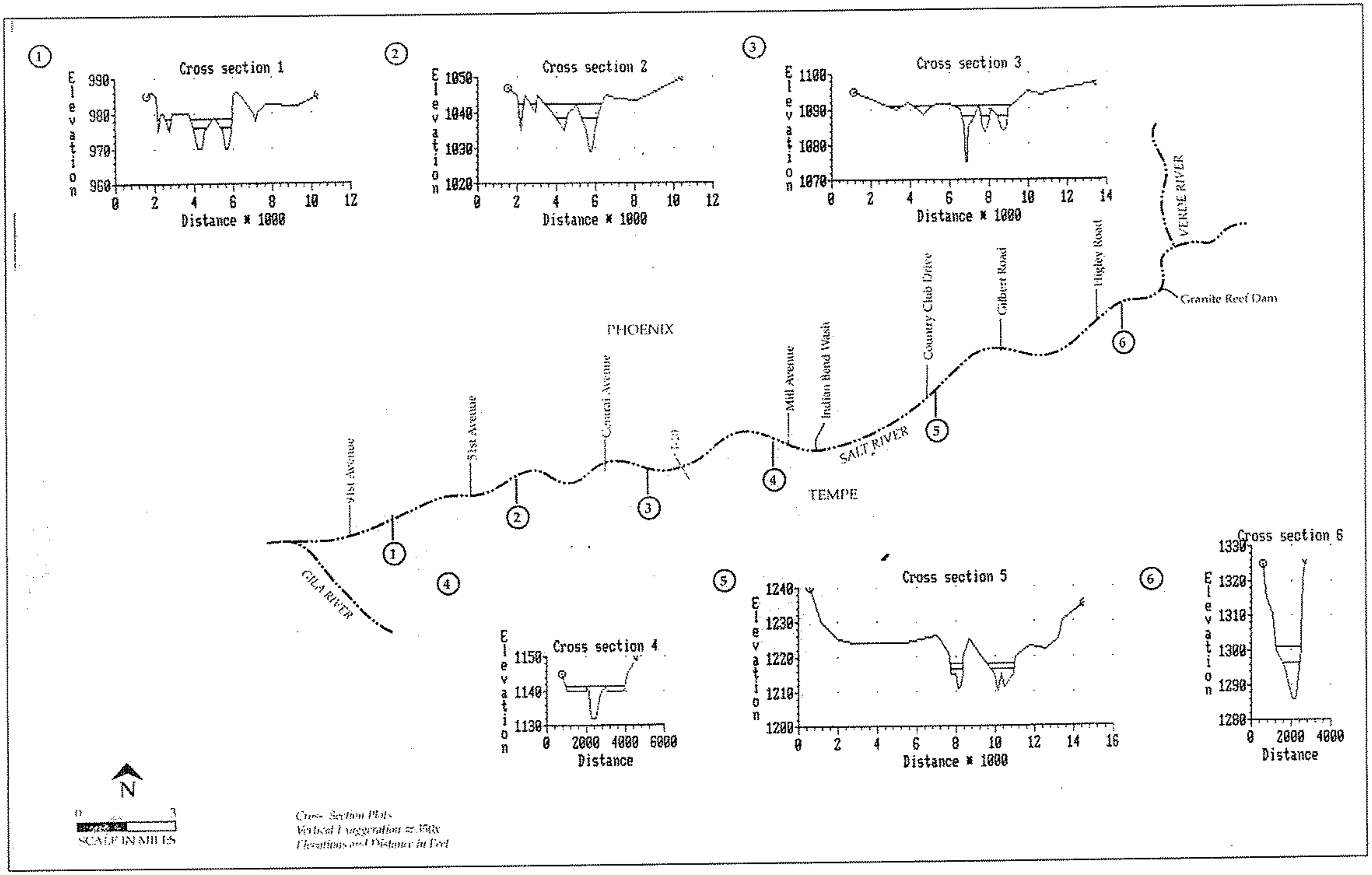

Figure 7-3. Salt River Rating Curve Cross Sections: Location and Channel Geometry

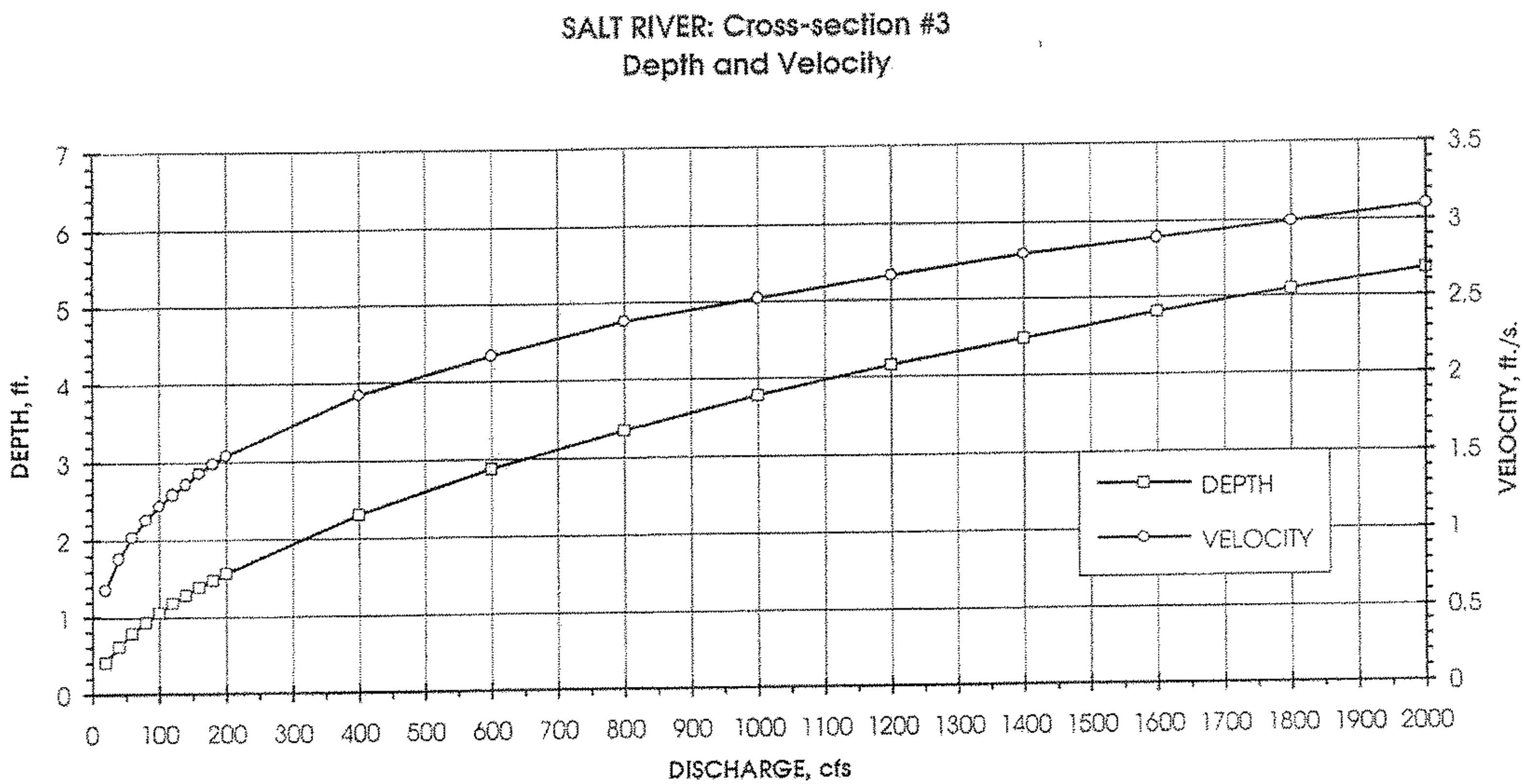

Figure 7-4. Typical Historic Salt River Low-Flow RatingCurve.

The location and cross section geometry of historical rating curve cross sections are shown in Figure 7-3. A typical rating curve for depth and velocity at one of the six cross sections is shown in Figure 7-4. More detailed documentation of rating curves and cross sections for the Salt River is attached in Appendix D. Not surprisingly, rating curves (and low flow channel hydraulics) are similar throughout the study reach. Maximum channel depths generally range between one and five feet. Average flow velocities are generally less than three feet per second. Channel topwidths are between 100 and 400 feet. These values generally agree with depths and widths reported by early explorers, cited by contemporary investigators and those measured by Graf (1981) from early survey data and other mapping. Hydraulic parameters for key flow rates in pre-statehood and statehood conditions are shown in Table 7-18.

Table 7-18
Average Hydraulic Characteristics for Pre-Statehood Salt River

Flow Rate (cfs)	Depth (ft)	Velocity (ft/sec)	Top width (ft)
20	0.3	0.5	160
300	1.4	1.3	210
1,400	3.2	2.2	300

Note: 20 - 300 cfs are typical low flows after canal diversions; 300 cfs is minimum monthly flow in pre-statehood records; 1400 cfs is approximately the mean annual flow prior to urbanization.

Summary

The Salt River Valley has a long history of reliance on the perennial flows of the Salt River watershed. After settlement of the Valley this reliance on the river for supplying irrigation water led to depletion of water flowing in the channel throughout much of the years immediately prior to statehood. Prior to Anglo settlement, the natural average annual discharge in the Lower Salt River was about 1,300 to 1,700 cfs. By the year of statehood, 1912, the typical flow condition in the Lower Salt River was more a function of upstream storage in reservoirs and diversions to meet irrigation demands, than response to natural inflow from the upper watershed. During this period parts of the study reach may have been dry for portions of the year, or flowed at significantly reduced flow rates compared to earlier years. In existing conditions, the Salt River is dry except when sustained high flows upstream necessitate sustained reservoir releases. These releases may cause flows several months in duration.

Given the criteria for navigability established by HB 2589, the hydrologic record for the Lower Salt River indicates the following:

- The Lower Salt River was perennial, with an average annual flow rate of about 1,500 cfs. The natural average flow rate during the month of February was about 1,200 cfs. These flow rates correspond to flow depths, widths, and velocities of about 3.5 feet, 300 feet, and 2 feet per second, respectively.

- For the year of statehood, 1912, the average annual flow rate was about 1,200 cfs. The average monthly natural flow rate for the month of February 1912 was about 400 to 500 cfs, most of which was probably diverted into various canals. A flow rate of about 500 cfs corresponds to flow depths, widths, and velocities of about 1.4 feet, 200 feet, and 1 feet per second, respectively.

- By the time of statehood, portions of the streambed of the Lower Salt River were periodically dry due to irrigation diversions and upstream reservoir impoundments. The average annual diversion rate at the time of statehood was estimated at about 1,000 cfs.

- By February 1912, the following reaches were probably the only remaining perennial reaches: (1) Granite Reef Dam to the Tempe Canal Head - supplied by water spilled from Granite Reef Dam to meet the Tempe Canal diversion requirement; (2) Tempe Butte to Jointhead Dam, including seepage past Jointhead Dam - supplied by groundwater forced to the surface by shallow bedrock; and (3) Central Avenue (approx.) to Gila River confluence - supplied by irrigation return flow and discharge from springs. Flow rates in these remaining perennial reaches ranged from about 50 to 100 cfs and corresponded to flow depths, widths, and velocities of less than 1 foot, 150 feet, and 1 foot per second, respectively.

Chapter 8
Boating on the Salt River

Introduction

The objective of this chapter is to provide information on federal boating criteria and the types of boating which have occurred historically on the Salt River. Several types of information are presented including:

- Federal navigability criteria
- Historical accounts of boating
- Modern boating records

Historical and modern accounts of boating on the Salt River are presented in this chapter. A general discussion of boating on Arizona rivers is attached as Appendix F. Other information relating to boating on the Lower Salt River was presented in Chapters 3 and 7.

Federal Criteria for Navigability

The federal government has not yet published universally applicable criteria to explicitly define title navigability. Rather, specific agencies use criteria defining title navigability that have been developed at the state level based on case law. These criteria vary somewhat from state to state. However, some federal agencies have formally described stream conditions which favor various types of boating. One such description was developed by an intergovernmental task force, the Instream Flow Group, to quantify instream flow needs for certain recreational activities including boating (US Fish and Wildlife, 1978). The US Department of the Interior independently developed their own boating standards (Cortell and Associates, 1977). These federal criteria, summarized in Tables 8-1 and 8-2, were developed primarily for recreational boating, not necessarily for commercial boating. Minimum stream conditions required are summarized in Table 8-1. Minimum and maximum conditions are summarized in Table 8-2.

Table 8-1
Minimum Required Stream Width and Depth for Recreation Craft

Type of Craft	Depth (ft.)	Width (ft.)
Canoe, Kayak	0.5	4
Raft, Drift Boat, Row Boat	1.0	6
Tube	1.0	4
Power Boat	3.0	6

Source: US Fish and Wildlife, 1978

Table 8-2 Minimum and Maximum Conditions for Recreational Water Boating						
Type of Boat	Minimum Condition			Maximum Condition		
	Width	Depth	Velocity	Width	Depth	Velocity
Canoe, Kayak	25 ft.	3-6 in.	5 fps	-	-	15 fps
Raft, Drift Boat	50 ft.	1 ft.	5 fps	-	-	15 fps
Low Power Boating	25 ft.	1 ft.	-	-	-	10 fps
Tube	25 ft.	1 ft.	1 fps	-	-	10 fps
Source: Cortell and Associates, 1977						

Some Arizona boaters surveyed for this study did not agree with the minimum velocity criteria given in Table 8-2. They argue that since boats can be used on lakes and ponds which have no measurable (zero) velocity, no real minimum velocity exists, except perhaps for tubing. Minimum velocities in Table 8-2 are probably intended to indicate what stream conditions are most typically considered "fun." Similarly, minimum width conditions listed in Table 8-2 probably do not represent the minimum possible conditions for use of a watercourse.

The Bureau of Land Management (BLM) apparently has adopted a "narrow" definition of navigability (Rosenkrance, 1992). BLM criteria to determine title navigability include:

- The original condition of waterway at date of statehood is used
- Use by small, flat bottom sport boats or canoes is not navigation
- Navigation must occur at times other than seasonal floods
- Unaccessible streams are not navigable
- Long obstructions such as bars makes upstream segments unnavigable

No documentation of application of these guidelines by the BLM in Arizona was uncovered, although BLM apparently did not consider the Salt River navigable at statehood, due to the closure of Roosevelt Dam (BLM, 1964). Other federal agencies have stated that the Salt and Verde are non-navigable streams, as discussed below, although specific criteria which formed the technical bases of these decisions are lacking.

Historical Accounts of Boating

Boats were in use during the period around statehood. Newspaper stories, contemporary reports, anecdotal information, and oral histories all provide evidence of boating on Arizona rivers. Documented uses of boats included:

- Travel
- Ferries
- Recreation

- Mail Delivery
- Flood Rescues
- Transport of Goods

Several accounts of floating logs down Arizona rivers are also documented. Review of historical records of boating gives the general impression is that there was no shortage of boats in the Salt River Valley. Whenever a boat was needed to cross a flooded river, even during the period of early exploration, boats were borrowed from local residents, used and returned. The presence of boats in arid regions like Phoenix, Tempe, and the Verde Valley, despite there being no nearby lakes, argues for use of boats on the rivers.

The most extensive documentation of historical river boating in Arizona is for the Salt River. Prior to statehood, before irrigation diversions and closure of dams upstream depleted river flows, at least five ferries were in operation at various locations between Granite Reef Dam and the Gila River. Sixteen episodes of boating, involving portions or the entire study reach, are recorded. A few, but not most of these boating episodes were unsuccessful, though not for lack of stream flow within the study area. Typical problems encountered included snags and sandbars, or narrow canyons on the upper Salt River above the study reach. Some accounts also mentioned that shallow water and rough channel bed material combined to damage the keels of some boats used on the Lower Salt River.

It is noted that for all of the recorded instances of boat use on the Salt River identified for this study, the boaters traveled downstream or across the river. No evidence of boating in the upstream direction was found. Furthermore, several accounts of taking boats upstream by wagon after or before boating were discovered. Boating on the Salt River apparently was not limited to the wetter months or seasonal floods. Several accounts of boating the Salt River during May and June, two months which typically have annual minimum flows. Both attempts to float logs were conceived and executed by Salt River Valley residents during summer months, not winter high flow periods. This fact suggests that the residents assumed the portion of the river they were most familiar with, the study reach, could support log transport during the summer low flow period. Finally, most of the accounts of boating on the Lower Salt River predate 1905. Few episodes of boating were recorded in the years nearest to statehood.

The type of boats typically used were flat-bottomed boats, skiffs, or canvas and wooden canoes. Information presented in Table 8-3 summarizes probable stream characteristic required to support use of the type of boats available at statehood. The criteria for canoes in use as of the time of Arizona statehood are not substantially different from criteria for canoes available today.

Table 8-3
Flow Requirements for Pre-1940 Canoeing

Boat Type	Depth
Flat Bottomed (Wood or Canvas)	4 in.
Round Bottomed (Wood or Canvas)	6 in.

Source: Slingluff, J., 1987

Historical Accounts of Fish

Although the presence of fish in a river does not indicate that boatable conditions exist, existence of certain species do provide some information about flow conditions. Archaeological evidence indicates that the same species found in Arizona rivers in prehistoric times were also present around the time of statehood (James, 1992). Change in fish species distributions did not occur in most rivers until the 1940's (Minkley, 1993). Some of the species found in the Salt River included very large fish such as squawfish (a.k.a. Salt River Salmon, Colorado River Salmon) some of which grow to over three feet long, razorback sucker, and flannelmouth sucker. The latter fish tend to indicate "big river" conditions (Minkley, 1993) by Arizona standards, at the river localities where these fish are found. Historical accounts of fishing are centered on early explorer routes and settlements. There are numerous accounts of "salmon" runs (actually squawfish) on the Salt River, and of catching hundreds of fish from the Salt River near Phoenix, and of fish left to die after canals diverted stream flow.

Modern Accounts of Boating

The Lower Salt River has been boated in its existing condition. While modern boat use of a river does not provide proof of susceptibility of a stream to navigation at statehood, it is evidence that is readily available for consideration. Boat-making technology has improved[1] since the times of statehood, with use of inflatable rafts, inflatable and hard-shell kayaks becoming one of the preferred modes of travel. However, while canoe technology has changed to make these boats more durable, the depth of water required for canoeing has not substantially changed. In addition, flow rates on Arizona rivers have generally declined since 1912. Therefore, modern use of a river reach by canoes probably indicates that canoes could have been used as of the time of statehood.

The Central Arizona Paddlers Club (CAPD), an organization of recreational boaters, recently conducted a survey of their members to determine what Arizona rivers had been boated (see Table 8-2). With 20 percent of members responding the survey indicated that all of the Lower Salt River has been boated in recent years (Central Arizona Paddlers Club, 1992). CH2M HILL informally polled CAPD members willing to be interviewed to determine flow conditions at the time various rivers were boated. A summary of the CAPD poll showing boated reaches is presented in Appendix F (Also see agency contact records, Appendix A).

Although the Salt River study area has been boated during winter flows in recent years, Arizona State Parks Department does not classify the River as a boating stream, downstream of Granite Reef Dam (or as a hiking or general recreation reach, 1989). There have been boating fatalities at grade control structures in the reach, and other boaters have been rescued by public safety personnel. Other boaters travel portions of the river without any apparent problems. The Salt

[1] One enterprising Arizonan redesigned a motorboat to be able to travel in shallow water only 2.5 inches deep (Ariz. Days and Ways, 1960). The news article describing the boat mentions that the driver cracked the boat's hull while traveling 35 miles per hour in an ankle deep stream.

River below Granite Reef Dam is not mentioned in a Arizona State Parks publication (Arizona State Parks, 1978) describe outdoor recreation, though other normally dry rivers are mentioned as hiking or wildlife watching areas. A boating guide to the southwest does not list the Salt River[2] (Anderson, 1982).

Table 8-4
Central Arizona Boaters Club
Survey Results: Selected Reaches Boated & Estimated Flow Conditions

River	Reach	Date mo-yr	Flow (cfs)	Depth (ft)	Width (ft)	Craft	Portage (%)
Salt	Granite Reef to McKellips Dr.	1-92	1,000	1-4	30-100	Kayak	0
	Gilbert Rd. to Priest Dr.	4-93	20,000	> 6	< 300	Kayak	0
	Gilbert Rd. to 51st Ave.	5-82	1,000	1-2	< 100	Kayak	0
	Mill Ave. to 115th Ave.	2-92	4,000	3-4	< 1,200	Canoe	0

Navigability Decisions

Some limited information on formal decisions of navigability of the Salt River were uncovered. These include, but probably are by no means limited to the following:

- Court Decisions. The Kent Decree stated that the Salt River was a non-navigable stream (Hurley v. Abbott, 1910). SRPMIC v. Arizona Sand and Rock (1976). A motion filed by attorneys claiming non-navigability of the Salt River was reportedly accepted by the court (Braselton, 1993).
- BLM (1964). BLM apparently did not consider the Salt River navigable at statehood due to the closure of Roosevelt Dam (BLM, 1964).

Summary

The historical record indicates that the Salt River was used for various types of boating and transport of materials in the years preceding the time of statehood (Table 3-1). Accounts of boating the Salt River are more sporadic and are limited to periods of flooding during the years closest to statehood. Recreational boaters currently float the Lower Salt River during periods of high flow. Historical hydrologic conditions in the Salt River (Compare Tables 7-18, 8-2 and 8-3) probably would have met current federal standards for recreational canoeing, kayaking, rafting, and drift or row boats. By 1912, depletion of flow for irrigation diversions left dry reaches during portions of the year that could not be boated by any craft, although some perennial reaches remained that probably could have been canoed or kayaked. Seasonal high flows in 1912 probably could have been boated by a variety of low-draft boats through the entire Lower Salt River. No evidence of boating in the upstream direction along the Salt River, or use of large machine-powered boats was found.

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[2] The upper Salt River is listed as a rafting river, but not within study reach.

Chapter 9
Conclusion

The Salt River has been a reliable source of water for the Salt River Valley for more than a millennium. Documented uses of the river include water supply for irrigation and municipal purposes, hydropower for mills and electricity, recreational and commercial boating, fishing, swimming and other recreation. This report documented continuous use of the Salt River from the time of the Hohokam, through the period around statehood, and up to the modern era.

The native American Hohokam civilization in central Arizona was dependent on water diverted from the Salt River to support their agricultural economy. The Hohokam built an extensive irrigation system that included about 315 miles of canals (not including laterals), some of which were more than 16 miles long. These canals provided water to about 140,000 acres of farmland and supported a population estimated at up to 200,000 persons. Individual canals measured 10 to 20 feet wide, and 3 to 12 feet deep, with a diversion capacity of up to about 240 cubic feet per second (cfs). The Hohokam may have even used rafts on these canals. Archaeological records indicate that numerous fish species, similar to those described by early Anglo residents and explorers, populated the Salt River and supplemented the diet of the Hohokam. Archaeological records also indicate that climatic conditions and streamflow rates were not significantly different from conditions around the time of statehood.

Geologic and hydrologic data provide evidence of the natural condition of the Salt River between the period of Hohokam occupation of the Salt River Valley and the early period of Anglo occupation. During this period, the Salt River was a perennial stream with average and median discharge rates over 1,000 cfs. Periods of low flow probably occurred during the early summer months of June and July, and may have been as low as 200 to 300 cfs. Average winter flow rates probably exceeded several thousand cfs, with annual flood discharges approaching 20,000 cfs. Flow depths in the low flow channel were probably one to three feet, with average flow widths of several hundred feet. Although groundwater levels were much higher during this period than occur today, the Salt River was a losing stream downstream of Granite Reef and downstream of Tempe Butte. Near Tempe Butte, groundwater was forced to the surface by shallow bedrock. The low flow channel of the Salt River had a sandy, gravelly bed, and was lined by stands of cottonwood and willow trees, as well as other riparian species. This low flow channel probably shifted somewhat during extreme floods, but apparently stayed within a fairly well defined floodplain.

The first Anglo explorers of the Salt River Valley found the Salt River in much the same condition left by the Hohokam, with reliable streamflow, beaver populations, a variety of large fish species, dense riparian vegetation, and evidence of periodic large floods. These settlers were even able to reuse portions of the Hohokam canal systems. Early Anglo residents floated canoes, flatboats, and logs through the study area, and used ferries at several river crossings, although alternative modes of transportation were the norm in the region. About 16 documented accounts of commercial and recreational boating on the Salt River between 1870 and 1912 were uncovered, not counting ferries which were used on the river as late as 1909. Some types of boating occurred during all months of the year during the period leading up to statehood, including one successful attempt to float logs to Tempe from upstream of Roosevelt that took place during the month of June (1885), typically a month of seasonal low flows. In 1867, ferries on the Salt River were viewed as "absolutely necessary" to maintain communication routes in central Arizona.

However, use of boats on the Salt River was limited to shallow water, low-draft, floating boats used only in the downstream direction. Steamboats and commercial shipping operations like those found on the Colorado and lower Gila Rivers apparently were not developed on the Salt River. Use of river water for irrigation supply probably was a higher priority than preserving river flow for navigation. The boats used on the Salt River sometimes encountered some difficulties in transit due to sand bars, snags, boulder riffles, or other natural hazards, and experience difficulties at man-made obstructions such as irrigation diversions.

Early Salt River Valley residents also fished and recreated in the pools of the river, and built mills and irrigation canals to exploit streamflow for commercial purposes. Oral history and documented accounts of river conditions generally support claims of boating on the Salt River from the period prior to statehood. These early accounts and recollections of the Salt River describe a stream with average flow depths of several feet and flow widths of several hundred feet. Long-term climatic data indicate that the period around statehood, from 1905 to 1920, was one of the wettest periods and had some of the highest average flow rates in over 1,500 years.

By 1912, irrigation diversions and reservoir impoundments lessened flow rates in the river channel itself, though the water supply upstream of Granite Reef Dam was no less reliable than in previous years. Irrigation demands often exceeded monthly flow rates during months of peak water use, which precipitated several early Arizona water rights studies and legal decisions, such as the Kent Decree. Documented accounts of boat use after 1910 on the Salt River downstream of Granite Reef Dam were limited to periods of high flow and floods, or to use on canals. Use of ferries declined or ceased altogether due to reduced flow conditions and construction of bridges, particularly in the reach near Tempe. During the period after Roosevelt Dam was closed, and Roosevelt Reservoir was filling, streamflow in the Salt River was limited to flood discharges, irrigation return flow, and flow to downstream irrigation diversion points. In addition, after December 1912, irrigation diversions were consolidated at Granite Reef Dam; other diversion points were abandoned. However, even during this period of reduced low flow in the Salt River, winter discharges could occupy the channel for months at a time, making the river susceptible to certain types of boating.

Since 1912, the Salt River has been characterized by a normally dry channel except during periods of sustained high flows which exceed reservoir storage and diversion capacities, or in reaches with irrigation return flows. Intense irrigation of farmland in the valley raised ground water levels which in turn created springs which discharged up to several hundred cfs into the lower Salt River. Long-term stream gage records and regional climatic data from this period indicate that the watershed has continued to supply enough water to support the types of boating and river activities that occurred during the period prior to statehood, if the stream flow were not impounded or diverted upstream of the study area. Upstream of the study area, both the Salt and Verde Rivers continue to be popular seasonal recreational boating streams. In spite of the impacts of modern urbanization which have effectively eliminated low flows in the Salt River, recreational boaters continued to take advantage of periodic flows in the river and have boated the entire study reach numerous times during recent years.

The Salt River could have and did support some types of boating during the period prior to statehood. By 1912, use of boats on the river had declined, but was still possible in some reaches during portions of some years, a condition which persists today.

Chapter 10
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1949 Partial. U.S. Department of Agriculture. Agricultural Commodity Stabilization and Conservation Service, Salt Lake City, Utah. Scale 1:20,000.

1951 Areal Photos. Army Corps of Engineers. Stored at the U.S. Geological Survey Offices, Phoenix, Arizona: Reaches A, B, C, D.

1954 Partial. U.S. Department of Agriculture. Agricultural Commodity Stabilization and Conservation Service, Salt Lake City, Utah. 1:20,000.

1957 Complete. Arizona Department of Transportation, Highway Division, Phoenix Office.

1961 Areal Photos. U.S. Geological Survey. Stored at Sioux Falls, South Dakota: Reaches A, B, C, D.

1961 Partial. U.S. Geological Survey, Sioux Falls, South Dakota. Project GS-VAJK. Scale 1:24,000.

1962 Partial. Maricopa County Flood Control District, Phoenix. Scale 1:24,000.

1964 Complete. Arizona Department of Transportation, Highway Division, Phoenix Office.

1964 Partial. U.S. Department of Agriculture. Agricultural Commodity Stabilization and Conservation Service, Salt Lake City, Utah. Scale 1:20,000.

1965 Aerial Photos. U.S. Geological Survey. Stored at Sioux Falls, South Dakota. (Also with U.S. Geological Survey in Phoenix): Reaches A, B.

1969 Partial. A rizona Department of Transportation, Highway Division, Phoenix Office.

1970 Partial. U.S. Department of Agriculture. Agricultural Commodity Stabilization and Conservation Service, Salt Lake City, Utah. Scale 1:20,000.

1971 Aerial Photography. Stored at Sioux Falls, South Dakota. (Also at Map Library, Arizona State University): Reaches A, B, C, D.

1973 Aerial Photography. Aerial photos taken by National Aeronautics and Space Administration, aerial mosaic compiled by U.S. Geological Survey. Stored at Sioux Falls, South Dakota (also at the Phoenix Office of the U.S. Geological Survey): Reaches A, B, C, D.

1976 Complete. Arizona Department of Transportation, Highway Division, Phoenix Office. Very large scale.

1978 Aerial Photos. Arizona Department of Transportation, Maricopa County. Stored at Phoenix, Arizona. (Photos taken 12/19/78, near peak of 1978 flood): Reaches A, B, C, D.

1978 (December), Complete. Arizona Department of Transportation, Highway Division, Phoenix Office. Very large scale.

1979 Aerial Photos. Maricopa County Flood Control District. Stored at Phoenix, Arizona. (Photos taken 2/15/79, at ebb of flood): Reaches A, B, C, D.

1979 (February), Complete. Maricopa County Flood Control District, Phoenix. Scale 1:24,000.

1980 Aerial Photos. Maricopa County Flood Control District. Stored at Phoenix, Arizona (Photos taken 2/16/80, near peak of flood): Reaches A, B, C, D.

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Appendix B

Newspaper Reseach: Salt River

Historical Newspaper Research

Earl Zarbin, retired Arizona Republic reported and local historian, was retained by SWCA to research news articles pertaining to boating, ferries, and fish in Arizona rivers. The following are summarized from Mr. Zarbin's letters to SWCA.

As to items from your letter of June 9, 1993, the *Weekly Arizona Miner* shows the events involving Charles Trumbull Hayden to have occurred in 1873, not 1875, to wit:

> *Weekly Arizona Miner*, June 14, 1873: "Charles Trumbull Hayden left his home at Hayden Ferry on the 24th ult. . . for the purpose of prospecting along Salt River for timber suitable to saw into lumber. . .";
>
> *Weekly Arizona Miner*, June 21, 1873: "The Hayden Party followed the Salt for nearly 200 miles and found nothing to interfere with floating logs down. . . Having found a good location where pines were plenty and good they made a canoe out of a tree and putting some logs into the river, left six of the party to drive them down while Hayden and Sugert returned home. . .";
>
> *Weekly Arizona Miner*, June 28, 1873: "The Hayden Party left up Salt River to come down in a canoe and drive some logs with them, have returned, and pronounce the scheme a failure. With much toil and difficulty, on account of rapids and boulders in the river, they descended a long way, when, having lost their arms, ammunition and provisions, excepting flour, they arrived at a cannon so narrow as to admit the passage of a log, and were compelled to abandon their boat and foot it. Mr. Hayden is still sanguine of getting sufficient timber o this side of the canons."

Among other items from my research that seem appropriate:

> *Arizona Gazette*, February 17, 1881: "Messrs. Cotton and Bingham will leave tomorrow for Yuma by way of the Salt and Gila rivers. They have constructed for the trip, an 18-foot skiff, flat-bottom, which will draw very little water,. . ."
>
> *Arizona Gazette*, February 14, 1883: "The Salt River is a navigable stream and should be included in the river and harbor appropriation bill. North Willcox and Dr. G.E. Andrews, U.S.A., of McDowell, landed at Barnum's pier, on the Salt River Valley Canal, at three o'clock yesterday afternoon, direct from McDowell [aside the Verde River], having accomplished the voyage from that point to this port, in a canvass skiff. The running time proper was about eighteen hours, and the trip would have been thoroughly pleasant, had rain not fell upon them, during the night in which they camped out. . ."

Phoenix Herald, February 19, 1884: "A raft is being constructed on the Salt River to ferry across goods, as there is little prospect of the river's being fordable for some time."

Phoenix Herald, March 24, 1884: "Jesse Bryant and H.H. Hufstetter have a good and safe ferry running on the Salt River between Phoenix and Maricopa, and it will be promptly attended to both day and night." (Did the writer of the item mean the Maricopa Dam, the Maricopa crossing, a Maricopa Indian Village, or some other Maricopa?)

Arizona Gazette, February 19, 1884: "The river this morning was reported as being four feet higher than it was yesterday, and it was deemed unsafe to ferry passengers, nothing but the mail being carried across by boat. The warm weather is melting the snow and a further rise is anticipated."

Arizona Gazette, March 5, 1884: "The river rose nearly four feet last night, and has not yet reached its flood. In this connection it will be good news to our business men to know that the new freight-boat, the dimensions of which are 11x28, will be completed and ready for business tomorrow."

Phoenix Herald, April 8, 1884: "Mr. A.J. McDonald is building a large ferry boat for the Gila and Salt River Ferry Company to be put on the Salt river below town. It will be of the same dimensions as the one sent to the Gila, viz: 16 by 48 feet. It will be worked on an inch and a quarter steel cable and be a permanent arrangement."

For the William Burch expedition on the Salt River in 1885, in addition to the dates of June 3, 5 and 6 from the Arizona Gazette, there also was this item:

Arizona Gazette of June 8, 1885: "The Box Canyon In our account of the recent exploration of the Box canon of the Salt River, we stated that the passage through the gorge. . . was the first ever made. It now turns out that we were premature in this statement. Postmaster Mowry related to the reporter this morning his recollection of the description of the canon and a trip made through the same by Frank Middleton, now of Flagstaff, and his brother-in-law, George Shute, now residing on the upper Salt River. This was eight or ten years ago. . ."

This is the only other item that mentions navigation on the Verde River:

Phoenix Herald, December 12, 1888: Major E.J. Spaulding, commandant at Ft. McDowell, was killed "While coming down to Phoenix with Capt. Hatfield in a canoe and shooting as they came, they were about to lift their boat over the Mesa dam, when the major attempted to remove his gun from the boat, and in doing so it was discharged, killing him almost instantly."

You have to read to the end of the first of the two items before coming upon navigating the Salt River. The second item mentions the ensuing trip:

> *Phoenix Herald*, February 18, 1895: "yesterday morning Amos Adams and G.W. Evans arrived in Phoenix having come all the way from Clifton to Sacaton in a boat. These gentlemen enjoy the proud distinction of being the first men to pass through the box canon of the Gila by water. They left Clifton on January second and launching their boat which had been especially constructed for the purpose on the San Francisco river, they journeyed down that stream to the Gila which they entered fourteen miles below Clifton. From that point they remained on the Gila, until they reached Sacaton, travelling by that stream about three hundred miles. There they disembarked and hauled their boat to Phoenix and after laying in provisions, etc., they will leave tomorrow on the Salt river, to the Gila, thence to the Colorado and by that stream to the Gulf";

> *Phoenix Herald*, February 25, 1895: "The following letter was received this morning from Mr. Amos Adams. . . who passed through the Salt River valley about a week ago. 'Gila Bend, Feb. 23. Editor Herald.—In terms of my promise to write I wish to say that we found nothing unusual on our voyage down the Salt and Gila rivers except that ducks were plentiful. . ."

> *Arizona Republican*, October 4, 1909: "Roosevelt, Oct. 2—'Jim Meadows, late of Yuma and formerly a pioneer of the Tonto Basin. . . in 1883. . . made the first attempt, with success attending him, to navigate the waters of the Salt River between Livingstone and Tempe, accompanied by two white men and negro (cq). In passing through the first box canyon the negro was scared stiff. In passing through the second box they got hung upon the rocks and had to roll more rocks into the water to raise the water high enough to float the boat clear. He is a brother of Charles Meadows, otherwise called Arizona Charlie, who took a wild west show to Australia a few years ago. . ."

A story about a rowboat trip from Roosevelt to Mesa appears in the Arizona Republican of Tuesday, June 28, 1910. I did not copy it, because I thought it was too long. But I made the following notation:

> *"Tale of two men who voyaged from Roosevelt to Mesa via rowboat on Salt River and the South Canal. P2,sec2."*

I have not attempted to list very item that mentions Hayden's or other ferries. Whenever the Salt River rose and became impassable, ferries and boats came into use. Periodically, the ferries broke from their cables and went down river. Some people evidently maintained boats to ride the river or canals when the water rose.

Boats also were used on the Salt River during construction of Theodore Roosevelt and

Granite Reef Diversion dams. My recollection is that boat use began at Roosevelt Dam after the dam was high enough to back up water and make creation of the Roosevelt navy feasible. At Granite Reef, after the dam was built or was near completion, an incident involving a couple of boats led to the drowning of a couple of men. I have not attempted to supply dates for these items, because the creation of reservoirs behind the dams made possible both the navy and the boating accident.

> The only use of boats on the Hassayampa River that I am aware of came with construction of the Walnut Grove Dam and the filling with water of a 750-acre reservoir. Fishing and boating occurred until the dam was washed away by high water in February 1890. I have no references to boating on the San Pedro River.

River Ferries

"Some encouragement should be given to the enterprising citizens who have established ferries on the Gila and Salt Rivers; such ferries being an absolute necessity to communication between the lower and upper country during several months in each year and the travel not yet being sufficient to support them." *Arizona Miner*, December 12, 1868.

"In 1867 (henry) Morgan came to the Gila river and built a station that was known afterward as Morgan's Ferry. It was on the main road leading to McDowell, and here Morgan labored at ferrying and trading with the Indians for 25 years. During this time he completely wore out four stoutly built ferry boats."—*Arizona Gazette*, June 23, 1900.

"Via Western Union and U.S. Military Lines—Phoenix, Feb. 25—A new ferryboat has been built at Hayden's crossing, so that in the future the river will cause no delay to passenger mail."—*Arizona Miner*, February 27, 1874.

"George H.N. Luhrs is building a large skiff for the stage company, to be used in transferring passengers and mails across the storm waters of the Salt."—*Phoenix Herald*, August 16,1881.

"Monihon's Ferry Privilege Act is meeting with great opposition from your county." (this was an act before the Arizona Legislature.)—*Phoenix Herald*, February 26, 1883.

"Mr. Trumbull has had a boat built at Mr. J. McDonald's shop, and took it down to the river this morning, where he will use it in crossing over some 60,000 pounds of freight that lies on the other side, but is now badly wanted on this side. Mr. Trumbull is to receive 12-1/2 cents per 100 for bringing the freight over, and doubtless plenty more will follow, if he is successful in the attempt."—*Phoenix Herald*, February 19, 1884.

"The Ferry and Bridge Company held a meeting on Saturday evening at the courthouse. Messrs. Coats, Ryder, and C. Goldman were appointed a committee on construction of boats, etc. Messrs. F. Fowler, P. Miner, and J.M. Gregory were made a committee on location of ferries. . ."—*Phoenix Herald*, March 17, 1884.

"Jesse Bryant and H.H. Hufstetter have a good and safe ferry running on the Salt River between Phoenix and Maricopa, and it will be promptly attended to both day and night."—*Phoenix Herald*, March 29, 1884.

"Mr. A.J. McDonald is building a large ferry boat for the Gila and Salt River Ferry Company to be put on the Salt river below town. It will be of the same dimensions as the one sent to Gila, viz: 16 by 48 feet. It will be worked on an inch and a quarter steel wire cable and be a permanent arrangement."—*Phoenix Herald*, May 9, 1884: "The new ferry boat has got at work on the Salt River at last and is making up for its long delay and many mishaps by giving entire satisfaction, as it works splendidly. It carries over the largest freight wagon, loaded and with team, with perfect ease, and gives no trouble in its management.:—Phoenix Herald, April 8, 1884.

". . . there was only one boat available and that was the one at the ferry at the Broadway crossing. J.P. Moffitt finally managed to secure this skiff and putting it on a wagon took it up the river,. . ."—*Arizona Gazette*, December 19, 1884.

"Both ferries are running on the Salt river although the stream is very high.:—*Arizona Gazette*, March 26, 18886. (Presumably, these are Hayden's ferry at Tempe and the Gila and Salt River Ferry Company south of Phoenix.)

"The old ferry formally used at the Gila crossing, has been taken down the river by Will Cox, and will be established at a point on the river convenient to Sentinel."—*Phoenix Herald*, February 5, 1889.

"It was stated in this morning's issue of the Gazette that the ferry boat belonging to C.J. Ulmer had broken loose from its moorings and floated down stream. It was the ferry boat belonging to Mr. Bryan that had broken loose near Gray's crossing. Mr. Bryan has commenced the construction of another ferry boat similar to the one lost."—*Arizona Gazette*, March 25, 1893.

Fish

Could the presence of fish in a river indicate navigability? I am thinking of fish in the Salt River. In my notes, I believe I have a story or two indicating that fish (Colorado salmon?) came up the Salt River on their way to spawning areas. My recollection is that the fish were described as three to four feet long, which suggests a rather good quantity of flowing water.

"It is regretted that Arizona has no law for the protection of fish in her rivers. Almost daily we see great loads of fish coming into Phoenix from the Salt river that have been caught by the use of Giant powder. No secret is made of the fact whatever. The worst feature of the matter is, that not only are fish fit for the market taken, but the fry are also destroyed and large quantities of fish considered too small to trouble with are left to decay. The river has been nicely stocked with excellent fish, but is being rapidly depopulated, and a couple of years more will leave that beautiful stream without a single fish, if some means are not found to check this wanton and wicked destruction of its finny inhabitants. . ."—*Phoenix Herald*, May 7, 1879.

"The restaurants occasionally furnish their boarders with excellent fish caught in Salt River."—*Phoenix Herald*, June 24, 1880.

"The bill prohibiting the killing of fish in the rivers of the Territory, by means of giant powder and other explosives, passed the House this morning."—*Arizona Gazette*, January 21, 1881. "The Governor has approved the following bills:. . .bill to prevent the destruction of fish;. . ."—*Arizona Gazette*, February 4, 1881.

"Two of the Herald boys went fishing yesterday and in a few hours they caught over a hundred pounds of fish."—*Phoenix Herald*, July 18, 1881.

"The Indians are supplying this market with fish."—*Arizona Gazette*, December 17, 1881.

"A lucky disciple of Izaak Walton succeeded in hauling a five pound fish from the Salt River this afternoon. It was a Colorado River salmon."—*Arizona Gazette*, March 7, 1882.

"The Indians have been supplying this city with fish, most abundantly, for several weeks past. However, we understand that they obtain their fish by illegal methods—they use of giant powder. The Salt River is now very low, and the pools are well filled with fish. The Indian, an apt scholar under his white teacher, takes a giant-powder cartridge, and, exploding it in the water, kills fish alike large and small. . ."—*Arizona Gazette*, November 13, 1882.

"A complaint was today filed with the district attorney accusing three Indians with using giant powder for the purpose of killing fish. The complaining witness states that on last Sunday the number of dead fish in the still water above the dam of the Salt river valley canal was estimated at least three wagon loads, and for more than week past dead fish have been floating down the city canal, creating considerable of a stench.:—*Arizona Gazette*, June 30, 1885.

"It is said that the river below the Arizona Canal dam is filled with dead fish. This is, without doubt, the result of there being no fish way in the dam. In all States there is a law requiring builders of dams to construct fish ways. There must be a United States law, covering the case in the Territories, as it is not likely the U.S. Fish Commission would distribute fish where the circumstances were unfavorable for their existence, but if there is no such law in force, it will be incumbent on our next Territorial Legislature to pass one."—*Phoenix Herald*, June 20, 1888.

"The farmers who live next to the big canals throughout the valley say they never saw the like of fish coming down the canals as there are this year. In irrigating, large numbers of the finny creatures are left in the fields after the water soaks away, and small boys and Indians gather great lots of them and bring them to town. There are many fine, large, German carp found."—*Arizona Gazette*, July 7, 1892.

"Many little folks are present today with their elders, and the small boys having a royal time catching fish below the (Granite Reef Diversion) dam. The cutting off of the water has resulted in the death of thousands of fish for several miles down the river. The pool immediately below the dam is filled with them and the youngsters have pulled out hundreds."—*Arizona Gazette*, June 13, 1908.

Appendix C

Note on Salt River Historical Sources

Note on Historical Sources: Salt River

The primary libraries for historical research in Arizona are (1) the Arizona State Library and Archives, (2) the Arizona Historical Society libraries in Tucson and Phoenix, (3) the University of Arizona Library, especially the special collections, (4) the Hayden Library at Arizona State University, especially the special collections and the Arizona Historical Foundation, which maintains an office in the Hayden Library. The Salt River Project maintains archives that are important in documenting the history of the Salt and other rivers. The Cline Library at Northern Arizona University and the library of the Museum of Northern Arizona have secondary sources, but with regard to the Salt River, duplicate the holdings of the libraries at the University of Arizona and Arizona State University. It should be noted that the computerized card catalog at the Cline Library at NAU can access the collections of the other university libraries in Arizona.

Secondary sources that cover the history of Arizona include Adams (1930), Bancroft (1888), Farish (1915), Hill and Goff (1970), McClintock (1916), Trimble (1977), and Wallace W. Elliott Co. (1884). Walker and Bufkin's (1986) *Historical Atlas of Arizona* provides a general history of the state, illustrated with maps. Barnes (1988) and Granger (1984, 1985) give background information on the history of Arizona place names. Guidebooks and boosters' accounts of Arizona (Hamilton 1884; Hodge 1877; McClintock 1901) also provide useful information on the state in the late nineteenth and early twentieth centuries.

Historical archaeology of the Salt River Valley is discussed in Ayres and Stone (1984) and Cable, Henry and Doyel (1984). Given the importance of Fort McDowell to the development of the Salt River Valley, Stein's (1984) historical archaeology of the fort should also be consulted. Cable and Doyel (1986) is the premier study of the archaeology of historic irrigation in the valley.

Behan (1988), Byrkit (1984), Lacy, Brown, and Preisler (1987), and Randall (1993) are histories of the Salt River. Accounts by Spanish and American explorers, military men, and early travelers (Bartlett 1854; Dunne 1955; Flint 1930; Hammond 1949) are relatively limited. Davis (1982) is a good secondary account of observations on fish, wildlife, and natural conditions by early American explorers and travelers.

The history of Fort McDowell is described in Reed (1977), Stein (1984), and the Surgeon General (1870). Barney (1933) and Mawn (1977, 1979) are scholarly histories of Phoenix. The histories of neighboring communities are covered in Robinson and Bonham (n.d.), Simkins (1989), and the United States Federal Emergency Management Agency (1979, 1980).

The history of irrigation in the valley has an immense bibliography. Examples include Anonymous (n.d.), Cable and Doyel (1986), Lewis (1963), Myres (1961), Parkman (1961), Peplow (1979), Pollard (1945), SRP (1966), Smith (1972), Worster (1985), and Zarbin (1984, 1986).

Myrick (1980) is the best general source on railroad history in the valley. Finch (1932), Fireman (1969), Hayden (1972), and McCroskey (1988) focus on or contain important information on ferries that operated in the valley.

Newspapers are an extremely important source of information on the history of river use. Newspapers are on microfilm at the State Library and Archives (as well as at the University of Arizona library, the Hayden Library at Arizona State University, and the Cline Library at Northern Arizona University). The State Library and Archives has a listing of all of the newspapers published in the state. Earl Zarbin has examined Arizona newspapers published between 1859 and 1918 and compiled an index of articles relating to water in Arizona (Zarbin n.d.). Mary Lu Moore, historian with the State Attorney General's Office has a copy of this index. The *Arizona Gazette*, *Arizona Republic*, *Arizona Republican*, *Mesa Free Press*, *Phoenix Gazette*, *Phoenix Herald*, *Tempe News*, *Tombstone Daily Prospector*, and the *Weekly Arizona Miner* were among the newspapers found to have articles relevant to the study of the use of the Salt River.

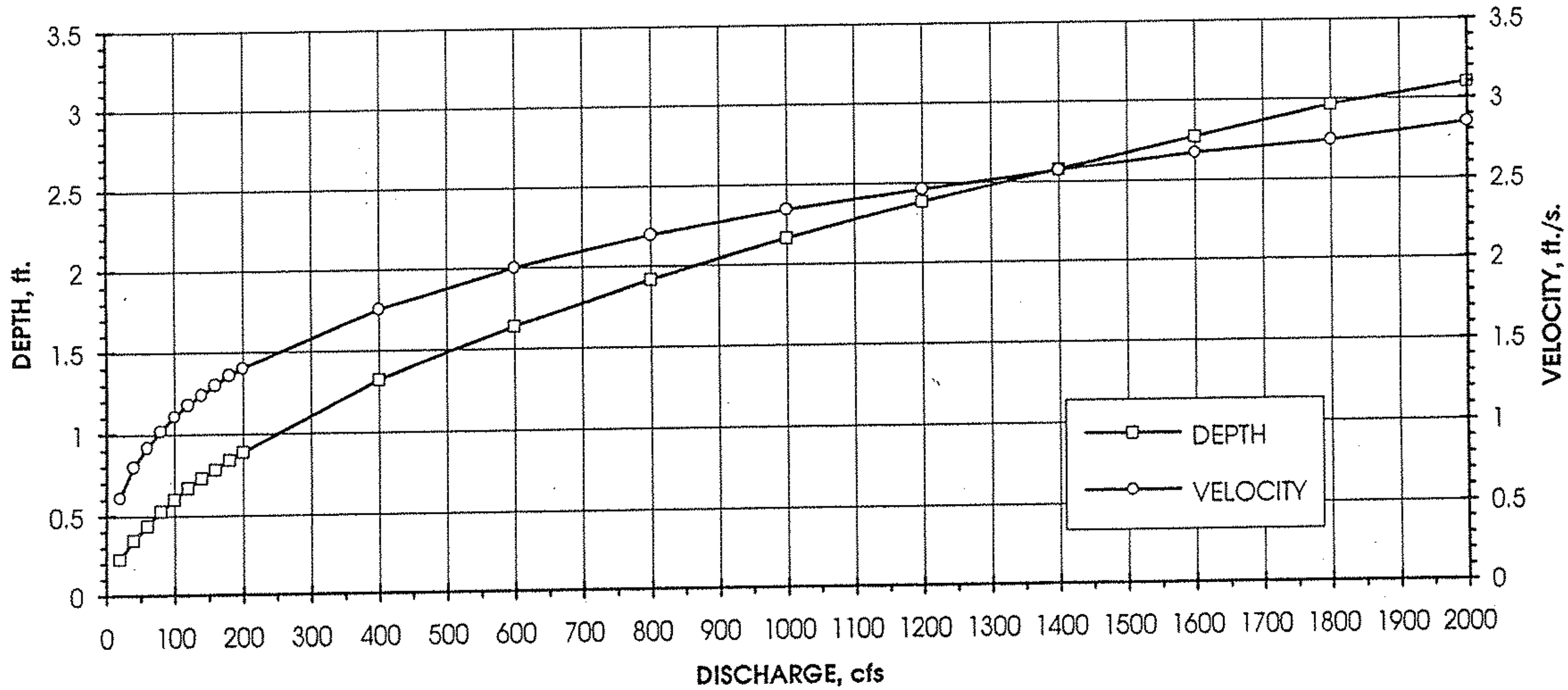
General Land Office maps, located in the State Library and Archives, were made between 1868 and 1932. Maps were not made for national forests, Indian reservations, or land grants. These maps provide information on activities along the river--including residences, roads, irrigation ditches, and other sites--during the period around the time of statehood. The maps showing the Salt River did not illustrate any sites associated with navigation.

Sanborne Fire Insurance Maps were produced for most of the communities along the river and can be found in the special collections of the Hayden Library at Arizona State University and the Library at Northern Arizona University. Like GLO maps, Sanborne Fire Insurance Maps provide information on activities along the river, but in the case of the Salt River did not illustrate any sites associated with navigation.

Many of the museums and libraries around the state maintain collections of photographs. Among the most extensive are those of the libraries of the state universities, the state historical societies, the state library and archives, and the Salt River Project, mentioned above. The Arizona Historical Foundation has a separate catalog of photographs in its collection.

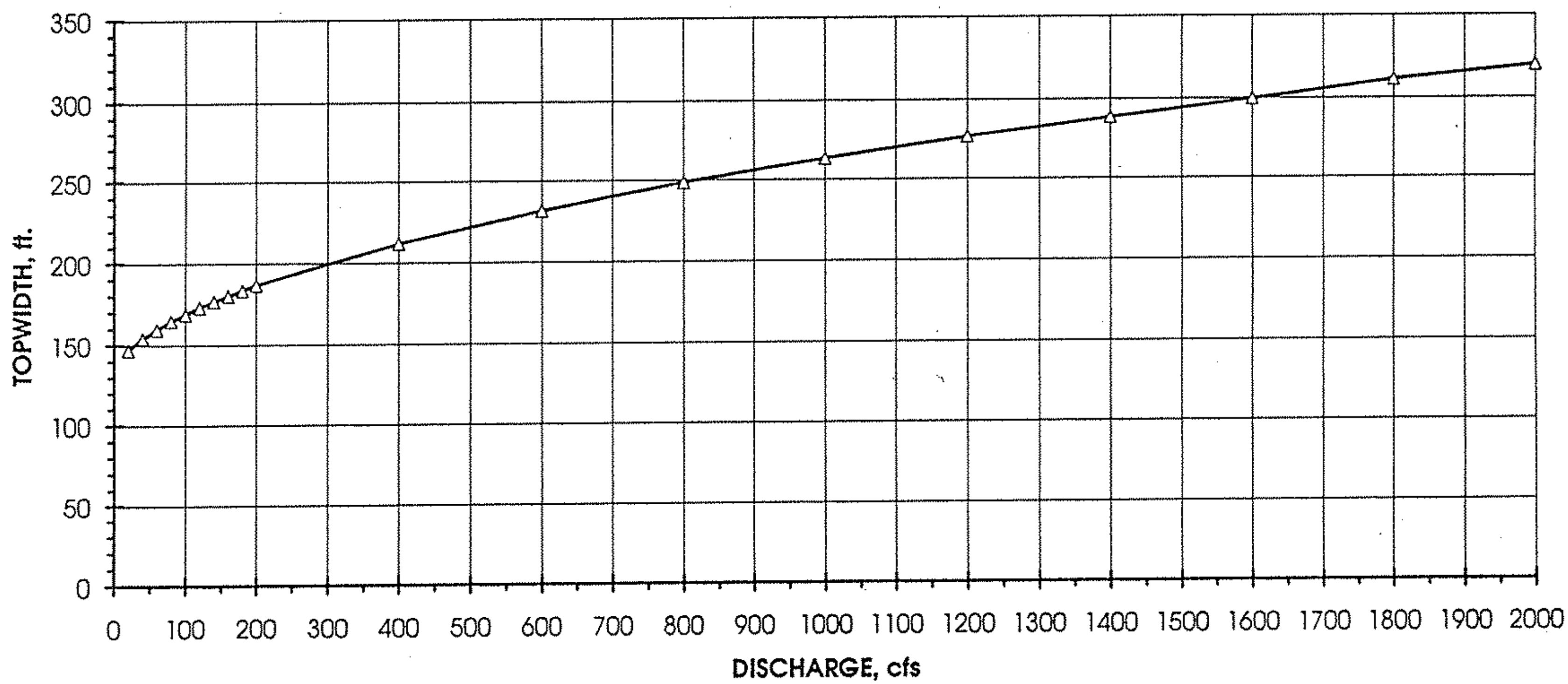
Appendix D
Historical Salt River Rating Curves

SALT RIVER: Cross-section #1
Depth and Velocity

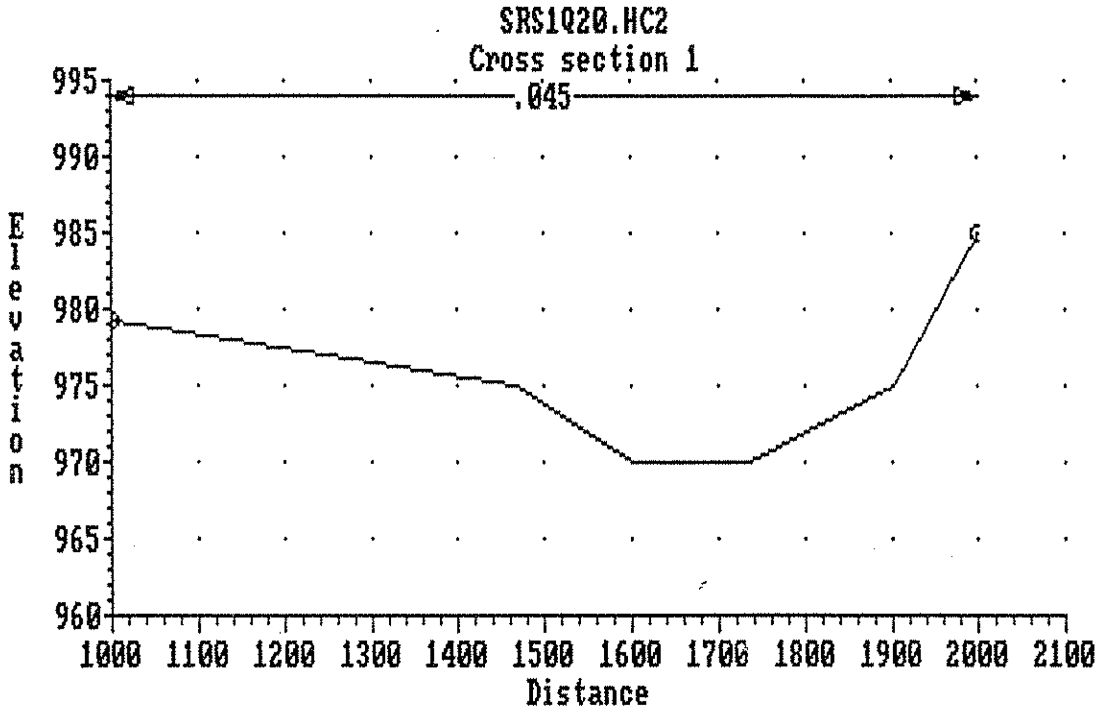


SRS1-DV.XLC

SALT RIVER: Cross-section #1
Topwidth

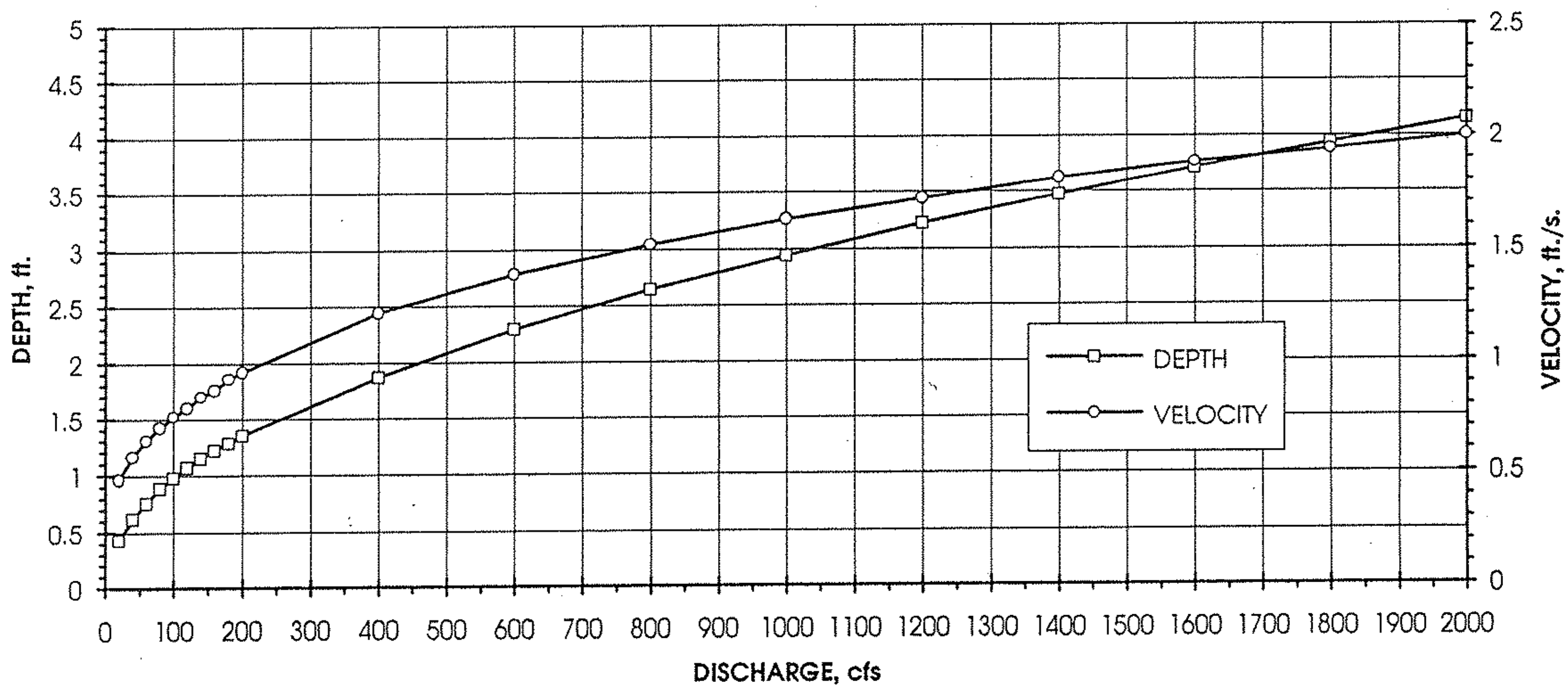


SRS1-TW.XLC



SRS1Q20.HC2
Cross section 1
.045
Elevation
995
990
985
980
975
970
965
960
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Distance

SALT RIVER: Cross-section #2
Depth and Velocity



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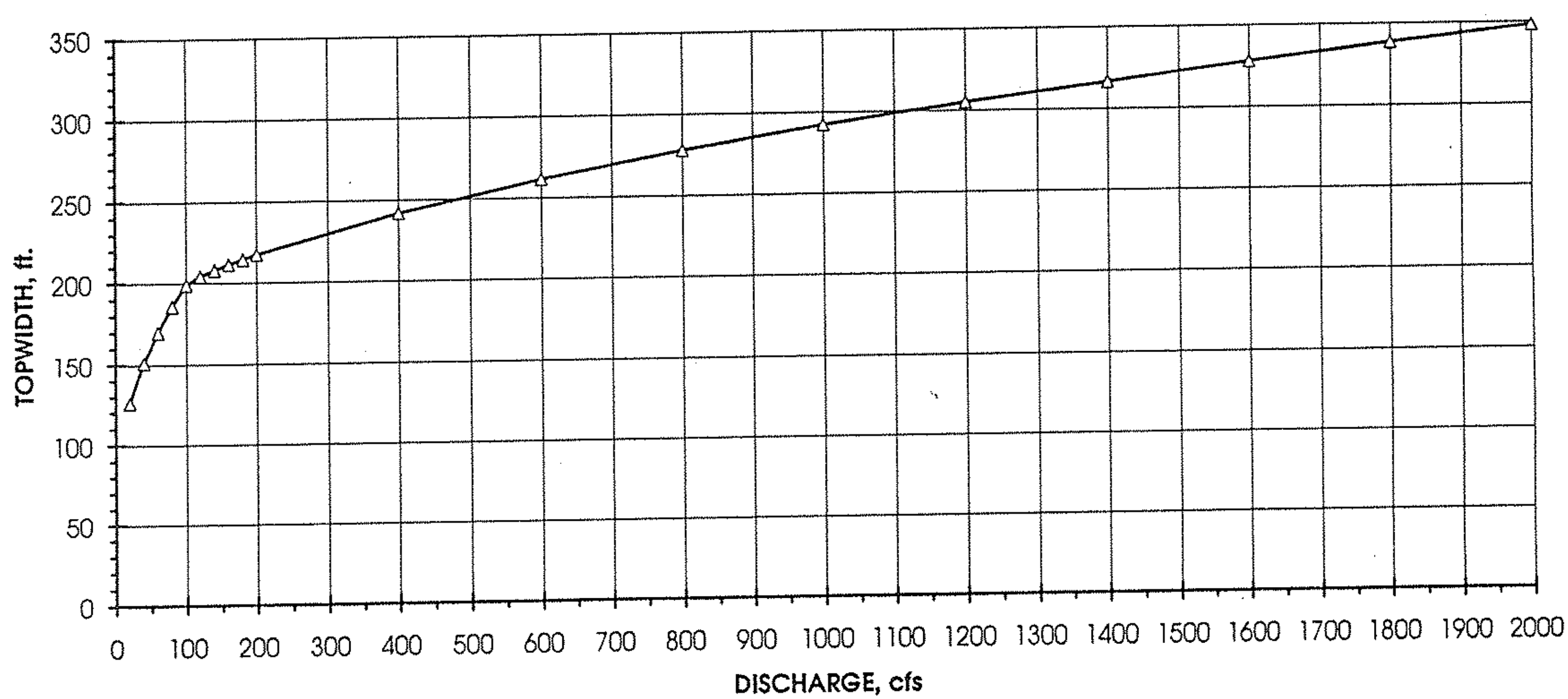
Topwidth



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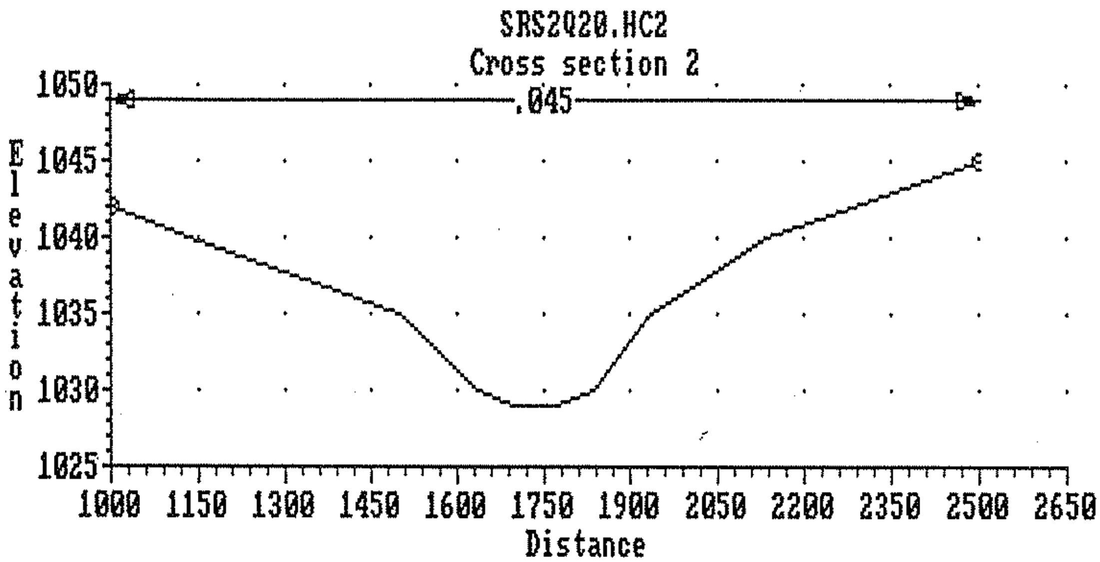
SRS2Q20.HC2
Cross section 2
.045
1050
1045
1040
1035
1030
1025
Elevation
1000
1150
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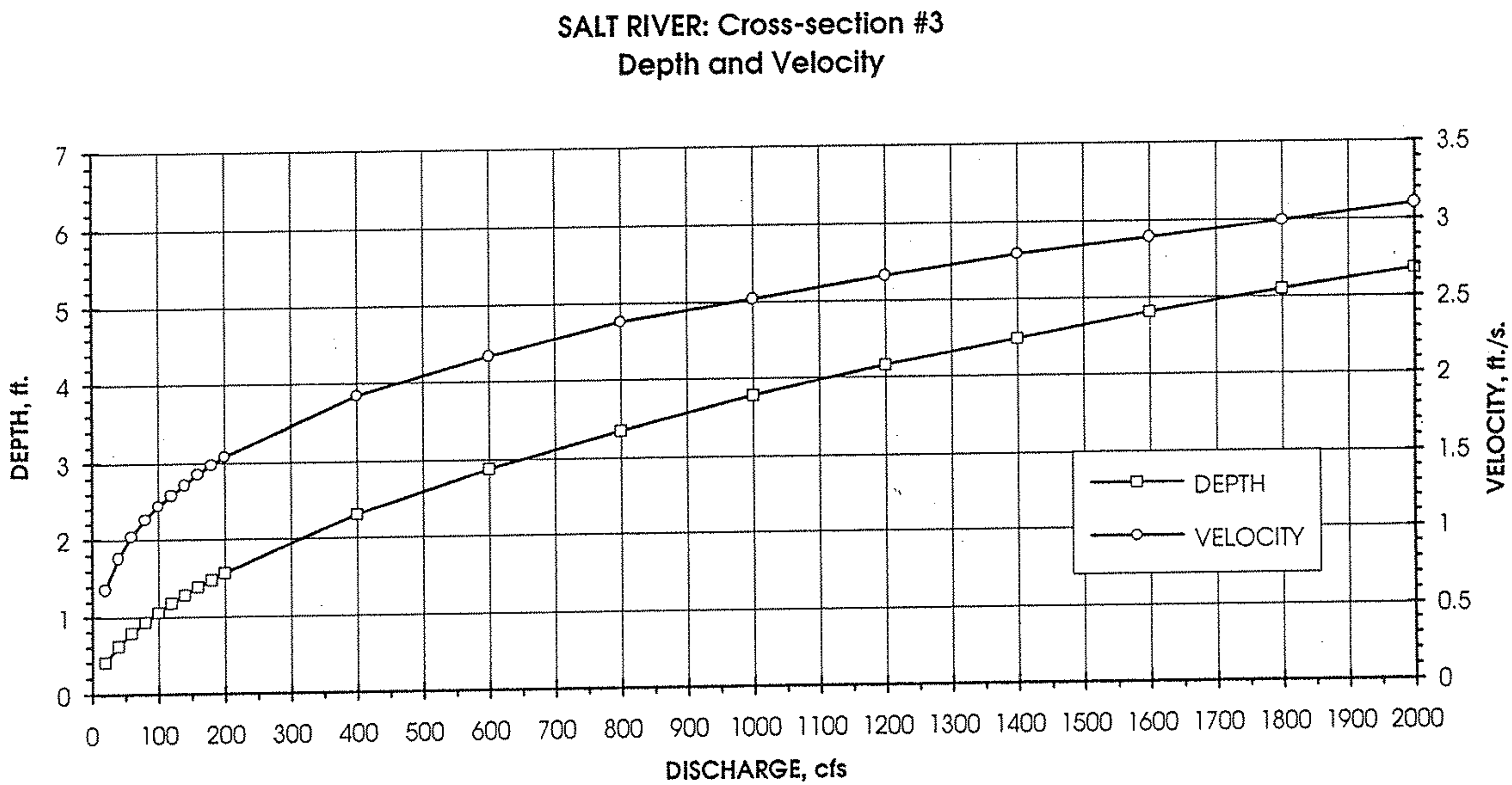
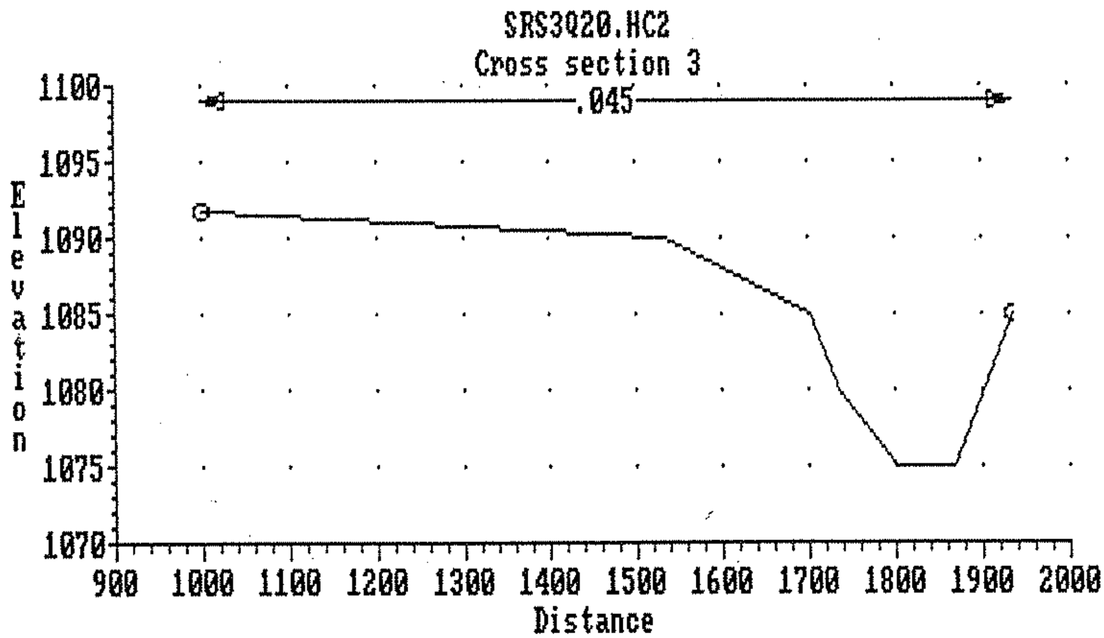
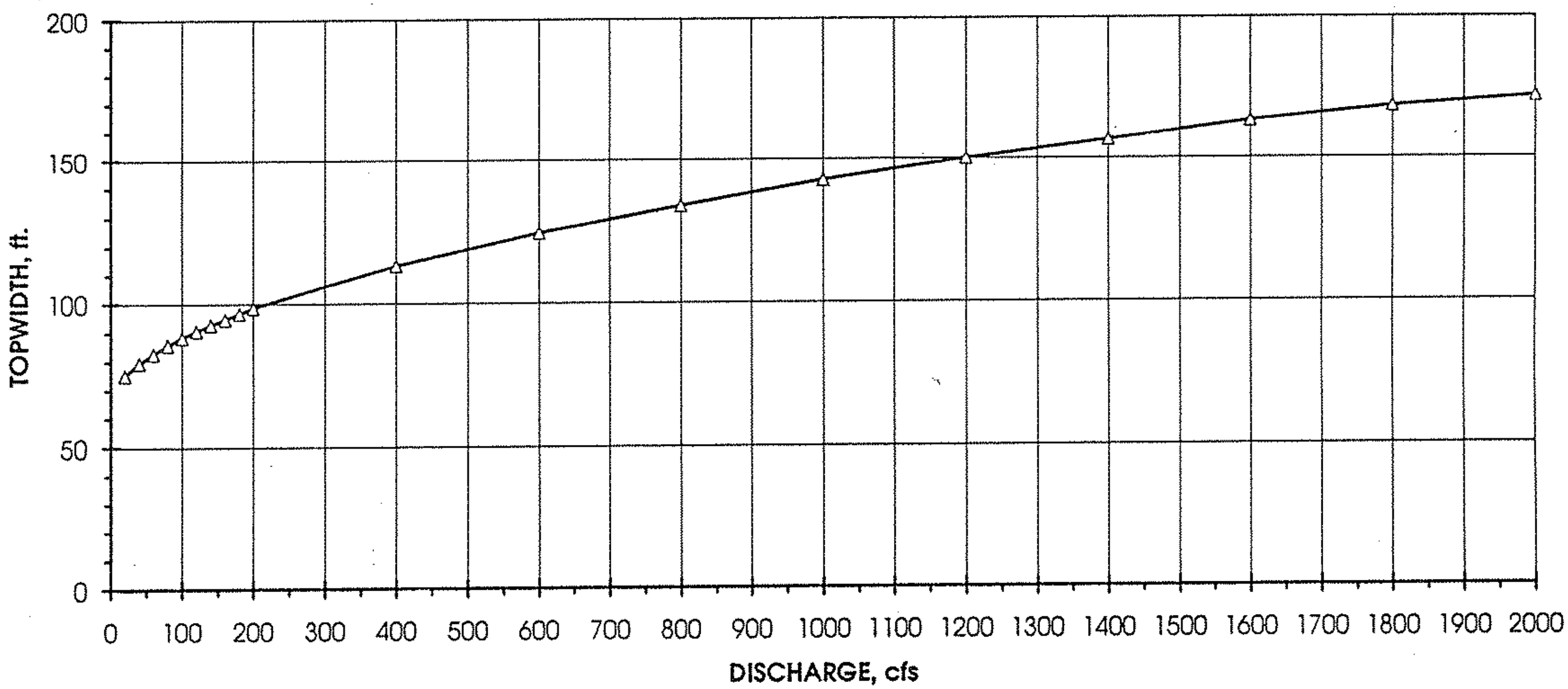
2200
2350
2500
2650
Distance


SALT RIVER: Cross-section #3
Depth and Velocity
DEPTH, ft.
VELOCITY, ft./s.
DISCHARGE, cfs
DEPTH
VELOCITY
0
1
2
3
4
5
6
7
0.5
1.5
2.5
3.5
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

SRS3-DV.XLC


SRS3Q20.HC2
Cross section 3
.045
1100
1095
1090
1085
1080
1075
1070
Elevation
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance

SALT RIVER: Cross-section #3
Topwidth



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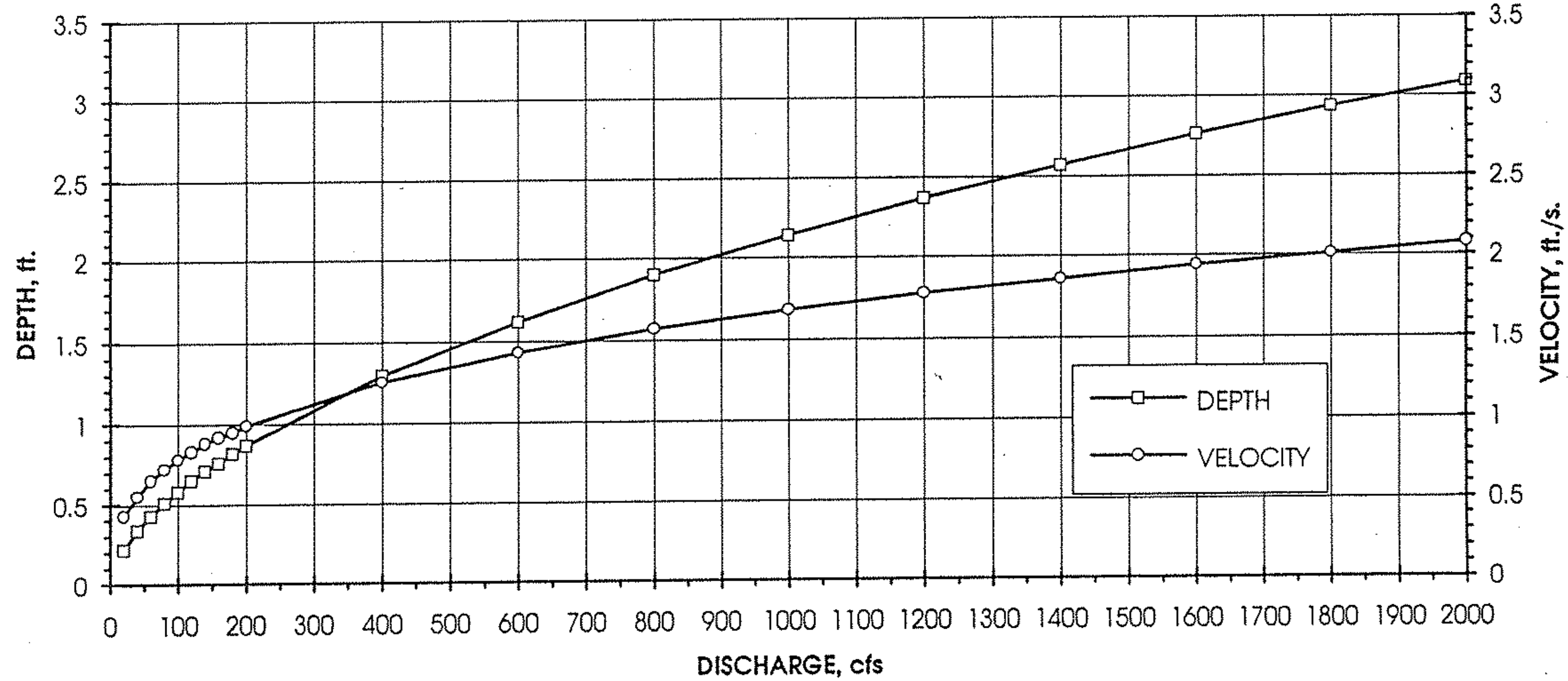
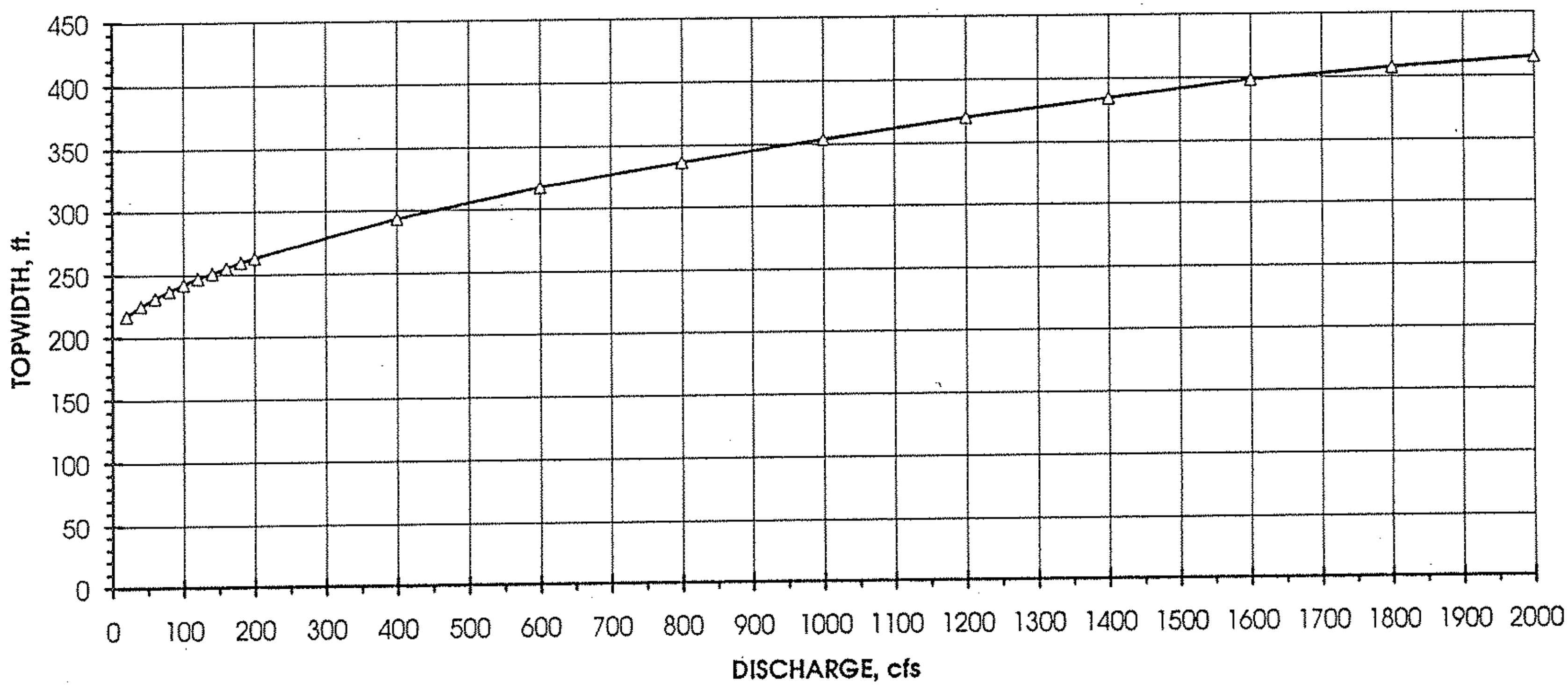
SALT RIVER: Cross-section #4
Depth and Velocity



SRS4-DV.XLC

SALT RIVER: Cross-section #4
Topwidth



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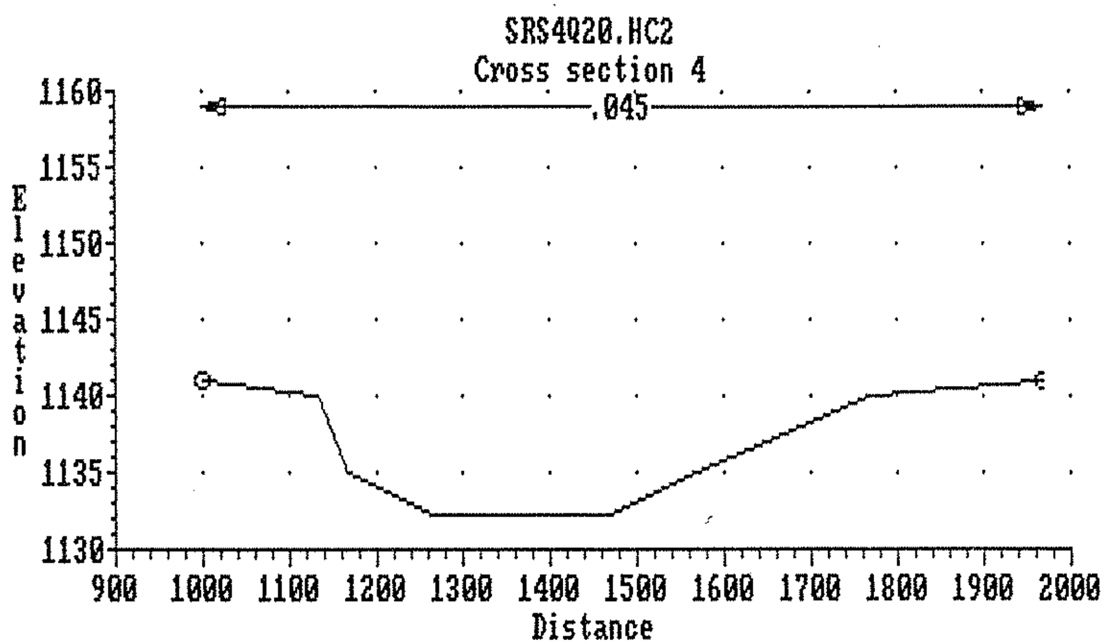
SRS4Q20.HC2
Cross section 4
.045
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1145
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1130
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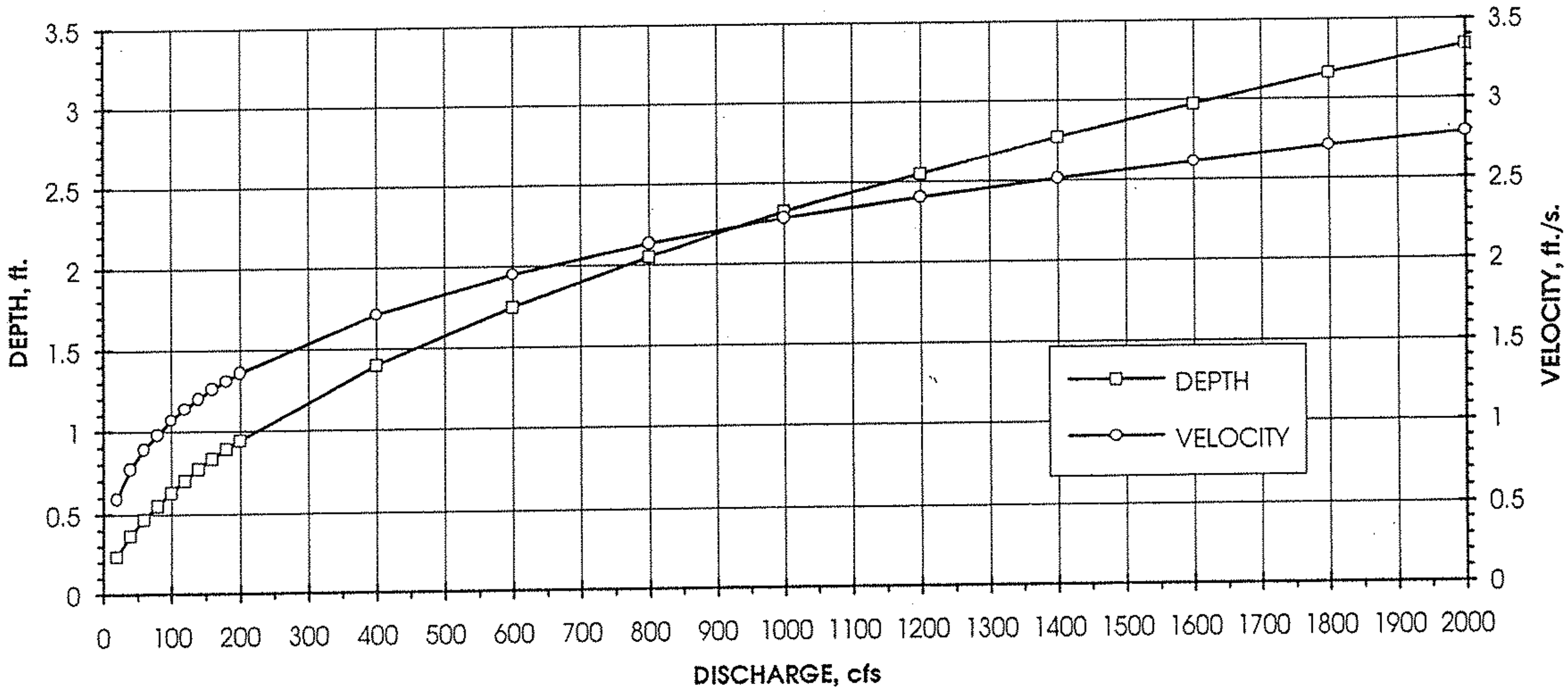
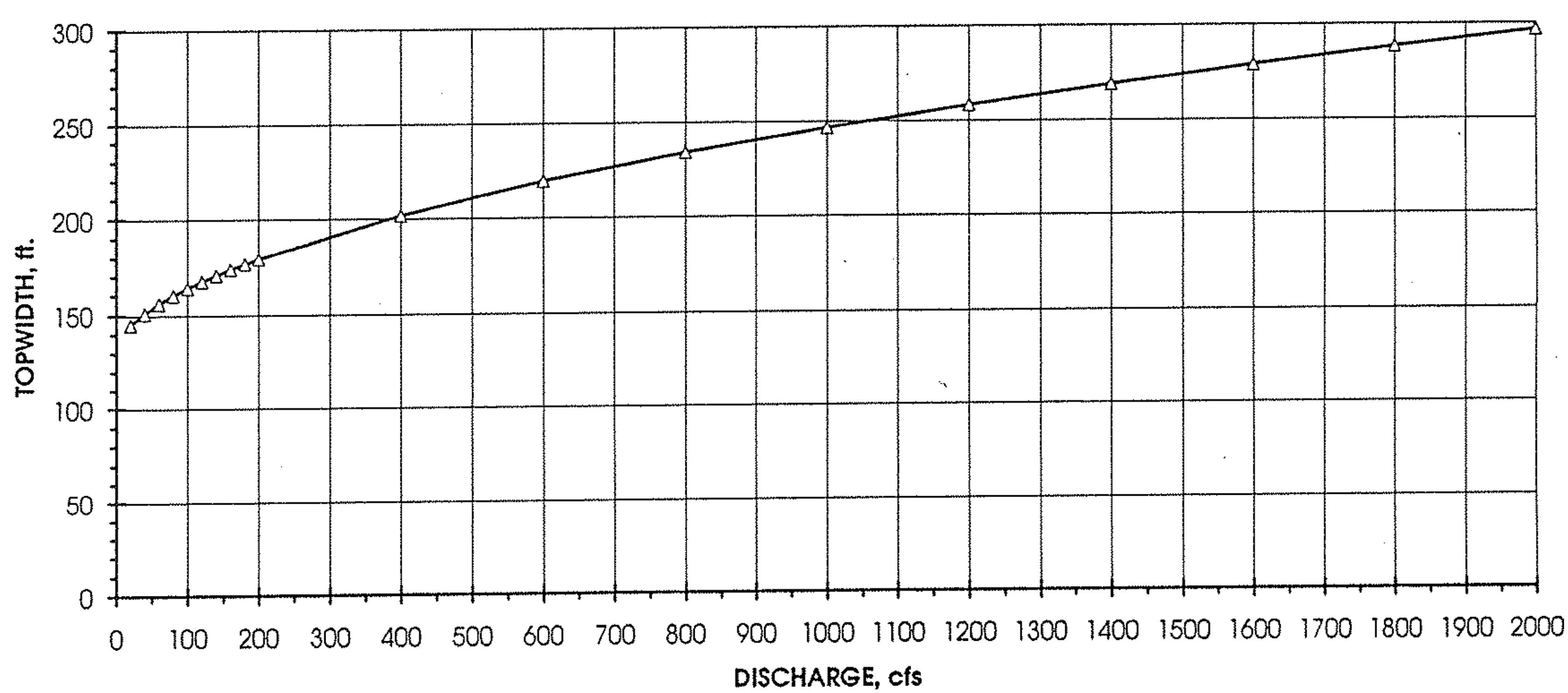
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance

SALT RIVER: Cross-section #5
Depth and Velocity



SRS5-DV.XLC

SALT RIVER: Cross-section #5
Topwidth



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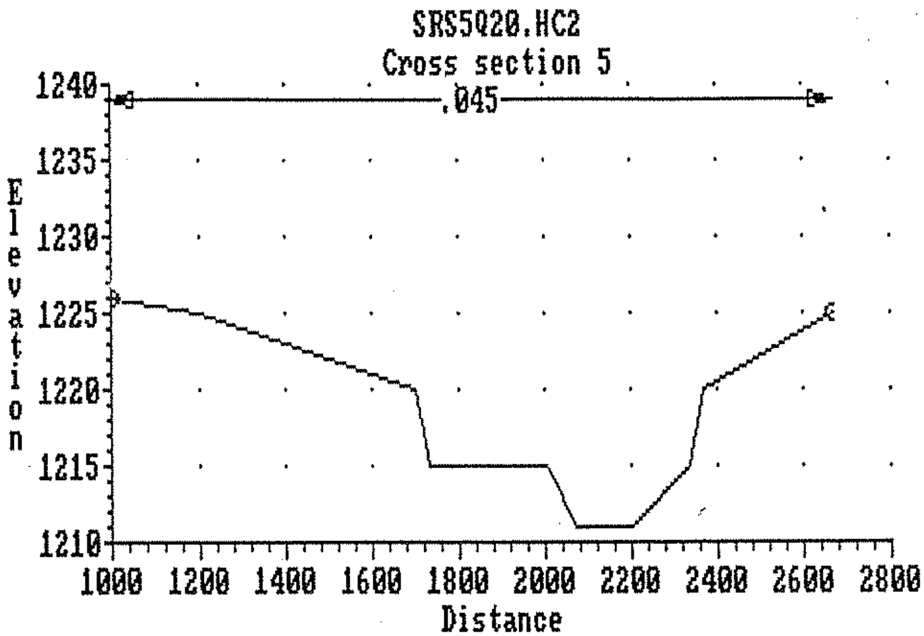
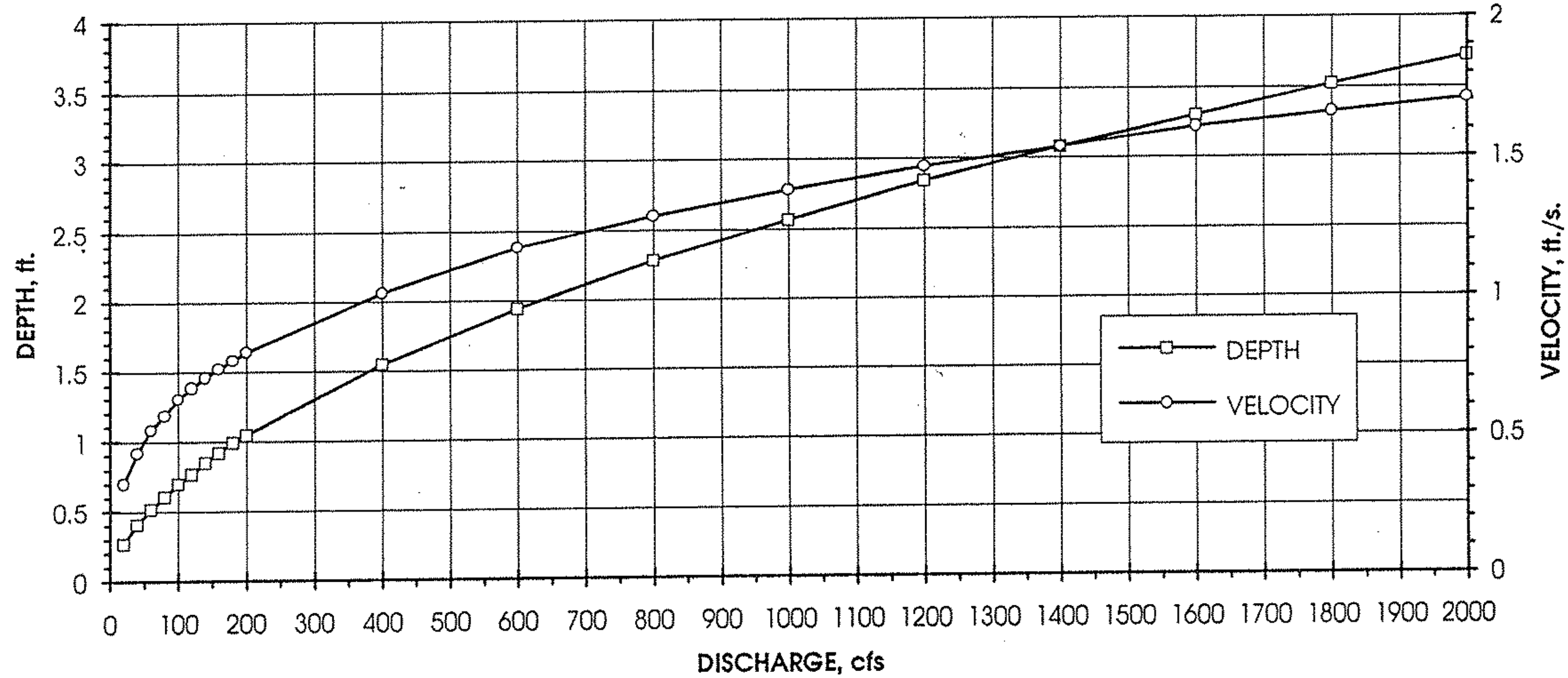


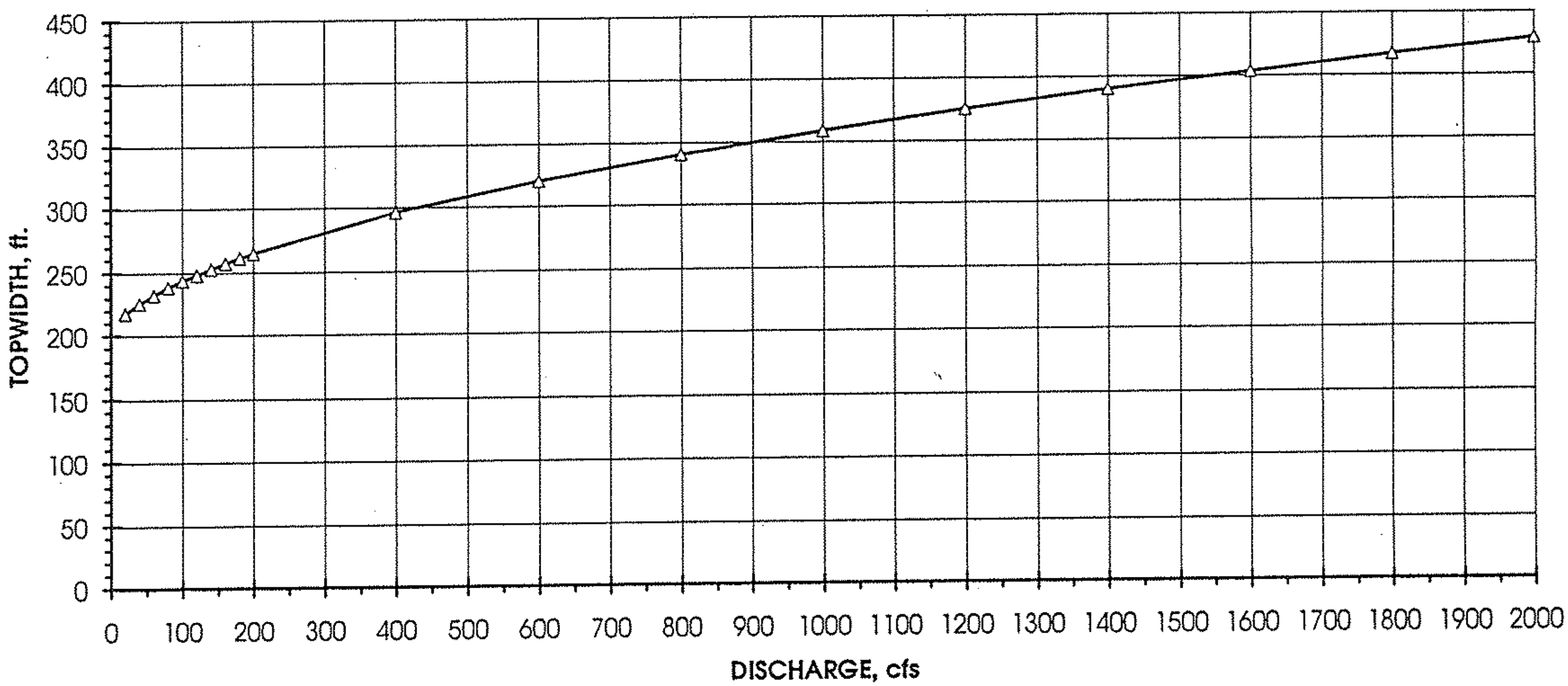
SRS5Q20.HC2
Cross section 5
.045
Elevation
1240
1235
1230
1225
1220
1215
1210
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
Distance

SALT RIVER: Cross-section #6
Depth and Velocity



SRS6-DV.XLC

SALT RIVER: Cross-section #6
Topwidth



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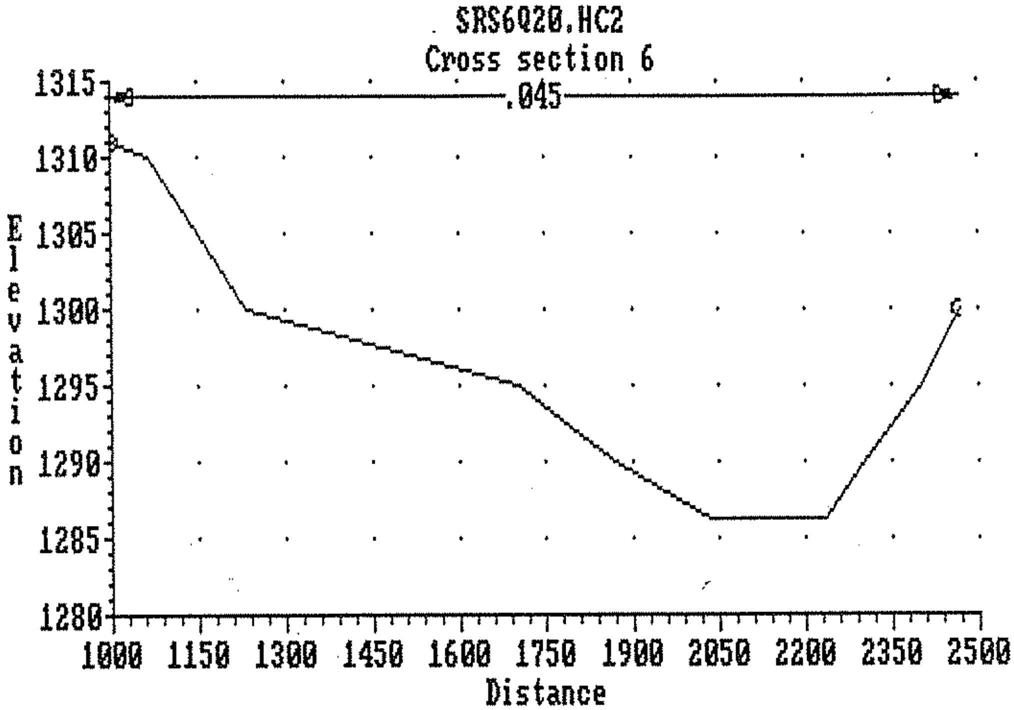
SRS6Q20.HC2
Cross section 6
.045
Elevation
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1285
1280
1000
1150
1300
1450
1600
1750
1900
2050
2200
2350
2500
Distance

Appendix E
Arizona Climatic Variation

Arizona Climatic Variation

Introduction

This appendix presents a brief overview of historical variation in Arizona climate with respect to potential navigability of Arizona. The objective of this overview is to provide information which may help address the following questions:

- Was the climate around the time of Arizona statehood (1912) significantly different from current or pre-statehood conditions?
- Does the period of record for stream gauges adequately represent long-term stream discharge rates?
- Have changes or fluctuations in Arizona climate changed streamflow conditions in a manner that would affect navigability?

Methodology

Information presented in this appendix is summarized from published sources. No new analyses of climatic data were conducted by the author. This summary focuses on climatic affects streamflow. Data from the published studies was derived from: daily precipitation and temperature readings for central and southern Arizona dating to the mid-1800's; stream flow gauge records by the U.S. Geological Survey (USGS), U.S. Reclamation Service (BUREC), and others dating to 1888; tree-ring records for the past 400 years; and other more recent regional or national weather data from the National Weather Service (NWS). Cited references have more detailed descriptions of data sources.

Stream Gauge Records

Gauge names and the periods of record for stream gauges used for stream navigability studies of the Salt, Verde, San Pedro, and Hassayampa Rivers are summarized in Table E-1. Only gauges with statistically significant periods of record were used. The gauge records generally do not account for irrigation diversions or other impoundments that would alter streamflow rates.

Table E-1 Period of Record for Key Stream Gauges Within Study Area	
Stream Gauge	**Period of Record (Water Years)**
Salt River @ McDowell Granite Reef (Arizona Dam)	 1-11/1889; 1901-1911
Verde River @ McDowell @ Tangle Creek nr. Camp Verde @ Camp Verde nr. Clarkdale nr. Paulden	 8-9/1889; 1897-1899; 1901-1936 1945-present 1934-1945; 1988-present 1914-1921 1915-present 1963-present
San Pedro River @ Palominas nr. Benson @ Fairbank @ Charleston nr. Tombstone nr. Redington @ Winkelman	 1930-1933; 1935-1940; 1950-1981 1966-1976 1912-1928 1904-1906; 1913-1926; 1929-1933; 1936-present 1967-1986 1943-1946; 1950-1978 5-8/1890; 1966-1978
Hassayampa River @ Walnut Grove/Wagoner nr. Wickenberg (Box Cyn) nr. Morristown nr. Arlington	 1912-1918 1921-1938; 1946-1982 1939-1947; 1964-1989 1961-1989

Arizona Climate Change

Climate change is measured by monitoring weather characteristics such as daily, monthly, seasonal, or annual temperature, precipitation, or relative humidity. Although weather records for the period prior to Arizona statehood in 1912 are not as extensive as for the period since statehood, sufficient data exist to give indications of pre-statehood climatic and streamflow conditions.

The BUREC began direct measurement of streamflow on the Salt-Verde system in late 1888 at the Arizona Dam irrigation diversion. Stream measurements have been continued to the present time by the USGS at several upstream locations. Smith and Stockton (1981) and Graybill (1989) used tree-ring[1] records to extend gauge records to 740 A.D.; Dean et al (1985), and Euler

[1] Tree ring studies assume the thickness of the individual annual rings are related to discharge. Wet year (high average annual flow) give rise to thicker rings. Individual tree rings can be readily matched to specific years. Smith and Stockton's data was calibrated using recent gauge data and recent tree ring records.

et al (1979) used tree-rings, pollen data, and alluvial sedimentation patterns to estimate periods of increased/decreased moisture to 600 A.D. Tree-ring records may be used to estimate annual flow volume. Smith and Stockton's interpretation of the tree-ring record indicates the following:

- The period from 1905-1920 (Arizona statehood) was the wettest period since 1580 in both the Salt and Verde River watersheds.

- The period from 1900 to 1979 (Salt River gauge record) had an average annual flow volume slightly greater than the 400 year mean annual volume.

- The period from 1940-1977 on the Salt River, and from 1932-1977 on the Verde River had below average annual runoff. This period corresponds to the majority of the gauge record of most Arizona stream gauges (Table E-1).

- Base flow in the Verde River is controlled by springs, rather than climatic factors. Low precipitation does not generally affect discharge from springs.

- Irrigation diversions impact Verde River streamflows.

Graybill's data also indicate that average flow from 740 -1370 A.D. was somewhat less than twentieth century average flows on the Salt River. However, summer low flows were found to have more predictable average flows during that period. Dean's and Euler's paleoenvironmental studies determined that there were no radical differences in the prehistoric Arizona climate compared to the modern climate.

Other tree-ring studies by Stockton (1975) elsewhere on the Colorado Plateau also found that the early 1900's was an unusually "wet" period. Unfortunately, tree ring data in the Hassayampa River and San Pedro River watersheds have not been analyzed. However, other investigations (c.f. BUREC, 1948) have demonstrated hydrologic similarity between the Hassayampa and Verde Rivers. Therefore, it is assumed that the long-term climatic trends predicted for the Verde River apply to the Hassayampa River.

For the San Pedro River, climatic data older than 1904 streamflow records and 1867 rainfall records are not available. However, the impact of climatic change on the San Pedro River has been extensively studied. Cooke and Reeves (1976) analyzed precipitation records from 1867 to 1960 for southern Arizona and concluded that the:

- Total annual, annual summer, and annual non-summer precipitation volumes did not significantly change from 1867 to 1960, although total precipitation volume varies significantly from year to year.

- Frequency of heavy rains (>1 inch/day) decreased significantly from 1867 to 1900, and decreased slightly thereafter.

- Frequency of light rains (<0.5 inch/day) increased significantly from 1867 to 1900, and increased slightly thereafter.

Hastings and Turner (1965) reach similar conclusions as Cooke and Reeves, and also note a slight increase in average temperature since 1895. Since the heavier rains result in stream runoff, decreasing intense rain events and increasing light rain events probably decreased stream runoff in the San Pedro River. Since the San Pedro is not strongly impacted by snowmelt runoff, increasing the total annual volume of light winter rains did not influence runoff. Finally, the Arizona Department of Water Resources (1991) also reports generally declining flow rates in the San Pedro between 1913 and 1988.

In regional climatic studies, Sellers (1960) recorded a decreasing, but not statistically significant, trend in total annual precipitation averaging about 0.03 inch/year. Thomsen and Eychaner (1991) statistical analysis of 109 years of rainfall records from the Tucson Basin indicated no trend in precipitation. Peterson (1950) demonstrated that total annual precipitation was above average between 1881 and 1884, a period of extensive channel change in southern Arizona. In northern Arizona, Hereford (1984) notes a period of lower than average runoff and precipitation and above average temperature in the 1940's and 1950's when compared to records for the rest of the twentieth century. This drought period affected most of the Rocky Mountain States. Hereford also concludes that beginning in 1900, precipitation abruptly increased until about 1910, at which a progressive decline began that lasted until 1956. Since 1956, average temperatures have cooled somewhat, and discharges increased somewhat. Regional analyses of archeological data have concluded that there were no radical differences in climate that would have affected streamflow (Graybill and Gregory, 1989).

Analysis of national climatic data by Diaz and Quayle (1980) indicates that in the southwest, the period between 1920 and 1954 had warmer winters, cooler summers and less precipitation than the period from 1895 to 1920. These data generally support the observations of Hereford (1984) and Stockton (1975) cited above, and suggest that climatic conditions may have favored higher runoff rates around the period of Arizona statehood.

Conclusions

The affects of climatic variations on potential stream navigability and channel conditions are complex, and cannot always be clearly distinguished from stream changes initiated by man. However, some basic conclusions can be drawn from the studies cited above.

First, Arizona's climate at statehood was not drastically different from existing or pre-statehood conditions. The same basic climatic patterns applied. Summers were warm and relatively dry with intense, late summer monsoonal rainfall. Winters were cool, with less intense Pacific frontal storms bringing snow to higher elevations and rain to lower elevations. However, subtle difference in rainfall and temperature patterns around the time of statehood may have resulted in higher average streamflow. These differences included:

- Generally higher precipitation and streamflow volumes

- More frequent intense monsoonal rainfall
- Cooler average temperatures, with warmer summers and cooler winters

Therefore, the period surrounding statehood was probably subject to higher than average streamflow, indicating that streams may have been more likely to have been navigable at statehood, than during other, less "wet" periods of Arizona history.[2] It is noted that some of Arizona's largest floods, in terms of both volume and peak flow rate, occurred in the twenty years prior to statehood.

Second, stream gauge records must be used cautiously to adequately predict the natural, long-term average discharge rates. Tree-ring records indicate that the average annual flow rates on the Salt and Verde Rivers between 1900 and 1980 are just slightly above the average annual flow rates for the past 400 years. Gauge records from 1905 to 1920 may predict average flow conditions well above long-term average rates, but may accurately reflect conditions at statehood. Gauge records with the majority of years of record in the 1940's and 1950's may predict average flow conditions below the long-term average, and well below the wetter conditions at statehood. Of course, stream gauge data must also be filtered to account for human impacts on streamflow, such as reservoirs, irrigation diversions, and groundwater withdrawal. *In general, use of the existing stream gauge database will probably result in prediction of flow rates less than those that existed at statehood.*

Third, changes in climatic conditions may have in fact altered stream conditions that would have affected navigability on some Arizona streams.

- For the Salt River, climatic changes are almost completely obscured by human impacts on the stream system. These human impacts include construction of reservoirs, irrigation diversion, groundwater withdrawal, channelization, mineral extraction from the river bed, and addition of urban storm waters. Climatic conditions may have contributed to somewhat higher low flow channel stability due to sustained, higher (low) flows. Conversely, extreme floods which occurred in the three decades prior to statehood may have adversely affected channel conditions.

- For the Verde River, climatic variation has little affect on low flow conditions due to steady base flow from springs and geologic control (bedrock) for much of the river. In the more densely populated, alluvial reaches of the Verde Valley urbanization may obscure climatic impacts. However, climatic records indicate that higher than average flow in the Verde River probably occurred around the time of statehood, making navigation more possible at statehood than during other periods of history.

---

[2] Human impacts such as reservoir construction, ground water withdrawal, etc., have tended to lessen average stream discharge rates obscuring climatic affects on some Arizona streams.

- For the Hassayampa River, like the Verde River, climatic changes probably had minimal impact on whether the Hassayampa River was navigable at statehood. Hassayampa River low flows and channel geometry are probably more controlled by geology (bedrock and springs) and flood hydraulics, than by minor climatic perturbations. Very little evidence of climatically induced channel change was uncovered.

- For the San Pedro River, climatic changes may have had a more significant impact on potential navigability of certain stream reaches, particularly for the period preceding statehood. Several studies have demonstrated a strong climatic influence on arroyo cutting in the San Pedro River in the late 1800's. Development of arroyos changed reaches of the San Pedro River from cienega's, beaver dam impoundments, and marshlands (which may have been navigable) to sand-bottomed channels with steep vertical banks. However, this arroyo cutting episode is thought have been substantially complete before statehood. Since statehood, the subtle climatic changes that have occurred tend to make the San Pedro River less navigable than at statehood. That is, runoff producing rainfall frequency has decreased. In addition, other factors have reduced average streamflow rates from statehood levels.

Summary

Some data available from which to evaluate climatic conditions at the time of statehood relative to the climate during other periods of Arizona history. These data indicate that the period around statehood favored higher runoff rates in many Arizona streams than in the years preceding or following statehood. Use of modern streamflow records will generally result in estimates of flow rates less than what actually occurred at the time of statehood. In general, however, these minor climatic perturbations have less impact on stream navigability than have human-induced changes to the watersheds and stream channels.

Appendix F

Boating on Arizona Rivers

Boating Survey Results
Central Arizona Paddlers Club

Received from.
Dorothy Lees Riddle
Central Arizona Paddlers Club
PO Box 45344
Phoenix, AZ 85064 - 5344
(602) 271 - 4012

Central Arizona Paddlers Club
Boating Survey of Arizona Rivers
1992

(Approximately 20% of our membership responded to the survey.)

River	Segments our members have boated
Salt	K&M Mine to Hwy. 60 Alma School Rd. to Mill Ave. (Mesa/Tempe) Hwy. 60 to Roosevelt Lake Granite Reef to McKellips Rd. (Past Tri-City Landfill) Saguaro Lake to Granite Reef (Tuber's Run) Hwy. 60 Bridge to Hwy. 288 Bridge (Bridge to Bridge) Upper Salt Lower Salt Horseshoe Bend 100% of Salt River including normally dry & lakes All Sections Country Club Rd. to 35th Ave. Source to Phoenix Granite Reef to Gilbert Road Lower Salt through town Upper, Middle, Lower, and In Town
Verde	Perkinsville to Clarkdale Camp Verde to Childs Beasley Flats to Childs Childs to Horseshoe Lake Rio Verde to Salt River Camp Verde to Sheep Bridge Needle Rock to Beeline Hwy. Lower Verde Upper Verde Camp Verde to Beasley Needle Rock to Salt River Horseshoe Lake to Salt All of Verde from Camp Verde down All Sections Camp Verde to Horseshoe Lake Clarkdale to Horseshoe Lake Between Horseshoe and Bartlett and below Bartlett
East Verde	Doll Baby to Verde to Horseshoe Lake
San Pedro	Palominas to Hereford Rd.

Agua Fria	Black Canyon/New River Area Black Canyon City to above Lake Pleasant
Gila	Gila Box 115 Ave. in Phoenix to Estrella Parkway 91st Ave. in Phoenix (Salt River) to Estrella Mineral Springs to Ashurst Hayden Dam Old Bridge (near Clifton) to Safford (Gila Box) Confluence of San Francisco to Safford San Carlos Dam to Ashurst Hayden Dam 10 miles above Winkelman to Winkelman Most of the Gila (dry parts too) through Arizona Winkelman to Ashurst Hayden Dam Winkelman to Kearny Gillespie Dam to Painted Rock Dam Below San Carlos Dam Clifton to Solomon, Arizona (Gila Box) Clifton to Safford Christmas to Winkelman
San Francisco	New Mexico to Clifton Clifton to Confluence of Gila
Colorado	Lee's Ferry to Phantom Ranch Diamond Creek to Pierce's Ferry Lee's Ferry to Pierce's Ferry Grand Canyon Below Hoover Dam Through Topock Canyon Hoover Dam to Yuma Parker to Lake Havasu Topock to Lake Havasu Below Hoover Dam (Black Canyon) Parker Dam to Martinez Lake Glen Canyon to Lee's Ferry All Sections
Little Colorado	
Blue	
Black	Bonita Creek to Black River Crossing Point of Pines to Salt River Source to Salt

White	Indian Reservation to K&M Mine Road White River Crossing to Salt River
Sycamore Creek	Hwy. 87 Bridge to Sugarloaf Mountain
Tonto Creek	Gisela to south of Jake's Corner Rye Creek to Roosevelt Lake Gisela to SRP Gauge Gisela to Roosevelt Tonto Box Rye Creek to Jake's Corner
Bonita Creek	Tonto Creek to Black River
Cherry Creek	
Fish Creek	
Burro Creek	
Indian Bend Wash	

Appendix G
Salt River GIS

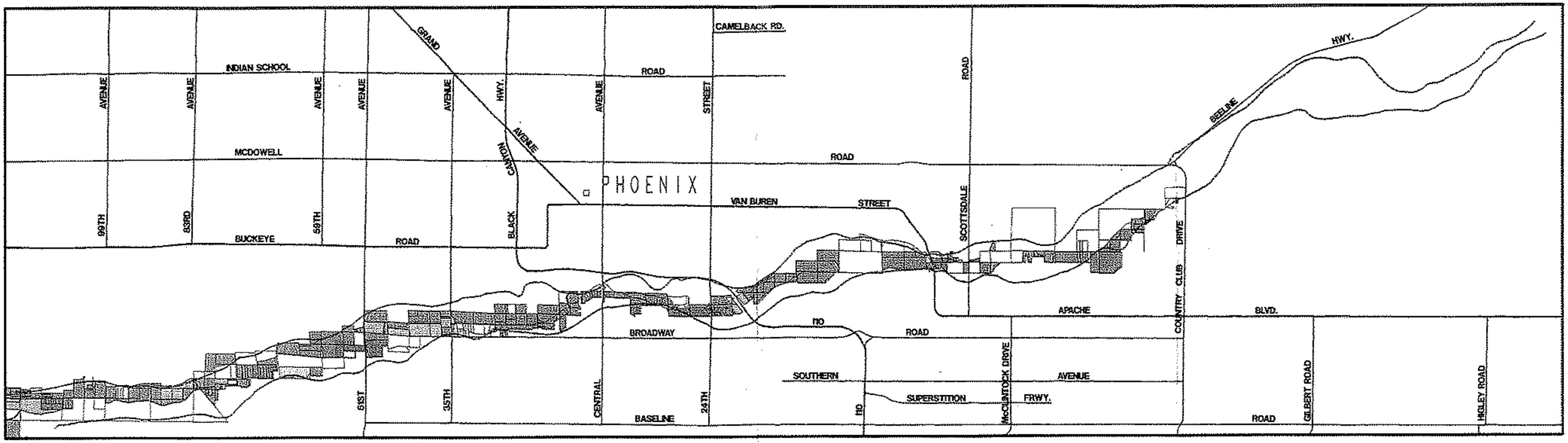
Salt River GIS

Note: The Maricopa County Flood Control District (FCD) maintains a GIS of a portion of the Salt and Gila Rivers. However, nearly 40% of the parcels are incomplete. The remaining parcels were updated with a more recent Metroscan dump, resulting in the statistics given in Tables 11 and 12 in the text.

Salt River GIS Plots

1. Land Ownership GIS & Ordinary Highwater Mark
2. Land Use

Land Ownership for Salt River Reach



Unknown
Private
State
BLM
Gila River Indian Res.

Ordinary Highwater Mark as of statehood

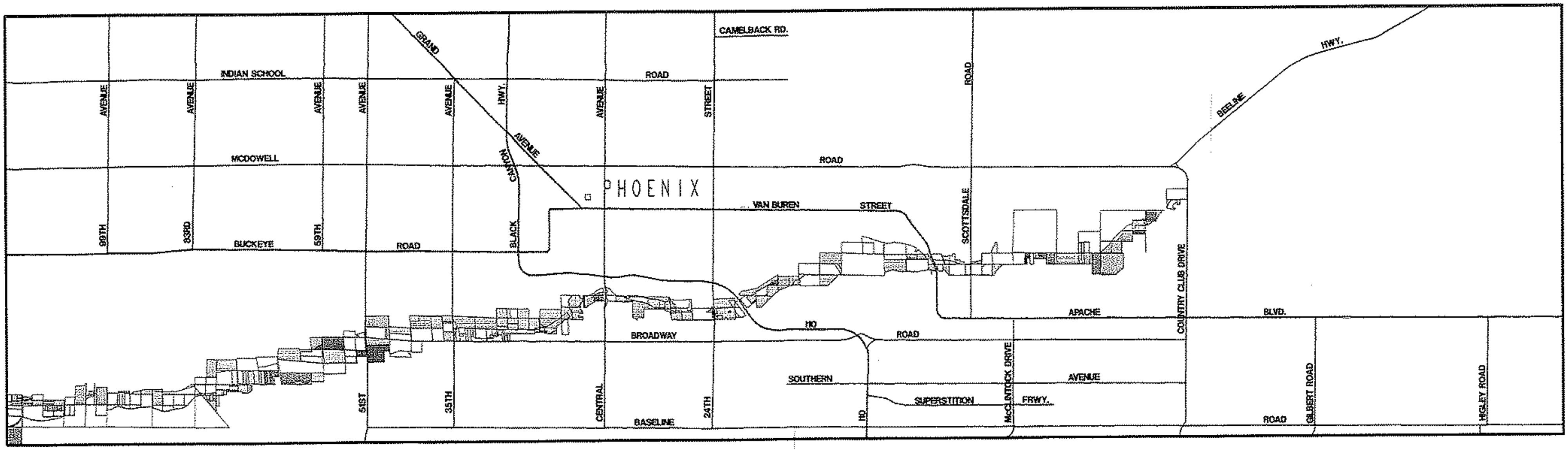
SWCA INC.

Arizona State Land Department, Natural Resources, 1915

Land ownership based on data from Maricopa County Assessor's Office

GIS data from Flood Control District Maricopa County

Land Use for Salt River Reach



- Unknown/Unclassified
- Misc. Undeveloped
- Crops/Orchards
- Misc. Developed
- Residential
- Misc. Commercial
- Retail/Wholesale/Warehouse
- Misc. Industrial
- Mineral/Mining
- Municipal/County
- Parks/Recreation/Drainage

0 2000 4000
meters

SWCA INC.

ARIZONA STATE LAND DEPARTMENT NATURAL RESOURCES 1915

☞Land use based on data from Maricopa County Assessor's Office

☞GIS data from Flood Control District Maricopa County

Appendix G.1: Data Formats

INFO (PAT) FILE FORMAT

QUAD	4 C
TOWNSHIP	4 C
RANGE	4 C
SECTION	2 C
COUNTY	2 I
BASELINE	1 I
TRS_SOURCE	2 I
OWNER	2 I
OWN_SOURCE	2 I
STATUS_DAT	8 D
BOOK	3 C
MAP	3 C
PARCEL	4 C
OWN_CODE	12 C

Items QUAD through STATUS_DAT are identical to the corresponding items in ALRIS's LAND library.

OWN_CODE = COUNTY+BOOK+MAP+PARCEL

RELATE FILE FORMAT (Privately owned and some agency lands)

OWN_CODE	12 C
OWNER	40 C
ADDRESS1	40 C
ADDRESS2	40 C
ADDRESS3	40 C
ADDRESS4	40 C
LANDUSE	4 C
STCODE	4 C [State landuse code]

SALTP PAT FORMAT (UNREVISED GIS)

OWNER	2 I
OWN_CODE	12 C
OWNER_C	40 C
ADDRESS1	40 C
ADDRESS2	40 C
LANDUSE	4 C
STCODE	4 C [State landuse code]

RVG AND TNK PAT FORMAT

TYPE	13 C	[National Wetlands Inventory Classification]
MO*	2 I	
YR*	2 I	
QUAD	4 C	
ACRES**	17 N 6	
KEY	4 C	[Simplified version of TYPE]

*Present only in "Final" layers
**Present only in RVG layer

STR PAT FORMAT

TYPE	13 C
QUAD	4 C

SPVEG PAT FORMAT

TYPE	13 C	[Brown and Lowe Digital Classification]
ACRES	17 N 6	
MAP_LABEL*	6 C	
DESCRIP*	32 C	

*Identical to items in ALRIS NATVEG layer.

Land Use Categories and Codes

0000	Unknown / unclassified undeveloped / open space
1000	Agency administered -- unclassified
1010	Wilderness or wildlife refuge
1100	Agricultural -- unclassified or multi-use
1110	Field Crops/Orchards
1120	Grazing/Pasture
1200	Timber sale
1300	Mining Claim
1400	Right-of-Way
1900	Undeveloped privately owned open space
2000	Developed -- unclassified
2100	Residential -- unclassified or multi-use
2110	Single Family
2120	Multi-family
2200	Commercial -- unclassified or multi-use
2210	Office / banking
2220	Retail / wholesale / warehouse
2300	Industrial -- unclassified or multi-use

2310 Mineral/mining
2320 Salvage yards / equipment storage
3000 Municipal / County
3100 Administrative
3200 Field facilities / shops
3300 Parks / recreation / drainage
3400 Water / wastewater treatment plants

Appendix G.2: Data Inventory

Land Ownership/Use GIS (names correspond to ALRIS LAND tiles):

Verde:	PPRESE, PSEDONW, PPAYW, PTRW
San Pedro:	PNOGE, PFORTHE, PTUCE, PMAME, PMAMW
Hassayampa:	PPHXSW, PPHXNW, PBRADW, PPRESW
Salt:	SALTP
Gila:	GILAP

Relate Files:

Verde:	VE_OWN
San Pedro:	SP_OWN
Hassayampa:	HA_OWN

Riparian Data

Verde Final GIS:	FRVG, FTNK, FSTR
San Pedro:	SPVEG

SALTP PAT FORMAT (UNREVISED GIS)

OWNER	2 I
OWN_CODE	12 C
OWNER_C	40 C
ADDRESS1	40 C
ADDRESS2	40 C
LANDUSE	4 C
STCODE	4 C [State landuse code]

Salt River Glossary

Glossary

Acequia. An irrigation ditch or canal.

Agglomerate. Sedimentary rock type formed of detrital volcanic material explosively ejected from a volcanic vent, with clasts larger than 32 millimeters.

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 Ground Water. Ground water found in alluvium, as opposed to ground water found in bedrock. See Alluvium and Ground Water.

Alluvial Stream. A stream whose bed and banks are formed in sediment transported by the stream itself; a stream with a non-bedrock channel.

Alluviation. Progressive deposition of sediment, raising the elevation of the depositional surface.

Alluvium. A general term for eroded rock material, including soil, deposited by rivers; loose sediment, often from the recent geologic past.

Amplitude. A characteristic of a river meander describing the distance, perpendicular to the river valley, between opposite river meanders; A meander with high amplitude has broad bends, a river with low amplitude meanders is relatively straight.

Anastomosing. A stream pattern characterized by a net-like or interwoven channel pattern, with individual flow paths better defined or permanent than braided channel flow paths.

Andesite. A volcanic rock type mostly composed of plagioclase (Calcium bearing feldspar minerals) and other mafic (Calcium- or magnesium-bearing) minerals.

Anecdotal. Undocumented evidence or accounting of an event.

Angle of Repose. The maximum slope at which cohensionless soil or sediment material will remain stable.

Apex. The point on an alluvial fan where the stream intersects the mountain front.

Aquifer. A water-bearing bedrock or alluvium layer.

Archeology. The systematic recovery, and scientific study, of material evidence of human life and culture from past ages. The study of antiquity.

Arkose. Rock type, generally sandstone, composed of more than 25 percent silica-feldspar minerals.

Armoring. A stream process by which fine sediments are eroded from the bed or floodplain of a stream, leaving only coarser sediments. The coarser sediments protect the stream bed from further erosion, "armoring" the bed.

Arroyo. A term used in the southwest to describe an entrenched, dry wash.

Artesian. Artesian wells tap surface water that is under suffient pressure to make the wells flow without pumping.

At-Grade Crossing. Road crossing of a stream that goes directly on the stream bed, rather than over a culvert or bridge.

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.

Axial Stream. A stream which drains the center of a valley, usually between opposite bajadas formed on parallel mountain fronts.

Bajada. A piedmont comprised of coalescing alluvial fans.

Bar and Swale Channel Form. Channel bars are small islands composed of the larger clasts (particles) of bed load material deposited during high flow and exposed during low flow. Channel swales are the low flow areas located between bars; the low flow thalweg.

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.

Bed Load. The portion of sediment in a stream which is transported by rolling, bouncing, or sliding on the stream bed.

Bedforms. Features formed on channel bottoms by sediment in transport, including dunes, ripples, and antidunes.

Bifurcation. The division of a stream into two or more channels in the downstream direction; a channel split.

Bimodal. A frequency distribution with two peaks is called bimodal.

Bioclimatic. Pertaining to relations of climate to biological or living matter.

Biotic. Having to do with living organisms.

Block Faulting. Large scale fracture of rock units resulting in tilting and uplift, usually to form mountains.

Bottomland. Floodplain.

Braided. A braided stream is one flowing with branching and reuniting channels. May be ephemeral or perennial.

Breccia. A rock unit composed of coarse highly angular fragments.

Cadastral Survey. A land (legal) survey.

Calcalkaline. Basic calcium bearing rock.

Calcareous. Calcium rich.

Caliche. Calcium carbonate ($CaCO_3$) deposited and illuviated in arid region soils cemented into a petrocalcic horizon; often as Stage IV carbonate.

Carbonate Stage. Stage I carbonate is loose disseminated $CaCO_3$ in the soil matrix. Stage II carbonate is thin, discontinuous coatings of $CaCO_3$ on the bottoms of coarse clasts in the soil matrix. Stage III carbonate is continuous coatings of $CaCO_3$ on the majority of coarse clasts in the soil matrix. Stage IV carbonate is replacement of the original soil matrix by a thick, well-cemented layer of $CaCO_3$.

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.

Check Dam. A small, or temporary dam, usually intended to maintain a desired water elevation in a canal.

Clasts. Rock fragments or other material which has been transported.

Concave Stream Profile. A stream whose slope decreases in the downstream direction appears concave in profile, opposite of convex.

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.

Contraction Scour. A form of river bottom scour frequently occurring at bridges where stream width rapidly decreases causing an increase in stream velocity and/or turbulence.

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."

Cratonic Sequence. A series of rock types deposited in a tectonically stable environment, usually on a continental shelf.

Crenulation Index. The ratio of the topographic contour length to the straight line distance along the arc of the contour. A low crenulation index indicates low relief and a uniform surface.

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. Also see continuous gage.

Cretaceous. A period of geologic time. See table attached to glossary.

Crystalloblastic. A crystalline texture due to metamorphic recrystallation such that original mineral may have inclusions of minerals formed during metamorphism.

Cyclonic. Arizona weather patterns derived from cyclones originating over the Pacific Ocean are called cyclonic storms.

Degradation. Channel bed erosion resulting in a topographically lower stream bed.

Dendritic Drainage Pattern. A drainage system with tributaries which join at all angles, similar to the branching pattern of a tree. The number of flow paths decrease in the downstream direction.

Desertification. The process of a landscape developing desert characteristics.

Detrital. Detritus is material carried and deposited by wind or water, especially grains of rock particles.

Difluence. See bifurcation. The p oint o f s eparation o f s tream c hannel i nto t wo o r m ore channels.

Dike. An thin, flat igneous rock unit which unconformably cuts across other rock units.

Dominant Discharge. The dominant discharge is believed to be the stream flow rate responsible for forming a stream's geometry. This theory is somewhat tenuous when applied to stream in Arizona or bedrock streams.

Dynamic Equilibrium. A natural condition of regular, expected channel change such the stream characteristics are adjusted to the physical conditions of the environment.

Emphemeral Stream. A stream which flows only in direct response to rainfall.

Empirical. Empirical methods are based on experimentally derived equations, rather than theoretically derived equations.

Entrenchment. (Entrench, E ntrench) P rogressive 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.

Equilibrium. Balance. When applied to streams, equilibrium means lack of change.

Erosion. Removal of bedrock or alluvium by water or wind.

Escarpment. A steep bluff, or cliff.

Ethnography. The scientific study of culture.

Euroamerican. North Americans of European descent.

Evaporites. Sedimentary rock types formed by evaporation of water; for example, halite and gypsum.

Evapotranspiration. Losses of water from a stream, lake, or other water body to the atmosphere; includes evaporation (transfer of water molecules from the liquid phase to the gas phase - vapor) and transpiration (transfer of water molecules to the atmosphere by plants, usually through their leaves during the process of photosynthesis).

Facies. A grouping of sediments, rocks, or soils with a common or related origin.

Fanglomerate. Rock and soil material originally deposited as an alluvial fan which has since been transformed into bedrock. Fanglomerates are characterized by a wide range of grain sizes and bedding types.

Faulting. Movement which displaces adjacent rock masses. E.g. offset on the San Andreas Fault in Southern California.

Faunal Remains. Animal bones and other parts that are recovered from archeological contexts.

Feldspar. A potassium bearing silicate mineral.

Felsic. A term applied to potassium feldspar and silica rich rock types.

Feral Salt Cedar. A wild, undomesticated tamarisk tree.

First Terrace. Term used by archaeologists to describe portion of a river floodplain closest to the river. See Terrace.

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.

Flexed Inhumation. Burial in a bent position.

Flow Duration Curve. A graph depicting the percent of time a given discharge on a stream is exceeded. For instance, a 10% flow of 20 cfs means that the stream discharge only exceeds 20 cfs, 10 percent of the time; a 90% flow of 1 cfs means that the stream flows at discharges greater than 1 cfs 90 percent of the time; the 50% 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.

Freshets. A flow of water, often a flash flood.

Gaining Stream. A gaining stream increases its flow rate in the downstream direction, usually due inflow of groundwater. See Losing Stream.

Geoclimatic. Pertaining to relations of climate to geological forces or materials.

Geologic Time Scale. See Figure G-1

Geomorphic. Parameters or variables relating to geomorphology.

Geomorphology. A branch of geology concerned with the formation, characteristics, and processes of landforms, including rivers.

Giant Powder. An explosive.

GIS. Geographic Information System. A database which relates information to spatial characteristics of some land area.

Gneiss. A type of metamorphic rock characterized by a lineation of the mineral grains which comprise the rock.

Grabens. Downdropped blocks of rock material bounded by normal faults. See Horsts.

Granite. An intrusive igneous rock consisting of primarily of quartz and alkali feldspar.

Granoblastic. A secondary texture found in metamorphic rock characterized by recrystallization to equigranular size.

Graywacke. A type of sandstone characterized by detrital sand grains in a clay matrix. A dirty hard sandstone.

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.

Horsts. Uplifted blocks of rock material bounded by normal faults. See Grabens.

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.

Igneous. Rocks formed from molten material, e.g. lava or magma.

Immature Vegetative Species/Communities. This term is used by the Soil Conservation Service to describe invasive plant species which are first to colonize a devegetated area. In Maricopa County, these species often include creosote, bursage, and salt cedar. Small, young plants of more stable species may also be included.

Incised Channel. A stream or waterway which has eroded its bed, creating steep or vertical stream banks. An arroyo, or degraded stream channel.

Inhumation. Burial.

Inselbergs. Isolated remnants of bedrock exposed as small hills or buttes in the alluvial plain or pediment.

Instantaneous Flow Rate. Stream discharge at an instant in time, as opposed to a discharge averaged over a period of time (See Mean Flow).

Interfluves. The area between braided flow channels. The area is usually vegetated, in contrast to the sandy channel beds.

Intermittant. A stream which flows only for portions of the year, but has sustained flow for a period after rainfall. See perennial and ephemeral.

Isoclinal. A structural fold of a rock unit with parallel limbs.

Lacustrine. Having to do with lakes. Lacustrine sediments were deposited in a lake.

Listric. Spoon-shaped. A listric fault is a spoon-shaped thrust fault, which curves upward toward a vertical plane.

Losing Stream. A losing stream decreases in discharge in the downstream direction, usually due to loss of stream flow to infiltration to the subsurface.

Ma. Million years before present.

Macrobotanical. Pertaining to large plant remains recovered from archeological contexts.

Mafic. Referring to dark, magnesium-rich minerals.

Manning's Equation. An empirical formula which relates steam velocity or discharge to measurable stream flow characteristics such as depth, flow area, and slope via coefficients.

Mannings Roughness Coefficient. An empirical parameter which describes energy loss in a stream reach, accounting for such factors as turbulence, eddying, and backwater.

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% of the time).

Metamorphic. Rock type formed by alteration by heat or pressure of other rocks.

Metamorphic Core Complex. A dome of ancient igneous or metamorphic rock with a shell of mylonite.

Metarhyolite. Metamorphosed rhyolite.

Mexican Period. The period from Mexican independence to the Mexican War (1846).

Morphology. The shape or geometric characteristics, especially of a stream, or stream reach.

Mylonitization. The process of forming mylonite, a fine-grained metamorphic rock characterized by mineral grains subjected to milling and brecciation (processes of breaking rocks into fine ground or fractured pieces) by movement along a fault zone. Mylonite is an intensely deformed metamorphic rock.

Navigable. or 'navigable watercourse' means 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."

Oral History. Historical knowledge that is passed on verbally.

Orogeny. The process or event of mountain building, especially by folding and thrusting.

Orographic. Relating to topography. Orographic precipitation is caused by changes in pressure and temperature caused when air masses are forced over topographic features such as mountains.

Ordinary High Water Mark. The line on the shore of a watercourse 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 or the presence of litter and debris, or by other appropriate means that consider the characteristics of the surrounding areas. Ordinary high watermark does not mean the line reached by unusual floods.

Oxbow. A crescent shaped lake occupying the abandoned channel of a stream meander that is isolated from the present channel by a meander cutoff and sedimentation.

Paleobotanical. Pertaining to prehistoric plant life.

Paleoclimatic. Pertaining to prehistoric climate conditions.

Paleoenvironmental. Pertaining to prehistoric environments

Paleofaunal. Pertaining to prehistoric animal life.

Paleoflood. Any flood which occurred prior to, or without, human records.

Paleo-Indian. The earliest stage of human occupation on the American continent, characterized by the hunting of big game.

Paleosols. Buried or relict soil layers, not formed during the present climatic conditions or at the existing soil surface.

Pediment. A gently sloped erosion surface composed of bedrock with a thin veneer of alluvium, often formed by mountain front planation.

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.

Petrocalcic. Calcium-rich rock material.

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.

Piedmont. A general term for the sloping land area adjacent to a mountain front.

Pier Scour. A form of channel bed scour caused by the turbulence created by bridge piers.

Placer Mine. A mining operation harvesting minerals from alluvial stream deposits, usually gravel bars along a stream or wash.

Planform. The channel pattern, as viewed from above; map view.

Pleistocene. The most recent geologic period, usually the past 1,000,000 years before present.

Plug. A rounded body of igneous rock material intruded into surround rock units.

Pluton. A body of igneous rock which formed beneath the earth's surface by crystallization of molten material.

Point of Zero Flow. The stage on a rating curve or gage record where no discharge occurs.

Porphyritic. A term describing rock texture in igneous rocks where larger crystals are set in a glassy or fine-grained matrix.

Precambrian. A period of geologic time. See Table G-1 attached to glossary.

Quaternary. A period of geologic time. See Table G-1 attached to glossary.

Rating Curve. A graph which relates stream discharge to some other measurable stream characteristic such as width, depth, or velocity.

Reach. A segment of a stream, usually with uniform characteristics.

Recurrence Interval. (aka Return Period) The average period of time in years within which a given event, usually a flood, will be equalled or exceeded. The 100-year, or 1% chance flood, has a recurrence interval of 100 years.

Regime. The flow and sediment transport characteristics of a stream. A stream reach "in regime" has balanced sediment transport in and out of the reach.

Return Flow. Water discharge to a stream that was originally diverted into irrigation canals. Return flow can either be water not applied to field which bypasses local canal turnouts, or seepage through soil under agricultural fields that returns to the stream.

Rhyolite. An igneous rock type with mineral content equivalent to granite, but with individual mineral grains too small to distinguish with the naked eye.

Riffles. Steeper reaches of a stream, often with coarse bed sediments such as cobbles and boulders which form small rapids.

Riparian. The environment impacted by a river.

Riprap. Rock material used to protect streambanks from erosion.

Runout Distance. The distance a debris flow travels from the mountain front or base of a slope to its resting point.

Salado River. A term used during the Spanish, Mexican, and Territorial periods to refer to the Salt River.

Salt River. Aka Black River, Rio Salinas, Rio Salado

San Francisco River. A term used during the Spanish, Mexican, and Territorial periods to refer to the Verde River.

Scarp. A cliff, embankment, or bluff.

Scour. Removal of stream bed material by flowing water.

Seasonal Exploitation. Use of an area for only a portion of the year, such as gathering native crops during their annual period of ripening.

Secondary Entrenchment. Degradation of a geomorphic surface, usually a stream channel or piedmont below its initial deposition surface, often forming terraces.

Seep. A small, diffuse spring generally of low discharge rate.

Shear Stress. Stress due to forces that tend to cause movement or strain parallel to the direction of the forces.

Sinuous. The "curviness" of the channel planform; the degree of meandering.

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.

Skiff. A small, light boat.

Slackwater. A low-energy zone in a stream characterized by near-zero velocity and sediment deposition.

Spanish Period. The period from 1540 to Mexican independence.

Spillway. A structure on a dam designed to convey water over or around the dam itself. Often used to discharge floodwater.

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 analagous to stream depth.

Strath Terrace. A stream terrace formed by erosion, rather than deposition.

Stream Capture. A process by which headward erosion on one stream intersects another stream, diverting it into a new flow path and abandoning its former channel.

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.

Stream Order. A geomorphic parameter used to describe the complexity of a drainage system. A first order stream has no tributaries. A third order stream is formed by the confluence of two second order streams. No stream order system specifically for alluvial fans exists.

Stream Power. The ability of a stream (flow) to do work, usually erosion.

Strike-slip Faulting. Tectonic movement along a fault line which is dominantly horizontal, rather than vertical. The San Andreas Fault is a strike-slip fault.

Suspended Load. The part of the total sediment load that moves above the bed load. The weight of the suspended sediment is totally supported by the fluid.

Syntectonic. Occurring in conjunction or concurrently with tectonic activity, usually emplacement of a pluton.

Talus. A loose, steeply sloped accumulation of rock debris deposited at the base of a mountain slope.

Tectonic Forces. Geologic forces generated from within the earth that result in uplift, movement or deformation of part of the earth's crust.

Tectonic. Tectonism. Deformation of the structure of the earth's crust by movement of crustal plates; includes mountain building by vulcanism and faulting.

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.

Tertiary. (Capitalized). A period of geologic time. See Table G-1 attached to glossary.

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.

Torrifluvents. A type of soil characterized by stream deposits of gravelly, sandy material, and lack of significant soil horizon development.

Transition Zone. See Central Mountain Province.

Transmission Losses. Reductions in stream flow due to infiltration of water into the stream bed and subsurface.

Trellis Drainage Pattern. A stream pattern where master and tributary channels are aligned at nearly right angles.

Tuff. A rock type formed of compacted volcanic fragments and ash.

U.S. Territorial Period. The period from 1863 to Statehood, in 1912.

Unentrenched. See entrenchment

Verde River. Aka San Francisco River,

Volcanics. Rocks formed by consolidation or crystallization of material deposited by volcanic eruptions.

Wash Load. The part of the sediment load composed of fine particles carried in permanent suspension, and generally not found in the stream bed.

Watershed. The land area draining into a stream, or other body of water.

Water Table. T he u pper surface of the underground zone of saturation; the plane which represents the elevation of ground water.

Wild Flooding Irrigation. An irrigation technique in which water from the canal is allowed to spread unhampered over the filed, without the use of control devices to direct the water.

Glossary Table
Geologic Time Scale

Era	Period	Epoch	Millions of Years Ago	Significant Geologic Events in Arizona
PHANEROZOIC				
Cenozoic	Quaternary	Holocene	0.01	Change to hotter drier climate.
		Pleistocene	1.8	
	Tertiary	Pliocene	5	
		Miocene	25	
		Oligocene	37	Basin and Range Crustal Extension and Volcanism Mid-Tertiary Orogeny.
		Eocene	55	
		Paleocene	65	
				Laramide Orogeny and Regression.
Mesozoic	Cretaceous		135	
	Jurassic		180	Plutonism and Volcanism in Southern Arizona.
	Triassic		230	
Paleozoic	Permian		275	
	Pennsylvanian		330	
	Mississippian		355	
	Devonian		410	
	Silurian		430	
	Ordovician		500	Regional Uplift and Erosion.
	Cambrian		600	
				Grand Canyon Disturbance.
PRECAMBRIAN				
Proterozoic			1000 1500 2000	Mazatzal Orogeny and Plutonism.
Archeozoic			3000 4500	