HAVASU NATIONAL WILDLIFE REFUGE

WATER MANAGEMENT PLAN

Final

September 12, 2006

Prepared for:

US Fish & Wildlife Service
Region 2
Albuquerque, NM

SHORELINE®
ENGINEERING & RESTORATION

HAVASU NATIONAL WILDLIFE REFUGE

WATER MANAGEMENT PLAN

Final

September 12, 2006

Prepared for:

US Fish & Wildlife Service
Region 2
Albuquerque, NM

Prepared by:

Shoreline Engineering & Restoration
Cameron Park, CA

SHORELINE®
ENGINEERING & RESTORATION

HAVASU NWR
WATER MANAGEMENT PLAN

Table of Contents

Appendices

Preface

An important part of the development of this document included professional critiques by individuals representing various agencies and backgrounds, but all familiar with the operation and history of the lower Colorado River. Most of the comments provided were incorporated into this final version of the plan, especially those that added clarification to the document, or enhanced factual information. As one would expect, some of the comments provided asked that the document provide information or direction beyond the plan's purpose, so such comments were acknowledged but often left unanswered.

The *Havasu Water Management Plan* is a resource for U.S. Fish and Wildlife Service personnel involved in the management and operation of the Havasu National Wildlife Refuge. It provides a collection of historical data and information pertaining to water use and management at the refuge, the refuge's entitlements to river water, and recommendations that may improve both water management and habitat value. A vision is presented in this plan, depicting physical and operational improvements that could help the Fish and Wildlife Service attain many of its goals. The plan does not provide a detailed map of how to get from "here to there".

Challenges that refuge management will face if recommendations provided herein are initiated include funding the improvements, local community support, and endangered species concerns, to name a few. Each of these challenges will require extensive time and effort of refuge staff and other critical participants to develop comprehensive programs that address conflicts associated with modifications to existing operations. This document is merely a starting point to gather around and open a constructive dialog among managers, planners, scientists, and the public.

Special thanks to the following for their involvement with the development of this document: John Earle, Lesley Fitzpatrick, Ruth Thayer, Jeffrey Addiego, Terry Murphy, William Werner, John Osterberg, and Andrew Hautzinger.

I. INTRODUCTION

Overview

The harnessing of Colorado River waters through dam and levee construction during the early and mid 1900's changed the river's normal flow patterns. Normal peak spring flows of 70,000 cfs or greater[1] have not occurred since the completion of Hoover Dam, and rarely exceed 20,000 cfs today. One consequence of these changes is the degradation of natural systems along the river, and the benefits of these systems to wildlife.

In 1935, after completion of Hoover Dam and while Parker Dam was still under construction, the federal government began preparations to create a migratory bird refuge in the vicinity of Needles, California. The area was recognized by the U.S. Migratory Waterfowl Division for its migratory waterfowl value, thus a site was surveyed, identified, and proposed for reserve as a wildlife refuge.

On January 22, 1941, President Franklin Roosevelt signed Executive Order No. 8647, which established the Havasu National Wildlife Refuge. The order stated that 37,870 acres would be set apart for use by the Department of the Interior as a refuge and breeding ground for migratory birds and other wildlife. (Additional lands totaling 2,757 acres were subsequently added on February 11, 1949, per Public Land Order 559).

By 1948, the right of the Department of Interior to use Colorado River water to operate and maintain the refuge was in question. The U.S. Fish and Wildlife Service requested a statement of ownership and control of Lake Mead's stored water for these purposes.[2] However, the request was not immediately accepted. After 16 years of discussion and controversy, the U.S. Supreme Court Decree per *Arizona vs California* dated March 9, 1964, solidified water rights for the Havasu National Wildlife Refuge.

Havasu NWR has a current entitlement to use water as reasonably necessary to fulfill the purposes of the refuge, not to exceed 41,839 acre-feet/year of water diverted from the river, or 37,339 acre-feet/year of consumptive use, whichever is less. Consumptive use is simplistically defined as river diversions minus return flows. Priority dates for Havasu NWR water entitlements are January 22, 1941, for lands reserved by Executive Order 8647, and a priority date of February, 11, 1949, for lands reserved by Public Land Order 559.

The area around Topock Marsh was the refuge's primary attraction at the time Havasu was created, and the focus of most refuge activities since. The marsh is a remnant of

---

[1] Reclamation historical flow data below Hoover Dam site (1906-2005).

[2] Williams and Associates, LLC, "Research Report on the History of Havasu (Including Bill Williams River NWR) and Imperial NWR with Respect to Secretarial Reservations and Cibola NWR with Respect to the Secretarial Contract", March 2000.

prior years when the river would spill its banks and scour a series of meandering channels running parallel to the river. The marsh was a significant meander created by flood waters pushing up against the topographic rise along the east side of the Mohave Valley. Prior to 1935, seasonal flows would spill into the meander, sending thousands of acre-feet of Colorado River water through the waterway, aggressively stripping vegetation and soil from the backwater. As waters receded, velocities in the meander slowed allowing sediment and nutrient deposition. Eventually, through time flows all but ceased, leaving behind a shallow wetland. The process would be repeated almost every spring. At the time Hoover Dam was completed, Topock still held its natural glory and was likely the incentive for the formation of the refuge at its present location.

Lower Colorado River below Topock Marsh

After the completion of Parker Dam in 1938, Topock marsh became a backwater of the river due to the raised surface elevation of Lake Havasu. At the time, the marsh had an average surface area of approximately 6,000 acres. The raised river elevations also threatened to flood the community of Needles. In 1949, the Bureau of Reclamation (BOR) straightened and deepened the river channel, which lowered the elevation of water in Topock Marsh.

In 1965, BOR determined that water consumption of the marsh due to evapotranspiration was approximately 9.0 acre-feet/year. Comparing this value against the refuge's water entitlement, the BOR concluded that it was necessary to reduce the marsh's surface area to approximately 4,000 acres to stay in compliance with the 1964 Supreme Court Decree. In response, the BOR began construction the 4.1 mile long South Dike to impound

portions of the marsh to limit its size, and the 4.0 mile long Inlet Canal to supply river water to the marsh's north end.

Attempts to maintain the marsh's original productivity have included construction of the Inlet Canal (1965), South Dike (1965), Farm Ditch (1968), North Dike (1968), and other miscellaneous improvements and management strategies. However, improvements have not successfully simulated pre-dam biological function and response, which is well documented in numerous refuge memorandums and studies. The general consensus among the numerous biologists and managers studying and managing the marsh is that current water entitlements and conveyance systems are inadequate to optimize marsh productivity in its present configuration.

Current refuge activities also include farming operations to produce food for migratory birds, riparian and native vegetation restoration, seasonal wetlands management, and the development of endangered bird and fish habitat. Recreational opportunities exist in the form of hunting, fishing, boating, and bird watching.

Water is an essential component of LCR refuge function and operation. The absence of sufficient quantity, quality, and conveyance of water restricts the use and productivity of refuge lands. The refuge has defined plans to increase habitat and biological diversity, native species revegetation, and enhance endangered species opportunities. However, since nearly all available water is currently committed to Topock Marsh operations, opportunities to realize many USFWS goals and objectives appear limited.

Finally, increasing competition for all LCR supplies has resulted in a heightened awareness of water use, encouraging all LCR diverters to maintain precise systems of water measurement and accounting, and compelling refuge staff to assess water management practices.

Refuge Goals and Objectives

USFWS goals and objectives for Havasu NWR have changed over time as the result of environmental legislation, better science, improved working knowledge of lower Colorado River (LCR) refuges, and administrative demands. In 1994, the USFWS released the *Lower Colorado River National Wildlife Refuge Comprehensive Management Plan*, which included 17 separate "Issues" that comprise goals and objectives for the four lower Colorado River National Wildlife Refuges. These issues are the result of: 1) legal mandates, statutes, policies, and administrative directives associated with the operation of the National Wildlife Refuges (NWR), 2) purposes for which the refuges were originally established, 3) goals of the NWR System, and 4) USFWS actions to implement these stated mandates. The 17 issues USFWS management are expected to promote at each of the LCR refuges are as follows:

- Biological Diversity and Habitat Management

- Endangered Species Management
- Fisheries Enhancement and Management
- Migratory Waterfowl Management
- Wetlands
- Water Rights
- Water Management
- Revegetation
- Water Quality and Contaminants
- Compatibility and Refuge Allowable Uses
- Land Status and Jurisdiction
- Non-Wildlife Oriented Recreation and Law Enforcement
- Environmental Education and Public Outreach
- Refuge Wildlife Recreation Management
- Area of Ecological Concern Interagency Coordination
- Refuge Relationship to Native American Governments
- Staffing, Funding, and Organizational Structure

In 2003, the USFWS conducted a review of Havasu NWR wildlife and habitat management programs to determine if current programs align with refuge and USFWS goals, identify potential improvements to the programs, and identify resources necessary to achieve refuge goals. A summary of that review process is entitled "Havasu National Wildlife Refuge Wildlife and Habitat Management Review, June 9-12, 2003".

Although nearly all refuge activities are interrelated, much of the review did not specifically address water management issues (i.e. wildlife species management, invasive species management, fire suppression, etc.). The following provides a brief list of those items identified by the review team[3] during the 2003 review that are directly related to water management:

1. Water Use – The review team made five (5) recommendations that were directly related to water management (Item A, *Water Management*), including:

    - Negotiate with the USGS and USBR to make the gauging station on the Inlet Canal at the Havasu NWR boundary and the station on the Farm Ditch the official measuring points for diversions;

    - Replace the South Dike structure and continue monitoring return flows to the river by taking measurements at the South Dike structure;

    - Accurate gauging of diversion and return flows will provide a record of water use under current management actions. Given that the Havasu NWR has a limited allocation, the Havasu NWR should assess future habitat creation or restoration project water needs compared to what is available;

[3] The review team consisted of 21 representatives from the USFWS, Bureau of Reclamation, USGS, BLM, State of Arizona, and the LCR Interagency Fire Management Group.

- Replace the Inlet Canal structure, and install a pump to better control water intake, and investigate lining the canal to further limit water loss;

- Investigate options to compartmentalize Topock Marsh for better water control.

Items identified in the 2003 review that are indirectly associated with the water management plan included:

- Improve growth of submerged aquatic vegetation by improving water management in Topock Marsh and enhancing water flow through the marsh (Item F-1, *Wildlife Species Management*);

- Close portions of Topock Marsh used historically as rookeries during the heron and egret breeding season (Item F-2, *Wildlife Species Management*);

- Protection and recovery of Southwest Willow Flycatcher and Yuma Clapper Rails (Item G, *Terrestrial T&E Species*)

Finally, the review identified priorities for implementation of goals, and those items associated with water management include:

Priority 1 – Replace the South Dike outlet water control structure;

Priority 2 – Replace the Inlet Canal water control structure, increase restoration projects for Topock Marsh, and increase acreage restored to native riparian habitat.

All of these items are addressed in this report to some degree, thereby further advancing USFWS's efforts to consistently improve its programs and activities in the direction of its ultimate goals and objectives.

Management Plan Purpose

The Havasu Water Management Plan (WMP) is intended to address several issues of concern to USFWS staff, as defined below:

1. ***Depict Past and Present Water Management Practices*** - Summarize the history of water management activities and programs at Havasu NWR.

2. ***Describe Water Entitlements and Restrictions*** - Provide a detailed description of the refuge's available water resources and legal entitlements to LCR water.

3. ***Consolidate Pertinent Documentation*** - Reference or summarize existing refuge documentation germane to water management, accounting, or practices.

4. ***Join USFWS Goals with Water Management Activities*** - Attempt to bring broader goals and objectives together with daily refuge operations and resource use.

5. ***Provide Direction for Future Refuge Operations*** - Present options for future refuge management and associated impacts.

The HWMP will act as a reference document for refuge staff for future operations and planning activities. In the event the USFWS desires to file for a change of use or location with the State of Arizona (e.g. consolidate LCR refuge water entitlements), a water management plan must be submitted with the application.

Site Characteristics

Havasu NWR is located along the LCR approximately 35 miles downstream of Davis Dam and 50 miles upstream of Parker Dam. The refuge property occupies the southern end of the Mohave Valley. Although the refuge headquarters is located in Needles, California, refuge lands are primarily in Mohave County, Arizona. A map of the refuge boundaries is shown in Exhibit 1.

The refuge falls along the boundary of the Mohave and Sonoran deserts, two of the four deserts identified in the United States. The climate is arid, with approximately 4 inches of annual precipitation in the form of rainfall, and approximately 84 inches of evapotranspiration.[4]

The site slopes to the south at approximately ½ foot per mile, or in the same direction as river flows. Elevations of the site vary from approximately 457' to 474' (NAVD29), with numerous undulations throughout. The lowest elevations in the study area are beneath areas of open water in Topock Marsh. Bring in Exhibit 2 here

Soils at the site consist primarily of course alluvium (sand and sandy loam) deposited by the river. Some sites have been identified with finer texture soils (silts and clays), but these sites make up a small portion of the study area. The BOR conducted soil investigations in 1997, 1999, and in 2002. Over 50 borings were logged identifying soil textures, depths to texture changes, salinity, and depth to groundwater. Some of the soils were tested for pH, conductivity, and percent clay content.

[4] Based on an average of Parker and Mohave AzMet stations for the periods 1987-2001 and 1992-2001, respectively.

In general, groundwater at the refuge is relatively high and variable. The combination of coarse soil texture and regular fluctuations in Colorado River flows have a direct influence on groundwater depths. Observations made with monitoring wells have shown that groundwater near the river will rise and fall with daily changes in river stage. Depending on the time of year (e.g. fluctuating river flows), the depth to groundwater in the study area can be over 10' from ground surface. Other lower-lying areas, like sections of Topock Marsh, are below the groundwater table, resulting in a permanent pool of water.

Figure I-1 – Havasu NWR is located just south of the intersection of the Colorado River and I-40, near the City of Needles on the east (Arizona) side of the river.

Resources and Past Studies

A primary objective of the WMP is to identify and consolidate important history and information relative to the use and management of water resources at Havasu, and make recommendations for future water management strategies based on established and accepted operational fundamentals. Several studies, reports, and USFWS records associated with Havasu water management were used to develop the WMP. Information was also collected through discussions and interviews with USFWS and BOR staff. Specifically, studies conducted by Dr. Bradley Evan Guay, and Williams and Associates, LLC, were crucial to the development of the WMP. A complete listing of resources can be found in Appendix A.

II. WATER ENTITLEMENTS AND ACCOUNTING

A complete history of the events and decisions surrounding the allocation of Colorado River water is a lengthy and complex topic that is far beyond the scope of this report. Multiple volumes of legal opinions, court cases and decrees, federal law, treaties, contracts, memorandums, and regulatory guidelines dating back to the late nineteenth century document the basis of how Colorado River water is managed today. Collectively, this history of actions and decisions is commonly known as the "Law of the River".

For the benefit of this report, a summary of major events and decisions that form cornerstones of the Law of the River is provided herein. In addition, a comprehensive collection of excerpts from past reports and other relevant documents are provided in the appendices. The purpose of the following section is to provide the reader with a concise review of the past and current water use practices as they relate to the Havasu NWR. References are provided should further research or understanding be desired.

It should also be noted that the arena of water entitlements and accounting is a moving target, both politically and technically, and this report does not represent the final word on these discussions. It is anticipated and expected that this report will require regular supplementation to remain current and continue to act as a valuable reference document for the refuge.

Colorado River Water Overview

The first modern accounts of the Colorado River began in 1869, when Major John Wesley Powell, accompanied by 9 men, 4 small wooden boats, rations, and the latest in scientific instrumentation (sextant, barometer, thermometer, compass) explored several hundred miles of the river from Green River City, Wyoming, to the confluence of the Virgin and Colorado Rivers. When presenting his findings to Congress upon his return, he adamantly suggested that the western states be divided by watershed boundaries, prophesizing that conflicts concerning the ownership of water would prevail.

By the early 1900's, discussions of controlling the Colorado River were in full force. The Davis and Lippincott report (1901) recommended that a Boulder Canyon dam and diversion facilities for Imperial Valley water be studied. The following year, the Federal Reclamation Act was passed, creating the Bureau of Reclamation.

Between the years of 1918 and 1924, several actions and events generated momentum for control of Colorado River waters.[5] However, the most important of these was the Colorado River Compact of 1922. The compact was negotiated by the seven Colorado River Basin states and the federal government defining the relationship between the upper basin states, where most of the river's water supply originates, and the lower basin states, where most of the water demands were developing. At the time, the upper basin states were concerned that plans for Boulder (Hoover) Dam and other water development projects in the lower basin would, under the Western water law doctrine of prior appropriation, deprive them of their ability to use the river's flows in the future. The compact was ratified by six of the seven states in 1923. Arizona refused, and did not sign until 1944. At total supply of 15 million acre-feet of annual Colorado River water was split equally between the upper and lower basins.

In 1928, congress signed the Boulder Canyon Act (BCPA). This act: (1) ratified the 1922 Compact; (2) authorized the construction of Hoover Dam and related irrigation facilities in the lower Basin; (3) apportioned the lower basin's 7.5 maf among the states of Arizona (2.8 maf), California (4.4 maf) and Nevada (0.3 maf); and (4) authorized and directed the Secretary of the Interior to function as the sole contracting authority for Colorado River water use in the lower basin. One of the main purposes identified for implementing the act was for "*improving navigation and regulating flows, controlling floods, and power generation"*. The priorities essentially gave congressional authority to develop and control the river in the lower basin.[6] In 1931, Arizona challenged the act and the 1922 Compact, but both were upheld by the Supreme Court.

The BCPA was significant in that it authorized the Secretary to contract for stored water resulting from construction and operation of the dam for irrigation and domestic use. Contracts would be for permanent service, and no person would be allowed to receive water without a contract. The Secretary's contracts would be subject to any compacts made between the states prior to January 1, 1929, and subordinate to any present perfected rights acquired under state law prior to 1929.[7]

The California Seven-Party Agreement of 1931 helped settle the long-standing conflict between California agricultural and municipal interests over Colorado River water priorities. The seven principal claimants - Palo Verde Irrigation District, Yuma Project, Imperial Irrigation District, Coachella Valley Irrigation District, Metropolitan Water District, and the City and County of San Diego - reached consensus in the amounts of water to be used on an annual basis by each entity within a priority system. Although the agreement did not resolve all priority issues, these regulations were also incorporated in

[5] All American Canal Board Recommendations for legislative control (1918), Kincaid Act, authorizing the Secretary to study water diversion and use (1920), Fall-Davis Report, recommending construction of the all-American canal and storage reservoir on the lower reach of the river (1922), and the Weymouth Report that outlined the Boulder Canyon Project Act (1924).

[6] The upper basin water supply is not managed in a "federalized" fashion like the lower basin. The upper basin states largely control water usage through the issuance of water rights permits.

[7] There are essentially two types of water entitlements: 1) present perfected rights (perfected prior to 1929), and 2) contract rights established through Section 5 or the BCPA, which include Secretarial reservations (e.g., Cibola NWR).

the major California water delivery contracts. The agreement also stated that the Secretary had the exclusive authority to allocate Colorado River water, except for pre-1929 present perfected rights.

In 1944, the Mexican Water Treaty was executed. This treaty reserved 1.5 million acre-feet of Colorado River water for Mexico, and possibly an additional 200,000 acre-feet when surplus water is available.

Perhaps two of the most important actions that impact Havasu NWR's water entitlements were the Supreme Court Opinion and Decree of 1963 and 1964. In 1963, the Supreme Court issued a decision settling a 25-year-old dispute between Arizona and California. The dispute stemmed from Arizona's desire to build the Central Arizona Project so it could use its full Colorado River apportionment. California objected and argued that Arizona's use of water from the Gila River, a Colorado River tributary, constituted use of its Colorado River apportionment, and that it had developed a historical use of some of Arizona's apportionment, which, under the doctrine of prior appropriation, precluded Arizona from developing the project. The Supreme Court rejected California's arguments, ruling that lower basin states have a right to appropriate and use tributary flows before the tributary co-mingles with the Colorado River, and that the doctrine of prior appropriation did not apply to apportionments in the lower basin. The Court held that Section 5 of the BCPA gave the Secretary authority to divide the lower states' 7.5 maf , and that he had executed this properly through contracts.

In the Supreme Court Opinion dated June 3, 1963, based on the Special Maser's Report (Simon Rifkin, 1960), the following were identified:

1. Quantification of lower basin Federal reserved water rights: Indian Reservations, fish and wildlife refuges, and national recreation areas, and

2. Secretary's water allocation and contracting authority, whereby the Secretary has exclusive authority to make allocations of water and to set the terms of the water service contracts in the lower basin.

In 1964, the Court issued its decree. This decree enjoined the Secretary of the Interior from delivering water outside the framework of apportionments defined by the law and mandated the preparation of annual reports documenting the uses of water (herein referred to as "decree accounting") in the three lower basin states.

Supplemental decrees of 1979, 1984, and a third pending decree provided additional clarification of water entitlements, including present perfected rights.

Other pertinent acts included the Colorado River Basin Act of 1968, the Colorado River Bain Salinity Control Act of 1974, the Grand Canyon Protection Act of 1992, the Reclamation Reform Act of 1982, and the Federal Advisory Committee Act (amended in 1995), as well as various long range operating criteria, and administrative and legal decisions.

Havasu Water Entitlements

In 1947, the BOR began channelization work on the river near the City of Needles to alleviate flooding concerns. Some FWS officials believed that the work would not adversely impact the refuge or harm the marsh areas since floodwaters would fill the backwater areas. However, in 1948 the issue of water supply for impoundments on the refuge became a topic of discussion. The FWS requested a statement of ownership and control of Colorado River water stored in Lake Mead for refuge use. At the time, it was estimated that approximately 40,000 acre-feet would be required to maintain refuge operations.

There was disagreement between BOR and the FWS regarding the Secretary's authority to provide water for purposes other than irrigation and domestic uses. BOR believed that the Secretary could authorize use of stored water, but not authorize water rights for an agency. The FWS believed that public law[8] mandated that BOR provide water rights, and continued to force the issue. After years of further discussion and controversy, a report from Special Master Simon H. Rifkin, dated December 5, 1960, found the following:

"*In withdrawing lands for the Havasu Lake National Wildlife Refuge the United States intended to reserve rights to the use of so much water from the Colorado River as might be reasonably needed to fulfill the purposes of the refuge".*

Judge Rifkin also concluded:

"The United States has the right to the annual diversion of a maximum of 41,839 acre-feet or to the annual consumptive use of 37,339 acre-feet, whichever is less, of water from the Colorado River for use in the Havasu Lake National Wildlife Refuge, with a priority date of January 22, 1941 as to land reserved by Executive Order No. 8647, and a priority of February 11, 1949, as to land reserved by Public Land Order 559".

The Supreme Court Decree of March 9, 1964, confirmed the entitlement as recommended by Judge Rifkin. The Court expressed that the United States has the right to reserve water rights for its reservations and its property, and that it was the intention of the United States government to reserve water sufficient for the future requirements of the Lake Mead National Recreation Area, the Havasu Lake NWR, Imperial National NWR, and the Gila National Forest. However, the Court also stated that the United States could not use water without charging the consumptive use of the water diverted against the apportionment of the state wherein the use took place.

The BOR developed a hierarchy of water use that is part of most post 1968 contracts with Arizona water users. During a year when shortage conditions exist (i.e. less than 7.5 million acre-feet of Colorado River water available for consumptive use within the lower

[8] Department of Interior Public Law 732 states "... provides for the prevention of damages to existing wildlife facilities".

basin Arizona water users must bear a shortage reduction. Arizona water delivery contracts are satisfied sequentially by applying six priority levels, starting with priority level 1. The HNWR entitlement is a federal reservation and considered a *perfected right* as defined by the 1964 Decree[9], and considered a *second priority* classification, meaning that only *present perfected rights*[10] (pre 1929) are of a higher standing. Thus, it is unlikely that HNWR will receive less than its full entitlement during periods of water shortage.[11]

Past and Present Water Accounting Practices

To comply with the 1964 Supreme Court Decree, the Secretary was required to account for LCR water use, and develop an annual report that identified all diversions, returns, and consumptive use of LCR water in California, Nevada, and Arizona. "Consumptive Use" is defined as diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation. Starting in 1964, the method that BOR used to calculate consumptive use was *measured* diversions from the river minus *measured* return flows to the river. However, establishing a universally accepted definition of consumptive use has been the center of controversy for many years."

In 1969, Arizona, California, and Nevada asked BOR to develop a method of water accounting that includes an *unmeasured* return flow component. The theory was that some diverted water would find its way back into the system even though it may not be measured. In 1970, a task force was established to research and recommend options for unmeasured return flow accounting. Several concepts were developed and tested, but none of the methods developed and tested by the task force were adopted.

In the early 1990's BOR staff and staff of the lower-basin state Colorado River water agencies developed estimates of unmeasured return flows for large agricultural diverters and selected domestic diverters along the LCR independently from the Task Force, including estimates of unmeasured return flow for HNWR. BOR applied these factors to most diverters so that the decree accounting report provided a sum of unmeasured return flows estimated for Arizona, California, and Nevada. Beginning with the decree accounting report for calendar year 2003, these estimates of unmeasured return flows are reported for each diverter.

---

[9] "Perfected Right" is generally acquired in accordance with state law, but for federal establishments the perfected right is a water right created by the reservation of a federal establishment under federal law, such as a wildlife refuge.

[10] "Present Perfected Right" defined as a perfected right existing as of June 25, 1929, the effective date of the BCPA.

[11] For the Arizona holders of lower Colorado River water, there are six priority levels that dictate the manner in which water shortages are managed. Fourth priority entitlements (e.g., C.A.P.) bear nearly all of the shortages for the Colorado River system when flows fall below 7.5 maf and reductions are necessary.

However, during the writing of this report a significant change was implemented by BOR. According to Ruth Thayer, Group Manager of Water Conservation & Accounting, BOR administration has decided that LCRAS will only be used in a limited capacity for LCR water accounting, and that decree accounting will be the primary accounting method. No formal written statement is expected from BOR, even though the decision represents a significant change in program direction since the inception of LCRAS. At this time, it is assumed that LCRAS will be a minor factor in accounting practices associated with LCR water diverted for HNWR.

With the acceptance of the unmeasured return flow concept, but in the absence of an accurate model for quantifying this return, estimates for each of the federal refuges were provided by BOR. HNWR was given an 88% return flow factor[12] (Cibola/Imperial were both given a return flow credit of 38%), although BOR has recently stated that the return flow credits were scheduled for evaluation, and it was expected that HNWR credit would be adjusted significantly downward. Regardless, there is no benefit to individual users (e.g. HNWR) since to the aggregate credit of the unmeasured return flow is received by the State of Arizona. Thus, the unmeasured return flow credit provides no benefit or incentive to HNWR (or other individual users).

Havasu NWR Water Use

As previously mentioned, most of the water actively diverted and categorized as consumptive use at HNWR is associated with operation of Topock Marsh to maintain water levels and water quality. Minor amounts of water are pumped or gravity flowed into the Pintail Slough Management Area, or used for crop irrigation at the farm unit (Bermuda Patch).

Most records of consumptive water use date back to 1966, as shown in Table II-1. The table provides annual diversion volumes from the Inlet Canal and Farm Field irrigation well, measured water returned to the LCR through South Dike, and the difference between the two (*Consumptive Use*).[13]

The average annual consumptive use is 30,886 acre-feet, or 83% of the refuges consumptive use entitlement. Measured return flows (for those years recorded) show that releases from South Dike averaged 8,800 acre-feet, and had a maximum release of 27,451 acre-feet. This value is significant since any water released and returned to the LCR in excess of 4,500 acre-feet does not allow the refuge to make maximum use of its consumptive use entitlement should the refuge desire to do so.[14]

---

[12] The unmeasured return flow factor for HNWR is unique in that it is applied to the difference between measured diversions and measured returns. All other unmeasured return flow factors are applied to diversions only. The unmeasured flow is defined as water that makes its way back to the river indirectly via seepage, infiltration, percolation, etc.

[13] Consumptive use (Diversions – Measured Returns) in Table II-1 may not agree due to two data sources.

[14] Consumptive use less than 37,339 acre-feet/year is effectively forfeited by the refuge. In 2001, for example, the refuge effectively lost 15,858 acre-feet of water back to the LCR system.

Table II-1 Havasu NWR Consumptive Use

Year	Diversion (Inlet Canal-USGS)[1]	Farm Field Well	Measured Return Flow (S. Dike)[2]	Consumptive Use (BOR Decree Accounting Rpt)[2]
1966	511	0	Not Available	511
1967	Not Available	164	Not Available	164
1968	100,960	164	Not Available	57,781
1969	38,697	237	8,851	30,083
1970	43,660	200	5,743	38,117
1971	37,241	238	3,095	34,384
1972	41,600	223	4,103	37,720
1973	45,080	222	2,734	42,568
1974	35,720	73	1,917	33,876
1975	40,730	550	5,910	35,370
1976	42,003	597	4,568	38,032
1977	38,283	61	4,261	34,083
1978	36,321	Not Available	2,561	33,760
1979	41,820	Not Available	7,081	34,739
1980	39,615	81	0	39,696
1981	39,482	80	0	39,562
1982	39,105	18	0	39,123
1983	21,669	Not Available	0	21,669
1984	0	Not Available	0	0
1985	0	Not Available	0	0
1986	38,326	Not Available	0	38,236
1987	38,156	75	0	38,231
1988	39,116	147	0	39,263
1989	42,987	205	0	43,192
1990	38,779	450	0	39,229
1991	39,479	230	0	39,709
1992	29,165	220	0	29,385
1993	41,233	156	2,460	38,929
1994	59,165	107	12,554	46,718
1995	60,742	237	11,533	49,446
1996	42,792	275	14,226	28,841
1997	58,082	180	27,451	30,811
1998	55,967	60	19,386	36,641
1999	43,930	154	16,236	27,848
2000	40,002	226	3,334	36,894
2001	37,839	214	16,572	21,481
2002	45,280	278	13,232	33,256
2003	42,280	190	5,868	37,129
2004	50,090	Not Available	Not Available	Not Available

1. Source: USGS Yuma Office, Station No. 09423550, *Topock Marsh Inlet Near Needles, CA* .
2. Source: FWS Region 2 based on BOR annual Decree Reports.

III. HABITAT IMPROVEMENTS AND ACTIVITIES

As stated, Topock Marsh is the heart of refuge habitat and historical water management efforts. The marsh receives most of Havasu's available water supplies, and has been the focus of habitat improvements since the creation of refuge. Other existing habitat improvements that are independent of the marsh but require the use of LCR water include Beal Lake, riparian restoration (near Beal Lake), Pintail Slough, Lost Lake, and the Farm Unit.

Each of the said habitat units have been directly or indirectly altered through physical changes or water management strategies in attempts to enhance its wildlife value, with the most extensive work centered around Topock Marsh. Efforts to date have resulted in an improved understanding of habitat response to water manipulation, though the response is not always predictable.

The following discussion is a historical accounting of the combined efforts of the USFWS, BOR, and other participants to improve habitat at the refuge. Each of the habitat units are discussed separately, although improvements have often affected more than one unit.

Topock Marsh – As water filled behind Parker Dam after its completion in 1938, the section of the river adjacent to the historical Topock Marsh slowed and began a rapid sediment deposition process. The creation of the new reservoir (Lake Havasu) also created a backwater effect, raising water levels near the marsh. At the time, the marsh was freely connected to the river, so water surface elevations were dependent on reservoir operations and river flows. When the reservoir was full, marsh elevations reached 458', expanding Topock's surface area to approximately 6000 acres.

The higher river surface elevations were cause for concern for the community of Needles, California, and resulted in an extensive channel dredging project executed by the BOR. In late 1948, a large dredging vessel was delivered to the site. In January, 1949, *The Colorado* began operations to channelize the LCR adjacent to Needles. After an eight month delay when *The Colorado* sank in November of 1949, the project was resumed and then completed in the spring of 1951.[15]

After the channel work was completed, water levels in the marsh varied. High water levels of 458.46' and 459.27' were recorded in 1952 and 1957, respectively. However, the average marsh elevation began to fall around 1960. Influenced by concession owners at Topock Marsh, the BOR began a marsh improvement project to stabilize water levels in 1965.

[15] Even though dredging operations were "complete" in 1951, maintenance dredging continued on and off for at least 10 years after. Ultimately, approximately 31 miles of channel were dredged.

About this time there was concern among BOR staff that the marsh was consuming more water than allocated for the refuge. The BOR estimated water consumption from a combination of open water, cattail, bulrush, and other losses at about 9.0 feet per acre annually. Based on this estimate, the marsh would need to be reduced to approximately 4,000 acres. Thus, the BOR proposed a project consisting of a 4.1 mile dike near the south end of the marsh to reduce its size, and a new 4 mile water canal and intake structure to deliver water from the river to the marsh's north end.[16] The project concept was to maintain a 4,000 acre marsh at approximately 455' elevation, and control water quality by adjusting inlet and outlet flows. The new marsh boundaries created an impounded water body approximately 7.5 miles long with widths as narrow as 800 feet and as wide as 2 miles. However, the marsh experienced poor water quality during the two years following construction.

Topock Marsh consists of a combination of deep, open water areas, hemi-marsh areas with emergent vegetation (shown), and very shallow sections that are exposed when the marsh surface elevation is low during the winter .[17] Exhibit 2 provides a clear illustration of varying marsh depths.

Extensive work began immediately to improve water quality. In 1967, the Beal Lake Ditch was constructed, and areas of the marsh were deepened[18] for better circulation. In 1968, the Farm Ditch[19] and North Dike were both constructed.[20] However, in 1969 water quality was recorded as being markedly worse.

---

[16] The South Dike was completed in 1965, the Inlet Canal was completed in 1966.
[17] Photo taken near the Beal Lake Ditch.
[18] Approximately 4,000 lineal feet of "ditch" was blasted with explosives to improve circulation near the Glory Hole.
[19] The 7,400 lineal foot Farm Ditch connects the LCR with the marsh near the Glory Hole.
[20] The North Dike was constructed to prevent circulation in shallow, backwater areas, now known as the Pintail Slough Management Area.

During the period of 1970 to 1971, approximately 3,300 lineal feet of dike work and other miscellaneous water control work was completed in the Goose Lake section of the marsh to improve circulation and minimize water loss.

In 1966, the Bureau of Sport Fisheries and Wildlife initiated an investigation to determine what actions may be possible to improve the quality of Topock water. After 4 years of study and water management experimentation, the general consensus among those involved felt it was not possible to effectively manage Topock Marsh to meet fish and wildlife objectives in the existing size and form, while also adhering to the maximum allowable water diversions.

In 1974, the Topock Marsh Habitat Enhancement Project was initiated. The concept of the project was to "make the most" of the habitat since optimum conditions were likely unobtainable given existing conditions. The work consisted of dredging and diking select areas of the marsh to improve water management and circulation patterns in an attempt to improve water quality. Work was stopped in 1975 and then resumed again in 1978. When completed in 1979, the result was an additional 6.2 miles of dikes, 7.4 miles of channel, and numerous low profile islands.[21]

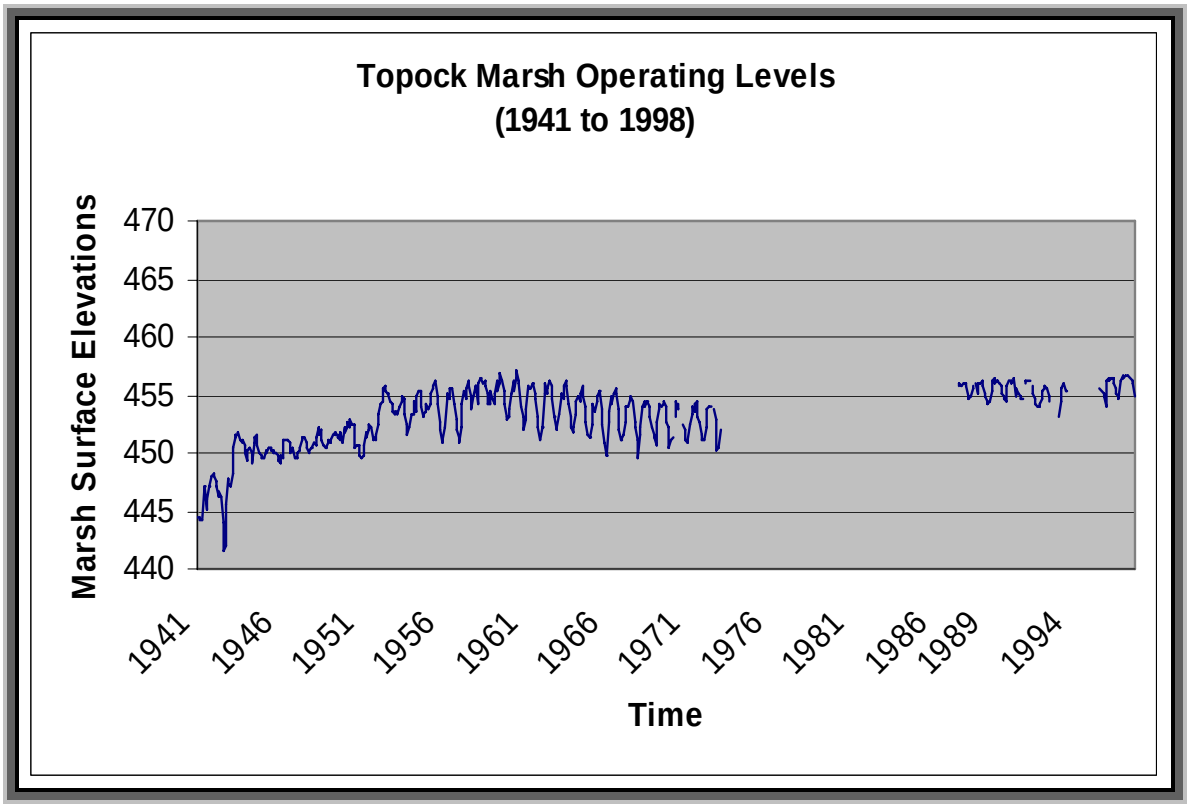
In July of 1983, the Topock Marsh Unit was flooded by abnormally high river flows. LCR flow rates were recorded at 45,000 cfs. River and Marsh water surface elevations reached approximately 461.1', or 5' above normal marsh water surface levels. Both the North and South Dikes were over topped. As a result of the floods, the BOR increased the elevation of the South Dike in 1986 to provide flood protection for LCR flows of 73,000 cfs.

From 1986 to present, a series of minor maintenance related projects were completed by the refuge, such as cleaning ditches, levee repairs, etc.

Refuge records of Topock Marsh water surface elevations from 1941 to 1998 are shown graphically in the following figure, providing an "at a glance" understanding of the general hydrologic dynamics and past patterns of marsh surface water elevations. Some of the breaks in the data are due to floods during the early to mid 1980's, and also lapses in refuge records. The data was collected from a combination of HNWR water management records on file at refuge headquarters.

A review of the graph illustrates that recent operations (post 1987) have maintained a tighter and higher water operating range than pre-1972, although the highest surface water levels during any period peak at approximately 456.5'-457.0'. Also, the marsh elevations were much more dynamic pre-1972.

[21] LCR NWR Comprehensive Management Plan, 1992.



Opinions and hypotheses of optimum water conditions for Topock Marsh, and reasons for poor vegetation response have varied with time. Refuge records provide some insight into past management practices and theories, as described herein:

- **1971 -** The *Havasu NWR Master Plan* describes in general the water management practices required to maximize habitat production,[22] although specific water operation levels are not identified. The plan suggests that with new levees located at the 455' contour, water can be raised without increasing surface area. It is proposed that higher water levels will reduce algae growth, maintain water temperatures, and increase circulation. In the winter, water levels are proposed to be drawn down to "… *evacuate stagnant water"*. The plan also states that a long-range water management plan is not possible at that time because of the many unknowns.

- **1979** - General Marsh Operations Explained in HNWR Annual Narratives: "*Spring and summer raise marsh to protect aquatic plants and fisheries from rising temps…more water cover implies more areas for plants to establish themselves…above 3 feet or so it provides cattail suppression…also coincides with peak river releases…In the fall, lower water levels to meet consumptive*

[22] Chapter 4 – Operational Criteria (pgs. 32-34).

use and expose vegetation to waterfowl… it is also the period when water can be released from marsh as river drops…"

- **1987** – The refuge established water specific water management plan criteria, as follows:

  1. After March 1, fill marsh rapidly to approximately 456.25';
  2. Maintain elevation throughout summer and fall;
  3. Drop marsh elevation rapidly to about 455.00' in late October, and attempt to maintain until mid-December;
  4. Mid-December, use inflows to maintain elevation at 455.50';
  5. Close diversion USGS gates (inflow) December 31.

- **1996** – Refuge attempts to raise high water level to 456.70' and hold until October, then lower to 455.00'. However, higher elevations were difficult to maintain.[23] If LCR water levels were high enough, filling of the marsh may be done as early as January.

An accounting of water management and the impact of marsh improvements, natural events, and changing water levels on marsh habitat, as described in the HNWR's annual narratives (ending in 1992), is summarized in the following table:

Table III-1 Historical Accounting of Topock Marsh Habitat Quality

Year	Accounting
1952	June marsh maximum elevation at 458.46'
1957	Marsh reaches 459.27' elevation
1959	Marsh elevation in May at 459.37'
1966	Marsh elevation 455.00' (June) after completion of Inlet Canal – Algae blooms reported
1967	Algae bloom recurs
1968	Marsh elevations maintained at 456.00', water quality good (no algae)- "..excellent production of spiny naiad and sago pondweed.."
1969	No algae, but water quality "..markedly worse than 1968 .." – Shallow marsh areas are predicted to be cause of poor water quality
1970	Good stands of aquatic plants
1971	Moderate stands of aquatic plants, but poor water quality (4th year of high turbidity)

[23] According to discussions with Greg Wolf (Refuge Manager) in 12/03, marsh elevations are difficult to maintain as early as August, depending on LCR operations. Marsh water elevations reached 456.70' in April of 2003, but could not be maintained.

1972	Aquatic vegetation excellent (no explanation since water management did not vary)
1976	Optimum marsh elevation thought to be 456.20', wind considered to be a key variable in plant production, excellent year for plant production
1978	Good plant production
1979	Plant production waning- Marsh raised to 456.66'- Turbidity a constant problem; causes 1) wind, 2) sedimentation from LCR, and 3) dredge and carp
1980	Not a good year for plants- Marsh at approximately 456.20'
1981	Poor plant production, but dense in sheltered areas
1982	Excellent year for aquatic plants
1983	Minimal aquatic plants due to floods- General thinking: Summer high water protects fishery from extreme heat and promotes production of aquatic plants; low winter water exposes plants to waterfowl
1985	Water quality "continue to plague" marsh; submergent vegetation almost eliminated
1986	Water quality problems (turbidity, high temps, sediment load, carp and poor circulation blamed), and limited aquatic vegetation
1987	Best aquatic vegetation production since 1983, no sago pondweed- Consensus that flushing is required but Inlet Canal not adequate
1988	Marsh aquatic vegetation remains monotypic
1990	Good aquatic vegetation
1992	Marsh at recent lowest elevation of 453.86'- Low aquatic vegetation production

All strategies for optimizing marsh habitat were developed based on the operation of the LCR. Surface elevations of the river have highly dynamic diurnal and seasonal fluctuations, and are often unpredictable. Since the marsh is dependent upon gravity flow from the river, significant changes from past water management practices appear limited given the current conditions. However, natural processes in the marsh and river are compounding the problem since surface water levels in the river are falling[24] and the marsh is infilling due to natural processes. Eventually, conveying water under gravity flow from the river to the marsh may be possible only during periods of peak river flow.

A quick review of river and marsh elevations reveals the problem. The United States Geological Survey (USGS) maintains gauges at the Inlet Canal structure, and another

[24] River levels are estimated to have dropped 8-9 feet since the construction of the Inlet Canal, HNWR Wildlife and Habitat Management Review, 2003, pg. 6.

located approximately 1.5 miles upstream at the Needles bridge. Three years of daily elevation readings for these gauges were collected and used to make estimates of the water elevation at the Inlet Canal structure. Data provided by the USGS for the Inlet Canal represent *daily mean* values, thus the actual elevations fluctuated above and below this value. Data for the Needles bridge gauge were provided as *daily maximum* values. USGS uses a factor of 1.6' as the difference in river surface elevations between the two gauges due to the river gradient.

The table below summarizes monthly USGS river gauge data for the period of October 1999 to September 2002.

Table III-2 River Elevation at the Inlet Canal Water Control Structure

Month	Mean	Average High	Maximum	Minimum
January	456.20	458.23	458.37	456.77
February	458.02	459.15	459.90	457.81
March	459.61	459.15	460.19	458.57
April	460.05	460.22	462.41	459.99
May	459.62	460.78	461.90	459.59
June	459.56	461.19	461.84	460.34
July	459.20	461.85	461.64	459.97
August	457.92	461.20	461.37	458.61
September	457.06	460.08	460.97	458.51
October	456.35	459.44	461.08	457.51
November	456.12	458.06	460.75	457.11
December	455.96	458.07	458.16	456.52

Note: "Average High" values based on USGS Needles bridge gauge data for water year 2001-2002. "Maximum", and "Minimum" values based on Needles bridge gauge data from October 1999 through September 2002. All elevations adjusted by -1.6' to estimate river surface elevations at the Inlet Canal structure (per USGS).

The high operating surface elevation for the marsh is 456.7'. Reviewing the mean values in the table above, it is obvious that maintaining the marsh at 456.7' elevation is difficult from October through January in most years. However, a difference in elevation (head) is required to convey water from the river to the marsh. For study purposes, the following are estimates of the hydraulic gradient necessary to convey high rates of river water (100 cfs+) to Topock Marsh:

Theoretical Gradient Loss of Gravity Flows

Loss through Inlet Structure	0.5’
Hydraulic Gradient in Canal	4.0’ (1.0’ per mile)
Loss through Inlet Canal Structures (near Pintail Slough)	0.5’
	5.0’

Thus, when comparing the river levels to marsh elevations, river elevations need to be 4’ to 5’ higher than marsh operating levels to develop sufficient head and flow rates. For example, it is estimated that river surface elevations need to be approximately 460.7’ to 461.7’ at the Inlet Canal structure to develop adequate flow rates from the river to the marsh. Again, comparing this to the mean elevation at the canal inlet structure, it can be seen that these conditions are not the norm (for the record of review). These deliveries are further complicated by the operation of private irrigation pumps that divert water from the Inlet Canal before it reaches the marsh.

It is also important to note that the problem is thought to be compounding. The natural process of a marsh is to infill over time due to sediment and nutrient deposition, thereby raising the marsh bottom elevation. At the same time, the river surface elevation could be lowering due to scouring from past “channalizing” for flood control. Complicating the situation further, any increase in future upstream diversions will also lower river elevations at the inlet.

In summary, there is a common theme that runs through historical observations of Topock Marsh, providing the impetus for the numerous improvements and water management strategies initiated throughout the years: *Marsh water quality (high concentrations of salinity, temperature, and turbidity) results in adverse impacts on habitat value, and current water entitlements and conveyance capacity are inadequate to correct the problem (through flushing and improved circulation)*. Since Topock Marsh uses most of the refuge’s water entitlement, it is critical to develop solutions that will reduce marsh water demands while also improving water quality, while not exceeding refuge water entitlements.

Beal Lake - Beal Lake consists of approximately 215 acres of open water and submergent vegetation adjacent to Topock Marsh. As part of the BOR South Dike work in 1966, Beal Lake was separated from the river along with Topock Marsh. In 1967, a ditch was constructed from Beal Lake to Topock Marsh to increase circulation through the lake. An 800 foot long dike was constructed along the north side of the lake to reduce shallow water surface areas in 1969.

In 1970, an attempt was made to pump Beal Lake dry. However, after various attempts, the effort failed due to excessive seepage from the river. By 1994, the lake was overgrown with cattails. A herbicide was applied in 1996, but was almost inundated by vegetation again by 1998.

Pintail Slough Management Area – With the completion of the North Dike in 1968, Topock Marsh was separated from a backwater area now known as the Pintail Slough Management Area. At the time, it was believed that shallow backwater areas were, at least, partially responsible for the high turbidity and algae blooms in Topock Marsh.

Expansion of Pintail Slough began in 1978 with the creation of what is now called Field 5. A portable pump was used to draw water from the Inlet Canal to irrigate crops on the field. In 1980, Fields 1 – 4 were constructed, bring the total field area to 130 acres. Initially, the fields were managed by a cooperative farmer, but after the 1983 floods, the farmer did not return.

In 1985, a gravity irrigation system (concrete ditch) was installed to supply water to the slough. Field irrigation was accomplished with the use of portable pumps to draw water from the ditch. In 1987, the refuge attempted to turn the farm fields into moist soil units, but soil texture was too porous to hold water. Thus, the fields were used to grow wheat. In 1989, the permanent low-head irrigation pump was installed to irrigate the fields.

Riparian vegetation projects were attempted in 1993 (between Fields 2 and 3), and in 1995 in Field 5. The success of these efforts has been marginal.

In September of 1999, a topographic survey of Pintail Slough was conducted, followed by an improvement plan in the spring of 2000. The plan proposed to improve the water conveyance capability of the system and increase habitat from approximately 190 acres to 310 acres. The improvements would add approximately 40 acres of wetlands and 100 acres of riparian vegetation habitats. Work on the Pintail Slough project included a new concrete lined ditch (approximately 5000 l.f), brush removal, leveling units and building boarders for flood irrigation, and installation of water control structures. Roads and parking areas were also improved for access and recreation. The project was completed in 2005.

The Farm Field is irrigated with groundwater from a well located on the east side of the field. The FWS experimented with flood irrigation of the fields, but found that the soils were too coarse. The FWS is replaced the wheel-line with a center pivot system in 2006.

Farm Fields – In the early 1960's, the refuge established an objective to produce crops and grains for resident and migratory waterfowl. In 1962, the "Bermuda Pasture" was cleared, and a small (8" diameter) irrigation well was drilled. However, the well failed to produce adequate water (110 gpm), so a second larger well (16" diameter and 96'deep) was drilled in 1965. The new well produced approximately 1800 gpm. The first irrigation system for the fields consisted of a buried pipeline from the well and a tow irrigation system.

In 1967, the refuge produced its first maze crop. The HNWR Master Plan (1971) states that the irrigated cropland production "*…has been extremely low"*, and recommends a total of 400 irrigated acres ultimately, but located in better suited areas. The soils in the Farm Field area are relatively coarse, thus flood irrigation is difficult due to a limited production of groundwater, and prevent moist soil type activities.

1999 NORTH AMERICAN WETLAND CONSERVATION ACT (NAWCA) GRANT

In 1999, the USFWS, BOR, and Ducks Unlimited, Inc. partnered to conduct habitat improvements at HNWR, and received a NAWCA grant for the work. The project included improvements in and around the Beal Lake area to create a diversity of habitats, as described herein:

- *Dredge Beal Lake* – In March of 2000, the BOR mobilized equipment to begin dredging Beal Lake to create deep water habitat for native endangered fish, primarily razorback sucker (*Xyrauchen texanus*) and bonytail chub

A permeable rock fish barrier was constructed by BOR in the Beal Lake ditch to separate predator fish in Topock Marsh from native fish planted in Beal Lake. The barrier was made up of various sized rock and gravels to screen predator fish larvae.

(*Gila elegans*) as part of its requirement to comply with the Endangered Species Act. Since it is believed by BOR that the decline of the species is due to the introduction of non-native fish species, raising native fish requires a protected area that is isolated from Topock Marsh and the river. As part of the project, a rock "fish barrier" was installed in the Beal Lake ditch (between Topock Marsh and Beal Lake) and at the outlet of Beal Lake to prevent predatory fish from entering the lake.

The first barrier (shown above) consisted of a passive design constructed of various sized rocks and gravels. Over time, the barrier became clogged with debris and organic matter. In the spring of 2005, BOR rebuilt the barrier using wire-wedge screens equipped with an air backwash system. A detailed description of the newly constructed barrier can be found in Appendix H.

- *Riparian and Moist Soil Units* - Spoils from the Beal Lake dredging operations were deposited on a 180 acre area cleared of salt cedar immediately east of the lake for the purpose of developing riparian and moist soil habitats. Site soils and spoils from the dredging were much coarser than expected, thus the entire 180 acre area was converted to riparian vegetation. The BOR provided plastic irrigation pipe with alfalfa valves, and a low-lift pump to irrigate the project. At the time of this writing, the BOR was finishing installation of the irrigation system.

Fields for riparian restoration at Beal Lake were cleared of vegetation, then divided into numerous cells for irrigation. Because the soils are very coarse (sands), the area of each cells were minimized, ranging from approximately 1 acre to no more than 5.5 acres. Each cell interior was leveled to promote efficient irrigation (shown).

The following is an excerpt from a BOR report dated 2005 that defines the current status of the project:

The Beal Lake Restoration Project (the project) is located on Havasu National Wildlife Refuge in Needles, California, within the historic floodplain of the lower Colorado River. When completed, it will include over 200 acres of cottonwood, willow and mesquite riparian habitat. Prior to restoration, Beal Lake was approximately 225 acres of shallow, low quality aquatic habitat. This lake was dredged to deepen it beginning in 2001, and the dredge material was distributed over adjacent areas, to be planted at a later date with native vegetation. Container plants grown in nurseries, cuttings and seeds have been used at the site. Phase 1 of the project, which is the focus of this report, resulted in 55 acres of cottonwood (Populus fremontii) and willow (Salix gooddingii, S. exigua) along with some naturally established arrowweed (Tessaria sericea) and saltcedar (Tamarix ramosissima) . Areas that contain saline soils will be planted with salt-tolerant shrubs (Atriplex spp., Baccharis spp.) and/or wetland plants such as bulrush (Scirpus californicus). This report will be updated as future phases of the project are completed.

A copy of the BOR report is provided in Appendix H.

- *Lost Lake Inlet* – A new LCR inlet and conveyance canal was constructed to allow fresh water to flow into the north end of Lost Lake. Lost Lake is directly connected to the river, so operates as a backwater area, rising and falling in response to river levels. HNWR management had the new inlet designed and constructed to keep the water in Lost Lake from becoming stagnant.

IV. Flow Measurement

Accurately recording water that is diverted for habitat use is an essential element for effective refuge management. The refuge has an obligation to use no more than its entitlement, but must ensure that it receives every legally available gallon for its operations since water is one of the refuge's primary limiting resources. There is also a compelling need to monitor water used for specific habitats within the refuge to optimize available water to meet principal goals and objectives, and plan future habitat improvements. To provide this need, water measuring stations and devices must be strategically located and properly selected for existing site conditions.

The difficulty with accurate flow measurement is that no one type or device works best in all situations. Despite a long history of use, many traditional flow measuring devices are prone to disruption or other shortcomings, such as sediment deposition, varying water conditions, vandalism, reliable data collection, etc. It is estimated that over 75% of flow measuring devices do not perform satisfactorily, and 90% of these problems are due to improper selection of either the type of measuring device or location. Thus, careful review of the site and range of operating conditions is crucial for meter accuracy and function.

Flow measurement can be roughly divided into two main categories: 1) open-channel flow measurement, and 2) closed conduit flow measurement. Open-channel flow measurement measures water with a "free" surface under gravity flow (e.g. ditch, channel, partially filled pipe, river, stream, etc.). A closed-conduit flow has no free surface thus the water has a pressure component (e.g. pumping water through a full pipe, water flowing in a pipe with head). Many flow measuring devices are designed to be used for either closed or open conduit conditions, although there are a limited number of devices that can be used for both conditions.

The basis of all flow measurement is the continuity equation, which states the flow (Q) is equal to the product of the velocity (V) and area (A). All flow measuring devices must either measure or estimate both water velocity and cross-sectional area. Many of the most commonly used flow measuring devices in open-channel flow conditions rely on hydraulic theory (e.g. flumes, weirs, orifice plates) to indirectly compute flow. These types of devices normally require that numerous site conditions be satisfied for the device to measure accurately, and incur some head loss since water must be forced into a "critical flow" condition. Even when conditions are good, accuracies are generally +/- 10%.

"Direct" flow measuring involves the use of various electronic devices based on electronic or acoustic principles to measure the water surface and cross-sectional area. These devices include particle-image velocimetry, lasers, radar, and acoustics. These types of technologies have only recently seen wide-spread use in open-channel use,

primarily due to their earlier prohibitive costs. However, the current cost and reliability of direct measuring devices has made them an attractive alternative to indirect measurement (i.e. flumes, weirs, etc.).

Current Conditions and Measuring Water enters and leaves the HNWR boundaries in a variety of ways. It can be actively diverted into the refuge from the river, actively returned from the refuge to the river, passively flow overland onto the refuge from precipitation runoff, or passively enter or leave the refuge boundaries through subsurface flows. Water also leaves through evaporation of surface water and evapotranspiration by vegetation.

Currently, water can be actively diverted to the refuge by gravity flow at three (3) locations. Two of these, the Inlet Canal and the Farm Ditch, are measured. The third, Lost Lake Diversion, is not measured, although none of the water diverted at this inlet is impounded so it is recognized as a "flow through" diversion with no consumptive use. The refuge also uses water from an existing well for crop irrigation at the Farm Fields.

A second location on the Inlet Canal is measured by the FWS as water enters Topock Marsh near the North Dike. Water is actively released to the river from Topock Marsh at the South Dike as it leaves the refuge. This location is also measured. Exhibit 1 shows the location of various diversion points and metered locations.

Current systems of water conveyance and measurement are further described as follows:

- **Inlet Structure** - Built in 1966, the Topock Marsh Inlet Gaging Station is located 32 river-miles downstream of Davis Dam, across from the City of Needles. The Inlet Gaging Station is a large structure with three (3) 42" diameter pipes and concrete headwall that provides water to the Inlet Canal. Each intake has a rectangular slide gate (3' high x 4' wide) to control flows.

Water flow from the LCR into the Inlet Canal is controlled by three slide gates (shown). Metering equipment is installed within the structure behind the gates. Debris build-up at the entrance and inside the structure is a continuous problem, and compounds metering errors.

Water flow measurement is accomplished through the use of three (3) rectangular orifices and two (2) float-tape stage recorders to measure head differential across one of the orifice plates. The orifices are adjustable by changing the opening of the slide gates. Since there is only one set of recorders, all orifice openings must be set at the same elevation. Typically, the gates are in a fully opened position to allow maximum flow through the structure, although the measuring accuracy is reduced.[25]

The station is operated and maintained by the United States Geological Survey (USGS). Data is recorded on a Design Analysis electronic data logger, interfaced with three Handar encoders, which record forebay and afterbay elevations, and the gate opening.

In theory, a rectangular orifice gage should have accuracies of +/- 2%, if conditions are correct. However, studies conducted at HNWR in the late 1990's [26] indicate that there are significant errors in the gage readings, as high as 50% when flows are low. The studies suggest that the operating criteria required for +/-2% accuracy is difficult to achieve at this location, primarily due to the wide range of water stages experienced at the structure. Recent calibration efforts by USGS (2003) indicated that at measured flows of 80.2 cfs and 138 cfs, errors ranged from 28% to 68%.

Perhaps the most difficult characteristic of the site is inconsistent water levels. As the Colorado River rises above the bottom of the orifice, water begins to flow through the structure and fill the inlet canal. Flows increase as water rises, moving from a free flow condition into a submerged condition. As the river elevation recedes (diurnal fluctuations occur every day due to water releases for energy production), backflow conditions occur.

Some floating debris carried in from the river is probable. Vandalism is also a concern since the location in not within a closed area of refuge property. Since this is the primary inlet for the refuge, it is critical that water measurement be accurate for all conditions.

Due to the difficulty of maintaining the flow meter at this site and suspicions regarding its accuracy, the USGS installed a direct reading instrument at the Inlet Canal in the spring of 2005. The device is a Sontek Argonaut SW vertical-reading sonic type device (similar to that installed at the inlet canal terminus at North Dike).

---

[25] According to W.P. Roberts of the USGS, the highest level of accuracy is achieved with gate openings at about 2 feet. In general, larger gate openings resulted in larger discrepancies between computed flow and measured flow.

[26] . "Preliminary Hydrologic Investigations of Topock Marsh, Arizona, 1995-98", Bradley Evan Guay, 2001.

- **Inlet Canal –** Water from the Inlet Structure is conveyed approximately 4.1 miles through an earthen ditch to the north end of Topock Marsh. Between the Inlet Structure and Topock Marsh, water conveyed in the Inlet Canal is actively diverted by three privately owned low-lift pumps for agricultural purposes. Measurement of these diversions is either inconsistent or nonexistent. The refuge also frequently diverts some of the Inlet Canal water for operation of the Pintail Slough Management Unit. These diversions are currently not measured.

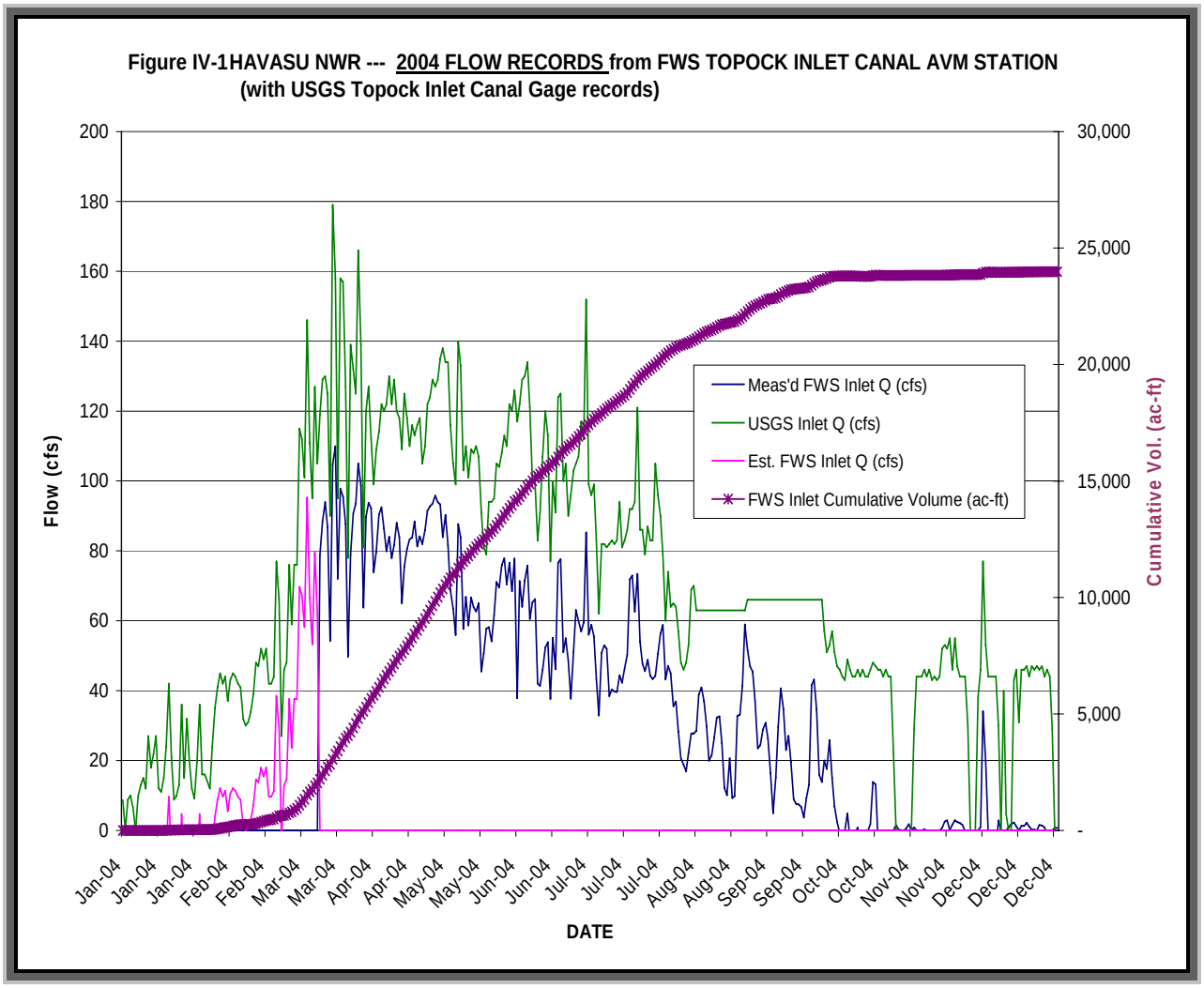
  Near the terminus of the Inlet Canal at the north side of Topock Marsh, water conveyed through the Inlet Canal is measured again with a Sontek acoustic flow meter along the North Dike. The gage is maintained by BOR and FWS cooperatively. Data is recorded with Sontek Argonaut-SW meter (replacing the SL model in 2005) with measurements taken every fifteen minutes. The electronics for this device are housed in a vertically mounted corrugated metal pipe on the ditch bank.

The Sontek Argonaut-SL (shown) is suspended from a galvanized rod in the Inlet Canal (cylindrical unit submerged at base of rod. Build up of debris on the unit and low water levels can disturb meter function, although the unit is less susceptible than other types of metering stations (e.g. flumes, weirs, etc.). This meter was replaced with a Argonaut SW in July, 2005

  Problems encountered through use of this measuring device include shifting substrate, aggrading channel, vegetative debris, and vandalism. Although backflow conditions may occur regularly, the Sontek device can measure bi-directional flow.

  There is a significant discrepancy when comparing data from the USGS metering station at the Inlet Structure and the BOR/FWS metering station at the terminus of the Inlet Canal. For example, reviewing 2004 flow

records for both stations reveals a difference in cumulative volume of approximately 25,000 ac-ft. The USGS station recorded total diversions of 48,721 ac-ft, whereas the BOR/FWS station measured only 23,988 ac-ft. Possible explanations for the difference include diversions from privately owned agricultural pumps in the canal between the two metering stations, errors in meter readings, and conveyance and evaporative loss along the 4 mile ditch. Figure IV-1 illustrates a comparison of data from the two metering stations.



- **Farm Ditch** – Located near the maintenance shop and farm fields, the Farm Ditch receives water from the river through a culvert and canal gate intake structure located on the Colorado River, and conveys the water to Topock Marsh near the "glory hole" through an earthen ditch approximately 2 miles in length. Water is measured through the use of an

acoustic meter (Argonaut SW), mounted in a 36" culvert. The electronics for this device are housed in a partially buried corrugated metal pipe directly above the culvert. Problems with this measuring device have included interference by wildlife (e.g. chewed through).

Conditions associated with this site are similar to those at the Inlet Canal. Due to river stage fluctuations, water flows vary daily, and reverse flow conditions may occur. Vegetative debris from the river and canal banks is probable.

- **South Dike -** The South Dike is equipped with a submerged adjustable rectangular orifice to measure discharge flows from Topock Marsh. Pressure transducers are mounted on each side of the structure to measure and record differential head. Measurements are taken automatically every 15-minutes. The data is recorded on Campbell Scientific Data Logger. Problems associated with the South Dike gauge include chronic dislodgement of shaft-encoder cable, leakage under gate, vegetative debris (beaver dam upstream), and vandalism.

FWS has identified a flow control and measuring devise for the South Dike, and is currently planning to improve the Topock Marsh outlet and measuring system by installing a Langemann Bifold Gate. The gate functions as a vertically adjustable weir. The gate has a water level sensing and control system that functions in either flow control or level control mode. For upstream level control a Langemann Gate can function in either manual or automated mode. It is also adapted to other control/communications systems. The proposed measuring system would consist of a 12 foot wide by 9 foot tall gate and open discharge channel.

Features of the Langemann Gate include:

- Low Power Requirements
  - Capable of operation with a battery and solar panel
  - Operates with a low voltage fractional HP motor
- Compact Design
  - Built to fit into existing stoplog guides
  - Incorporates its own stilling well
- Ease of Installation
  - Can be installed in the wet if desired
- Automatic Operation in Flow or Level Control Mode
  - Uses industrial off-the-shelf components
  - Automation performs either function
- Use as Turnout, Checking Gate or Spill Gate

- **Farm Fields Groundwater Well**

  The Farm Fields are irrigated with a water well and wheel-line irrigation system. Water use from the well is recorded using a propeller meter to totalize flows. Total production from the farm well is shown in Table II-1. Due to the proximity of the LCR, water pumped from the well is considered a diversion from the river and counted as part of Havasu's entitlement.

Internal Unmeasured Flows There are several locations where water passes between irrigation canals and habitat units that are not currently measured, including Pintail Slough, Beal Lake, and Lost Lake. The importance of measuring refuge internal flows is to provide biological staff with a greater understanding of the relationship between applied water and habitat response. The benefits of collecting this data include: 1) developing a quantitative and documented history of successful habitat management practices, and 2) developing specific values of water demands for various habitats to properly plan new projects.

The devices used for refuge internal flows may consist of permanent or temporary type devices. Some locations may require a permanent device if water is applied throughout the year (e.g. Beal Lake). Other locations may only receive water seasonally, whereby a temporary device may be more appropriate. Water applied to small individual habitat units (e.g. farm fields in Pintail Slough) could be measured by temporarily installing "portable" type flow measuring devices.

Selecting Measuring Devices The first process in flow meter selection is to determine what flows need to be measured. Sometimes flow meter devices can be eliminated or avoided by combining the readings of other devices, reducing the number of supply channels or pipes that may be redundant, etc. All flow meters require calibration, regular maintenance, and periodic repair. Thus, recommendations to install of flow measuring devices should be made with care.

Appendix I provides a recommended step-by-step process to select a flow meter. The process is intended to allow persons making decisions regarding flow meter selection to prioritize and account for all site and device characteristics. For example, if a device cannot perform in the environment required (step 1), the cost is irrelevant. It is important to note that the process must be conducted for each site requiring flow measurement since every site has unique characteristics. A brief description of each step is listed as follows:

1. Compatibility of Device – The first step is to determine if the device is suitable for the site and flow conditions present or expected. Examples include the need for power supply, range of flow conditions, sensitivity of

the device to vandalism, irregularity of the channel, etc. In the case of indirect flow devices, are conditions required for accurate measurement present and consistent? In the case of indirect flow devices, would sedimentation, debris, or turbidity adversely affect accuracy?

2. Accuracy/Reliability – The second step is to make a realistic estimate of the device's accuracy given the site conditions. The purpose of the device must be examined to determine the importance of the data generated (accuracy, lost data, etc.). If the device overmeasures flow rates by 10%, or if data is lost due to improperly functioning data collection systems, would there be significant impacts?

3. Head Loss – If an indirect measuring device is used, some head loss should be expected. Some systems may not be able to afford minor losses to adequately supply water. Also, some site conditions may not always provide a sufficient upstream/downstream differential, resulting in a submerged condition.

4. Maintenance and Service – This is a very important characteristic in the selection process, and is often overlooked or minimized. There are many examples where highly accurate flow devices were selected for a particular installation, but required far more attention or expertise than was available from the owner. Ultimately, unsupported meters fall out of use or calibration, and provide no benefit to the owner. Before a meter is selected, the owner should understand and commit resources for maintaining and servicing the device.

5. Cost – This characteristic is self evident. The meter must be affordable both in its purchase and maintenance.

6. Compatibility – This characteristic requires the owner to look at existing flow measuring systems and project the direction of future programs that may require flow devices, and determine if new devices installed will be compatible with both situations. For example, if it is the owner's desire to ultimately have remote monitoring of all flow measuring stations, does the device have telemetry capability?

7. Credibility – The last characteristic to consider is the audience that will review the data. For example, if the wholesaler of a water entitlement does not recognize the credibility of a device, the data may not be useful.

V. Recommendations

The HNWR has great potential to provide a variety of habitats and fulfill the goals and objectives established by the USFWS. Characteristics such as size, location, soil textures, depth to groundwater, and water quality, are all conducive for development of a large and productive complex for native vegetation and resident and migratory wildlife.

A review of past studies and discussions with refuge personnel have identified several opportunities for improving habitat at HNWR. The management of Topock Marsh has consumed most of the refuge's resources since its establishment in 1941, and continues today despite relatively disappointing results and evolving FWS objectives. Thus, any significant improvements in refuge value must focus on changes to Topock Marsh operations.

When considering alternatives for improving marsh habitat, it is important to consider how the marsh functioned prior to dam construction on the LCR. As an overflow meander to the main channel, the "marsh" likely received water during most years when spring flows topped the river banks. Flows passed through the area, destroying vegetation, scouring and removing salty soils, depositing sand, and flooding depressions. When flooded, water depths were relatively shallow, with depths likely averaging less than 1 foot. As flood waters receded, pockets of impounded water remained as wetlands. These wetlands continued to diminish during the summer and fall through evaporation and percolation, and most areas dried completely. Salts left behind from evaporation would be washed away come the following spring. It was a highly dynamic area that was in a constant state of change.

Today the marsh sees only a fraction of these historical flows, and does not experience the draconian disturbances of the past. Consequently, the marsh remains in a stable yet "stale" state with limited biodiversity. Attempting to simulate historical conditions is infeasible due to the control of the river, Havasu's existing water entitlements, and limited diversion capacity.

The first and most important task for USFWS staff is to develop a firm vision for the marsh and its contribution to the refuge. Although the area now referred to as Topock Marsh was once a shallow ephemeral wetland channel, it is managed similar to an impounded reservoir. Even the most comprehensive investigation completed of the marsh to date[27] used an approach that resembled the study of a lake, analyzing algae blooms, euptrophication, sediment loading, dissolved oxygen content, and problems with

[27] B. Guay, 2001, Preliminary Hydrologic Investigation of Topock Marsh, Arizona (1995-1998).

carp. Although having permanent water on the refuge is likely a desirable feature for breeding native fish and recreation, it has not been identified as the primary goal.[28] In brief, major problems identified with current conditions and operating procedures include the following:

- The quality and diversity of habitat desired by refuge management for Topock Marsh has been elusive, despite many years of extensive physical and program modifications;
- Current Topock Marsh operations leave a limited amount of water available for other habitat improvements and goals;
- Managing the marsh as one large impoundment results in average water depths that do not promote "marsh" habitat nor production of SAV (submerged aquatic vegetation);
- Existing systems for conveying water from the LCR to Topock Marsh are inefficient, have insufficient capacity for creating hydrologic disturbances, and are dependent upon BOR's river operations;
- Conveyance of water is expected to become more difficult with time due to an aggrading marsh bottom and eroding Colorado River channel;
- The lengthy detention time of water in the marsh (due to low inflow), and sporadic outflow increases its salinity;
- Many water measuring devices for measuring LCR diversions are either problematic or ineffective;

Present Conditions Currently, water is held at the South Dike to a surface elevation necessary to "push" water to back to the North Dike, where it is of sufficient depth to allow a functioning boat ramp. The length and orientation of the marsh (land slopes to the south at approximately 1' per mile) creates a deep and voluminous reservoir of water that requires significant inflows to make a substantial impact on fill rates and water quality. Areas of the marsh at the south end are as deep as 10 feet (See Exhibit 2). Thus, the marsh is managed in a "compromised" mode, trying to balance SAV production, emergent vegetation suppression, endangered species habitat, recreation, and wintering habitat for migratory wildlife.

Two factors that adversely influence the productivity of the marsh include turbidity and salinity (Guay). The combination of persistent turbidity (> 25 NTU) and average marsh depth of 3.6' to 4'[29] may limit the production of submergent aquatic vegetation. According to Guay, the average marsh depth is at or near the limit of the photic zone based on turbidity studies conducted between 1995 and 1998. Studies also show that salinity increases significantly in concentration (>50%) as water slowly moves through the marsh.[30] [31]

[28] Havasu NWR Wildlife and Habitat Managemnt Review, June 2003.
[29] B. Guay, 2001, Preliminary Hydrologic Investigation of Topock Marsh, Arizona (1995-1998), pg 53.
[30] B. Guay, 2001, Prelimiary Hydrologic Investigation of Topock Marsh, Arizona (9195-1998), pg 101.

The current management and operation of Topock Marsh restrict the refuge's ability to make substantial improvements in overall habitat and biological value since:

1) The relatively static (passive) water elevations of the marsh does not promote biological diversity or attempt to simulate historic hydrologic conditions;

2) Approximately 27,000 acre feet (72%) of the refuge's water entitlement are lost to transevaporative loses and are not available for other uses (i.e. revegetation of native riparian habitat, moist soil units, native fish habitat, etc.).

3) "Pass-through" or flushing flows used to improve marsh water quality are counted against the refuge's entitlements. Any releases back to the LCR in excess of 4,500 ac-ft (diversion entitlement – consumptive use entitlement) are theoretically forfeited.

   For example, the refuge can divert up to 41,839 acre-feet/year and consume up to 37,339 acre-feet/year, a difference of 4,500 acre-feet/year. If the refuge diverts 41,839 acre-feet, it must return 4,500 acre-feet to the river so its consumptive use entitlement is not exceeded. Although an unmeasured return flow of 88% (or 36,818 acre-feet) is credited by BOR, it provides no benefit to the refuge. However, if the refuge were to divert 41,839 acre-feet and release 10,000 acre-feet from Topock Marsh to the river, it could not divert additional water beyond 41,839 acre-feet, even though it only consumed 31,839 acre-feet. Therefore, any water released beyond 4,500 acre-feet is not available for refuge use and permanently lost.

Water Conveyance and Flushing Existing water conveyance systems are lacking in several aspects, as defined below:

- All diversions of water from the river to the refuge are dependent upon river stage (gravity flow), so there are significant periods when water is unavailable to the refuge;
- Main diversion ditches are wide, unlined, and nearly flat, so water is lost during transport through percolation and evaporation;
- There are no systems to reuse or recirculate water;
- Private irrigation activities indirectly take water from Topock marsh by pumping water from the inlet canal during periods when there is no inlet flow from the river.

[31] Detention time during the summer is estimated at approximately 150 days based on an average ET of 9.7 inches and an average inflow rate of 60 cfs.

- Since the marsh is not segmented, it must be managed as one large unit which limits the refuge's ability to implement multiple objectives, habitats for a variety of high-priority species, etc.

It has been suggested in past studies and reports that the solution to improving the marsh is to increase the flow capacity and efficiency of the Inlet Canal to allow flushing of the marsh and minimize conveyance losses. Ignoring "short-circuiting" issues due to vegetation, marsh geometry, and stratification, problems with this scenario include: 1) the amount of additional flow required to have a significant impact on marsh quality would be excessive, likely exceeding 300 cfs or greater[32], 2) the cost to construct and operate facilities (pumps, canals, etc.) to carry 300 + cfs is likely cost prohibitive, and 3) water entitlements required to allow extensive flushing flows of the marsh are not currently available. For example, the cost to install a concrete lining on the Inlet Canal capable of carrying 300 cfs would cost approximately $3.0 M[33], and at 300 cfs, all of the refuge's entitlements would be depleted in approximately 70 days. Also, the energy cost to pump 300 cfs would exceed $10,000 per month.

Once refuge staff determines the type and amount of habitats that are most important and can be supported with available resources (e.g. water, staff, equipment, etc.), a detailed water budget and associated schedule can be developed. However, for general discussion it is beneficial to note that 41,839 acre-feet annually equates to a daily mean flow rate of approximately 58 cfs. Depending on the type of habitats developed at the refuge and how water use is scheduled, the pumping/conveyance system may not need to exceed this value significantly, especially if sections of the marsh can be used as storage.

Developing New Sources As stated above, the cost of installing and maintaining water infrastructure to provide significant flow increases necessary to have an impact on Topock Marsh water quality is extensive, but could not be initiated without additional water supplies. According to Williams and Associates, LLC:

> *"Under California law, the FWS could develop either surface or groundwater sources to achieve its objectives of habitat restoration. However, the practical issue of a lack of available water renders such an idea almost moot. Further, any source that might be found would have to exist outside of the Colorado River floodplain or out of hydrologic connection with the river aquifer if it were to be free of the constraints described above. If such water were available, California would not likely look favorably upon the use of its water supplies to grow riparian vegetation in an area that delivers water out of its control and into that of the Bureau of Reclamation. However, water has been determined to be an article of interstate commerce and the US Supreme Court has frustrated states when they*

[32] At 300 cfs, the detention time ("turn over") would be approximately 30 days.
[33] Requires a trapezoid canal with a 12' base x 6' height (assuming s=0.0002, n=0.013, and z=1.5), estimated unit cost to construct of $125 per foot.

tried to retain it within state borders.[34] *This notwithstanding, however, the practical limitation of availability seems likely to render such issues of little more than academic interest."* [35]

Thus, a list of water management actions that should be considered by refuge staff to improve program success include the following:

1. **Maximize Use of Available Water -** Physical and operational changes should be implemented to maximize water resources. This includes:

    - Reduce water consumed by Topock Marsh;
    - Provide the ability to reuse or recirculate water rather than releasing water back to the LCR;
    - Reduce "carriage" losses within the refuge by using pipes and concrete lined ditches;
    - Install precise water measuring devices to ensure the refuge receives its allotted entitlement;
    - Strategically select habitat improvements that offer maximum value with minimal water use without forfeiting diversity or other critical needs;
    - Minimize water demands by locating water-intensive habitat in areas with low permeability soils, when feasible.

2. **Improve Habitat in Topock Marsh -** Improve the quality and biodiversity of Topock Marsh by actively creating disturbances in all or sections of the marsh, including:

    - Bifurcating the marsh into separate units to
    - Allow easier and varied management capability;
    - Lower average marsh water depths to allow greater light penetration and encourage submergent aquatic vegetation growth;
    - Introduce dry periods to stimulate vegetation and invertebrate response, and manage emergent vegetation,
    - Create smaller isolated units for existing sport and fishing activities;

3. **Improve Water Delivery Systems** – New conveyance systems to move water from the LCR to specific habitats without a dependency on river stage or incurring carriage losses, including:

    - Construct pumping stations to move water from the LCR to Topock Marsh and other habitat areas regardless of river stage;

[34] In Sporhase v. Nebraska ex rel. Douglas, 458 U.S. 941 (1982), the U.S. Supreme Court held that groundwater can become an article of interstate commerce and therefore subject to congressional regulation.

[35] Refuge Water Management Plan, Cibola NWR, 2004 (pg. 63).

- Construct a system of pipe and concrete lined ditches to move water, thereby reducing system loss during conveyance;
- Enhance gravity flow facilities to take advantage of higher river levels when available;

4. **Expand Habitat Diversity** – Improve refuge habitat diversity by:

   - Identify locations on the refuge that are most suitable for desirable habitats, including riparian, moist soil, seasonal wetland, native fish, and mesquite, with consideration of soil texture, soil salinity, depth to ground water, and water consumption;
   - Develop a water budget based on proposed habitat development and available water;
   - Design water delivery systems according to the water budget, accounting for time and duration of irrigation;

Recommendations

The recommendations presented herein are intended to provide guidance for refuge management to pursue goals and objectives as identified earlier in this plan. Recommendations are based on the assumption that the refuge's water entitlements will not increase or decrease in the future, so efficient use of available water is stressed.

The recommendations focus on use and management of water, but do not address possible constraints due to special status species, or other political or legal issues. Temporary or permanent impacts to existing recreational activities, endangered species habitat, local agricultural interests, etc. are beyond the scope of this plan. Each of these issues is critical and must be considered during implementation of any plan to improve refuge habitats. *Improvements or changes in marsh management is expected to be a difficult and controversial action. The alternative (ignoring evidence that indicates the quality of marsh is in decline and recognizing resource limitations) may result in USFWS's failure to achieve its broader goals.*

Implementation of refuge improvements could be a long and slow process. For example, it is desirable to ultimately relocate existing southwestern willow flycatcher nesting habitat away from stands of tamarisk near the marsh to native riparian that can be managed independent of Topock marsh, a transition that may take many years to complete. Preserving recreational opportunities that currently exist will require a public outreach effort and consideration of alternatives to minimize impacts to local business that rely on the marsh. Thus, it is recommended that a stakeholder committee be created to identify all critical items and develop an implementation plan that addresses all concerns.

It is also important to note that implementation costs were not used as a constraint. Identifying and securing funding for the improvements is also beyond the plan's scope.

However, all of the improvements recommended can be implemented with standard materials and construction practices typically found and used at LCR refuges.

1. Topock Marsh

a. **Divide Topock Marsh into Smaller Units** – Physical and operational changes to the marsh are intended to improve habitat value and create surplus water for other types of habitat improvements. The benefits of bifurcating the marsh into smaller units are numerous. Each unit will be capable of independent operations, allowing some to function as seasonal wetland habitat and others to continue functioning primarily for recreation, for example. Creating separate units will resolve problems associated with the current "compromise" management practice.

During periods of highest evaporative loss (April through September), many of the units can remain dry, simulating historical processes and managing vegetation growth. Water can then be introduced during the winter months to create habitat for migratory birds, shorebirds, etc., and maintained at depths that are conducive to wintering habitat.

All of the units can be operated at lower depths, if appropriate, to generate SAV response. Smaller units will also have lower detention times, thereby reducing salinity build-up, and allow more effective flushing.

A conceptual division of the marsh is shown in Exhibit 3. Some of the lower marsh bottom elevations are likely influenced by local ground water and adjacent Colorado River elevations, and may never dry completely.[36] These areas will be most conducive to permanent water for fishing, boating, etc. Other marsh areas (north and west) are shallow and should be easily dewatered during select periods to act as seasonal wetlands. Divisions in the units follow natural contour breaks, with the attempt to minimize earthwork and keep individual unit bottom elevations consistent. In addition, consideration of water supply systems are incorporated.

Operations are proposed as described below:

Fall/Winter – Slowly fill seasonal wetlands for migratory birds, raise and maintain water levels in permanent water areas. Pump water from seasonal wetlands and apply to riparian/mesquite habitats.

Spring/Summer – Remove water from seasonal wetlands, lower water levels in permanent water areas to promote SAV production and reduce evaporative losses.[37]

[36] B. Guay, 2001, Preliminary Hydrologic Investigation of Topock Marsh, Arizona (1995-1998), pg 28.
[37] Of course, interim operations that are compatible with high-priority species may dictate.

2. **Water Conveyance Systems** – Water conveyance systems will consist of a combination of piped, pumped, and gravity flow facilities designed to provide an uninterrupted water supply and minimal conveyance loss. Exhibit 4 shows the proposed water supply facilities. Key changes in the plan include:

    - Construct a new supply facility near the "fire break", including pumps on the LCR;
    - Construct a water distribution system to move water to various locations on the refuge;
    - Discontinue use of the Inlet Canal due to its inefficiencies;
    - Develop a new gravity flow canal to feed Beal Lake and permanent water areas of the marsh;
    - Construct pumps to take water from the marsh and apply on other habitat areas;
    - Use a combination of concrete lined ditches (higher flows > 15 cfs) and pipe (lower flows).

    Water can be supplied to all habitat units through construction of the new pumping facility located on the LCR near the fire break. Water is pumped from the river into a new concrete lined ditch where water can be conveyed to all parts of the refuge. In addition, construction of a new LCR gravity flow intake will place water directly into Beal Lake. The intake ditch can be constructed with a fish barrier to allow native fish activities in Beal Lake. Water can subsequently flow through Beal Lake into permanent water areas of Topock Marsh. This proposed "serial" operation will maintain high water quality in Beal Lake.

3. **Water Measurement and Accounting** – Install water measuring systems that are capable of precise flow measurement and conducive to the location. Use a combination of long-throated flumes, solid state technology (acoustic), and magnetic flow meters where 120 V power is available (pump discharge).

    Specific recommendations for water measurement include:

    - Use magnetic flow meters on all pumps, when feasible;
    - Install long-throated flumes on concrete ditches with solid-state equipment to record flows;
    - Install acoustic flow measuring devices in pipe (defined area) to measure gravity flows.

4. **Habitat Diversity and Expansion** – There are many opportunities for a variety of habitat improvements on the refuge. The success of future habitat restoration depends at least partially on matching habitat with suitable conditions. Although some research has been conducted on site conditions at the refuge (e.g. soil

conditions, depth to groundwater, soil salinity, etc.)[38], additional ground work is needed, including:

- A comprehensive geotechnical investigation of the refuge that includes texture, salinity, and depth to groundwater;
- Based on the results of the geotechnical investigation, determine the potential acres of various habitats (e.g. moist soils, riparian, mesquite, etc.);
- Develop a water budget based on potential habitats, and balance available water;
- Locate and size irrigation and water supply systems accordingly.

[38] Havasu NWR Conceptual Master Plan for Habitat Restoration, (2003).

Appendix A

Resources

REFERENCES & CITED LITERATURE

Ducks Unlimited, Inc, (2003), Havasu NWR Conceptual Master Plan for Habitat Restoration.

John Earle, Refuge Manager, Havasu NWR (acting).

Bradley Evan Guay, (2001), Preliminary Hydroligic Investigation of Topock Marsh, Arizona, 1995-98.

Havasu NWR Water Management Records.

Andrew Hautzinger, Hydrologist, USFWS Region 2.

Terry Murphy, Restoration Group Manager, USBR, Boulder City

J.A. Replogle, (2001), Water Measurement with Flumes and Weirs.

Ruth Thayer, Group Manager, Water Conservation & Accounting, USBR Boulder Canyon Operations Office.

USFWS, Bureau of Sport Fisheries and Wildlife, (1973), Final Environmental Statement, Proposed Habitat Enhancement Project For Topock Marsh Unit HNWR, AZ and CA.

USFWS Southwest Region, (1971), Master Plan Backup Volume.

USFWS Southwest Region, (1992), LCR National Wildlife Refuges Comprehensive Management Plan (Draft) 1992-2012.

USFWS Southwest Region, (2003), Havasu National Wildlife Refuge Wildlife and Habitat Management Review June 9-12, 2003.

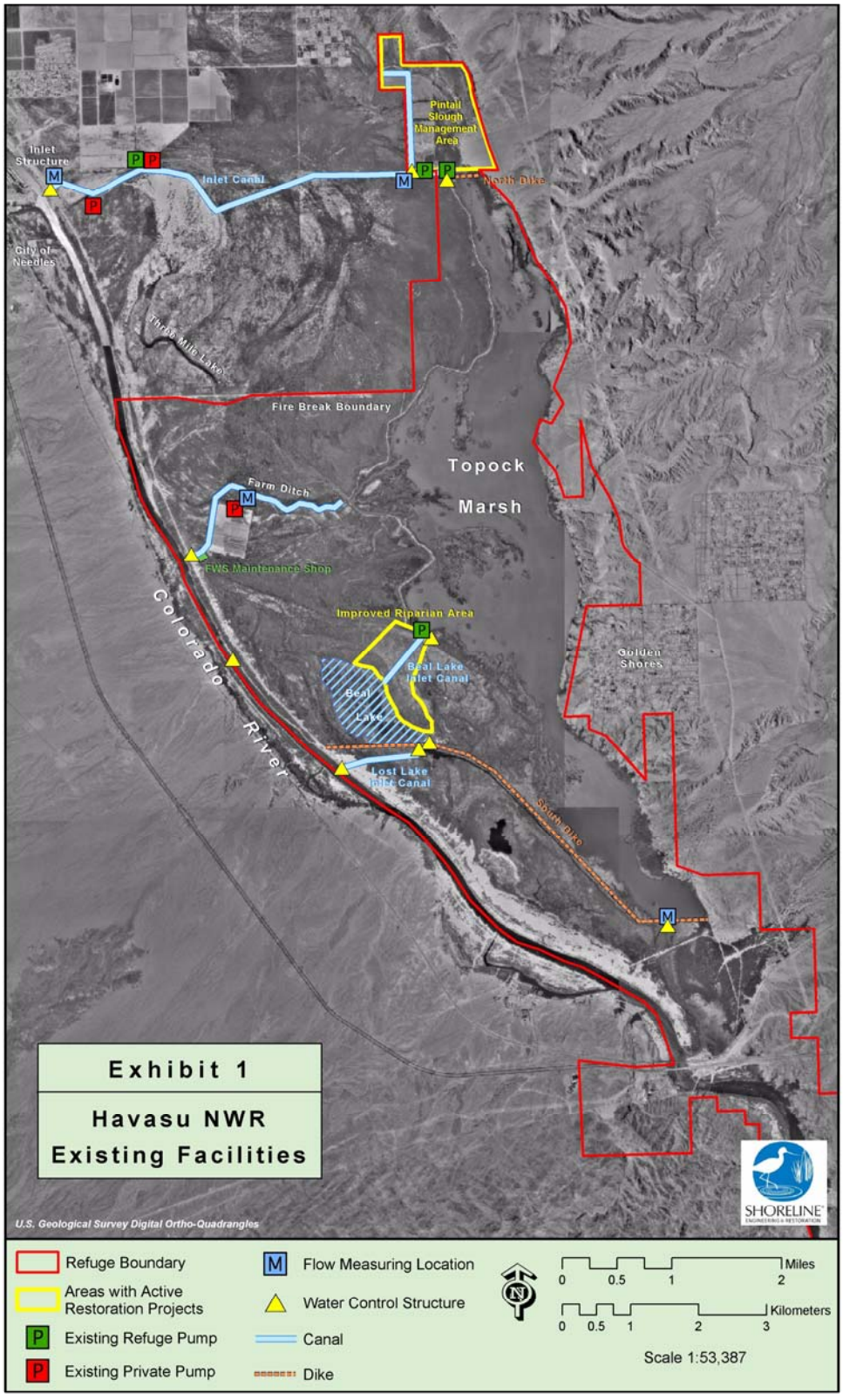
Williams and Associates, LLC (2004), Cibola NWR Water Management Plan.

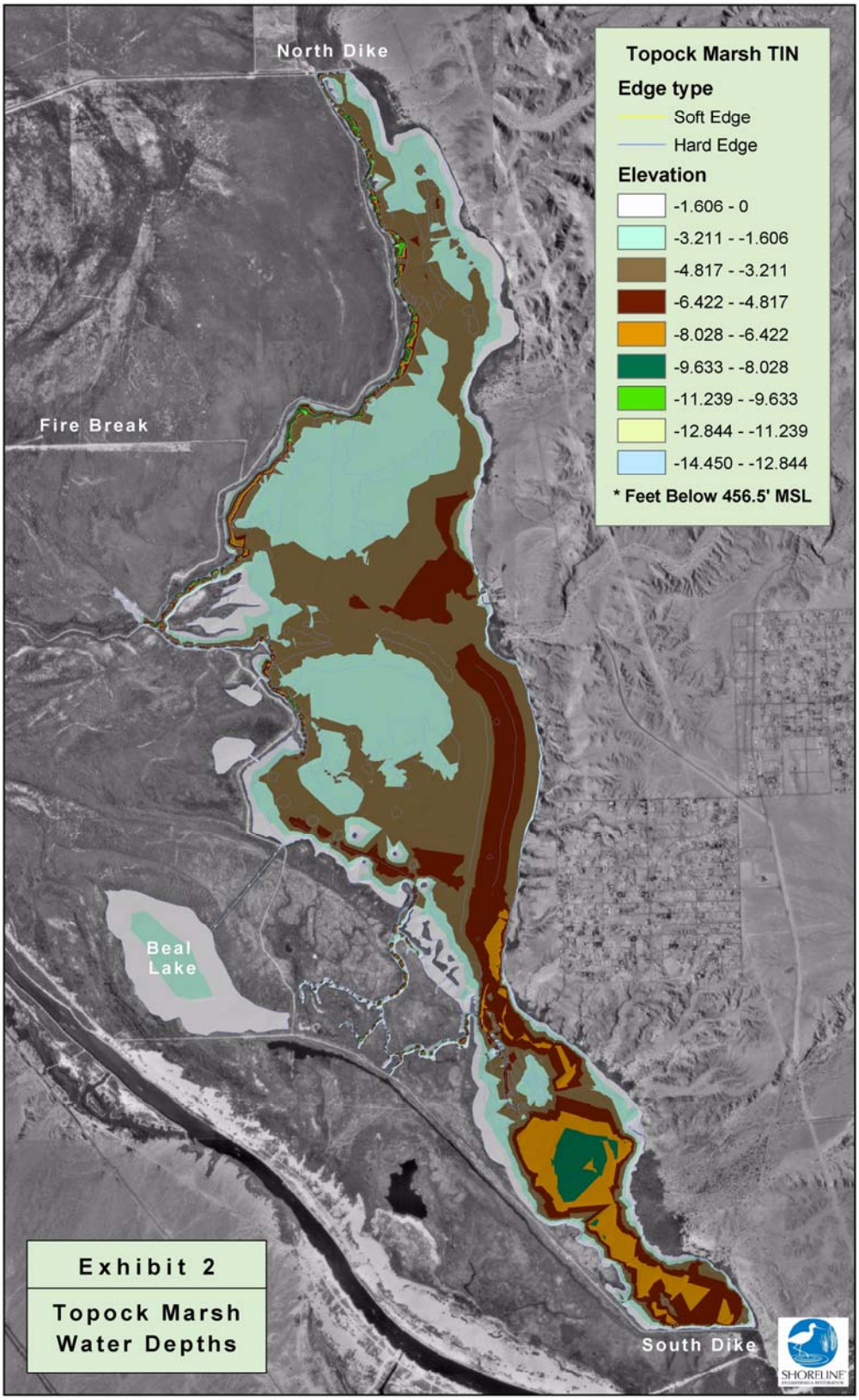
Williams and Associates, LLC, (2000), Item 4 – Research Report On The History Of Havasu (Including Bill Williams River NWR) And Imperial NWR With Respect To Secretarial Reservations And Cibola NWR With Respect To The Secretarial Contract (Draft), pgs 3-11.

Greg Wolf, Refuge Manager, Havasu NWR (past).

Appendix B

Exhibits


Pintail Slough Management Area
Inlet Structure
Inlet Canal
North Dike
City of Needles
Three Mile Lake
Fire Break Boundary
Topock Marsh
Farm Ditch
FWS Maintenance Shop
Improved Riparian Area
Beal Lake Inlet Canal
Beal Lake
Golden Shores
Colorado River
Lost Lake Inlet Canal
South Dike
Exhibit 1
Havasu NWR
Existing Facilities
U.S. Geological Survey Digital Ortho-Quadrangles
SHORELINE
Refuge Boundary
Areas with Active Restoration Projects
Existing Refuge Pump
Existing Private Pump
Flow Measuring Location
Water Control Structure
Canal
Dike
Miles
0 0.5 1 2
Kilometers
0 0.5 1 2 3
Scale 1:53,387


North Dike
Fire Break
Beal Lake
South Dike
Topock Marsh TIN
Edge type
Soft Edge
Hard Edge
Elevation
-1.606 - 0
-3.211 - -1.606
-4.817 - -3.211
-6.422 - -4.817
-8.028 - -6.422
-9.633 - -8.028
-11.239 - -9.633
-12.844 - -11.239
-14.450 - -12.844
* Feet Below 456.5' MSL
Exhibit 2
Topock Marsh Water Depths
SHORELINE

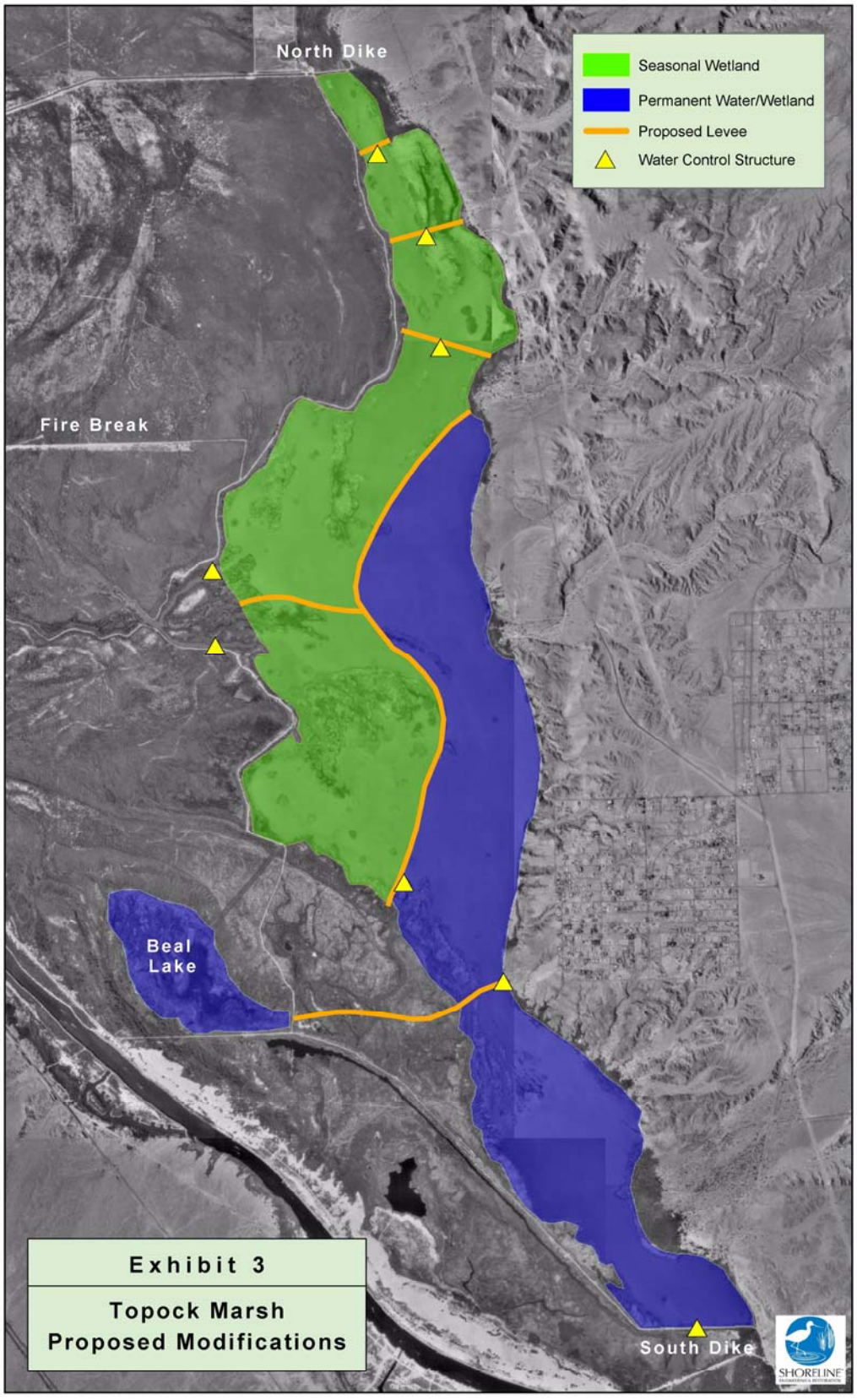
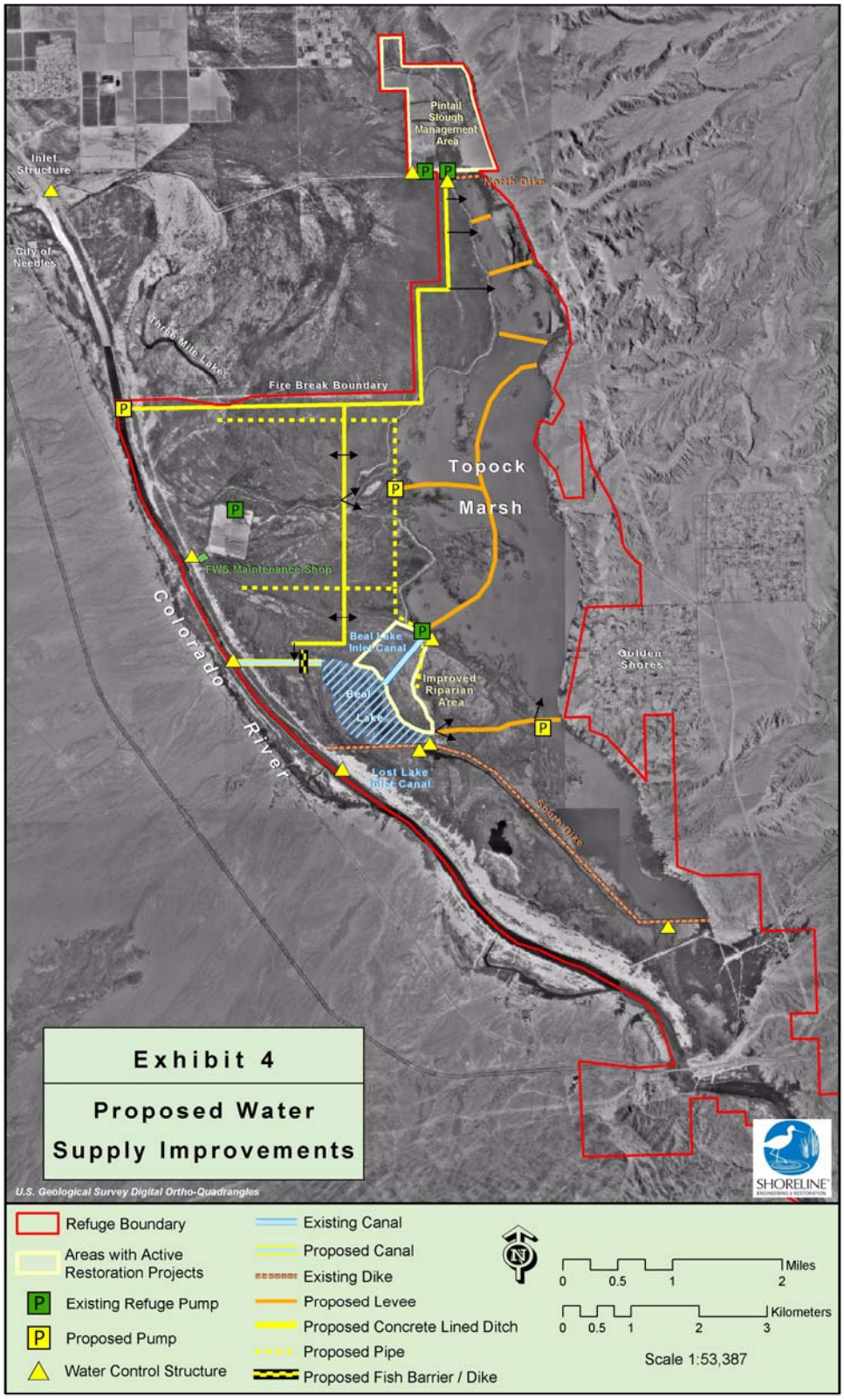


Exhibit 3

Topock Marsh
Proposed Modifications


Pintail Slough Management Area
Inlet Structure
North Dike
City of Needles
Three Mile Lake
Fire Break Boundary
Topock Marsh
FWS Maintenance Shop
Colorado River
Beal Lake Inlet Canal
Beal Lake
Improved Riparian Area
Golden Shores
Lost Lake Inlet Canal
South Dike
Exhibit 4
Proposed Water Supply Improvements
U.S. Geological Survey Digital Ortho-Quadrangles
SHORELINE
Refuge Boundary
Areas with Active Restoration Projects
Existing Refuge Pump
Proposed Pump
Water Control Structure
Existing Canal
Proposed Canal
Existing Dike
Proposed Levee
Proposed Concrete Lined Ditch
Proposed Pipe
Proposed Fish Barrier / Dike
N
0 0.5 1 2 Miles
0 0.5 1 2 3 Kilometers
Scale 1:53,387

Appendix C

1964 Supreme Court Decree

SUPREME COURT OF THE UNITED STATES

No. 8, ORIGINAL

STATE OF ARIZONA, PLAINTIFF

v.

STATE OF CALIFORNIA, ET AL., DEFENDANTS

DECREE.–MARCH 9, 1964.

It is ORDERED, ADJUDGED AND DECREED that

I. For purposes of this decree:

(A) "Consumptive use" means diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation;

(B) "Mainstream" means the mainstream of the Colorado River downstream from Lee Ferry within the United States, including the reservoirs thereon;

(C) Consumptive use from the mainstream within a state shall include all consumptive uses of water of the mainstream, including water drawn from the mainstream by underground pumping, and including but not limited to, consumptive uses made by persons, by agencies of that state, and by the United States for the benefit of Indian reservations and other federal establishments within the state;

(D) "Regulatory structures controlled by the United States" refers to Hoover Dam, Davis Dam, Parker Dam, Headgate Rock Dam, Palo Verde Dam, Imperial Dam, Laguna Dam and all other dams and works on the mainstream now or hereafter controlled or operated by the United States which regulate the flow of water in the mainstream or the diversion of water from the mainstream;

(E) "Water controlled by the United States" refers to the water in Lake Mead, Lake Mohave, Lake Havasu and all other water in the mainstream below Lee Ferry and within the United States;

(F) "Tributaries" means all stream systems the water of which naturally drain into the mainstream of the Colorado River below Lee Ferry;

(G) "Perfected right" means a water right acquired in accordance with state law, which right has been exercised by the actual diversion of a specific quantity of water that has been applied to a defined area of land or to definite municipal or industrial works, and in addition shall include water rights created by the reservation of mainstream water for the use of federal establishments under federal law whether or not the water has been applied to beneficial use;

(H) "Present perfected rights" means perfected rights, as here defined, existing as of June 25, 1929, the effective date of the Boulder Canyon Project Act;

(I) "Domestic use" shall include the use of water for household, stock, municipal, mining, milling, industrial, and other like purposes, but shall exclude the generation of electrical power;

(J) "Annual" and "Year," except where the context may otherwise require, refer to calendar years;

(K) Consumptive use of water diverted in one state for consumptive use in another state shall be treated as if diverted in the state for whose benefit it is consumed.

II. The United States, its officers, attorneys, agents and employees be and they are hereby severally enjoined:

(A) From operating regulatory structures controlled by the United States and from releasing water controlled by the United States other than in accordance with the following order of priority:

(1) For river regulation, improvement of navigation, and flood control;

(2) For irrigation and domestic uses, including satisfaction of present perfected rights; and

(3) For power;

Provided, however, that the United States may release water in satisfaction of its obligations to the United States of Mexico under the treaty dated February 3, 1944, without regard to priorities specified in this subdivision (A);

(B) From releasing water controlled by the United States for irrigation and domestic use in the States of Arizona, California and Nevada, except as follows:

(1) If sufficient mainstream water is available for release, as determined by the Secretary of the Interior, to satisfy 7,500,000 acre-feet of annual consumptive use in the aforesaid three states, then of such 7,500,000 acre feet of consumptive use, there shall be apportioned 2,800,000 acre-feet for use in Arizona, 4,400,000 acre-feet for use in California, and 300,000 acre-feet for use in Nevada;

(2) If sufficient mainstream water is available for release, as determined by the Secretary of Interior, to satisfy annual consumptive use in the aforesaid states in excess of 7,500,000 acre feet, such excess consumptive use is surplus, and 50% thereof shall be apportioned for use in Arizona and 50% for use in California; provided, however, that if the United States so contracts with Nevada, then 46% of such surplus shall be apportioned for use in Arizona and 4% for use in Nevada;

(3) If insufficient mainstream water is available for release, as determined by the Secretary of the Interior, to satisfy annual consumptive use of 7,500,000 acre feet in the aforesaid three states, then the Secretary of the Interior, after providing for satisfaction of present perfected rights in the order of their priority dates without regard to state lines and after consultation with the parties to major delivery contracts and such representatives as the respective states may designate, may apportion the amount remaining available for consumptive use in such manner as is consistent with the Boulder Canyon Project Act as interpreted by the opinion of this Court herein, and with other applicable federal statutes, but in no event shall more than 4,400,000 acre feet be apportioned for use in California including all present perfected rights;

(4) Any mainstream water consumptively used within a state shall be charged to its apportionment, regardless of the purpose for which it was released;

(5) Notwithstanding the provisions of Paragraphs (1) through (4) of this subdivision (B), mainstream water shall be released or delivered to water users (including but not limited to, public and municipal corporations and other public agencies) in Arizona, California, and Nevada only pursuant to valid contracts therefor made with such users by the Secretary of the Interior, pursuant to Section 5 of the Boulder Canyon Project Act or any other applicable federal statue;

(6) If, in any one year, water apportioned for consumptive use in a state will not be consumed in that state, whether for the reason that delivery contracts for the full amount of the state's apportionment are not in effect or that users cannot apply all of such water to beneficial uses, or for any other reason, nothing in this decree shall be construed as prohibiting the Secretary of the Interior from releasing such apportioned but unused water during such year for consumptive use in the other states. No rights to the recurrent use of such water shall accrue by reason of the use thereof;

(C) From applying the provisions of Article 7 (d) of the Arizona water delivery contract dated February 9, 1944, and the provisions of Article 5 (a) of the Nevada water delivery contract dated March 30, 1942, as amended by the contract dated January 3, 1944, to reduce the apportionment or delivery of mainstream waters to users within the States of Arizona and Nevada by reason of any uses in such states form the tributaries flowing therein;

(D) From releasing water controlled by the United States for use in the States of Arizona, California, and Nevada for the benefit of any federal establishment named in this subdivision (D) except in accordance

with the allocations made herein; provided, however, that such release may be made notwithstanding the provisions of Paragraph (5) of subdivision (B) of this Article; and provided further that nothing herein shall prohibit the United States from making future additional reservations of mainstream water for use in any of such States as may be authorized by law and subject to present perfected rights and rights under contract theretofore made with water users in such State under Section 5 of the Boulder Canyon Project Act or any other applicable federal statue:

(1) The Chemehuevi Indian Reservation in annual quantities not to exceed (in) 11,340 acre feet of diversions from the mainstream or (ii) the quantity of mainstream water necessary to supply the consumptive use required for irrigation of 1,900 acres and for the satisfaction of related uses, whichever of (in) or (ii) is less, with a priority date of February 2, 1907;

(2) The Cocopah Indian Reservation in annual quantities not to exceed (in) 2,744 acre feet in diversions from the mainstream or (ii) the quantity of mainstream water necessary to supply the consumptive use required for irrigation of 431 acres and for the satisfaction of related uses, whichever (in) or (ii) is less, with a priority date of September 27, 1917;

(3) The Yuma Indian Reservation in annual quantities not to exceed (in) 51,616 acre feet in diversions from the mainstream or (ii) the quantity of mainstream water necessary to supply the consumptive use required for irrigation of 7,743 acres and for the satisfaction of related uses, whichever (in) or (ii) is less, with a priority date of January 9, 1884;

(4) The Colorado River Reservation in annual quantities not to exceed (in) 717,148 acre feet in diversions from the mainstream or (ii) the quantity of mainstream water necessary to supply the consumptive use required for irrigation of 107,588 acres and for the satisfaction of related uses, whichever (in) or (ii) is less, with priority dates of March 3, 1865, for lands reserved by the Act of March 3, 1965 (13 Stat. 541, 559); November 22, 1873, for lands reserved by the Executive Order of said date; November 16, 1874, for lands reserved by the Executive Order of said date, except as later modified; May 15, 1876, for lands reserved by the Executive Order of said date; November 22, 1915, for lands reserved by the Executive Order of said date;

(5) The Fort Mohave Reservation in annual quantities not to exceed (in) 122,648 acre feet in diversions from the mainstream or (ii) the quantity of mainstream water necessary to supply the consumptive use required for irrigation of 18,974 acres and for the satisfaction of related uses, whichever (in) or (ii) is less, and, subject to the next succeeding proviso, with priority dates of September 18, 1890, for lands transferred by the Executive Order of said date; February 2, 1911, for lands reserved by the Executive Order of said date; provided, however, that lands conveyed to the State of California pursuant to the Swamp and Overflow Lands Act [9 Stat. 519 (1850] as well as any accretions thereto to which the owners of such land may be entitled, and lands patented to the Southern Pacific Railroad pursuant to the Act of July 27, 1966 (14 Stat. 292) shall not be included as irrigable acreage within the Reservation and that the above specified diversion requirement shall be reduced by 6.4 acre feet per acre of such land that is irrigable; provided that the quantities fixed in this paragraph and paragraph (4) shall be subject to appropriate adjustment by agreement or decree of this Court in the event that the boundaries of the respective reservations are finally determined;

(6) The Lake Mead National Recreation Area in annual quantities reasonably necessary to fulfill the purposes of the Recreation Area, with priority dates of March 3, 1929, for lands reserved by the Executive Order of said date (No. 5105), and April 25, 1930, for lands reserved by the Executive Order of said date (No. 5339);

(7) The Havasu Lake National Wildlife Refuge in annual quantities reasonably necessary to fulfill the purposes of the Refuge, not to exceed (in) 41,839 acre feet of water diverted from the mainstream or (ii) 37,339 acre feet of consumptive use of mainstream water, whichever of (in) or (ii) is less, with a priority date of January 22, 1941, for lands reserved by the Executive Order of said date (No. 8647), and a priority date of February 11, 1949, for land reserved by the Public Land Order of said date (No. 559);

(8) The Imperial National Wildlife Refuge in annual quantities reasonably necessary to full the purposes of the Refuge not to exceed (in) 28,000 acre feet of water diverted from the mainstream or (ii)

23,000 acre feet of consumptive use of mainstream water, whichever of (in) or (ii) is less, with a priority date of February 14, 1941;

(9) Boulder City, Nevada, as authorized by the Act of September 2, 1958, 72 Stat. 1726, with a priority date of May 15, 1931;

Provided further, that consumptive uses from the mainstream for the benefit of the above-named federal establishments shall, except as necessary to satisfy present perfected rights in the order of their priority dates without regards to state liens, be satisfied only out of water available, as provided in subdivision (B) of this Article, to each state wherein such uses occur and subject to, in the case of each reservation, such rights as have been created prior to the establishment of such reservation by contracts executed under Section 5 of the Boulder Canyon Project Act or any other applicable federal statute.

III. The States of Arizona, California and Nevada, Palo Verde Irrigation District, Imperial Irrigation District, Coachella Valley County Water District, Metropolitan Water District of Southern California, City of Los Angeles, City of San Diego, and County of San Diego, and all other users of water from the mainstream in said states, their officers, attorneys, agents and employees, be and they are hereby several enjoined:

(A) From interfering with the management and operation, in conformity with Article II of this decree, of regulatory structures controlled by the United States;

(B) From interfering with or purporting to authorize the interference with releases and deliveries, in conformity with Article II of this decree, of water controlled by the United States;

(C) From diverting or purporting to authorize the diversion of water from the mainstream the diversion of which has not been authorized by the United States for use in the respective states; and provided further that no party named in this Article and no other user of water in said states shall divert or purport to authorize the diversion of water from the mainstream the diversion of which has not been authorized by the United States for its particular use;

(D) From consuming or purporting to authorize the consumptive use of water from the mainstream in excess of the quantities permitted under Article II of this decree.

IV. The State of New Mexico, its officers, attorneys, agents and employees, be and they are after four years from the date of this decree hereby severally enjoined:

(A) From diverting or permitting the diversion of water from the San Simon Creek, its tributaries and underground water sources for irrigation of more than a total of 2,900 acres during any one year, and from exceeding a total consumptive use of such water, for whatever purpose, of 72,000 acre feet during any period of ten consecutive years; and from exceeding a total consumptive use of such water, for whatever purpose, of 8,220 acre feet during any one year;

(B) From diverting or permitting the diversion of water from the San Francisco River, its tributaries and underground water sources for the irrigation within each of the following areas of more than the following number of acres during any one year:

Luna Area	225
Apache Creek-Aragon Area	316
Reserve Area	725
Glenwood Area	1,003

and from exceeding a total consumptive use of such water for whatever purpose, of 31,870 acre-feet during any period of ten consecutive years; and from exceeding a total consumptive use of such water, for whatever purpose, of4,112 acre-feet during any one year;

(C) From diverting or permitting the diversion of water form the Gila River, its tributaries (exclusive of the San Francisco River and San Simon Creek and their tributaries) and underground water sources for the

irrigation within each of the following areas of more than the following number of acres during any one year:

Upper Gila Area	287
Cliff-Gila and Buckhorn-Duck Creek Area	5,314
Red Rock Area	1,456

and from exceeding a total consumptive use of such water (exclusive of uses in Virden Valley, New Mexico), for whatever purpose, of 136,620 acre feet during any period of ten consecutive years; and from exceeding a total consumptive use of such water (exclusive of uses in Virden Valley, New Mexico), for whatever purpose, of 15,895 acre feet during any one year;

(D) From diverting or permitting the diversion of water form the Gila River and its underground water sources in the Virden Valley, new Mexico, except for use on lands determined to have the right to the use of such water by the decree entered by the United States District Court for the District of Arizona on June 29, 1935, in *United States v. Gila Valley Irrigation District, et al.* (Globe Equity No. 59) (herein referred to as the Gila Decree), and except pursuant to and in accordance with the terms and provisions of the Gila Decree; provided, however, that:

(1) This decree shall not enjoin the use of underground water on any of the following lands:

Owner	Subdivision and Legal Description	Sec.	Twp.	Rng.	Acreage
Marvin Arnett and J.C. O'Dell	Part Lot 3	6	19S	21W	33.84
	Part Lot 4	6	19S	21W	52.33
	NW¼SW¼	5	19S	21W	38.36
	SW¼SW¼	5	19S	21W	29.80
	Part Lot 1	7	19S	21W	50.68
	NW¼NW¼	8	19S	21W	38.03
Hyrum M. Pace, Ray Richardson, Harry Dan and N. O. Pace, Est.	SW¼NE¼	12	19S	21W	8.00
	SW¼NE¼	12	19S	21W	15.00
	SE¼NE¼	12	19S	21W	17.00
C. C. Martin	S. part SE¼SW¼SE¼	1	19S	21W	0.93
	W½W½W½NE¼NE¼	12	19S	21W	0.51
	NW¼NE¼	12	19S	21W	18.01
A. E. Jacobson	SW part Lot 1	6	19S	21W	11.58
W. LeRoss Jones	W. Central part: E½E½E½NW¼NW¼	12	19S	21W	0.70
	SW part NE¼NW¼	12	19S	21W	8.93
	N. Central part: N½N½NW¼SE¼NW¼	12	19S	21W	0.51
Conrad and James R. Donaldson	N½N½N½SE¼	18	19S	20W	8.00
James D. Freestone	Part W½NW¼	33	18S	21W	7.79
Virgil W. Jones	N½SE¼NW¼; SE¼NE¼NW¼	12	19S	21W	7.40

Darrell Brooks	SE¼SW¼	32	18S	21W	6.15
Floyd Jones	Part N½SE¼NE¼	13	19S	21W	4.00
	Part NW¼SW¼NW¼	18	19S	20W	1.70
L. M. Hatch	SW¼SW¼.	32	18S	21W	4.40
	Virden Townsite	. . .	. . .	. . . .	3.90
Carl M. Donaldson . .	SW¼SE¼.	12	19S	21W	3.40
Mack Johnson	Part NW¼NW¼NE¼.	10	19S	21W	2.80
	Part NE¼NW¼NW¼.	10	19S	21W	0.30
	Part N½N½S½NW¼NE¼	10	19S	21W	0.10
Chris Dotz	SE¼SE¼; SW¼SE¼.	3	19S	21W	2.66
	NW¼NE¼; NE¼NE¼.	10	19S	21W	
Roy A. Johnson . . .	NE¼SE¼SE¼	4	19S	21W	1.00
Ivan and Antone Thygerson	NE¼SE¼SE¼	32	18S	21W	1.00
John W. Bonine . . .	SW¼SE¼SW¼	34	18S	21W	1.00
Marion K. Mortenson	SW¼SW¼SE¼	33	18S	21W	1.00
Total	. . . . .	. . . .	. . .	. . .	380.81

or on lands or for other uses in the Virden Valley to which such use may be transferred or substituted on retirement from irrigation of any of said specifically described lands, up to a maximum total consumptive use of such water of 838.2 acre-feet per annum, unless and until such uses are adjudged by a court of competent jurisdiction to be an infringement or impairment of rights confirmed by the Gila Decree; and

(2) This decree shall not prohibit domestic use of water from the Gila River and its underground water sources on lands with rights confirmed by the Gila Decree, or on farmsteads located adjacent to said lands, or in the Virden Townsite, up to a total consumptive use of 265 acre feet per annum in addition to the uses confirmed by the Gila Decree, unless and until such use is adjudged by a court of competent jurisdiction to be an infringement or impairment of rights confirmed by the Gila Decree;

(E) Provided, however, that nothing in this Article IV shall be construed to affect rights as between individual water users in the State of New Mexico, nor shall anything in this Article be construed to affect possible superior rights of the United States asserted on behalf of National Forests, Parks, memorials, Monuments, and lands administered by the Bureau of Land Management; and provided further that in addition to the diversions authorized herein the United States has the right to divert water from the mainstream of the Gila and San Francisco Rivers in quantities reasonably necessary to fulfill the purposes of the Gila National Forest with priority dates as of the date of withdrawal for forest purposes of each area of the forest within which the water is used.

(F) Provided, further, that no diversion from a stream authorized in Article IV (A) through (D) may be transferred to any of the other streams, nor may any use for irrigation purposes within any area on one of the streams be transferred for use for irrigation purposes to any other area on that stream.

V. The United States shall prepare and maintain, or provide for the preparation and maintenance of, and shall make available, annually and at such shorter intervals as the Secretary of the Interior shall deem

necessary or advisable, for inspection by interested persons at all reasonable times and at a reasonable place or places, complete, detail and accurate records of:

(A) Releases of water through regulatory structures controlled by the United States;

(B) Diversions of water from the mainstream, return flow of such water to the stream as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation, and consumptive use of such water. These quantities shall be stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California and Nevada;

(C) Releases of mainstream water pursuant to orders therefor but not diverted by the party ordering the same, and the quantity of such water delivered to Mexico in satisfaction of the Mexican Treaty or diverted by others in satisfaction of rights decreed herein. These quantities shall be stated separately as to each diverter from the mainstream, each point of diversion, and each of the States of Arizona, California and Nevada;

(D) Deliveries to Mexico of water in satisfaction of the obligations of Part III of the Treaty of February 3, 1944, and, separately stated, water passing to Mexico in excess of treaty requirements;

(E) Diversion of water from the mainstream of the Gila and San Francisco Rivers and the consumptive use of such water, for the benefit of the Gila National Forest.

VI. Within two years from the date of this decree, the States of Arizona, California, and Nevada shall furnish to this Court and to the Secretary of the Interior a list of the present perfected rights, with their claimed priority dates, in waters of the mainstream within each state, respectively, in terms of consumptive use, except those relating to federal establishments. Any named party to this proceeding may present its claim of present perfected rights or its opposition to the claims of others. The Secretary of the Interior shall supply similar information, within a similar period of time, with respect to the claims of the United States to present perfected rights within each states. If the parties and the Secretary of the Interior are unable at that time to agree on the present perfected rights to the use of mainstream water in each state, and their priority dates, any party may apply to the Court for the determination of such rights by the Court.

VII. The State of New Mexico shall, within four years from the date of this decree, prepare and maintain, or provide for the preparation and maintenance of, and shall annually thereafter make available for inspection at all reasonable times and at a reasonable place or places, complete, detailed and accurate records of:

(A) The acreages of all lands in New Mexico irrigated each year from the Gila River, the San Francisco River, San Simon Creek and their tributaries and all of their underground water sources, stated by legal description and component acreages and separately as to each of the areas designated in Article IV of this decree and as to each of the three streams;

(B) Annual diversions and consumptive uses of water in New Mexico, from the Gila River, the San Francisco River and San Simon Creek and their tributaries, and all their underground water sources, stated separately as to each of the three streams.

VIII. This decree shall not affect:

(A). The relative rights *inter sese* of water users within any one of the states, except as otherwise specifically provided herein;

(B) The rights or priorities to water in any of the Lower Basin tributaries of the Colorado River in the States of Arizona, California, Nevada, New Mexico and Utah except the Gila River System;

(C) The rights or priorities, except as specific provision is made herein, of any Indian Reservation, National Forest, Park, Recreation Area, Monument or Memorial, or other lands of the United States;

(D) Any issue of interpretation of the Colorado River Compact.

IX. Any of the parties may apply at the foot of this decree for its amendment or for further relief. The Court retains jurisdiction of this suit for the purpose of any order, direction, or modification of the

decree, or any supplementary decree, that may at any time be deemed proper in relation to the subject matter in controversy.

MR. JUSTICE DOUGLAS dissents.

MR. JUSTICE HARLAN and MR. JUSTICE STEWART dissent to the extent that the decree conflicts with the views expressed in the dissenting opinion of MR. JUSTICE HARLAN, 373 U.S. 546, 603.

THE CHIEF JUSTICE took no part in the consideration or decision of this case.

Appendix D

1962 Supreme Court Exception to Special Master Ripkin Report

U.S. Supreme Court

ARIZONA v. CALIFORNIA, 373 U.S. 546 (1963)

373 U.S. 546

**ARIZONA v. CALIFORNIA ET AL.
ON EXCEPTIONS TO SPECIAL MASTER'S REPORT AND RECOMMENDED DECREE.**

No. 8, Original. Argued January 8-11, 1962. Restored to calendar for reargument June 4, 1962. Reargued November 13-14, 1962. Decided June 3, 1963.

This original suit was brought in this Court by the State of Arizona against the State of California and seven of its public agencies. Later Nevada, New Mexico, Utah and the United States became parties. The basic controversy is over how much water each State has a legal right to use out of the waters of the Colorado River and its tributaries. A Special Master appointed by the Court conducted a lengthy trial and filed a report containing his findings, conclusions and recommended decree, to which various parties took exceptions. Held:

1. In passing the Boulder Canyon Project Act, Congress intended to, and did, create its own comprehensive scheme for the apportionment among California, Arizona and Nevada of the Lower Basin's share of the mainstream waters of the Colorado River, leaving each State her own tributaries. It decided that a fair division of the first 7,500,000 acre-feet of such mainstream waters would give 4,400,000 acre-feet to California, 2,800,000 to Arizona, and 300,000 to Nevada, and that Arizona and California should each get one-half of any surplus. Congress gave the Secretary of the Interior adequate authority to accomplish this division by giving him power to make contracts for the delivery of water and by providing that no person could have water without a contract. Pp. 546-590.
(a) Apportionment among the Lower Basin States of that Basin's Colorado River water is not controlled by the doctrine of equitable apportionment or by the Colorado River Compact. Pp. 565-567.
(b) No matter what waters the Compact apportioned, the Project Act itself dealt only with water of the mainstream and reserved to each State the exclusive use of the waters of her own tributaries. Pp. 567-575. [373 U.S. 546, 547]
(c) The legislative history of the Act, its language and the scheme established by it for the storage and delivery of water show that Congress intended to provide its own method for a complete apportionment of the Lower Basin's share of the mainstream water among Arizona, California and Nevada; and Congress intended the Secretary of the Interior, through his contracts under 5, both to carry out the allocation of the waters of the main

Colorado River among the Lower Basin States and to decide which users within each State would get water. Pp. 575-585.
(d) It is the Act and the contracts made by the Secretary of the Interior under 5, not the law of prior appropriation, that control the apportionment of water among the States; and the Secretary, in choosing between the users within each State and in settling the terms of his contracts, is not required by 14 and 18 of the Act to follow state law. Pp. 585-586.
(e) Section 8 of the Reclamation Act does not require the United States, in the delivery of water, to follow priorities laid down by state law; and the Secretary is not bound by state law in disposing of water under the Project Act. Pp. 586-587.
(f) The general saving language of 18 of the Project Act does not bind the Secretary by state law or nullify the contract power expressly conferred upon him by 5. Pp. 587-588.
(g) Congress has put the Secretary of the Interior in charge of a whole network of useful projects constructed by the Federal Government up and down the Colorado River, and it has entrusted him with sufficient power, principally the 5 contract power, to direct, manage and coordinate their operation. This power must be construed to permit him to allocate and distribute the waters of the mainstream of the Colorado River within the boundaries set down by the Act. Pp. 588-590.
2. Certain provisions in the Secretary's contracts are sustained, with one exception. Pp. 590-592.
(a) The Secretary's contracts with Arizona and Nevada are sustained, insofar as they provide that any waters diverted by those States out of the mainstream above Lake Mead must be charged to their respective Lower Basin apportionments; but he cannot reduce water deliveries to those States by the amount of their uses from tributaries above Lake Mead, since Congress intended to apportion only the mainstream, leaving to each State her own tributaries. Pp. 590-591. [373 U.S. 546, 548]
(b) The fact that the Secretary has made a contract directly with the State of Nevada, through her Colorado River Commission, for the delivery of water does not impair the Secretary's power to require Nevada water users, other than the State, to make further contracts. Pp. 591-592.
3. In case of water shortage, the Secretary is not bound to require a pro rata sharing of shortages. He must follow the standards set out in the Act; but he is free to choose among the recognized methods of apportionment or to devise reasonable methods of his own, since Congress has given him full power to control, manage and operate the Government's Colorado River works and to make contracts for the sale and delivery of water on such terms as are not prohibited by the Act. Pp. 592-594.
4. With respect to the conflicting claims of Arizona and New Mexico to water in the Gila River, the compromise settlement agreed upon by those States and incorporated in the Master's recommended decree is accepted by this Court. Pp. 594-595.
5. As to the claims asserted by the United States to waters in the main river and some of its tributaries for use on Indian reservations, national forests, recreational and wildlife areas and other government lands and works, this Court approves the Master's decision as to which claims required adjudication, and it approves the decree he recommended for the government claims he did decide. Pp. 595-601.
(a) This Court sustains the Master's finding that, when the United States created the Chemehuevi, Cocopah, Yuma, Colorado River and Fort Mohave Indian Reservations in Arizona, California and Nevada, or added to them, it reserved not only the land but also

the use of enough water from the Colorado River to irrigate the irrigable portions of the reserved lands. Pp. 595-597.
(1) The doctrine of equitable apportionment should not be used to divide the water between the Indians and the other people in the State of Arizona. P. 597.
(2) Under its broad powers to regulate navigable waters under the Commerce Clause and to regulate government lands under Art. IV, 3, of the Constitution, the United States had power to reserve water rights for its reservations and its property. Pp. 597-598.
(3) The reservations of land and water are not invalid though they were originally set apart by Executive Order. P. 598. [373 U.S. 546, 549]
(4) The United States reserved the water rights for the Indians, effective as of the time the Indian reservations were created, and these water rights, having vested before the Act became effective in 1929, are "present perfected rights" and as such are entitled to priority under the Act. Pp. 598-600.
(5) This Court sustains the Master's conclusions that enough water was intended to be reserved to satisfy the future, as well as the present, needs of the Indian reservations and that enough water was reserved to irrigate all the practicably irrigable acreage on the reservations, and also his findings as to the various acreages of irrigable land existing on the different reservations. Pp. 600-601.
(b) This Court disagrees with the Master's decision to determine the disputed boundaries of the Colorado River Indian Reservation and the Fort Mohave Indian Reservation, since it is not necessary to resolve those disputes here. P. 601.
(c) This Court agrees with the Master's conclusions that the United States intended to reserve water sufficient for the future requirements of the Lake Mead National Recreational Area, the Havasu Lake National Wildlife Refuge, the Imperial National Wildlife Refuge and the Gila National Forest. P. 601.
(d) This Court rejects the claim of the United States that it is entitled to the use, without charge against its consumption, of any waters that would have been wasted but for salvage by the Government on its wildlife preserves. P. 601.
(e) This Court agrees with the Master that all uses of mainstream water within a State are to be charged against that State's apportionment, which, of course, includes uses by the United States. P. 601.

Mark Wilmer reargued the cause for complainant. With him on the briefs were Chas. H. Reed, William R. Meagher, Burr Sutter, John E. Madden, Calvin H. Udall, John Geoffrey Will, W. H. Roberts and Theodore Kiendl.

Northcutt Ely, Special Assistant Attorney General of California, reargued the cause for the State of California et al., defendants. With him on the briefs were Stanley Mosk, Attorney General, Charles E. Corker and Gilbert [373 U.S. 546, 550] F. Nelson, Assistant Attorneys General, Burton J. Gindler, John R. Alexander and Gerald Malkan, Deputy Attorneys General, Shirley M. Hufstedler, Howard I. Friedman, C. Emerson Duncan II, Jerome C. Muys, Francis E. Jenney, Stanley C. Lagerlof, Roy H. Mann, Harry W. Horton, R. L. Knox, Jr., Earl Redwine, James H. Howard, Charles C. Cooper, Jr., H. Kenneth Hutchinson, Frank P. Doherty, Roger Arnebergh, Gilmore Tillman, Alan M. Firestone, Jean F. DuPaul and Henry A. Dietz.

Solicitor General Cox reargued the cause for the United States, intervener. With him on the briefs were John F. Davis, David R. Warner, Walter Kiechel, Jr. and Warren R. Wise.

R. P. Parry reargued the cause for the State of Nevada, intervener. With him on the briefs were Roger D. Foley, Attorney General, W. T. Mathews and Clifford E. Fix.

Walter L. Budge, Attorney General of Utah, and Dennis McCarthy, Special Assistant Attorney General, filed a statement on behalf of the State of Utah.

Earl E. Hartley, Attorney General of New Mexico, Thomas O. Olson, First Assistant Attorney General, and Claude S. Mann and Dudley Cornell, Special Assistant Attorneys General, filed a brief for the State of New Mexico.

MR. JUSTICE BLACK delivered the opinion of the Court.

In 1952 the State of Arizona invoked the original jurisdiction of this Court 1 by filing a complaint against the [373 U.S. 546, 551] State of California and seven of its public agencies. 2 Later, Nevada, New Mexico, Utah, and the United States were added as parties either voluntarily or on motion. 3 The basic controversy in the case is over how much water each State has a legal right to use out of the waters of the Colorado River and its tributaries. After preliminary pleadings, we referred the case to George I. Haight, Esquire, and upon his death in 1955 to Simon H. Rifkind, Esquire, as Special Master to take evidence, find facts, state conclusions of law, and recommend a decree, all "subject to consideration, revision, or approval by the Court." 4 The Master conducted a trial lasting from June 14, 1956, to August 28, 1958, during which 340 witnesses were heard orally or by deposition, thousands of exhibits were received, and 25,000 pages of transcript were filled. Following many motions, arguments, and briefs, the Master in a 433-page volume reported his findings, conclusions, and recommended decree, received by the Court on January 16, 1961. 5 The case has been extensively briefed here and orally argued twice, the first time about 16 hours, the second, over six. As we see this case, the question of each State's share of the waters of the Colorado and its tributaries turns on the meaning and the scope of the Boulder Canyon Project Act passed by Congress in [373 U.S. 546, 552] 1928. 6 That meaning and scope can be better understood when the Act is set against its background - the gravity of the Southwest's water problems; the inability of local groups or individual States to deal with these enormous problems; the continued failure of the States to agree on how to conserve and divide the waters; and the ultimate action by Congress at the request of the States creating a great system of dams and public works nationally built, controlled, and operated for the purpose of conserving and distributing the water.

The Colorado River itself rises in the mountains of Colorado and flows generally in a southwesterly direction for about 1,300 miles through Colorado, Utah, and Arizona and along the Arizona-Nevada and Arizona-California boundaries, after which it passes into Mexico and empties into the Mexican waters of the Gulf of California. On its way to the sea its receives tributary waters from Wyoming, Colorado, Utah, Nevada, New Mexico, and Arizona. The river and its tributaries flow in a natural basin almost surrounded by

large mountain ranges and drain 242,000 square miles, an area about 900 miles long from north to south and 300 to 500 miles wide from east to west - practically one-twelfth the area of the continental United States excluding Alaska. Much of this large basin is so arid that it is, as it always has been, largely dependent upon managed use of the waters of the Colorado River System to make it productive and inhabitable. The Master refers to archaeological evidence that as long as 2,000 years ago the ancient Hohokam tribe built and maintained irrigation canals near what is now Phoenix, Arizona, and that American Indians were practicing irrigation in that region at the time white men first explored it. In the second half of the nineteenth century a group [373 U.S. 546, 553] of people interested in California's Imperial Valley conceived plans to divert water from the mainstream of the Colorado to give life and growth to the parched and barren soil of that valley. As the most feasible route was through Mexico, a Mexican corporation was formed and a canal dug partly in Mexico and partly in the United States. Difficulties which arose because the canal was subject to the sovereignty of both countries generated hopes in this country that some day there would be a canal wholly within the United States, an all-American canal. 7

During the latter part of the nineteenth and the first part of the twentieth centuries, people in the Southwest continued to seek new ways to satisfy their water needs, which by that time were increasing rapidly as new settlers moved into this fast-developing region. But none of the more or less primitive diversions made from the mainstream of the Colorado conserved enough water to meet the growing needs of the basin. The natural flow of the Colorado was too erratic, the river at many places in canyons too deep, and the engineering and economic hurdles too great for small farmers, larger groups, or even States to build storage dams, construct canals, and install the expensive works necessary for a dependable year-round water supply. Nor were droughts the basin's only problem; spring floods due to melting snows and seasonal storms were a recurring menace, especially disastrous in California's Imperial Valley where, even after the Mexican canal provided a more dependable water supply, the threat of flood remained at least as serious as before. Another troublesome problem was the erosion of land and the deposit of silt which fouled waters, choked irrigation works, and damaged good farmland and crops. [373 U.S. 546, 554]

It is not surprising that the pressing necessity to transform the erratic and often destructive flow of the Colorado River into a controlled and dependable water supply desperately needed in so many States began to be talked about and recognized as far more than a purely local problem which could be solved on a farmer-by-farmer, group-by-group, or even state-by-state basis, desirable as this kind of solution might have been. The inadequacy of a local solution was recognized in the Report of the All-American Canal Board of the United States Department of the Interior on July 22, 1919, which detailed the widespread benefits that could be expected from construction by the United States of a large reservoir on the mainstream of the Colorado and an all-American canal to the Imperial Valley. 8 Some months later, May 18, 1920, Congress passed a bill offered by Congressman Kinkaid of Nebraska directing the Secretary of the Interior to make a study and report of diversions which might be made from the Colorado River for irrigation in the Imperial Valley. 9 The Fall-Davis Report, 10 submitted to Congress in compliance with the Kinkaid Act, began by declaring, "The control of the floods and

development of the resources of the Colorado River are peculiarly national problems . . ." 11 and then went on to give reasons why this was so, concluding with the statement that the job was so big that only the Federal Government could do it. 12 Quite naturally, therefore, the [373 U.S. 546, 555] Report recommended that the United States construct as a government project not only an all-American canal from the Colorado River to the Imperial Valley but also a dam and reservoir at or near Boulder Canyon. 13

The prospect that the United States would undertake to build as a national project the necessary works to control floods and store river waters for irrigation was apparently a welcome one for the basin States. But it brought to life strong fears in the northern basin States that additional waters made available by the storage and canal projects might be gobbled up in perpetuity by faster growing lower basin areas, particularly California, before the upper States could appropriate what they believed to be their fair share. These fears were not without foundation, since the law of prior appropriation prevailed in most of the Western States. 14 Under that law the one who first appropriates water and puts it to beneficial use thereby acquires a vested right to continue to divert and use that quantity of water against all claimants junior to him in point of time. 15 "First in time, first in right" is the shorthand expression of this legal principle. In 1922, only four months after the Fall-Davis Report, this Court in Wyoming v. Colorado, 259 U.S. 419 , held that the [373 U.S. 546, 556] doctrine of prior appropriation could be given interstate effect. 16 This decision intensified fears of Upper Basin States that they would not get their fair share of Colorado River water. 17 In view of California's phenomenal growth, the Upper Basin States had particular reason to fear that California, by appropriating and using Colorado River water before the upper States, would, under the interstate application of the prior appropriation doctrine, be "first in time" and therefore "first in right." Nor were such fears limited to the northernmost States. Nevada, Utah, and especially Arizona were all apprehensive that California's rapid declaration of appropriative claims would deprive them of their just share of basin water available after construction of the proposed United States project. It seemed for a time that these fears would keep the States from agreeing on any kind of division of the river waters. Hoping to prevent "conflicts" and "expensive litigation" which would hold up or prevent the tremendous benefits expected from extensive federal development of the river, 18 the basin States requested and Congress passed an Act on August 19, 1921, giving the [373 U.S. 546, 557] States consent to negotiate and enter into a compact for the "equitable division and apportionment . . . of the water supply of the Colorado River." 19

Pursuant to this congressional authority, the seven States appointed Commissioners who, after negotiating for the better part of a year, reached an agreement at Santa Fe, New Mexico, on November 24, 1922. The agreement, known as the Colorado River Compact, 20 failed to fulfill the hope of Congress that the States would themselves agree on each State's share of the water. The most the Commissioners were able to accomplish in the Compact was to adopt a compromise suggestion of Secretary of Commerce Herbert Hoover, specially designated as United States representative. 21 This compromise divides the entire basin into two parts, the Upper Basin and the Lower Basin, separated at a point on the river in northern Arizona known as Lee Ferry. (A map showing the two basins and other points of interest in this controversy is printed as an Appendix facing p. 602.)

Article III (a) of the Compact apportions to each basin in perpetuity 7,500,000 acre-feet of water 22 a year from the Colorado River System, defined in Article II (a) as "the Colorado River and its tributaries within the United States of America." In addition, Article III (b) gives the Lower Basin "the right to increase its beneficial consumptive use 23 of such waters by one million acre-feet per annum." Article III (c) provides that future Mexican [373 U.S. 546, 558] water rights recognized by the United States shall be supplied first out of surplus over and above the aggregate of the quantities specified in (a) and (b), and if this surplus is not enough the deficiency shall be borne equally by the two basins. Article III (d) requires the Upper Basin not to deplete the Lee Ferry flow below an aggregate of 75,000,000 acre-feet for any 10 consecutive years. Article III (f) and (g) provide a way for further apportionment by a compact of "Colorado River System" waters at any time after October 1, 1963. While these allocations quieted rivalries between the Upper and Lower Basins, major differences between the States in the Lower Basin continued. Failure of the Compact to determine each State's share of the water left Nevada and Arizona with their fears that the law of prior appropriation would be not a protection but a menace because California could use that law to get for herself the lion's share of the waters allotted to the Lower Basin. Moreover, Arizona, because of her particularly strong interest in the Gila, intensely resented the Compact's inclusion of the Colorado River tributaries in its allocation scheme and was bitterly hostile to having Arizona tributaries, again particularly the Gila, forced to contribute to the Mexican burden. Largely for these reasons, Arizona alone, of all the States in both basins. refused to ratify the Compact. 24

Seeking means which would permit ratification by all seven basin States, the Governors of those States met at Denver in 1925 and again in 1927. As a result of these meetings the Governors of the upper States suggested, as a fair apportionment of water among the Lower Basin States, that out of the average annual delivery of water at [373 U.S. 546, 559] Lee Ferry required by the Compact - 7,500,000 acre-feet - Nevada be given 300,000 acre-feet, Arizona 3,000,000, and California 4,200,000, and that unapportioned waters, subject to reapportionment after 1963, be shared equally by Arizona and California. Each Lower Basin State would have "the exclusive beneficial consumptive use of such tributaries within its boundaries before the same empty into the main stream," except that Arizona tributary waters in excess of 1,000,000 acre-feet could under some circumstances be subject to diminution by reason of a United States treaty with Mexico. This proposal foundered because California held out for 4,600,000 acre-feet instead of 4,200,000 25 and because Arizona held out for complete exemption of its tributaries from any part of the Mexican burden. 26

Between 1922 and 1927 Congressman Philip Swing and Senator Hiram Johnson, both of California, made three attempts to have Swing-Johnson bills enacted, authorizing construction of a dam in the canyon section of the Colorado River and an all-American canal. 27 These bills would have carried out the original Fall-Davis Report's recommendations that the river problem be recognized and treated as national, not local. Arizona's Senators and Congressmen, still insisting upon a definite guaranty of water from the mainstream, bitterly fought these proposals because they failed to provide for

exclusive use of her own tributaries, particularly the Gila, and for exemption of these tributaries from the Mexican burden. [373 U.S. 546, 560]

Finally, the fourth Swing-Johnson bill passed both Houses and became the Boulder Canyon Project Act of December 21, 1928, 45 Stat. 1057. The Act authorized the Secretary of the Interior to construct, operate, and maintain a dam and other works in order to control floods, improve navigation, regulate the river's flow, store and distribute waters for reclamation and other beneficial uses, and generate electrical power. 28 The projects authorized by the Act were the same as those provided for in the prior defeated measures, but in other significant respects the Act was strikingly different. The earlier bills had offered no method whatever of apportioning the waters among the States of the Lower Basin. The Act as finally passed did provide such a method, and, as we view it, the method chosen was a complete statutory apportionment intended to put an end to the long-standing dispute over Colorado River waters. To protect the Upper Basin against California should Arizona still refuse to ratify the Compact, 29 4 (a) of the Act as finally passed provided that, if fewer than seven States ratified within six months, the Act should not take effect unless six States including California ratified and unless California, by its legislature, agreed "irrevocably and unconditionally . . . as an express covenant" to a limit on its annual consumption of Colorado River water of "four million four hundred thousand acre-feet of the waters apportioned to the lower [373 U.S. 546, 561] basin States by paragraph (a) of Article III of the Colorado River compact, plus not more than one-half of any excess or surplus waters unapportioned by said compact." Congress in the same section showed its continuing desire to have California, Arizona, and Nevada settle their own differences by authorizing them to make an agreement apportioning to Nevada 300,000 acre-feet, and to Arizona 2,800,000 acre-feet plus half of any surplus waters unapportioned by the Compact. The permitted agreement also was to allow Arizona exclusive use of the Gila River, wholly free from any Mexican obligation, a position Arizona had taken from the beginning. Sections 5 and 8 (b) of the Project Act made provisions for the sale of the stored waters. The Secretary of the Interior was authorized by 5 "under such general regulations as he may prescribe, to contract for the storage of water in said reservoir and for the delivery thereof at such points on the river and on said canal as may be agreed upon, for irrigation and domestic uses . . . ." Section 5 required these contracts to be "for permanent service" and further provided, "No person shall have or be entitled to have the use for any purpose of the water stored as aforesaid except by contract made as herein stated." Section 8 (b) provided that the Secretary's contracts would be subject to any compact dividing the benefits of the water between Arizona, California, and Nevada, or any two of them, approved by Congress on or before January 1, 1929, but that any such compact approved after that date should be "subject to all contracts, if any, made by the Secretary of the Interior under section 5 hereof prior to the date of such approval and consent by Congress."

The Project Act became effective on June 25, 1929, by Presidential Proclamation, 30 after six States, including California, had ratified the Colorado River Compact and [373 U.S. 546, 562] the California legislature had accepted the limitation of 4,400,000 acre-feet 31 as required by the Act. Neither the three States nor any two of them ever entered into any apportionment compact as authorized by 4 (a) and 8 (b). After the construction of

Boulder Dam the Secretary of the Interior, purporting to act under the authority of the Project Act, made contracts with various water users in California for 5,362,000 acre-feet, with Nevada for 300,000 acre-feet, and with Arizona for 2,800,000 acre-feet of water from that stored at Lake Mead.

The Special Master appointed by this Court found that the Colorado River Compact, the law of prior appropriation, and the doctrine of equitable apportionment - by which doctrine this Court in the absence of statute resolves interstate claims according to the equities - do not control the issues in this case. The Master concluded that, since the Lower Basin States had failed to make a compact to allocate the waters among themselves as authorized by 4 (a) and 8 (b), the Secretary's contracts with the States had within the statutory scheme of 4 (a), 5, and 8 (b) effected an apportionment of the waters of the mainstream which, according to the Master, were the only waters to be apportioned under the Act. The Master further held that, in the event of a shortage of water making it impossible for the Secretary to supply all the water due California, Arizona, and Nevada under their contracts, the burden of the shortage must be borne by each State in proportion to her share of the first 7,500,000 acre-feet allocated to the Lower Basin, that is, 4.4/7.5 by California, 2.8/7.5 by Arizona, and .3/7.5 by Nevada, without regard to the law of prior appropriation.

Arizona, Nevada, and the United States support with few exceptions the analysis, conclusions, and recommendations [373 U.S. 546, 563] of the Special Master's report. These parties agree that Congress did not leave division of the waters to an equitable apportionment by this Court but instead created a comprehensive statutory scheme for the allocation of mainstream waters. Arizona, however, believes that the allocation formula established by the Secretary's contracts was in fact the formula required by the Act. The United States, along with California, thinks the Master should not have invalidated the provisions of the Arizona and Nevada water contracts requiring those States to deduct from their allocations any diversions of water above Lake Mead which reduce the flow into that lake.

California is in basic disagreement with almost all of the Master's Report. She argues that the Project Act, like the Colorado River Compact, deals with the entire Colorado River System, not just the mainstream. This would mean that diversions within Arizona and Nevada of tributary waters flowing in those States would be charged against their apportionments and that, because tributary water would be added to the mainstream water in computing the first 7,500,000 acre-feet available to the States, there would be a greater likelihood of a surplus, of which California gets one-half. The result of California's argument would be much more water for California and much less for Arizona. California also argues that the Act neither allocates the Colorado River waters nor gives the Secretary authority to make an allocation. Rather she takes the position that the judicial doctrine of equitable apportionment giving full interstate effect to the traditional western water law of prior appropriation should determine the rights of the parties to the water. Finally, California claims that in any event the Act does not control in time of shortage. Under such circumstances, she says, this Court should divide the waters

according to the doctrine of equitable apportionment or [373 U.S. 546, 564] the law of prior appropriation, either of which, she argues, should result in protecting her prior uses.

Our jurisdiction to entertain this suit is not challenged and could not well be since Art. III, 2, of the Constitution gives this Court original jurisdiction of actions in which States are parties. In exercising that jurisdiction, we are mindful of this Court's often expressed preference that, where possible, States settle their controversies by "mutual accommodation and agreement." 32 Those cases and others 33 make it clear, however, that this Court does have a serious responsibility to adjudicate cases where there are actual, existing controversies over how interstate streams should be apportioned among States. This case is the most recent phase of a continuing controversy over the water of the Colorado River, which the States despite repeated efforts have been unable to settle. Resolution of this dispute requires a determination of what apportionment, if any, is made by the Project Act and what powers are conferred by the Act upon the Secretary of the Interior. Unless many of the issues presented here are adjudicated, the conflicting claims of the parties will continue, as they do now, to raise serious doubts as to the extent of each State's right to appropriate water from the Colorado River System for existing or new uses. In this situation we should and do exercise our jurisdiction.

I.

ALLOCATION OF WATER AMONG THE STATES AND DISTRIBUTION TO USERS.

We have concluded, for reasons to be stated, that Congress in passing the Project Act intended to and did [373 U.S. 546, 565] create its own comprehensive scheme for the apportionment among California, Arizona, and Nevada of the Lower Basin's share of the mainstream waters of the Colorado River, leaving each State its tributaries. Congress decided that a fair division of the first 7,500,000 acre-feet of such mainstream waters would give 4,400,000 acre-feet to California, 2,800,000 to Arizona, and 300,000 to Nevada; Arizona and California would each get one-half of any surplus. Prior approval was therefore given in the Act for a tri-state compact to incorporate these terms. The States, subject to subsequent congressional approval, were also permitted to agree on a compact with different terms. Division of the water did not, however, depend on the States' agreeing to a compact, for Congress gave the Secretary of the Interior adequate authority to accomplish the division. Congress did this by giving the Secretary power to make contracts for the delivery of water and by providing that no person could have water without a contract.

A. Relevancy of Judicial Apportionment and Colorado River Compact. - We agree with the Master that apportionment of the Lower Basin waters of the Colorado River is not controlled by the doctrine of equitable apportionment or by the Colorado River Compact. It is true that the Court has used the doctrine of equitable apportionment to decide river controversies between States. 34 But in those cases Congress had not made any statutory

apportionment. In this case, we have decided that Congress has provided its own method for allocating among the Lower Basin States the mainstream water to which they are entitled under the Compact. Where Congress has so exercised its constitutional power over waters, courts have no power to substitute their own notions of an "equitable apportionment" for the apportionment chosen by Congress. [373 U.S. 546, 566] Nor does the Colorado River Compact control this case. Nothing in that Compact purports to divide water among the Lower Basin States nor in any way to affect or control any future apportionment among those States or any distribution of water within a State. That the Commissioners were able to accomplish even a division of water between the basins is due to what is generally known as the "Hoover Compromise."

> "Participants [in the Compact negotiations] have stated that the negotiations would have broken up but for Mr. Hoover's proposal: that the Commission limit its efforts to a division of water between the upper basin and the lower basin, leaving to each basin the future internal allocation of its share." 35

And in fact this is all the Compact did. However, the Project Act, by referring to the Compact in several places, does make the Compact relevant to a limited extent. To begin with, the Act explicitly approves the Compact and thereby fixes a division of the waters between the basins which must be respected. Further, in several places the Act refers to terms contained in the Compact. For example, 12 of the Act adopts the Compact definition of "domestic," 36 and 6 requires satisfaction of "present perfected rights" as used in the Compact. 37 Obviously, therefore, those particular terms, though originally formulated only for the Compact's allocation of water between basins, are incorporated into the Act and are made applicable to the Project Act's allocation among Lower Basin [373 U.S. 546, 567] States. The Act also declares that the Secretary of the Interior and the United States in the construction, operation, and maintenance of the dam and other works and in the making of contracts shall be subject to and controlled by the Colorado River Compact. 38 These latter references to the Compact are quite different from the Act's adoption of Compact terms. Such references, unlike the explicit adoption of terms, were used only to show that the Act and its provisions were in no way to upset, alter, or affect the Compact's congressionally approved division of water between the basins. They were not intended to make the Compact and its provisions control or affect the Act's allocation among and distribution of water within the States of the Lower Basin. Therefore, we look to the Compact for terms specifically incorporated in the Act, and we would also look to it to resolve disputes between the Upper and Lower Basins, were any involved in this case. But no such questions are here. We must determine what apportionment and delivery scheme in the Lower Basin has been effected through the Secretary's contracts. For that determination, we look to the Project Act alone.

B. Mainstream Apportionment. - The congressional scheme of apportionment cannot be understood without knowing what water Congress wanted apportioned. Under California's view, which we reject, the first 7,500,000 acre-feet of Lower Basin water, of which California has agreed to use only 4,400,000, is made up of both mainstream and tributary water, not just mainstream water. Under the view of Arizona, Nevada, and the United States, with which we agree, the tributaries are not included in the waters to be

divided but remain for the exclusive use of each State. Assuming 7,500,000 acre-feet [373 U.S. 546, 568] or more in the mainstream and 2,000,000 in the tributaries, California would get 1,000,000 acre-feet more if the tributaries are included and Arizona 1,000,000 less. 39

California's argument that the Project Act, like the Colorado River Compact, deals with the main river and all its tributaries rests on 4 (a) of the Act, which limits California to 4,400,000 acre-feet "of the waters apportioned to the lower basin States by paragraph (a) of Article III of the Colorado River compact, plus not more than one-half of any excess or surplus waters unapportioned by said compact . . . ." And Article III (a), referred to by 4 (a), apportioned in perpetuity to the Lower Basin the use of 7,500,000 acre-feet of water per annum "from the Colorado River System," which was defined in the Compact as "that portion of the Colorado River and its tributaries within the United States of America."

Arizona argues that the Compact apportions between basins only the waters of the mainstream, not the mainstream and the tributaries. We need not reach that question, however, for we have concluded that whatever waters the Compact apportioned the Project Act itself dealt only with water of the mainstream. In the first place, the Act, in 4 (a), states that the California limitation, which is in reality her share of the first 7,500,000 acre-feet of Lower Basin water, is on "water of and from the Colorado River," not of and from the "Colorado River System." But more importantly, the negotiations among the States and the congressional debates leading to the passage of the Project Act clearly show that the language used by Congress in the Act was meant to refer to mainstream waters only. Inclusion of the tributaries in the Compact was natural in view of the upper States' strong feeling that the Lower Basin [373 U.S. 546, 569] tributaries should be made to share the burden of any obligation to deliver water to Mexico which a future treaty might impose. But when it came to an apportionment among the Lower Basin States, the Gila, by far the most important Lower Basin tributary, would not logically be included, since Arizona alone of the States could effectively use that river. 40 Therefore, with minor exceptions, the proposals and counterproposals over the years, culminating in the Project Act, consistently provided for division of the mainstream only, reserving the tributaries to each State's exclusive use.

The most important negotiations among the States, which in fact formed the basis of the debates leading to passage of the Act, took place in 1927 when the Governors of the seven basin States met at Denver in an effort to work out an allocation of the Lower Basin waters acceptable to Arizona, California, and Nevada. Arizona and California made proposals, 41 both of which suggested giving Nevada 300,000 acre-feet out of the mainstream of the Colorado River and reserving to each State the exclusive use of her own tributaries. Arizona proposed that all remaining mainstream water be divided equally between herself and California, which would give each State 3,600,000 acre-feet out of the first 7,500,000 acre-feet of mainstream water. California rejected the proposed equal division of the water, suggesting figures that would result in her getting about 4,600,000 out of the 7,500,000. The Governors of the four Upper Basin States, trying to bring Arizona and California together, asked each State to reduce its demands and suggested

this compromise: Nevada 300,000 acre-feet, Arizona 3,000,000, and California [373 U.S. 546, 570] 4,200,000. 42 These allocations were to come only out of the mainstream, that is, as stated by the Governors, out of "the average annual delivery of water to be provided by the states of the upper division at Lees Ferry, under the terms of the Colorado River Compact." The Governors' suggestions, like those of the States, explicitly reserved to each State as against the other States the exclusive use of her own tributaries. Arizona agreed to the Governors' proposal, but she wanted it made clear that her tributaries were to be exempted from any Mexican obligation. 43 California rejected the whole proposal, insisting that she must have 4,600,000 acre-feet from the mainstream, or, as she put it, "from the waters to be provided by the States of the upper division at Lee Ferry under the Colorado River compact." 44 Neither in the States' original offers, nor in the Governors' suggestions, nor in the States' responses was the "Colorado River System" - mainstream plus tributaries - ever used as the basis for Lower Basin allocations; rather, it was always mainstream water, or the water to be delivered by the upper States at Lee Ferry, that is to say, an annual average of 7,500,000 acre-feet of mainstream water.

With the continued failure of Arizona and California to reach accord, there was mounting impetus for a congressional solution. A Swing-Johnson bill containing no limitation on California's uses finally passed the House in 1928 over objections by Representatives from Arizona and Utah. 45 When the bill reached the Senate, it was amended in committee to provide that the Secretary in his water delivery contracts must limit California to 4,600,000 acre-feet "of the water allocated to the lower basin by [373 U.S. 546, 571] the Colorado River compact . . . and one-half of the unallocated, excess, and/or surplus water . . . ." 46 On the floor, Senator Phipps of Colorado proposed an amendment which would allow the Act to go into effect without any limitation on California if seven States ratified the Compact; if only six States ratified and if the California Legislature accepted the limitation, the Act could still become effective. 47 Arizona's Senator Hayden had already proposed an amendment reducing California's share to 4,200,000 acre-feet (the Governors' proposal), plus half of the surplus, leaving Arizona exclusive use of the Gila free from any Mexican obligation, 48 but this the Senate rejected. 49 Senator Bratton of New Mexico, noting that only 400,000 acre-feet kept Arizona and California apart, immediately suggested an amendment by which they would split the difference, California getting 4,400,000 acre-feet "of the waters apportioned to the lower basin States by the Colorado River compact," plus half of the surplus. 50 It was this Bratton amendment that became part of the Act as passed, 51 which had been amended on the floor so that the limitation referred to waters apportioned to the Lower Basin "by paragraph (a) of Article III of the Colorado River compact," instead of waters apportioned "by the Colorado River compact." 52 [373 U.S. 546, 572]

Statements made throughout the debates make it quite clear that Congress intended the 7,500,000 acre-feet it was allocating, and out of which California was limited to 4,400,000, to be mainstream water only. In the first place, the basin Senators expressly acknowledged as the starting point for their debate the Denver Governors' proposal that specific allocations be made to Arizona, California, and Nevada from the mainstream, leaving the tributaries to the States. For example, Senator Johnson, leading spokesman for California, and Senator Hayden, leading spokesman for Arizona, agreed that the

Governors' recommendations could be used as "a basis for discussion." 53 Hayden went on to observe that the Committee amendment would give California the same 4,600,000 acre-feet she had sought at Denver. 54 Later, Nevada's Senator Pittman stated that the committee "put the amount in there that California demanded before the four governors at Denver," and said that the Bratton amendment would split the 400,000 acre-feet separating the Governors' figure and the Committee's figure. 55 All the leaders in the debate - Johnson, Bratton, King, Hayden, Phipps, and Pittman - expressed a common understanding that the key issue separating Arizona and California was the difference of 400,000 acre-feet, 56 precisely the same 400,000 acre-feet of mainstream water [373 U.S. 546, 573] that had separated the States at Denver. Were we to sustain California's argument here that tributaries must be included, California would actually get more than she was willing to settle for at Denver.

That the apportionment was from the mainstream only is also strongly indicated by an analysis of the second paragraph of 4 (a) of the Act. There Congress authorized Arizona, Nevada, and California to make a compact allocating to Nevada 300,000 acre-feet and to Arizona 2,800,000 plus one-half of the surplus, which, with California's 4,400,000 and half of the surplus, would under California's interpretation of the Act exhaust the Lower Basin waters, both mainstream and tributaries. But Utah and New Mexico, as Congress knew, had interests in Lower Basin tributaries which Congress surely would have protected in some way had it meant for the tributaries of those two States to be included in the water to be divided among Arizona, Nevada, and California. We cannot believe that Congress would have permitted three States to divide among themselves water belonging to five States. Nor can we believe that the representatives of Utah and New Mexico would have sat quietly by and acquiesced in a congressional attempt to include their tributaries in waters given the other three States.

Finally, in considering California's claim to share in the tributaries of other States, it is important that from the beginning of the discussions and negotiations which led to the Project Act, Arizona consistently claimed that she must have sole use of the Gila, upon which her existing economy depended. 57 Arizona's claim was supported by the fact that only she and New Mexico could effectively use the Gila waters, which not only entered the Colorado [373 U.S. 546, 574] River too close to Mexico to be of much use to any other State but also was reduced virtually to a trickle in the hot Arizona summers before it could reach the Colorado. In the debates the Senators consistently acknowledged that the tributaries - or at least the waters of the Gila, the only major Arizona tributary - were excluded from the allocation they were making. Senator Hayden, in response to questions by Senator Johnson, said that the California Senator was correct in stating that the Senate had seen fit to give Arizona 2,800,000 acre-feet in addition to all the water in the Gila. 58 Senator Johnson had earlier stated, "[I]t is only the main stream, Senators will recall, that has been discussed," and one of his arguments in favor of California's receiving 4,600,000 acre-feet rather than 4,200,000 was that Arizona was going to keep all her tributaries in addition to whatever portion of the main river was allocated to her. 59 Senator Johnson also argued that Arizona should bear more than half the Lower Basin's Mexican burden because in addition to the 2,800,000 acre-feet allotted her by the Act she would get the Gila, which he erroneously estimated at 3,500,000 acre-feet. 60 Senator

Pittman, who had sat in on the Governors' conference, likewise understood that the water was being allocated from "the main Colorado River." 61 And other interested Senators similarly distinguished between the mainstream and the tributaries. 62 While the debates, extending over a long period of years, undoubtedly contain statements which support inferences in conflict with those we have drawn, we are persuaded by the legislative history as a whole that the Act was not intended to give [373 U.S. 546, 575] California any claim to share in the tributary waters of the other Lower Basin States.

C. The Project Act's Apportionment and Distribution Scheme. - The legislative history, the language of the Act, and the scheme established by the Act for the storage and delivery of water convince us also that Congress intended to provide its own method for a complete apportionment of the mainstream water among Arizona, California, and Nevada.

First, the legislative history. In hearings on the House bill that became the Project Act, Congressman Arentz of Nevada, apparently impatient with the delay of this much needed project, told the committee on January 6, 1928, that if the States could not themselves allocate the water, "there must be some power which will say to California `You can not take any more than this amount and the balance is allocated to the other States.'" 63 Later, May 25, 1928, the House passed the bill, 64 but it did not contain any allocation scheme. When the Senate took up that bill in December, pressure mounted swiftly for amendments that would provide a workable method for apportioning the waters among the Lower Basin States and distributing them to users in the States. The session convened on December 3, 1928, on the fifth the Senate took up the bill, 65 nine days later the bill with significant amendments passed the Senate, 66 four days after that the House concurred in the Senate's action, 67 and on the twenty-first the President signed the bill. 68 When the bill first reached the Senate floor, it had [373 U.S. 546, 576] a provision, added in committee, limiting California to 4,600,000 acre-feet, 69 and Senator Hayden on December 6 proposed reducing that share to 4,200,000. 70 The next day, December 7, Mr. Pittman, senior Senator from Nevada, vigorously argued that Congress should settle the matter without delay. He said,

> "What is the difficulty? We have only minor questions involved here. There is practically nothing involved except a dispute between the States of Arizona and California with regard to the division of the increased water that will be impounded behind the proposed dam; that is all. . . . Of the 7,500,000 acre-feet of water let down that river they have gotten together within 400,000 acre-feet. They have got to get together, and if they do not get together Congress should bring them together." 71

The day after that, December 8, New Mexico's Senator Bratton suggested an amendment splitting the difference between the demands of Arizona and California by limiting California to 4,400,000 acre-feet. 72 On the tenth, reflecting the prevailing sense of urgency for decisive action. Senator Bratton emphasized that this was not a dispute limited simply to two States:

> "The two States have exchanged views, they have negotiated, they have endeavored to reach an agreement, and until now have been unable to do so. This controversy does not affect those two States alone. It affects other States in the Union and the Government as well.
> "Without undertaking to express my views either way upon the subject, I do think that if the two [373 U.S. 546, 577] States are unable to agree upon a figure then that we, as a disinterested and friendly agency, should pass a bill which, according to our combined judgment, will justly and equitably settle the controversy. I suggested 4,400,000 acre-feet with that in view. I still hold to the belief that somewhere between the two figures we must fix the amount, and that this difference of 400,000 acre-feet should not be allowed to bar and preclude the passage of this important measure dealing with the enormous quantity of 15,000,000 acre-feet of water and involving seven States as well as the Government." 73

The very next day, December 11, this crucial amendment was adopted, 74 and on the twelfth Senator Hayden pointed out that the bill settled the dispute over Lower Basin waters by giving 4,400,000 acre-feet to California and 2,800,000 to Arizona:

> "One [dispute] is how the seven and a half million acre-feet shall be divided in the lower basin. The Senate has settled that by a vote - that California may have 4,400,000 acre-feet of that water. It follows logically that if that demand is to be conceded, as everybody agrees, the remainder is 2,800,000 acre-feet for Arizona. That settles that part of the controversy." 75

On the same day, Senator Pittman, intimately familiar with the whole water problem, 76 summed up the feeling [373 U.S. 546, 578] of the Senate that the bill fixed a limit on California and "practically allocated" to Arizona her share of the water:

> "The Senate has already determined upon the division of water between those States. How? It has determined how much water California may use, and the rest of it is subject to use by Nevada and Arizona. Nevada has already admitted that it can use only an insignificant quantity, 300,000 acre-feet. That leaves the rest of it to Arizona. As the bill now stands it is just as much divided as if they had mentioned Arizona and Nevada and the amounts they are to get . . . .
> . . . . .
>
> "As I understand this amendment, Arizona to-day has practically allocated to it 2,800,000 acre-feet of water in the main Colorado River." 77

The Senator went on to explain why the Senate had found it necessary to set up its own plan for allocating the water:

> "Why do we not leave it to California to say how much water she shall take out of the river or leave it to Arizona to say how much water she shall take out of the

river? It is because it happens to become a duty of the United States Senate to settle this matter, and that is the reason." 78

Not only do the closing days of the debate show that Congress intended an apportionment among the States [373 U.S. 546, 579] but also provisions of the Act create machinery plainly adequate to accomplish this purpose, whatever contingencies might occur. As one alternative of the congressional scheme, 4 (a) of the Act invited Arizona, California, and Nevada to adopt a compact dividing the waters along the identical lines that had formed the basis for the congressional discussions of the Act: 4,400,000 acre-feet to California, 300,000 to Nevada, and 2,800,000 to Arizona. Section 8 (b) gave the States power to agree upon some other division, which would have to be approved by Congress. Congress made sure, however, that if the States did not agree on any compact the objects of the Act would be carried out, for the Secretary would then proceed, by making contracts, to apportion water among the States and to allocate the water among users within each State.

In the first section of the Act, the Secretary was authorized to "construct, operate, and maintain a dam and incidental works . . . adequate to create a storage reservoir of a capacity of not less than twenty million acre-feet of water . . ." for the stated purpose of "controlling the floods, improving navigation and regulating the flow of the Colorado River, providing for storage and for the delivery of the stored waters thereof for reclamation of public lands and other beneficial uses . . .," and generating electrical power. The whole point of the Act was to replace the erratic, undependable, often destructive natural flow of the Colorado with the regular, dependable release of waters conserved and stored by the project. Having undertaken this beneficial project, Congress, in several provisions of the Act, made it clear that no one should use mainstream waters save in strict compliance with the scheme set up by the Act. Section 5 authorized the Secretary "under such general regulations as he may prescribe, to contract for the storage of water in said reservoir and for the delivery thereof at such points on the river . . . as may be agreed upon, for irrigation and [373 U.S. 546, 580] domestic uses . . . ." To emphasize that water could be obtained from the Secretary alone, 5 further declared, "No person shall have or be entitled to have the use for any purpose of the water stored as aforesaid except by contract made as herein stated." The supremacy given the Secretary's contracts was made clear in 8 (b) of the Act, which provided that, while the Lower Basin States were free to negotiate a compact dividing the waters, such a compact if made and approved after January 1, 1929, was to be "subject to all contracts, if any, made by the Secretary of the Interior under section 5" before Congress approved the compact.

These several provisions, even without legislative history, are persuasive that Congress intended the Secretary of the Interior, through his 5 contracts, both to carry out the allocation of the waters of the main Colorado River among the Lower Basin States and to decide which users within each State would get water. The general authority to make contracts normally includes the power to choose with whom and upon what terms the contracts will be made. When Congress in an Act grants authority to contract, that authority is no less than the general authority, unless Congress has placed some limit on it. 79 In this respect it is of interest that in an earlier version the bill did limit the

Secretary's contract power by making the contracts "subject to rights of prior appropriators." 80 But that restriction, which preserved the law of prior appropriation, did not survive. It was [373 U.S. 546, 581] stricken from the bill when the requirement that every water user have a contract was added to 5. 81 Significantly, no phrase or provision indicating that the Secretary's contract power was to be controlled by the law of prior appropriation was substituted either then or at any other time before passage of the Act, and we are persuaded that had Congress intended so to fetter the Secretary's discretion, it would have done so in clear and unequivocal terms, as it did in recognizing "present perfected rights" in 6.

That the bill was giving the Secretary sufficient power to carry out an allocation of the waters among the States and among the users within each State without regard to the law of prior appropriation was brought out in a colloquy between Montana's Senator Walsh and California's Senator Johnson, whose State had at least as much reason as any other State to bind the Secretary by state laws. Senator Walsh, who was thoroughly versed in western water law and also had previously argued before this Court in a leading case involving the doctrine of prior appropriation, 82 made clear what would follow from the Government's impounding of the Colorado River waters when he said, "I always understood that the interest that stores the water has a right superior to prior appropriations that do not store." He sought Senator Johnson's views on what rights the City of Los Angeles, which had filed claims to large quantities of Colorado River water, would have after the Government had built the dam and impounded the waters. In reply to Senator Walsh's specific question whether the Government might "dispose of the stored water as it sees fit," Senator Johnson said. [373 U.S. 546, 582] "Yes; under the terms of this bill." Senator Johnson added that "everything in this scheme, plan, or design" was "dependent upon the Secretary of the Interior contracting with those who desire to obtain the benefit of the construction . . . ." He admitted that it was possible that the Secretary could "utterly ignore" Los Angeles' appropriations. 83

In this same discussion, Senator Hayden emphasized the Secretary's power to allocate the water by making contracts with users. After Senator Walsh said that he understood Senator Johnson to be arguing that the Secretary must satisfy Los Angeles' appropriations, Senator Hayden corrected him, pointing out that Senator Johnson had qualified his statement by saying that "after all, the Secretary of the Interior could allow the city of Los Angeles to have such quantity of water as might be determined by contract." Senator Hayden went on to say that, where domestic and irrigation needs conflicted, "the Secretary of the Interior will naturally decide as between applicants, one who desires to use the water for potable purposes in the city and another who desires to use it for irrigation, if there is not enough water to go around, that the city shall have the preference." 84 It is also significant [373 U.S. 546, 583] that two vigorous opponents of the bill, Arizona's Representative Douglas and Utah's Representative Colton, criticized the bill because it gave the Secretary of the Interior "absolute control" over the disposition of the stored waters. 85

The argument that Congress would not have delegated to the Secretary so much power to apportion and distribute the water overlooks the ways in which his power is limited and

channeled by standards in the Project Act. In particular, the Secretary is bound to observe the Act's limitation of 4,400,000 acre-feet on California's consumptive uses out of the first 7,500,000 acre-feet of mainstream water. This necessarily leaves the remaining 3,100,000 acre-feet for the use of Arizona and Nevada, since they are the only other States with access to the main Colorado River. Nevada consistently took the position, accepted by the other States throughout the debates, that her conceivable needs would not exceed 300,000 acre-feet, which, of course, left 2,800,000 acre-feet for Arizona's use. Moreover, Congress indicated that it thought this a proper division of the waters when in the second paragraph of 4 (a) it gave advance consent to a tri-state compact adopting [373 U.S. 546, 584] such division. While no such compact was ever entered into, the Secretary by his contracts has apportioned the water in the approved amounts and thereby followed the guidelines set down by Congress. And, as the Master pointed out, Congress set up other standards and placed other significant limitations upon the Secretary's power to distribute the stored waters. It specifically set out in order the purposes for which the Secretary must use the dam and the reservoir:

> "First, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and satisfaction of present perfected rights in pursuance of Article VIII of said Colorado River compact; and third, for power." 6.

The Act further requires the Secretary to make revenue provisions in his contracts adequate to ensure the recovery of the expenses of construction, operation, and maintenance of the dam and other works within 50 years after their construction. 4 (b). The Secretary is directed to make water contracts for irrigation and domestic uses only for "permanent service." 5. He and his permittees, licensees, and contractees are subject to the Colorado River Compact, 8 (a), and therefore can do nothing to upset or encroach upon the Compact's allocation of Colorado River water between the Upper and Lower Basins. In the construction, operation, and management of the works, the Secretary is subject to the provisions of the reclamation law, except as the Act otherwise provides. 14. One of the most significant limitations in the Act is that the Secretary is required to satisfy present perfected rights, a matter of intense importance to those who had reduced their water rights to actual beneficial use at the time the Act became effective. 6. And, of course, all of the powers granted by the Act are exercised by the Secretary and his well-established executive department, [373 U.S. 546, 585] responsible to Congress and the President and subject to judicial review. 86

Notwithstanding the Government's construction, ownership, operation, and maintenance of the vast Colorado River works that conserve and store the river's waters and the broad power given by Congress to the Secretary of the Interior to make contracts for the distribution of the water, it is argued that Congress in 14 and 18 of the Act took away practically all the Secretary's power by permitting the States to determine with whom and on what terms the Secretary would make water contracts. Section 18 states:

> "Nothing herein shall be construed as interfering with such rights as the States now have either to the waters within their borders or to adopt such policies and

> enact such laws as they may deem necessary with respect to the appropriation, control, and use of waters within their borders . . . ."

Section 14 provides that the reclamation law, to which the Act is made a supplement, shall govern the management of the works except as otherwise provided, and 8 of the Reclamation Act, much like 18 of the Project Act, provides that it is not to be construed as affecting or interfering with state laws "relating to the control, appropriation, use, or distribution of water used in irrigation . . . ." 87 In our view, nothing in any of these provisions [373 U.S. 546, 586] affects our decision, stated earlier, that it is the Act and the Secretary's contracts, not the law of prior appropriation, that control the apportionment of water among the States. Moreover, contrary to the Master's conclusion, we hold that the Secretary in choosing between users within each State and in settling the terms of his contracts is not bound by these sections to follow state law.

The argument that 8 of the Reclamation Act requires the United States in the delivery of water to follow priorities laid down by state law has already been disposed of by this Court in Ivanhoe Irr. Dist. v. McCracken, 357 U.S. 275 (1958), and reaffirmed in City of Fresno v. California, 372 U.S. 627 (1963). In Ivanhoe we held that, even though 8 of the Reclamation Act preserved state law, that general provision could not override a specific provision of the same Act prohibiting a single landowner from getting water for more than 160 acres. We said:

> "As we read 8, it merely requires the United States to comply with state law when, in the construction and operation of a reclamation project, it becomes necessary for it to acquire water rights or vested interests therein. But the acquisition of water rights must not be confused with the operation of federal projects. As the Court said in Nebraska v. Wyoming, supra, at 615: `We do not suggest that where Congress has provided a system of regulation for federal projects it must give way before an inconsistent state system.' . . . We read nothing in 8 that compels the United States to deliver water on conditions imposed by the State." Id., at 291-292. [373 U.S. 546, 587]

Since 8 of the Reclamation Act did not subject the Secretary to state law in disposing of water in that case, we cannot, consistently with Ivanhoe, hold that the Secretary must be bound by state law in disposing of water under the Project Act.

Nor does 18 of the Project Act require the Secretary to contract according to state law. That Act was passed in the exercise of congressional power to control navigable water for purposes of flood control, navigation, power generation, and other objects, 88 and is equally sustained by the power of Congress to promote the general welfare through projects for reclamation, irrigation, or other internal improvements. 89 Section 18 merely preserves such rights as the States "now" have, that is, such rights as they had at the time the Act was passed. While the States were generally free to exercise some jurisdiction over these waters before the Act was passed, this right was subject to the Federal Government's right to regulate and develop the river. 90 Where the Government, as here, has exercised this power and undertaken a comprehensive project for the improvement of

a great river and for the orderly and beneficial distribution of water, there is no room for inconsistent state laws. 91 As in Ivanhoe, where the general provision preserving state law was held not to override a specific provision stating the terms for disposition of the water, here we hold that the general saving [373 U.S. 546, 588] language of 18 cannot bind the Secretary by state law and thereby nullify the contract power expressly conferred upon him by 5. 92 Section 18 plainly allows the States to do things not inconsistent with the Project Act or with federal control of the river, for example, regulation of the use of tributary water and protection of present perfected rights. 93 What other things the States are free to do can be decided when the occasion arises. But where the Secretary's contracts, as here, carry out a congressional plan for the complete distribution of waters to users, state law has no place. 94

Before the Project Act was passed, the waters of the Colorado River, though numbered by the millions of acre-feet, flowed too haltingly or too freely, resulting in droughts and floods. The problems caused by these conditions proved too immense and the solutions too costly for any one State or all the States together. In addition, the States, despite repeated efforts at a settlement, were unable to agree on how much water each State should get. With the health and growth of the Lower Basin at stake. Congress responded to the pleas of the States to come to their aid. The result was the Project Act and the [373 U.S. 546, 589] harnessing of the bountiful waters of the Colorado to sustain growing cities, to support expanding industries, and to transform dry and barren deserts into lands that are livable and productive.

In undertaking this ambitious and expensive project for the welfare of the people of the Lower Basin States and of the Nation, the United States assumed the responsibility for the construction, operation, and supervision of Boulder Dam and a great complex of other dams and works. Behind the dam were stored virtually all the waters of the main river, thus impounding not only the natural flow but also the great quantities of water previously allowed to run waste or to wreak destruction. The impounding of these waters, along with their regulated and systematic release to those with contracts, has promoted the spectacular development of the Lower Basin. Today, the United States operates a whole network of useful projects up and down the river, including the Hoover Dam, Davis Dam, Parker Dam, Headgate Rock Dam, Palo Verde Dam, Imperial Dam, Laguna Dam, Morelos Dam, and the All-American Canal System, and many lesser works. It was only natural that the United States, which was to make the benefits available and which had accepted the responsibility for the project's operation, would want to make certain that the waters were effectively used. All this vast, interlocking machinery - a dozen major works delivering water according to congressionally fixed priorities for home, agricultural, and industrial uses to people spread over thousands of square miles - could function efficiently only under unitary management, able to formulate and supervise a co-ordinated plan that could take account of the diverse, often conflicting interests of the people and communities of the Lower Basin States. Recognizing this, Congress put the Secretary of the Interior in charge of these works [373 U.S. 546, 590] and entrusted him with sufficient power, principally the 5 contract power, to direct, manage, and coordinate their operation. Subjecting the Secretary to the varying, possibly inconsistent, commands of the different state legislatures could frustrate efficient operation of the project and

thwart full realization of the benefits Congress intended this national project to bestow. We are satisfied that the Secretary's power must be construed to permit him, within the boundaries set down in the Act, to allocate and distribute the waters of the mainstream of the Colorado River.

II.

PROVISIONS IN THE SECRETARY'S CONTRACTS.

A. Diversions above Lake Mead. - The Secretary's contracts with Arizona and Nevada provide that any waters diverted by those States out of the mainstream or the tributaries above Lake Mead must be charged to their respective Lower Basin apportionments. The Master, however, took the view that the apportionment was to be made out of the waters actually stored at Lake Mead or flowing in the mainstream below Lake Mead. He therefore held that the Secretary was without power to charge Arizona and Nevada for diversions made by them from the 275-mile stretch of river between Lee Ferry and Lake Mead 95 or from the tributaries above Lake Mead. This conclusion was based on the Master's reasoning that the Secretary was given physical control over the waters stored in Lake Mead and not over waters before they reached the lake.

We hold that the Master was correct in deciding that the Secretary cannot reduce water deliveries to Arizona [373 U.S. 546, 591] and Nevada by the amount of their uses from tributaries above Lake Mead, for, as we have held, Congress in the Project Act intended to apportion only the mainstream, leaving to each State its own tributaries. We disagree, however, with the Master's holding that the Secretary is powerless to charge States for diversions from the mainstream above Lake Mead. What Congress was doing in the Project Act was providing for an apportionment among the Lower Basin States of the water allocated to that basin by the Colorado River Compact. The Lower Basin, with which Congress was dealing, begins at Lee Ferry, and it was all the water in the mainstream below Lee Ferry that Congress intended to divide among the States. Were we to refuse the Secretary the power to charge States for diversions from the mainstream between Lee Ferry and the damsite, we would allow individual States, by making diversions that deplete the Lower Basin's allocation, to upset the whole plan of apportionment arrived at by Congress to settle the long-standing dispute in the Lower Basin. That the congressional apportionment scheme would be upset can easily be demonstrated. California, for example, has been allotted 4,400,000 acre-feet of mainstream water. If Arizona and Nevada can, without being charged for it, divert water from the river above Lake Mead, then California could not get the share Congress intended her to have.

B. Nevada Contract. - Nevada has excepted to her inclusion in Paragraph II (B) (7) of the Master's recommended decree, which provides that "mainstream water shall be delivered to users in Arizona, California and Nevada only if contracts have been made by the Secretary of the Interior, pursuant to Section 5 of the Boulder Canyon Project Act, for delivery of such water." While the California contracts are directly with water users and the Arizona contract specifically contemplates further subcontracts with actual users, it is

argued that the Nevada contract, [373 U.S. 546, 592] made by the Secretary directly with the State of Nevada through her Colorado River Commission, should be construed as a contract to deliver water to the State without the necessity of subcontracts by the Secretary directly with Nevada water users. The United States disagrees, contending that properly construed the Nevada contract, like the Secretary's general contract with Arizona, does not exhaust the Secretary's power to require Nevada water users other than the State to make further contracts. To construe the Nevada contract otherwise, the Government suggests, would bring it in conflict with the provision of 5 of the Project Act that "No person shall have or be entitled to have the use for any purpose of the water stored as aforesaid except by contract [with the Secretary] made as herein stated." Acceptance of Nevada's contention here would not only undermine this plain congressional requirement that water users have contracts with the Secretary but would likewise transfer from the Secretary to Nevada a large part, if not all, of the Secretary's power to determine with whom he will contract and on what terms. We have already held that the contractual power granted the Secretary cannot be diluted in this manner. We therefore reject Nevada's contention.

III.

APPORTIONMENT AND CONTRACTS IN TIME OF SHORTAGE.

We have agreed with the Master that the Secretary's contracts with Arizona for 2,800,000 acre-feet of water and with Nevada for 300,000, together with the limitation of California to 4,400,000 acre-feet, effect a valid apportionment of the first 7,500,000 acre-feet of mainstream water in the Lower Basin. There remains the question of what shall be done in time of shortage. The Master, while declining to make any findings as to what future [373 U.S. 546, 593] supply might be expected, nevertheless decided that the Project Act and the Secretary's contracts require the Secretary in case of shortage to divide the burden among the three States in this proportion: California 4.4/7.5; Arizona 2.8/7.5; Nevada .3/7.5. While pro rata sharing of water shortages seems equitable on its face, 96 more considered judgment may demonstrate quite the contrary. Certainly we should not bind the Secretary to this formula. We have held that the Secretary is vested with considerable control over the apportionment of Colorado River waters. And neither the Project Act nor the water contracts require the use of any particular formula for apportioning shortages. While the Secretary must follow the standards set out in the Act, he nevertheless is free to choose among the recognized methods of apportionment or to devise reasonable methods of his own. This choice, as we see it, is primarily his, not the Master's or even ours. And the Secretary may or may not conclude that a pro rata division is the best solution.

It must be remembered that the Secretary's decision may have an effect not only on irrigation uses but also on other important functions for which Congress brought this great project into being - flood control, improvement of navigation, regulation of flow, and generation and distribution of electric power. Requiring the Secretary to prorate shortages would strip him of the very power of choice which we think Congress, for

reasons satisfactory to it, vested in him and which we should not impair or take away from him. For the same reasons we cannot accept California's contention that in case of shortage each State's share of water should be determined by the [373 U.S. 546, 594] judicial doctrine of equitable apportionment or by the law of prior appropriation. These principles, while they may provide some guidance, are not binding upon the Secretary where, as here, Congress, with full power to do so, has provided that the waters of a navigable stream shall be harnessed, conserved, stored, and distributed through a government agency under a statutory scheme.

None of this is to say that in case of shortage, the Secretary cannot adopt a method of proration or that he may not lay stress upon priority of use, local laws and customs, or any other factors that might be helpful in reaching an informed judgment in harmony with the Act, the best interests of the Basin States, and the welfare of the Nation. It will be time enough for the courts to intervene when and if the Secretary, in making apportionments or contracts, deviates from the standards Congress has set for him to follow, including his obligation to respect "present perfected rights" as of the date the Act was passed. At this time the Secretary has made no decision at all based on an actual or anticipated shortage of water, and so there is no action of his in this respect for us to review. Finally, as the Master pointed out, Congress still has broad powers over this navigable international stream. Congress can undoubtedly reduce or enlarge the Secretary's power if it wishes. Unless and until it does, we leave in the hands of the Secretary, where Congress placed it, full power to control, manage, and operate the Government's Colorado River works and to make contracts for the sale and delivery of water on such terms as are not prohibited by the Project Act.

IV.

ARIZONA-NEW MEXICO GILA CONTROVERSY.

Arizona and New Mexico presented the Master with conflicting claims to water in the Gila River, the tributary [373 U.S. 546, 595] that rises in New Mexico and flows through Arizona. Having determined that tributaries are not within the regulatory provisions of the Project Act the Master held that this interstate dispute should be decided under the principles of equitable apportionment. After hearing evidence on this issue, the Master accepted a compromise settlement agreed upon by these States and incorporated that settlement in his findings and conclusions, and in Part IV (A) (B) (C) (D) of his recommended decree. No exceptions have been filed to these recommendations by any of the parties and they are accordingly accepted by us. Except for those discussed in Part V, we are not required to decide any other disputes between tributary users or between mainstream and tributary users.

V.

CLAIMS OF THE UNITED STATES.

In these proceedings, the United States has asserted claims to waters in the main river and in some of the tributaries for use on Indian Reservations, National Forests, Recreational and Wildlife Areas and other government lands and works. While the Master passed upon some of these claims, he declined to reach others, particularly those relating to tributaries. We approve his decision as to which claims required adjudication, and likewise we approve the decree he recommended for the government claims he did decide. We shall discuss only the claims of the United States on behalf of the Indian Reservations.

The Government, on behalf of five Indian Reservations in Arizona, California, and Nevada, asserted rights to water in the mainstream of the Colorado River. 97 The [373 U.S. 546, 596] Colorado River Reservation, located partly in Arizona and partly in California, is the largest. It was originally created by an Act of Congress in 1865, 98 but its area was later increased by Executive Order. 99 Other reservations were created by Executive Orders and amendments to them, ranging in dates from 1870 to 1907. 100 The Master found both as a matter of fact and law that when the United States created these reservations or added to them, it reserved not only land but also the use of enough water from the Colorado to irrigate the irrigable portions of the reserved lands. The aggregate quantity of water which the Master held was reserved for all the reservations is about 1,000,000 acre-feet, to be used on around 135,000 irrigable acres of land. Here, as before the Master, Arizona argues that the United States had no power to make a reservation of navigable waters after Arizona became a State; that navigable waters could not be reserved by Executive Orders; that the United States did not intend to reserve water for the Indian Reservations; that the amount of water reserved should be measured by the reasonably foreseeable needs of the Indians living on the reservation rather than by the number of irrigable acres; and, finally, that the judicial doctrine of equitable apportionment [373 U.S. 546, 597] should be used to divide the water between the Indians and the other people in the State of Arizona.

The last argument is easily answered. The doctrine of equitable apportionment is a method of resolving water disputes between States. It was created by this Court in the exercise of its original jurisdiction over controversies in which States are parties. An Indian Reservation is not a State. And while Congress has sometimes left Indian Reservations considerable power to manage their own affairs, we are not convinced by Arizona's argument that each reservation is so much like a State that its rights to water should be determined by the doctrine of equitable apportionment. Moreover, even were we to treat an Indian Reservation like a State, equitable apportionment would still not control since, under our view, the Indian claims here are governed by the statutes and Executive Orders creating the reservations.

Arizona's contention that the Federal Government had no power, after Arizona became a State, to reserve waters for the use and benefit of federally reserved lands rests largely upon statements in Pollard's Lessee v. Hagan, 3 How. 212 (1845), and Shively v.

Bowlby, 152 U.S. 1 (1894). Those cases and others that followed them 101 gave rise to the doctrine that lands underlying navigable waters within territory acquired by the Government are held in trust for future States and that title to such lands is automatically vested in the States upon admission to the Union. But those cases involved only the shores of and lands beneath navigable waters. They do not determine the problem before us and cannot be accepted as limiting the broad powers of the United States to regulate navigable waters under the Commerce Clause and to regulate [373 U.S. 546, 598] government lands under Art. IV, 3, of the Constitution. We have no doubt about the power of the United States under these clauses to reserve water rights for its reservations and its property.

Arizona also argues that, in any event, water rights cannot be reserved by Executive Order. Some of the reservations of Indian lands here involved were made almost 100 years ago, and all of them were made over 45 years ago. In our view, these reservations, like those created directly by Congress, were not limited to land, but included waters as well. Congress and the Executive have ever since recognized these as Indian Reservations. Numerous appropriations, including appropriations for irrigation projects, have been made by Congress. They have been uniformly and universally treated as reservations by map makers, surveyors, and the public. We can give but short shrift at this late date to the argument that the reservations either of land or water are invalid because they were originally set apart by the Executive. 102

Arizona also challenges the Master's holding as to the Indian Reservations on two other grounds: first, that there is a lack of evidence showing that the United States in establishing the reservations intended to reserve water for them; second, that even if water was meant to be reserved the Master has awarded too much water. We reject both of these contentions. Most of the land in these reservations is and always has been arid. If the water necessary to sustain life is to be had, it must come from the Colorado River or its tributaries. It can be said without overstatement that when the Indians were put on these reservations they were not considered to be located in the most desirable area of the Nation. It is [373 U.S. 546, 599] impossible to believe that when Congress created the great Colorado River Indian Reservation and when the Executive Department of this Nation created the other reservations they were unaware that most of the lands were of the desert kind - hot, scorching sands - and that water from the river would be essential to the life of the Indian people and to the animals they hunted and the crops they raised. In the debate leading to approval of the first congressional appropriation for irrigation of the Colorado River Indian Reservation, the delegate from the Territory of Arizona made this statement:

> "Irrigating canals are essential to the prosperity of these Indians. Without water there can be no production, no life; and all they ask of you is to give them a few agricultural implements to enable them to dig an irrigating canal by which their lands may be watered and their fields irrigated, so that they may enjoy the means of existence. You must provide these Indians with the means of subsistence or they will take by robbery from those who have. During the last year I have seen a number of these Indians starved to death for want of food." Cong. Globe, 38th Cong., 2d Sess. 1321 (1865).

The question of the Government's implied reservation of water rights upon the creation of an Indian Reservation was before this Court in Winters v. United States, 207 U.S. 564 , decided in 1908. Much the same argument made to us was made in Winters to persuade the Court to hold that Congress had created an Indian Reservation without intending to reserve waters necessary to make the reservation livable. The Court rejected all of the arguments. As to whether water was intended to be reserved, the Court said, at p. 576:

> "The lands were arid and, without irrigation, were practically valueless. And yet, it is contended, the [373 U.S. 546, 600] means of irrigation were deliberately given up by the Indians and deliberately accepted by the Government. The lands ceded were, it is true, also arid; and some argument may be urged, and is urged, that with their cession there was the cession of the waters, without which they would be valueless, and `civilized communities could not be established thereon.' And this, it is further contended, the Indians knew, and yet made no reservation of the waters. We realize that there is a conflict of implications, but that which makes for the retention of the waters is of greater force than that which makes for their cession."

The Court in Winters concluded that the Government, when it created that Indian Reservation, intended to deal fairly with the Indians by reserving for them the waters without which their lands would have been useless. Winters has been followed by this Court as recently as 1939 in United States v. Powers, 305 U.S. 527 . We follow it now and agree that the United States did reserve the water rights for the Indians effective as of the time the Indian Reservations were created. This means, as the Master held, that these water rights, having vested before the Act became effective on June 25, 1929, are "present perfected rights" and as such are entitled to priority under the Act.

We also agree with the Master's conclusion as to the quantity of water intended to be reserved. He found that the water was intended to satisfy the future as well as the present needs of the Indian Reservations and ruled that enough water was reserved to irrigate all the practicably irrigable acreage on the reservations. Arizona, on the other hand, contends that the quantity of water reserved should be measured by the Indians' "reasonably foreseeable needs," which, in fact, means by the number [373 U.S. 546, 601] of Indians. How many Indians there will be and what their future needs will be can only be guessed. We have concluded, as did the Master, that the only feasible and fair way by which reserved water for the reservations can be measured is irrigable acreage. The various acreages of irrigable land which the Master found to be on the different reservations we find to be reasonable.

We disagree with the Master's decision to determine the disputed boundaries of the Colorado River Indian Reservation and the Fort Mohave Indian Reservation. We hold that it is unnecessary to resolve those disputes here. Should a dispute over title arise because of some future refusal by the Secretary to deliver water to either area, the dispute can be settled at that time.

The Master ruled that the principle underlying the reservation of water rights for Indian Reservations was equally applicable to other federal establishments such as National Recreation Areas and National Forests. We agree with the conclusions of the Master that the United States intended to reserve water sufficient for the future requirements of the Lake Mead National Recreation Area, the Havasu Lake National Wildlife Refuge, the Imperial National Wildlife Refuge and the Gila National Forest.

We reject the claim of the United States that it is entitled to the use, without charge against its consumption, of any waters that would have been wasted but for salvage by the Government on its wildlife preserves. Whatever the intrinsic merits of this claim, it is inconsistent with the Act's command that consumptive use shall be measured by diversions less returns to the river.

Finally, we note our agreement with the Master that all uses of mainstream water within a State are to be charged against that State's apportionment, which of course includes uses by the United States. [373 U.S. 546, 602]

VI.

DECREE.

While we have in the main agreed with the Master, there are some places we have disagreed and some questions on which we have not ruled. Rather than adopt the Master's decree with amendments or append our own decree to this opinion, we will allow the parties, or any of them, if they wish, to submit before September 16, 1963, the form of decree to carry this opinion into effect, failing which the Court will prepare and enter an appropriate decree at the next Term of Court.

It is so ordered.

THE CHIEF JUSTICE took no part in the consideration or decision of this case.

[For opinion of MR. JUSTICE HARLAN, joined by MR. JUSTICE DOUGLAS and MR. JUSTICE STEWART, see post, p. 603.]

[For dissenting opinion of MR. JUSTICE DOUGLAS, see post, p. 627.]

Footnotes

[Footnote 1] "The judicial Power shall extend . . . to Controversies between two or more States . . . . "In all Cases . . . in which a State shall be Party, the supreme Court shall have original Jurisdiction." U.S. Const., Art. III, 2. See also 28 U.S.C. 1251 (a) (1). Three

times previously Arizona has instituted actions in this Court concerning the Colorado River. Arizona v. California, 283 U.S. 423 [373 U.S. 546, 551] (1931); Arizona v. California, 292 U.S. 341 (1934); Arizona v. California, 298 U.S. 558 (1936). See also United States v. Arizona, 295 U.S. 174 (1935).

[Footnote 2] Palo Verde Irrigation District, Imperial Irrigation District, Coachella Valley County Water District, Metropolitan Water District of Southern California, City of Los Angeles, City of San Diego, and County of San Diego.

[Footnote 3] 344 U.S. 919 (1953) (intervention by United States); 347 U.S. 985 (1954) (intervention by Nevada); 350 U.S. 114 (1955) (joinder of Utah and New Mexico).

[Footnote 4] The two orders are reported at 347 U.S. 986 (1954), and 350 U.S. 812 (1955).

[Footnote 5] 364 U.S. 940 (1961).

[Footnote 6] Boulder Canyon Project Act, 45 Stat. 1057 (1928), 43 U.S.C. 617-617t.

[Footnote 7] "[The All-American Canal] will end an intolerable situation, under which the Imperial Valley now secures its sole water supply from a canal running for many miles through Mexico . . . ." S. Rep. No. 592, 70th Cong., 1st Sess. 8 (1928).

[Footnote 8] Department of the Interior, Report of the All-American Canal Board (1919), 23-33. The three members of the Board were engineers with long experience in Western water problems.

[Footnote 9] 41 Stat. 600 (1920).

[Footnote 10] S. Doc. No. 142, 67th Cong., 2d Sess. (1922).

[Footnote 11] Id., at 1.

[Footnote 12] The reasons given were: "1. The Colorado River is international. "2. The stream and many of its tributaries are interstate. [373 U.S. 546, 555] "3. It is a navigable river. "4. Its waters may be made to serve large areas of public lands naturally desert in character. "5. Its problems are of such magnitude as to be beyond the reach of other than national solution." Ibid.

[Footnote 13] Id., at 21.

[Footnote 14] This law prevails exclusively in all the basin States except California. See I Wiel, Water Rights in the Western States 66 (3d ed., 1911); Hutchins, Selected Problems in the Law of Water Rights in the West 30-31 (1942) (U.S. Dept. of Agriculture Misc. Pub. No. 418). Even in California it is important. See 51 Cal. Jur. 2d Waters 257-264 (1959).

[Footnote 15] Hinderlider v. La Plata River & Cherry Creek Ditch Co., 304 U.S. 92, 98 (1938); Arizona v. California, 283 U.S. 423, 459 (1931).

[Footnote 16] The doctrine continues to be applied interstate. E. g., Nebraska v. Wyoming, 325 U.S. 589, 617 -618 (1945).

[Footnote 17] "Delph E. Carpenter, Colorado River Commissioner for the State of Colorado, summarized the situation produced by that decision as follows: "`The upper state has but one alternative, that of using every means to retard development in the lower state until the uses within the upper state have reached their maximum. The states may avoid this unfortunate situation by determining their respective rights by interstate compact before further development in either state, thus permitting freedom of development in the lower state without injury to future growth in the upper.' "The final negotiation of the compact took place in the atmosphere produced by that decision." H. R. Doc. No. 717, 80th Cong., 2d Sess. 22 (1948).

[Footnote 18] H. R. Rep. No. 191, 67th Cong., 1st Sess. (1921).

[Footnote 19] 42 Stat. 171 (1921).

[Footnote 20] The Compact can be found at 70 Cong. Rec. 324 (1928), and U.S. Dept. of the Interior, Documents on the Use and Control of the Waters of Interstate and International Streams 39 (1956).

[Footnote 21] H. R. Doc. No. 717, 80th Cong., 2d Sess. 22 (1948).

[Footnote 22] An acre-foot of water is enough to cover an acre of land with one foot of water.

[Footnote 23] "Beneficial consumptive use" means consumptive use measured by diversions less return flows, for a beneficial (nonwasteful) purpose.

[Footnote 24] Arizona did ratify the Compact in 1944, after it had already become effective by six-state ratification as permitted by the Boulder Canyon Project Act.

[Footnote 25] Hearings on H. R. 5773 before the House Committee on Irrigation and Reclamation, 70th Cong., 1st Sess. 402-405 (1928).

[Footnote 26] Id., at 30-31. Arizona also objected to the provisions concerning electrical power.

[Footnote 27] H. R. 11449, 67th Cong., 2d Sess. (1922); H. R. 2903, S. 727, 68th Cong., 1st Sess. (1923); H. R. 9826, S. 3331, 69th Cong., 1st Sess. (1926).

[Footnote 28] Another purpose of the Act was to approve the Colorado River Compact, which had allocated the water between the two basins.

[Footnote 29] The Upper Basin States feared that, if Arizona did not ratify the Compact, the division of water between the Upper and Lower Basins agreed on in the Compact would be nullified. The reasoning was that Arizona's uses would not be charged against the Lower Basin's apportionment and that California would therefore be free to exhaust that apportionment herself. Total Lower Basin uses would then be more than permitted in the Compact, leaving less water for the Upper Basin.

[Footnote 30] 46 Stat. 3000 (1929).

[Footnote 31] California Limitation Act, Cal. Stat. 1929, c. 16, at 38.

[Footnote 32] Colorado v. Kansas, 320 U.S. 383, 392 (1943); Nebraska v. Wyoming, 325 U.S. 589, 616 (1945).

[Footnote 33] E. g., Kansas v. Colorado, 185 U.S. 125 (1902); New Jersey v. New York, 283 U.S. 336 (1931).

[Footnote 34] E. g., Wyoming v. Colorado, 259 U.S. 419 (1922); Nebraska v. Wyoming, 325 U.S. 589 (1945).

[Footnote 35] H. R. Doc. No. 717, 80th Cong., 2d Sess. 22 (1948).

[Footnote 36] "`Domestic' whenever employed in this Act shall include water uses defined as `domestic' in said Colorado River compact."

[Footnote 37] The dam and reservoir shall be used, among other things, for "satisfaction of present perfected rights in pursuance of Article VIII of said Colorado River compact."

[Footnote 38] 1, 8 (a), 13 (b) and (c).

[Footnote 39] Also, California would reduce Nevada's share of the mainstream waters from 300,000 acre-feet to 120,500 acre-feet.

[Footnote 40] Not only does the Gila enter the Colorado almost at the Mexican border, but also in dry seasons it virtually evaporates before reaching the Colorado.

[Footnote 41] See 69 Cong. Rec. 9454 (1928).

[Footnote 42] See 70 Cong. Rec. 172 (1928).

[Footnote 43] Hearings on H. R. 5773, supra note 25, at 30-31.

[Footnote 44] Id., at 402.

[Footnote 45] H. R. 5773, 70th Cong., 1st Sess.; 69 Cong. Rec. 9989-9990 (1928).

[Footnote 46] S. Rep. No. 592, 70th Cong., 1st Sess. 2 (1928).

[Footnote 47] 70 Cong. Rec. 324 (1928).

[Footnote 48] Id., at 162.

[Footnote 49] Id., at 384.

[Footnote 50] Id., at 385.

[Footnote 51] 45 Stat. 1057 (1928). Arizona's Senators Ashurst and Hayden voted against the bill, which did not exempt the Gila from the Mexican burden. 70 Cong. Rec. 603 (1928).

[Footnote 52] 70 Cong. Rec. 459 (1928). That this change was not intended to cause the States to give up their tributaries may reasonably be inferred from the fact that the amendment was agreed to by Senator Hayden, who was a constant opponent of including the tributaries.

[Footnote 53] Id., at 77.

[Footnote 54] Ibid. Later, Senator Hayden said that his amendment incorporated the Governors' proposal. Id., at 172-173.

[Footnote 55] Id., at 386.

[Footnote 56] Id., at 164 (King), 165 (Johnson, Bratton), 382 (Hayden, Phipps), 385 (Bratton), 386 (Pittman). Senator Hayden's statement is representative: "I want to state to the Senate that what I am trying to accomplish is to get a vote on the one particular question of whether the quantity of water which the State of California may divert from the Colorado River should be 4,200,000 acre-feet or 4,600,000 acre-feet." Id., at 382.

[Footnote 57] E. g., Report, Colorado River Commission of Arizona (1927), reprinted in Hearings on H. R. 5773, supra note 25, at 25-31; 69 Cong. Rec. 9454 (1928) (Arizona's proposal at Denver).

[Footnote 58] 70 Cong. Rec. 467-468 (1928). See also id., at 463-464, 465.

[Footnote 59] Id., at 237.

[Footnote 60] Id., at 466-467.

[Footnote 61] Id., at 469. See also id., at 232.

[Footnote 62] See id., at 463 (Shortridge); id., at 465 (King).

[Footnote 63] Hearings on H. R. 5773, supra note 25, at 50.

[Footnote 64] 69 Cong. Rec. 9990 (1928).

[Footnote 65] 70 Cong. Rec. 67 (1928).

[Footnote 66] Id., at 603.

[Footnote 67] Id., at 837-838.

[Footnote 68] 45 Stat. 1057.

[Footnote 69] See S. Rep. No. 592, 70th Cong., 1st Sess. 2 (1928).

[Footnote 70] 70 Cong. Rec. 162 (1928).

[Footnote 71] Id., at 232.

[Footnote 72] Id., at 277, 385.

[Footnote 73] Id., at 333.

[Footnote 74] Id., at 387.

[Footnote 75] Id., at 467. See also id., at 465.

[Footnote 76] For example, Senator Pittman's active role in resolving the whole Colorado River problem was acknowledged by Senator Hayden on the Senate floor: "When Congress assembled in December, 1927, no agreement had been made. The senior Senator from Nevada [MR. PITTMAN], in [373 U.S. 546, 578] continuation of the earnest efforts that he has made all these years to bring about a settlement of the controversy between the States with respect to the Colorado River, invited a number of us to conferences in his office and there we talked over the situation." Id., at 172.

[Footnote 77] Id., at 468-469.

[Footnote 78] Id., at 471. The Senator added, "We have already decided as to the division of the water, and we say that if the States wish they can enter into a subsidiary agreement confirming that." Ibid.

[Footnote 79] In the debates leading to the passage of the bill, Senator Walsh observed that "to contract means a liberty of contract" and asked if this did not mean that the Secretary could "give the water to them [appropriators] or withhold it from them as he sees fit," to which Senator Johnson answered "certainly." 70 Cong. Rec. 168 (1928).

[Footnote 80] See Hearings on H. R. 6251 and 9826 before the Committee on Irrigation and Reclamation, 69th Cong., 1st Sess. 12 (1926).

[Footnote 81] See id., at 97, 115.

[Footnote 82] Bean v. Morris, 221 U.S. 485 (1911). This case was relied on by Mr. Justice Van Devanter in Wyoming v. Colorado, 259 U.S. 419, 466 (1922).

[Footnote 83] 70 Cong. Rec. 168 (1928). Other statements by Senator Johnson are less damaging to California's claims. For example, the Senator at another point in the colloquy with Senator Walsh said that he doubted if the Secretary either would or could disregard Los Angeles and contract with someone having no appropriation. Ibid. It is likely, however, that Senator Johnson was talking about present perfected rights, as a few minutes before he had argued that Los Angeles had taken sufficient steps in perfecting its claims to make them protected. See id., at 167. Present perfected rights, as we have observed in the text, are recognized by the Act. 6.

[Footnote 84] 70 Cong. Rec. 169 (1928). At one point Senator Hayden seems to say that the Secretary's contracts are to be governed by state law: "The only thing required in this bill is contained in the amendment [373 U.S. 546, 583] that I have offered, that there shall be apportioned to each State its share of the water. Then, who shall obtain that water in relative order of priority may be determined by the State courts." Ibid. But, in view of the Senator's other statements in the same debate, this remark of a man so knowledgeable in western water law makes sense only if one understands that the "order of priority" being talked about was the order of present perfected rights - rights which Senator Hayden recognized, see id., at 167, and which the Act preserves in 6.

[Footnote 85] 69 Cong. Rec. 9623, 9648, 9649 (1928). We recognize, of course, that statements of opponents of a bill may not be authoritative, see Schwegmann Bros. v. Calvert Distillers Corp., 341 U.S. 384, 394 -395 (1951), but they are nevertheless relevant and useful, especially where, as here, the proponents of the bill made no response to the opponents' criticisms.

[Footnote 86] See, e. g., Ickes v. Fox, 300 U.S. 82 (1937); cf. Best v. Humboldt Placer Mining Co., 371 U.S. 334 (1963); Boesche v. Udall, ante. p. 472.

[Footnote 87] "Nothing in . . . [this Act] shall be construed as affecting or intended to affect or to in any way interfere with the laws of any State or Territory relating to the control, appropriation, use, or distribution of water used in irrigation, or any vested right acquired thereunder, and the Secretary of the Interior, in carrying out the provisions of such sections, shall proceed in conformity with such [373 U.S. 546, 586] laws, and nothing . . . [herein] shall in any way affect any right of any State or of the Federal Government or of any landowner, appropriator, or user of water in, to, or from any interstate stream or the waters thereof." 43 U.S.C. 383.

[Footnote 88] Arizona v. California, 283 U.S. 423 (1931).

[Footnote 89] United States v. Gerlach Live Stock Co., 339 U.S. 725, 738 (1950).

[Footnote 90] First Iowa Hydro-Elec. Coop. v. Federal Power Comm'n, 328 U.S. 152, 171 (1946). See United States v. Chandler-Dunbar Water Power Co., 229 U.S. 53, 62 -72 (1913); United States v. Willow River Power Co., 324 U.S. 499 (1945).

[Footnote 91] See Arizona v. California, 283 U.S. 423 (1931); Nebraska v. Wyoming, 325 U.S. 589, 615 (1945); First Iowa Hydro-Elec. Coop. v. Federal Power Comm'n, 328 U.S. 152 (1946).

[Footnote 92] Nebraska v. Wyoming, 325 U.S. 589 (1945), holds nothing to the contrary. There the Court found it unnecessary to decide what rights the United States had under federal law to the unappropriated water of the North Platte River, since the water rights on which the projects in that case rested had in fact been obtained in compliance with state law.

[Footnote 93] See First Iowa Hydro-Elec. Coop. v. Federal Power Comm'n, 328 U.S. 152, 175 -176 (1946), where this Court limited the effect of 27 of the Federal Power Act, which expressly "saved" certain state laws, to vested property rights.

[Footnote 94] By an Act of September 2, 1958, 72 Stat. 1726, the Secretary must supply water to Boulder City, Nevada. It follows from our conclusions as to the inapplicability of state law that, contrary to the Master's conclusion, Boulder City's priorities are not to be determined by Nevada law.

[Footnote 95] The location of Hoover Dam is a result of engineering decisions. As Senator Pittman pointed out, "There is no place to impound the flood waters except at the lower end of the canyon." 68 Cong. Rec. 4413 (1927).

[Footnote 96] Proration of shortage is the method agreed upon by the United States and Mexico to adjust Mexico's share of Colorado River water should there be insufficient water to supply each country's apportionment.

[Footnote 97] The Reservations were Chemehuevi, Cocopah, Yuma, Colorado River and Fort Mohave.

[Footnote 98] Act of March 3, 1865, 13 Stat. 541, 559.

[Footnote 99] See Executive Orders of November 22, 1873, November 16, 1874, and May 15, 1876. See also Executive Order of November 22, 1915. These orders may be found in 1 U.S. Dept. of the Interior, Executive Orders Relating to Indian Reservations 6-7 (1912); 2 id., at 5-6 (1922).

[Footnote 100] Executive Orders of January 9, 1884 (Yuma), September 19, 1890 (Fort Mohave), February 2, 1911 (Fort Mohave), September 27, 1917 (Cocopah). For these orders, see 1 id., at 12-13, 63-64 (1912); 2 id., at 5 (1922). The Chemehuevi Reservation

was established by the Secretary of the Interior on February 2, 1907, pending congressional approval.

[Footnote 101] See, e. g., United States v. California, 332 U.S. 19, 29 -30 (1947); United States v. Holt State Bank, 270 U.S. 49, 54 -55 (1926).

[Footnote 102] See United States v. Midwest Oil Co., 236 U.S. 459, 469 -475 (1915); Winters v. United States, 207 U.S. 564 (1908). [373 U.S. 546, 603]

Appendix E

Excerpt from *Research Report on the History of Havasu*, 2000, Williams and Associates, LLC

ITEM - 4 RESEARCH REPORT ON THE HISTORY OF HAVASU (INCLUDING BILL WILLIAMS RIVER NWR) AND IMPERIAL NWR WITH RESPECT TO SECRETARIAL RESERVATIONS AND CIBOLA NWR WITH RESPECT TO THE SECRETARIAL CONTRACT

By

Williams and Associates, LLC[39].[40]

INTRODUCTION

To provide background and guidance in the development of water management plans for the US Department of the Interior, Fish and Wildlife Service (FWS) refuges on the lower Colorado River in Arizona and California, we have been asked to prepare a report that documents the history of these refuges. Of particular interest are the Secretarial Reservations of water for Havasu and Imperial National Wildlife Refuges and the Secretarial Contract for water at Cibola National Wildlife Refuge.

Copies of the documents summarized here were acquired from the FWS, the National Archives and elsewhere. Some of the documents have been included with this and the other reports prepared as part of this project. The remainder have been assembled and delivered to the FWS as a separate product.

---

[39] Prepared by Mary Shivers Culpin
[40] 3448 Moonfall Lane, Elizabeth, CO 80107

ESTABLISHMENT OF THE HAVASU NATIONAL WILDLIFE REFUGE

As early as 1935, while the Parker Dam on the Colorado River was under construction, the Migratory Waterfowl Division of the Bureau of Biological Survey requested the preparation of an Executive Order to create a migratory bird refuge in the area. The new dam, which was planned to divert water for the Metropolitan Water District of Los Angeles, would provide a consistent water level for the recognized important flyway of migratory waterfowl. By 1937, the dam was one of the few Bureau of Reclamation (BuRec) projects that had primary waterfowl values and it was considered superior to the Boulder Canyon project for waterfowl and wildlife, thus the Migratory Waterfowl Division continued to request for an Executive Order to set aside the area as a refuge. The Bureau of Biological Survey also wanted to preclude the appearance of the National Park Service, who had expressed interest in the mid-1930s.[41]

In 1939, the Acting Regional Director of the Bureau of Biological Survey in Portland, Oregon, T.B. Murray suggested to Dr. Ira Gabrielson, Chief of the Bureau, that a reconnaissance and topographic survey of the Parker Dam area be completed to determine the advisability for going forward with the creation of the refuge. Murray urged that "clearly defined limitations should be placed on usage other than for wildlife production and protection" in the preparation of an Executive Order. The Chief of the Bureau's Division of Wildlife Refuges, J. Clark Sayler II, suggested that the Executive Order include the entire BuRec withdrawal and language that permitted the designation of hunting areas at the discretion of the Secretary of Agriculture.[42]

The Executive Order was drafted in the spring of 1939, but was held up because of unrestricted hunting rights issues with the Bureau of Indian

---

[41] J. Clark Sayler II, Migratory Waterfowl Division, Bureau of Biological Survey to Rudolph Dieffenbach, Chief, Division of Land Acquisition, Bureau of Biological Survey, 16 March 1935. J. Clark Sayler II, Migratory Waterfowl Division to Dr. Ira Gabrielson, Chief, Bureau of Biological Survey, 22 January 1937. National Archives. Record Group 22, Records of the Biological Survey. Entry 161, Box: 235, File: Proposed -- Arizona, 1931-1936.

[42] T.B. Murray, Acting Regional Director, Bureau of Biological Survey, to Dr. Ira Gabrielson, Chief, Bureau of Biological Survey, 10 February 1939. J. Clark Salyer II, Chief, Division of Wildlife Refuges, Bureau of Biological Survey, to Dr. Ira Gabrielson, Chief, Bureau of Biological Survey, 12 April 1939. National Archives. Record Group 22, Records of the Bureau of Biological Survey, Entry 162, Box: 70, File: Havasu.

Affairs and pressure from local game protective associations on open public shooting areas. In October 1939, a meeting in Washington D.C., between the Bureau of Biological Survey, the Bureau of Indian Affairs, and representatives of the Colorado Indian Agency began the formal discussions regarding the hunting rights issue. Following the meeting, the Bureau of Biological Survey notified the Commissioner of Indian Affairs that the Survey would have no objections to fishing, boating and bathing rights, but the hunting rights would be contrary to the purpose of the refuge. It was pointed out that the area was significant for wintering waterfowl in their flight to the mouth of the Colorado River in Mexico. The Bureau pointed out that it appeared to be the consensus of opinion at the October meeting that the areas that the Survey wanted to exclude from hunting would not present a "hardship on the Indians in the vicinity."[43]

The 1938 appraisal by BuRec for the United States and the Metropolitan Water District of California was based upon title in fee simple absolute. According to BuRec, at that time, there had been no suggestion that the agencies wanted any reservation of rights in the lands or in the reservoir under construction. However, the following year, the Bureau of Indian Affairs expressed a desire for certain hunting, fishing, boating, and bathing rights in the reservoir. A further delay in the passage of the Executive Order arose after BuRec requested a decision from the Department of Interior Solicitor regarding the Indian rights issues.[44]

In addition to the Bureau of Indian Affairs concern over hunting rights, the local game protective associations were pressuring the Arizona State Game Department and the Bureau of Biological Survey offices with concerns regarding public shooting areas. In early 1940, the Arizona State Game Department had approved the Division of Wildlife Refuges proposal to assign definite closed areas and open public shooting zones with recreational activities covering the entire area as long as it was not detrimental to the to the purposes of the closed areas. In a March 1940 letter, the Secretary of Interior's office reassured Arizona Senator Carl Hayden that if the reservoirs

---

[43] Rudolph Dieffenbach, Chief, Division of Land Acquisition, Bureau of Biological Survey to Dr. Ira Gabrielson, Chief, Bureau of Biological Survey, 23 May 1939. J. Clark Sayler II, Division of Wildlife Refuges to Acting Regional Director, Bureau of Biological Survey, 12 July 1939. Chief, Bureau of Biological Survey to Commissioner of Indian Affairs, 18 October 1939. National Archives. Record Group 22, Records of the Biological Survey, Entry 162, Box: 70, File: Havasu.

[44] John C. Page, Commissioner, Bureau of Reclamation to Commissioner of Indian Affairs, 19 December 1939. National Archives. Record Group 22, Records of the Biological Survey, Entry 62, Box: 70, File: Havasu.

were established as wildlife refuges, certain areas would be zoned for public shooting, certain areas zoned for recreational activities and other areas would be zoned as "inviolate sanctuaries." The following month, Secretary of the Interior Harold Ickes met with the Office of Indian Affairs, BuRec, the Bureau of Fisheries, the Bureau of Biological Survey and the National Park Service whereupon all agencies agreed to the creation of wildlife areas at Parker Dam's newly created Lake Havasu and at Imperial Dam. The group also agreed that the Indians should have fishing and hunting rights, "but not in a way that would be detrimental to the primary use nor become a preferential right over other users." Ickes requested the Bureau of Biological Survey prepare and transmit the Executive Order and that the Office of Indian Affairs "should immediately reach an agreement with the Bureau of Reclamation on the necessary legislation."[45]

During the summer of 1940, the wording of the Executive Order received the scrutiny of not only the Department of the Interior Solicitor, but also the Attorney General. The Attorney General held that it would probably be unnecessary to cite the Act of June 25, 1910 (36 Stat. 847) and the "non-statutory power vested in the President alternatively to cover both public lands and lands purchased or otherwise acquired by the Government and which are included within the Havasu project." As a result of the recently passed Act of July 8, 1940 (Public No. 730 -- 76th Congress), according to the Department of Interior Solicitor, "all the right, title, and interest of the Indians in and to the tribal and allotted lands of the Fort Mojave Indian Reservation in Arizona and the Chemehuevi Reservation in California as may be designated by the Secretary of the Interior," any special rights in the Lake Havasu area were eliminated.[46]

On January 22, 1941, President Franklin Roosevelt signed Executive Order No. 8647 establishing the Havasu Lake National Wildlife Refuge. The order stated:

---

[45] Malcom Allison, Associate Refuge Manager to Chief, Bureau of Biological Survey, June 19, 1939. J. Clark Sayler II, to Thomas Lawhorn, 26 January 1940. E.K. Burlew, Acting Secretary of the Interior to Senator Carl Hayden, March 8, 1940. Secretary of the Interior Harold Ickes to Office of Indian Affairs, Bureau of Reclamation, Bureau of Fisheries, National Park Service, and Bureau of Biological Survey, 4 April 1940. National Archives. Record Group 22, Entry 162, Box: 70, File: Havasu.

[46] A.C. Elmer, Division of Wildlife Refuges, Bureau of Biological Survey to Rudolph Dieffenbach, 19 September 1940. National Archives. Record Group 22, Records of the Bureau of Biological Survey, Entry 162, Box: 70, File: Havasu.

> . . . approximately 37,870 acres, in Mohave and Yuma Counties, Arizona and San Bernardino County, California, be, and they are hereby, reserved and set apart, subject to valid existing rights, f or the use of the Department of the Interior as a refuge and breeding ground for migratory birds and other wildlife; and all lands hereafter acquired by the United States within such areas, including tribal and allotted Indian lands in which complete interests may hereafter be acquired by the United States pursuant to the act of July 8, 1940, Public No. 730, shall upon acquisition thereof become and be reserved as a part of the said refuge . . . As the lands herein described have been reserved or acquired for purposes of the Parker Dam Project, their reservation as the Havasu Lake National Wildlife Refuge is subject to their use for the purposes of the Parker Dam Project. It is unlawful for any person to pursue, hunt, trap, capture, willfully disturb, or kill any bird or wild animal of any kind whatsoever within the limits of the refuge, or to enter thereon, except under such rules and regulations as may be prescribed by the Secretary of the Interior.[47]

Shortly after the creation of the refuge and before the Secretary of the Interior prepared the written rules and regulations for the refuge, the newly organized FWS (formerly the Bureau of Biological Survey) received additional pressure from the protective game associations regarding the extent of the wildlife refuge boundaries. At the sportsmen's request, Senator Carl Hayden called for a full report on the idea of the portion of the lake below Topock being set aside as an area open to regulated hunting and fishing. An immediate response from the FWS clarified the earlier decision to include the entire area as a measure of administrative efficiency, with the definite understanding that a public shooting area was set aside. He added public fishing would be permitted in the entire lake area, with the possibility of some limited closures during the open waterfowl season.[48]

---

[47] President. Executive Order, "Establishing the Havasu Lake National Wildlife Refuge Arizona and California, Executive Order No. 8647," *Federal Register*, no. 17 (25 January 1941).

[48] Senator Carl Hayden to Dr. Ira Gabrielson, 25 February 1941. W.C. Henderson, Acting Director, Fish and Wildlife Service to Senator Carl Hayden, 28 February 1941. National Archives. Record Group 22, Records of the Fish and Wildlife Service, Entry 162, Box: 70, File: Havasu.

HAVASU NATIONAL WILDLIFE REFUGE WATER RIGHTS ISSUES

1941

Executive Order of 1941, creating the refuge withdrew wildlife habitat lands, ponds, and marshes because of their suitability for waterfowl and other wildlife.

1946

Act of August 14, 1946 required the Department of the Interior to preserve the lands for the purpose for which it was withdrawn insofar as it's feasible.

1947

As a result of BuRec's proposed channelization project to protect the city of Needles, California from Colorado River flooding, some Fish and Wildlife officials believed the effect on the refuge would not seriously harm the marsh areas because the floodwaters would fill the numerous small ponds.[49]

1948

In order to protect and preserve the existing marsh area for fish and wildlife in view of the channelization project, the construction of several cross dikes on the east side of the Colorado River was proposed. However, water supply for the impoundments became an issue. BuRec believed the Secretary of the Interior could authorize the use of stored water in Lake Mead, but probably would not authorize water rights for an agency. The Fish and Wildlife Agency requested a statement of ownership and control of Lake Mead's stored water and a statement on the likelihood of the BuRec delivering water to FWS. No definite amount of water had been determined in May, 1948, but the amount projected was less than 40,000 acre-feet annually.

Discussions began with the State of Arizona Water Commissioner and the Arizona Game and Fish Commission regarding the preservation and

[49] Clarence Cottam, "Report of Inspection of Havasu Lake National Wildlife Refuge, Parker, Arizona, July 1 and 2, 1947." Clarence Cottam was the Asst. Director, Fish and Wildlife Service. National Archives. Record Group 22, Records of the Fish and Wildlife Service, Entry 162, Box: 71.

maintenance of the marsh areas and the procedure for the FWS to divert Colorado River water. C.H.W. Smith, State of Arizona Water Commissioner, believed there were two choices depending on whether more water will be consumed through evaporation after dike construction and impoundment than was consumed before dredging or whether the water used for the impoundment will not exceed the amount of water consumed in the ponds and marsh prior to any development -- to make an application with the State of Arizona or by agreement with BuRec. The BuRec Regional Director responded to the FWS request for ownership and control of Lake Mead water -- based upon the Boulder Canyon Project Act, the Secretary of the Interior was authorized to deliver water only for irrigation and domestic uses and generation of electrical power, not to "preserve swamp conditions on Havasu Lake National Wildlife Refuge."[50]

Not satisfied with the BuRec response, FWS officials believed BuRec should restore the swamp area through Public Law 732. They also believed that if the Bureau could not provide water under the Boulder Canyon Project Act, they should agree with FWS's filing for 20,000 acre-feet of water with the Arizona State Engineer for wildlife purposes. However, State Engineer O.C. Williams believed the filing might add "additional fuel to the fire between Arizona and California regarding the Colorado River Compact" and interfere with the authorization of the Central Arizona Project. He added that since water for wildlife was already recognized by the State of Arizona as a beneficial use, it might not be necessary to file.[51] FWS official, Rudolph Dieffenbach denied the regional office request to file for the 20,000 acre-feet with the Arizona State Engineer.[52]

1950

Not having resolved the water filing issue in 1948, FWS Regional Director, John Gatlin continued to seek resolution for obtaining water for the refuge. Two years after FWS Coordinator, River Basin Studies, Rudolph

---

[50] Memorandum from Regional Engineer, Fish and Wildlife Service Regional Office to Regional Director, Fish and Wildlife Service Regional Office, 3 June 1948. Memorandum to the Files from Fish and Wildlife Service Regional Refuge Supervisor, 24 September 1948. Fish and Wildlife Service Regional Office, Albuquerque, New Mexico. Water Rights Office, File: Arizona, Folder: Havasu NWR, Pre- 1960.

[51] Memorandum to the Files from Regional Refuge Supervisor, Albuquerque, New Mexico, 24 September 1948.

[52] Memorandum to Director, Fish and Wildlife Service from Regional Director, Fish and Wildlife Service, 24 February 1950. National Archives. Record Group 22. Records of the Fish and Wildlife Service, Entry 162, Box: 71.

Dieffenbach denied the region's request to file with the Arizona State Engineer, he reversed his decision. In a memorandum to Regional Director Gatlin, he wrote:

> We agree, along with the Branch of Wildlife Refuges, that it is imperative a water right for the Federal area be filed with the State of Arizona. You might wish to consider a joint filing with the state for the amount necessary for both areas. The situation with regard to the state interests is a delicate one and while it may be necessary to leave the state out of the picture, for the moment, while the land status in its proposed area is being settled, it might tend to assure them of our cooperation if both agencies filed for the water together. The time element may prevent this, however, so I shall leave the matter entirely up to you. The thought occurred to me that it would be easier to file for all the water at this time rather than get it in a piecemeal fashion.[53]

1951

In a March 27, 1951, Secretary of the Interior Oscar Chapman directed the BuRec to seek funding for measures to protect the wildlife refuge and maintain it "in its present effectiveness." The Department of the Interior cited Public Land Law 732, which "provides for the prevention of damages to existing wildlife facilities."[54]

1960

The "Report of the Special Master Simon H.Rifkind, December 5, 1960" (*Arizona vs. California*) found that "In withdrawing lands for the Havasu Lake National Wildlife Refuge the United States intended to reserve rights to the use of so much water from the Colorado River as might be reasonably needed to fulfill the purposes of the Refuge." He also found that the "Annual diversions of 41,839 acre-feet and annual consumptive use of 37,339 acre-feet of water from the Colorado River will satisfy the estimated water requirement of the development plan for the Havasu Lake National Wildlife Refuge." Judge Rifkind concluded the following:

---

[53] Memorandum to Regional Director J. Gatlin from Coordinator, River Basin Studies Rudolph Dieffenbach, 7 March 1950. National Archive. Record Group 22. Records of Fish and Wildlife Service, Entry 162, Box: 71.

[54] Memorandum to Director, Fish and Wildlife Service and Commissioner, Bureau of Reclamation, 13 April 1951. National Archives. Record Group 22. Records of the Fish and Wildlife Service, Entry 162, Box: 71.

> The United States has the right to the annual diversion of a maximum of 41,839 acre-feet or to the annual consumptive use of 37,339 acre-feet (whichever is less) of water from the Colorado River for use in the Havasu Lake National Wildlife Refuge, with a priority date of January 22, 1941 as to land reserved by Executive Order No. 8647, and a priority of February 11, 1949 as to land reserved by Public Land Order 559.

1964

The *Arizona vs. California* U.S. Supreme Court Decree of March 9, 1964, allocated certain water rights to the Havasu National Wildlife Refuge to fulfill the purposes of the refuge not to exceed 41,839 acre-feet of water diverted from the mainstream or 37,339 acre-feet of consumptive use of mainstream water, whichever is less.[55]

[55] Fish and Wildlife Service Regional Director James Young to Robert Chaney, 7 September 1990. Fish and Wildlife Regional Office, Albuquerque, New Mexico. Water Rights Office, File: Arizona, Folder: Havasu NWR - Correspondence.

Appendix F

Excerpt from *Refuge Water Management Plan, Cibola NWR,* 2004, Williams and Associates, LLC

(Excerpt from Cibola NWR Water Management Plan, 2004, pgs 16 – 18, Williams and Associates, LLC)

The Nature Of Water Rights To The Lower Colorado River

The water rights to the lower Colorado River are largely controlled by federal law. Federal involvement grew out of the enormous task of creating a great system of dams and public works for the purpose of conserving and distributing waters of the Colorado River. In order to study the problem Congress commissioned the Fall-Davis Report, which was duly submitted to Congress in compliance with the Kinkaid Act of 1920 (41 Stat. 600). The report declared that: "The control of the floods and development of the resources of the Colorado river are peculiarly national problems..." [56] (Id. at 21) In addition, the report concluded that the task of controlling floods and developing water resources of the Colorado River were too big for the states and recommended that the United States construct a dam at Black Canyon or Boulder Canyon and the all-American canal[57] from the Colorado River to Imperial and Coachella Valleys in California.

The possibility that a dam would be constructed storing floodwaters of the Colorado River raised fears by the Upper Basin States (Colorado, Utah, Wyoming, and New Mexico) that the ability of the faster growing Lower Basin States (California, Nevada, and Arizona) would acquire these additional waters. This fear was not without basis since the Supreme Court had recently held that the law of prior appropriation, which recognized a first in time first in right priority to those who were earliest in putting water to beneficial use, could be given interstate affect. (See *Wyoming v. Colorado*, 259 U.S. 419 (1922).) In addition, Nevada and Arizona were worried that California's early and rapid use of Colorado River water would deprive them of their fair share of water. As the result of these fears, Congress authorized the seven Colorado River basin States to negotiate a compact equitably dividing the waters of the Colorado River. (42 Stat. 71 (1921). The result was the Colorado River Compact of 1922, which apportioned 7.5 million acre-feet (maf) a year to the Upper Basin and 7.5 maf to the Lower Basin.[58] The Compact provided that the then future Mexican water rights would be supplied by surplus water and, if there was no surplus, Mexican requirements would be shared equally by the States. All of the States except Arizona ratified the resulting Compact. Arizona refused to ratify the Compact because the Compact failed to apportion water to each of the States and failed to recognize Arizona's exclusive right to the waters of the Gila River.[59]

Between 1922 and 1927 Congress made several attempts to enact legislation authorizing construction of the recommended dam and the all-American canal. Finally, in 1928

---

[56] S. Doc. No. 142, 67th Cong. 2d Sess. (1922)

[57] A canal serving Imperial Valley with Colorado River water had previously been built partly through Mexico; thus, the name "all-American" for its substitute.

[58] The Compact can be found at I-4, Nathanson, Milton N. Updating the Hoover Dam Documents, 1978.

[59] Arizona finally ratified the Compact in 1944 after it had already become effective by six-state ratification as permitted by the boulder Canyon Project Act.

Congress passed the Boulder Canyon Project Act (45 Stat. 1057) ("BCPA"). The Act authorized the Secretary of the Interior to construct, operate, and maintain a dam on the Colorado River at Boulder Canyon[60] or Black Canyon. The Act also authorized construction of the all-American canal. The Dam was to be used: "First, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and satisfaction of present perfected rights in pursuance of Article VIII of said Colorado River compact; and third, for power." (Section 6) The Act authorized ratification of the Compact by six-states, if California would limit its claim to 4.4 million acre-feet. The Act authorized Arizona and Nevada to come to an agreement apportioning 300,000 acre-feet to Nevada and the remaining 2.8 maf to Arizona. (Section 4)

Most significantly, the Secretary of the Interior was authorized by Section 5 of the BCPA to contract for the storage of water in the reservoir resulting from the dam and for the delivery of water at such points on the river and on said canal "as may be agreed upon, for irrigation and domestic uses...." The contracts were to be for "permanent service," and no person was to receive water without a contract (Section 5). The Secretary's contracts were to be subject to any compact between the States prior to January 1, 1929, but that any such compact approved after that date would be subject to the contracts made by the Secretary. (Section 8). In addition, Section 6 provided that the Secretary was required to satisfy present perfected rights, which are vested property rights acquired under state law prior to 1929 the effective date of BCPA.[61] In addition, the BCPA authorized the States of Nevada and Arizona to reach an agreement apportioning 300,000 acre-feet to Nevada, and 2.8 maf to Arizona. These states failed to reach an agreement and, after the BCPA became effective, the Secretary followed these statutory guidelines and apportioned the water to California, Nevada and Arizona through various water users (following the Act's guidelines) in California for 5,362,000 acre-feet,[62] with the States of Nevada for 300,000 acre-feet and with Arizona for 2,800,000 acre-feet.

Thus, there are essentially two types of water rights to Colorado River water in the lower basin States: present perfected rights (rights perfected prior to 1929) and Section 5 contract rights (which includes water made by Secretarial reservation) which are largely acquired and defined through permanent service water delivery contracts with the Bureau of Reclamation acting for the Secretary of the Interior.

The Relevance And Applicability Of Arizona v. California, 373 U.S. 546 (1963)

In 1952, Arizona invoked the original jurisdiction of the United States Supreme Court and brought suit against the State of California and various public agencies seeking an

---

[60] Thus the name Boulder Dam, later changed to Hoover Dam.

[61] In this way Congress avoided claims that the government had taken already vested property rights by storing waters to which prior appropriators had a previous vested or perfected water right.

[62] The fact that the Secretary made contracts in excess of California's apportioned 4.4 million acre limitation reflects the fact that for many years Nevada and Arizona did not divert and consume their contractual entitlements, leaving "unused apportionment" available to California users. Also, in some years there was a surplus of water available for diversion and use above the 7.5 maf. In recent years California has adopted and is implementing a "4.4 Plan" to reduce its Colorado River diversions and bring its use within its 4.4 maf limitation.

adjudication over how much water each State can use from the Colorado River and its tributaries. *Arizona v. California* 373 U.S. 546 (1963). Later, Nevada, New Mexico, Utah, and the United States were added as parties. The Supreme Court held that Section 5 of the Boulder Canyon Project Act gave adequate authority to the Secretary of the Interior to divide the 7.5 maf accorded the lower basin States among Arizona, Nevada and California, and that he had done so properly through his contracts. Further, the Court held that the BCPA dealt only with mainstream waters of the Colorado River, leaving it up to each State's jurisdiction over tributary waters within their respective boundaries.

The United States made claims to waters in the mainstream and in some of the tributaries for use on Indian Reservations, National Forests, Recreational and Wildlife Areas and other government lands and works. The Court expressed no doubt regarding the power of the United States to reserve water rights for its reservations and its property. *Arizona v. California*, 373 U.S. at 598.[63] The Court found that the United States intended to reserve water sufficient for the future requirements of the Lake Mead National Recreation Area, the Havasu Lake National Wildlife Refuge, the Imperial National Wildlife Refuge and the Gila National Forest. 373 U.S. 601. However, the Court recognized that the United States was not entitled to use, without charge against its consumptive use, any waters that would have been wasted but for salvage by the government on its wildlife preserves. The Court stated: "Whatever the intrinsic merits of this claim, it is inconsistent with the Act's command that consumptive use shall be measured by diversions less returns to the river." *Arizona v. California*, 373 U.S. 601.[64]

Thereafter, the Supreme Court entered a decree setting forth the quantified amounts apportioned to the States, and present perfected rights holders, including Indian reservations, the Lake Mead National Recreation Area, the Havasu Lake National Wildlife Refuge, and the Imperial National Wildlife Refuge. *Arizona v. California*, 376 U.S. 340 (1964)[65].

---

[63] The power of the United States to reserve water when it reserves land is now settled law and is called the reserved rights doctrine, Winters v. United States, 207 U.S. 565 (1908). When the federal government withdraws land from the public domain and reserves it for a federal purpose, the government impliedly reserves sufficient unappropriated appurtenant water reasonably necessary to fulfill the primary purpose of that reservation. This reservation of water is accomplished without regard to the limitations of state law. The right vests at the date of the reservation and is superior to all subsequent users or appropriators of water thereafter (*see* Cappaert v. United States, 426 U.S. 128, 138 (1976); United States v. New Mexico, 438 U.S. 696, 698 (1978).) The doctrine applies not only to Indian reservations but also to other federal reservations of land from the public domain such as national parks, forests, monuments, military bases, and significantly, wildlife refuges (id. at 138-39; Arizona v. California, 373 U.S. 546, 601.)

[64] The significance of the Court's ruling is that the US FWS may not add to its Secretarial reservation the quantity of water which it may conserve through phreatophyte control, or similar measures that conserve water. Conserved water thus stays in the system and becomes available to other users, some of whom may not be taking conservation measures. This ruling tends to discourage conservation measures since it fails to provide an incentive to conserve water by water users since they do not gain the benefit of the water which they have conserved.

[65] Supplemental decrees were subsequently entered in Arizona v. California, 439 U.S. 420 (1979), Arizona v. California, 466 U.S. 144 (1984); and Arizona v. California, 530 U.S. 1 (2000).

Appendix G

Havasu Water Records

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION NUMBER 09423550 TOPOCK MARSH INLET NEAR NEEDLES, CA SOURCE AGENCY USGS STATE 04 COUNTY 015
LATITUDE 345010 LONGITUDE 1143503 NAD27 DRAINAGE AREA CONTRIBUTING DRAINAGE AREA DATUM 400. NGVD29
Date Processed: 2005-06-17 12:38 By wprobert
APPROVED
DD #1, DCP
Discharge, cubic feet per second
DAILY MEAN VALUES

WTR YR 1967	TOTAL 29313	MEAN 107	MAX 154	MIN 11	AC-FT 58140	
CAL YR 1967	TOTAL 34412.00	MEAN 94.3	MAX 154	MIN 0.00	AC-FT 68260	
WTR YR 1968	TOTAL 47195.80	MEAN 129	MAX 225	MIN 0.00	AC-FT 93610	
CAL YR 1968	TOTAL 50893.8	MEAN 139	MAX 225	MIN 8.8	AC-FT 100900	
WTR YR 1969	TOTAL 23082.20	MEAN 63.2	MAX 158	MIN 0.00	AC-FT 45780	
CAL YR 1969	TOTAL 19514.10	MEAN 53.5	MAX 149	MIN 0.00	AC-FT 38710	
WTR YR 1970	TOTAL 21267.90	MEAN 58.3	MAX 196	MIN 0.00	AC-FT 42180	
CAL YR 1970	TOTAL 22017.00	MEAN 60.3	MAX 196	MIN 0.00	AC-FT 43670	
WTR YR 1971	TOTAL 19914.20	MEAN 54.6	MAX 176	MIN 0.00	AC-FT 39500	
CAL YR 1971	TOTAL 18776.20	MEAN 51.4	MAX 176	MIN 0.00	AC-FT 37240	
WTR YR 1972	TOTAL 18364.00	MEAN 50.2	MAX 130	MIN 0.00	AC-FT 36420	
CAL YR 1972	TOTAL 20970.00	MEAN 57.3	MAX 157	MIN 0.00	AC-FT 41590	
WTR YR 1973	TOTAL 24384.00	MEAN 66.8	MAX 188	MIN 0.00	AC-FT 48370	
CAL YR 1973	TOTAL 22729.00	MEAN 62.3	MAX 188	MIN 0.00	AC-FT 45080	
WTR YR 1974	TOTAL 17783.00	MEAN 48.7	MAX 162	MIN 0.00	AC-FT 35270	
CAL YR 1974	TOTAL 17785.50	MEAN 48.7	MAX 167	MIN 0.00	AC-FT 35280	
WTR YR 1975	TOTAL 21723.40	MEAN 59.5	MAX 205	MIN 0.00	AC-FT 43090	
CAL YR 1975	TOTAL 20535.90	MEAN 56.3	MAX 205	MIN 0.00	AC-FT 40730	
WTR YR 1976	TOTAL 22486.00	MEAN 61.4	MAX 249	MIN 0.00	AC-FT 44600	
CAL YR 1976	TOTAL 21176.24	MEAN 57.9	MAX 249	MIN 0.00	AC-FT 42000	
WTR YR 1977	TOTAL 18685.24	MEAN 51.2	MAX 225	MIN 0.00	AC-FT 37060	
CAL YR 1977	TOTAL 19300.50	MEAN 52.9	MAX 225	MIN 0.00	AC-FT 38280	
WTR YR 1978	TOTAL 20006.50	MEAN 54.8	MAX 212	MIN 0.00	AC-FT 39680	
CAL YR 1978	TOTAL 18426.86	MEAN 50.5	MAX 212	MIN 0.00	AC-FT 36550	
WTR YR 1979	TOTAL 18769.06	MEAN 51.4	MAX 160	MIN 0.00	AC-FT 37230	
CAL YR 1979	TOTAL 21199.40	MEAN 58.1	MAX 160	MIN 0.00	AC-FT 42050	
WTR YR 1980	TOTAL 22814.50	MEAN 62.3	MAX 187	MIN 0.00	AC-FT 45250	
CAL YR 1980	TOTAL 20194.30	MEAN 55.2	MAX 187	MIN 0.00	AC-FT 40060	
WTR YR 1981	TOTAL 21266.00	MEAN 58.3	MAX 175	MIN 0.00	AC-FT 42180	
CAL YR 1981	TOTAL 20126.97	MEAN 55.1	MAX 175	MIN 0.00	AC-FT 39920	
WTR YR 1982	TOTAL 20970.27	MEAN 57.5	MAX 174	MIN 0.00	AC-FT 41590	
CAL YR 1982	TOTAL 21227.31	MEAN 58.2	MAX 174	MIN 0.00	AC-FT 42100	
WTR YR 1983	TOTAL 12184.25	MEAN 33.4	MAX 208	MIN 0.00	AC-FT 24170	

CAL YR 1983 TOTAL 10924.24 MEAN 29.9 MAX 208 MIN 0.00 AC-FT 21670
WTR YR 1984 TOTAL 0.00 MEAN 0.00 MAX0.00 MIN 0.00 AC-FT 0.00

CAL YR 1984 TOTAL 0.00 MEAN 0.00 MAX 0.00 MIN 0.00 AC-FT 0.00
WTR YR 1985 TOTAL 5067.00 MEAN 13.9 MAX 88 MIN 0.00 AC-FT 10050

CAL YR 1985 TOTAL 7601.30 MEAN 20.8 MAX 88 MIN 0.00 AC-FT 15080
WTR YR 1986 TOTAL 14225.30 MEAN 39.0 MAX 109 MIN 0.00 AC-FT 28220

CAL YR 1986 TOTAL 19271.00 MEAN 52.8 MAX 169 MIN 0.00 AC-FT 38220
WTR YR 1987 TOTAL 23894.70 MEAN 65.5 MAX 169 MIN 0.00 AC-FT 47400

CAL YR 1987 TOTAL 19236.30 MEAN 52.7 MAX 165 MIN 0.00 AC-FT 38160
WTR YR 1988 TOTAL 20581.60 MEAN 56.2 MAX 129 MIN 0.00 AC-FT 40820

CAL YR 1988 TOTAL 19721.00 MEAN 53.9 MAX 129 MIN 0.00 AC-FT 39120
WTR YR 1989 TOTAL 22935.10 MEAN 62.8 MAX 148 MIN 0.00 AC-FT 45490

CAL YR 1989 TOTAL 21679.50 MEAN 59.4 MAX 148 MIN 0.00 AC-FT 43000
WTR YR 1990 TOTAL 18256.40 MEAN 50.0 MAX 135 MIN 0.00 AC-FT 36210

CAL YR 1990 TOTAL 19274.60 MEAN 52.8 MAX 135 MIN 0.00 AC-FT 38230
WTR YR 1991 TOTAL 20266.10 MEAN 55.5 MAX 136 MIN 0.00 AC-FT 40200

CAL YR 1991 TOTAL 19910.50 MEAN 54.5 MAX 136 MIN 0.00 AC-FT 39490
WTR YR 1992 TOTAL 14499.80 MEAN 39.6 MAX 131 MIN 0.00 AC-FT 28760

CAL YR 1992 TOTAL 14699.40 MEAN 40.2 MAX 131 MIN 0.00 AC-FT 29160
WTR YR 1993 TOTAL 19104.70 MEAN 52.3 MAX 220 MIN 0.00 AC-FT 37890

CAL YR 1993 TOTAL 20788.10 MEAN 57.0 MAX 220 MIN 0.00 AC-FT 41230
WTR YR 1994 TOTAL 30539.00 MEAN 83.7 MAX 210 MIN 0.00 AC-FT 60570

CAL YR 1994 TOTAL 33311.11 MEAN 91.3 MAX 210 MIN 0.00 AC-FT 66070
WTR YR 1995 TOTAL 35303.69 MEAN 96.7 MAX 286 MIN 0.00 AC-FT 70020

CAL YR 1995 TOTAL 31154.48 MEAN 85.4 MAX 286 MIN 0.00 AC-FT 61790
WTR YR 1996 TOTAL 24059.40 MEAN 65.7 MAX 169 MIN 0.00 AC-FT 47720

CAL YR 1996 TOTAL 23226.00 MEAN 63.5 MAX 169 MIN 0.00 AC-FT 46070
WTR YR 1997 TOTAL 27314.90 MEAN 74.8 MAX 186 MIN 0.00 AC-FT 54180

CAL YR 1997 TOTAL 29782.33 MEAN 81.6 MAX 186 MIN 0.00 AC-FT 59070
WTR YR 1998 TOTAL 29166.57 MEAN 79.9 MAX 178 MIN 0.00 AC-FT 57850

CAL YR 1998 TOTAL 28866.64 MEAN 79.1 MAX 178 MIN 0.00 AC-FT 57260
WTR YR 1999 TOTAL 23582.80 MEAN 64.6 MAX 154 MIN 0.00 AC-FT 46780

CAL YR 1999 TOTAL 22665.00 MEAN 62.1 MAX 154 MIN 0.00 AC-FT 44960
WTR YR 2000 TOTAL 19571.60 MEAN 53.5 MAX 164 MIN 0.00 AC-FT 38820

CAL YR 2000 TOTAL 20625.40 MEAN 56.4 MAX 164 MIN 0.00 AC-FT 40910
WTR YR 2001 TOTAL 21626.4 MEAN 59.3 MAX 158 MIN 0.00 AC-FT 42900

CAL YR 2001 TOTAL 19915.60 MEAN 54.6 MAX 158 MIN 0.00 AC-FT 39500
WTR YR 2002 TOTAL 23692.70 MEAN 64.9 MAX 157 MIN 0.50 AC-FT 46990

CAL YR 2002 TOTAL 23296.78 MEAN 63.8 MAX 157 MIN 0.00 AC-FT 46210
WTR YR 2003 TOTAL 20772.44 MEAN 56.9 MAX 171 MIN 0.00 AC-FT 41200

CAL YR 2003 TOTAL 22446.66 MEAN 61.5 MAX 171 MIN 0.00 AC-FT 44520
WTR YR 2004 TOTAL 24817.48 MEAN 67.8 MAX 179 MIN 0.00 AC-FT 49230
CAL YR 2004 TOTAL 25251.68 MEAN 69.0 MAX 179 MIN 0.00 AC-FT 50090

Appendix H

Beal Lake Riparian Update, 2005, Bureau of Reclamation

saltcedar, with sparse cattail (*Typha latifolia*) and bulrush in wetter areas. The material from the dredging of Beal Lake in 2001-02 covered this at first, but these species soon re-established. Re-vegetation of riparian habitat adjacent to the lake began in late 2002 and continues to the present. This report describes Phase 1 of the project including various methods of creating functioning riparian habitat with as little non-native vegetation encroachment as possible.

Materials and Methods

Soil Testing

Prior to construction, analysis of aerial photos indicated distinct differences in vegetation types and densities within the proposed planting area. Based on this, soil sampling was conducted to determine if this visual difference translated to soils higher in salts and if so, salt tolerant plants could be planted in these areas. Prior to planting, one soil sample per field or approximately 1 sample per 3.5 acres was taken for analysis of salinity, soil texture and depth to groundwater. Sample size refers to number of individual holes from which soil was collected. All soils were collected with soil augers measuring 16 cm x 10 cm at a minimum of three depths per sample and analyzed at Reclamation's Lower Colorado Regional Laboratory in Boulder City, Nevada. Analysis of soils followed the protocol of the U. S. Department of Agriculture's 1996 methods manual (USDA 1996). Soil salinity is reported as a measure of electro-conductivity (EC) in milli-Siemens per centimeter (mS/cm); texture is reported in percentages of sand, silt and clay per sample. Sand is defined as particles between 0.5- 2 mm, silt is between 0.002-0.05 mm and clay is less than 0.002 mm (Kilmer 1982, USDA 1996).

Nutrients were not analyzed at the time the first soil samples were taken as some literature (Asplund and Gooch 1988) and personal communications with experts in the field (Pat Shafroth, USGS, Ft. Collins, CO) indicate that nutrients may not be a significant factor in natural establishment of cottonwood and willow from seed. Asplund and Gooch (1988) use the term "inorganic surface" to describe the alluvium where these species germinate. However, Marler et al. (2001) report a clear benefit to cottonwood and willow from elevated nutrient levels provided by treated effluent. It is possible that these species will establish naturally with low nutrient levels, but also benefit if it is provided. Regardless, after planting, a visible difference in vegetative growth and distribution in some fields was observed and soil nutrients were then analyzed to assist in determining the cause.

Site Preparation and Irrigation

Restoration began with the clearing of vegetation, mainly sparse arrowweed (*Pluchea purpurascens*), and saltcedar (*Tamarix ramosissima*) followed by root plowing to a depth of 18 inches to remove saltcedar roots. The 55 acres were then laser leveled and divided by berms into 17 individual fields in order to irrigate each field separately (Figure 1). On January 15, 2003, 120 lbs of solum certified barley seed purchased from Fertizona, Buckeye, Arizona, was drilled in as a temporary cover crop on all fields. A non-invasive cover crop helps to stabilize the soils, prevent weed infestation, and, when it is disked

into to the soils, increases moisture retention and nutrients. A Rain-for-Rent sprinkler system was used to irrigate the cover crop beginning 18 March 2003.

After testing the permanent system on 19 May 2003, flood irrigation began and is the ongoing method of irrigation at the site (Figure 3). The irrigation system includes a product cooled, variable speed, diesel driven pump with a maximum flow rate of 9,000 gpm and a total lift of 10 feet. A 1,000 gallon, above ground, double walled, concrete ConVault diesel fuel storage tank was placed adjacent to the pump. Water is pumped from a small reservoir between Beal Ditch, which runs adjacent to the east side of the site (Figure1), and Topock Marsh. Beal ditch connects Topock Marsh to the north with Beal Lake to the south. Water is transported to each field via 4,000 linear feet of 24 inch diameter, bell and spigot gasketed, 100 psi, SDR 41, 0.605 inch walled PVC pipe. Two separate 24 inch butterfly valves were installed to control irrigation into two portions of the irrigation system. Within each field, the 24 inch diameter main was reduced to 18 inches diameter and connected to 18 inch diameter alfalfa valves. Heavy rock was deposited around each valve to reduce erosion.

Planting Materials

Dormant cuttings from both cottonwood and willow readily sprout from cuttings if placed directly into wet soil or to the water table (Pope et al. 1990). Cuttings can be collected on the lower Colorado River (LCR) any time after the source trees become dormant, typically November through February. If irrigated, results with poles are typically equal to using rooted container plants. However, construction of the irrigation system and site preparation activities was underway and precluded planting poles at the Beal site.

Container plants for Phase 1 (*P. fremontii, Salix exigua* and *S. goodingii*) were purchased from the nursery at the Colorado River Indian Tribes' Ahahkav Tribal Preserve (CRIT). All were grown in gallon sized containers from cuttings collected on CRIT lands near Parker, Arizona in December 2002 and January 2003 and were 1-3 ft in height when planted between 28 May – 6 June 2003 and 21 January – 3 February 2004. Details on the planting in each field can be found Table 1.

Seed collection is possible from March through July along the lower Colorado River and its tributaries. On the Bill Williams River (BWR), a tributary that joins the LCR near Parker, AZ, Fremont cottonwood seed begins dispersing the first week of March, with Goodding's willow following 2- 4 weeks later (Tables 1 & 2). Patches of these early seeding trees can be found elsewhere on the LCR where cuttings or poles from the BWR have been used in restoration projects. This seeding phenology is likely due to differences in timing of historical flood events on the two rivers. On the BWR, floods are a result of heavy rainfall in late winter/early spring whereas flood events occurred on the LCR in the late spring and early summer from snow melt in the Rocky Mountains. On the LCR, cottonwood and willow begin seed dispersal later. Seeding times are also associated with latitude. Seeds were collected from various locations along the LCR using a variety of methods, depending on site conditions (Table 1). Near roads where trees could be easily accessed, they were collected using a dry-vacuum system equipped with an extended piece of PVC pipe to reach high branches and connected to a small gas generator. Seeds were vacuumed into mesh or cotton laundry bags placed inside of the dry-vacuum bucket.

If trees were some distance from a road, a long pruning pole was used to cut small seed-laden branches from the trees. Seeds and/or seed pods were then either stripped from the branches or small branches were left intact with seeds still on them. All seeds and branches were transported and stored (in cloth bags) either outdoors in the shade or indoors and placed on racks to allow air movement and prevent mold and mildew. Because cottonwood and willow seeds are reported to be viable for only 1-5 weeks after maturity, depending on conditions (Stromberg 1993), seeds were collected directly from the trees and not from ground litter. No information could be found regarding the best developmental stage to collect seed from the trees. Therefore, germination and viability testing of the cottonwood and willow seeds were intended to first, measure the effects of the developmental stage of the seed and pods at the time of collection and second, to determine the effects of age of the seed at the time of testing.

Classifications of the developmental stages of seeds are based on observations in the field during spring 2003 and 2004. Pictures of most developmental stages and corresponding description and germination rates are in Figures 5a and 5b and Table 7 (information and photographs continue to be collected). Once un-opened green seed pods were shipped (overnight mail) to the laboratory, treatment of them was not controlled and unfortunately, whether they opened fully prior to testing not documented. Age of parent tree, fertilization probabilities (presence of male trees in vicinity), temperature, humidity, storage conditions, and countless other variables that may affect germination were not held constant. To confirm if age was related to viability, seeds were stored for various amounts of time and then tested to determine viability. Tetrazolium absorption testing (Leist and Kramer 2003) was performed on cottonwood seeds and direct germination testing (due to the small size of the seed) was performed on willow seed by the Arizona Department of Agriculture's State Agricultural Laboratory in Phoenix. In addition to cottonwood and willow, seeds of salt tolerant shrubs were purchased from Granite Seed, Lehi, UT, and planted in Fields N, and A, and the southern edges of J and E (Tables 1 & 3) where soil salinities were high. *Baccharis sarothoides*, collected from the Pratt Restoration Site, near Yuma, AZ (Raulston 2003), and *Baccharis* sp. collected from the Bill Williams River National Wildlife Refuge (BWRNWR) were also planted.

Planting Container Plants

Based on prior experience, container plants grown in local nurseries from cuttings started in December - January are typically ready for planting beginning in mid-April, but can be later, depending on weather conditions. Soil temperatures on the LCR can exceed 100^{o} F by June and every effort is made to plant prior to the onset of hot weather. However, due to delays in the completion of the permanent irrigation system at Beal, planting occurred from 28 May to 6 June 2003. Cottonwoods and willows in 1-gallon containers were planted in Fields B, D, E, J, and I. These fields are along the outer perimeter of the site and were planted to physically block windborne seeds and lessen the establishment of saltcedar in the inner fields. All container plants were planted using a two-seated tree planter (Tree Equipment Design, Inc., New Ringgold, PA) pulled behind a tractor. Mesquites from 1-gallon containers were also planted in the southern half of Field A

because of the higher soil salinities in this area. Although mesquites are more tolerant of saline soils than cottonwood or willow (Jackson et al. 1990), the water table in this area is also very high which may prevent long term survival of mesquites at this site. Mesquites are generally found in the higher terraces along natural river systems, where water tables are deeper and inundation by flooding is less frequent (Rosenberg et al. 1991). Because the remaining container plants were not available from the nursery by June, Fields C, L, P and O were planted with Regreen™ as a cover crop, a wheat-wheatgrass hybrid purchased from Seed Solutions, Denver, CO. Regreen™ was chosen as a cover crop because it can germinate and grow in hot temperatures, is drought tolerant, forms a dense root structure to stabilize sandy soils, and it is sterile.

Seeds

The barley cover crop was disked into the soil a few weeks prior to dispersing cottonwood and willow seed in fields F, G, H, Q, K and M. Dates and methods of planting, species planted and weight of seed per field, and other details are in Table 1. Hydroseeding involved spraying a mix of water, mulch (Conwed Fibers, Inc. pure wood fiber mulch (35 lb per 1000 gallons water), tackifier for adhesion (1 lb per 1000 gallons water), fertilizer (16% N, 20% Phosphate, 13% Sulfur; 5 lb per 1000 gallons water;) and seed onto the wet surface of each field. One field was used to determine the feasibility of hydroseeding as a method to grow cottonwood from seed. Field M, 2.6ac, was divided into seven areas of equal size, approximately 0.4 acres each. All combinations (Seed Only, Seed+Fertilizer, Seed+Tackifier, Seed+Mulch, Seed+Fertilizer+Mulch, Seed+Tackifier+Fertilizer and Seed+Mulch+Tackifier+Fertilizer of the ingredients in the hydroseed mix, as well as 2.4 lb of cottonwood seed were sprayed onto the field on 20 March 2003, immediately after irrigating. This field was then irrigated along with all other fields according to the irrigation schedule in Table 4. At the end of the growing season, all cottonwoods in each of the seven areas were counted.

Seed-laden branches were also cut and placed directly into wet soil on site to allow for gradual wind dispersal of the seeds over the fields. Loose seed collected by stripping seed and pods from branches was also dispersed by hand onto either wet soil or the water surface of flooded fields.

At the end of the first growing season, the seeded areas were evaluated to determine what percentage of the area had developed into cottonwood and willow habitat. Vegetation classifications were created based the percentage of dominant species observed. Perimeters of the different vegetation types were mapped using points collected with a hand-held Corvalis GPS unit. Areas with sparse cottonwood and willow, or none at all were cleared and re-seeded with willow in May and June, 2004 (Table 1).

Costs

Except for leveling the fields and seed testing, all costs reported are based on work performed “in-house” by either the US Bureau of Reclamation or the US Fish and Wildlife Service (Table 8).

Results

Soils

With few exceptions, higher ECs were found in soils collected at the surface (Tables 4 & 5). Soil collected from Fields A and N had the highest ECs. For all samples at all depths, soil salinities averaged 4.1 mS/cm and ranged from 25.7 – 0.52 mS/cm (Table 5).

By July 2003, observable differences existed within and among seeded fields in density of planted and naturally established vegetation. In Field C for instance, a clear diagonal line existed with Regreen™ growing on one side and little to no vegetation of any kind on the other. In other fields such as H and M, cottonwood and willow had become established in half of the field, with arrowweed and saltcedar on the other half. In Field K, little to no vegetation of any kind was observed. To rule out soil differences (salinity, nutrients, texture) as the cause of differing vegetation in the fields, additional soil samples were taken in September 2003 from each area. No significant differences were found in EC, nitrates, organophosphates, or ammonia (ANOVA $P > 0.05$, t-test for equal variances $P > 0.05$) in areas where vegetation was growing well versus where it was sparse or solely volunteer arrowweed or saltcedar. There were also no textural differences observed, 90% of the soil samples were classified as sand. Soil samples taken from 1-3 foot depths had EC values that are well within the acceptable levels for cottonwood and willow, with somewhat higher values taken from the soil surface (Table 6).

Site Preparation and Irrigation

During the first growing season, May – October 2003, 257,640,000 gallons or 790.7 af was used for irrigation. The amount of water used by month from February through May 2004 is in Table 4.

Seeds

Field M was surveyed on 12 December 2003 to determine the number of cottonwoods established from the hydroseeding test, with results in the following table. There were a total of 551 cottonwoods counted, 212/acre, with the remaining areas covered by arrowweed. The highest number of cottonwoods was found in the Seed+Mulch+Fertilizer+Tackifier treatment area, and generally decreased with increasing distance from the irrigation valve.

Treatment	# Cottonwoods
Seed Only	15
Seed+Fertilizer	5
Seed+Tackifier	13
Seed+Mulch	8
Seed+Fertilzer+Mulch	151
Seed+Fertilizer+Tackifier	177
Seed+Fertilizer+Tackifier+Mulch	182

Preliminary results of viability of different aged seeds are shown in Tables 5a, 5b and 7. Tests indicate that seeds stored while still on the branches until dispersed may have a longer "shelf-life" than seeds stripped from branches and then stored.

Results of germination tests suggest that cottonwood seed has a higher germination rate in the early developmental stages than willows. Between 56-78% of cottonwood seeds germinated in Stages 1 and 2 whereas 18-21% of willow seeds germinated during these stages. Cottonwoods had the highest probability of germinating in Stages 3-5, willows in Stages 3–4. (Tables 5a and 5b and Table 7). As a general rule, the optimal period to collect seeds from either species is once the tree begins dispersing seeds. In willows, this usually occurred after some of the pods had begun turning slightly yellow, and in cottonwoods when some pods have begun to open slightly. Green and/or unopened pods were also present at this point, but viability in both species once these open after collection was high.

Within the seeded areas, success varied. Cottonwood and willow became established in discrete patches throughout Fields F, G, H, Q and M, while arrowweed (*Pluchea purpurascens*) and to a lesser extent, saltcedar, established in others. There were also large areas of bare sand where nothing grew, including saltcedar and other non-native weeds. At the end of the growing season in 2003, cottonwood or willow established in approximately 6 acres or 38% of a total of 15.8 acres that were seeded using the various methods described previously. Although quantitative data on growth and various habitat parameters (density, species diversity, etc.) is not yet available, trees established from seed range in size from 2-12 feet in height at the beginning of their second growing season. More diversity in species and size of plants was observed in the seeded areas than in areas where container plants were used.

The vegetation maps, based on dominant vegetation types, were used to determine which polygons within the seeded areas needed to be replanted. None of the seeded fields developed into 100% cottonwood and willow. Instead, they had mixes of arrowweed, saltcedar, as well as other volunteer shrub and groundcover species. Fields containing substantial percentages of cottonwood and/or willow were: F (0.2ac, 45%), G (0.1ac, 70%), H (0.5ac, 55%), M (0.2 ac, 73%,), and Q (0.2ac, 65%). Field K was essentially bare sand except for a small patch of arrowweed and saltcedar. Within Fields A and N, native salt tolerant shrubs that were hydroseeded (Tables 1 & 3), namely *Atriplex* sp. and *Baccharis* sp. and some brittlebush (*Encelia farinosa*), as well as volunteer screwbean mesquites were interspersed with saltcedar and arrowweed. These two fields were left intact to determine which vegetation would eventually dominate.

Approximately half of Fields F, G, H, Q and M were cleared. The remaining vegetation was retained and consisted of cottonwood and willow with an understory of arrowweed. Fields F and G had small, narrow bands of cottonwood and willow that were retained, and all of Field K was cleared. Clearing took place from 17 - 21 May 2004. Currently, the newly seeded fields are being kept wet on the surface and monitored for germination.

Container Plants

Container plants grew as much as 12' in height during the first growing season, and growth was very uniform within species. Vegetative reproduction of coyote willow has been observed within Field J, E and I and seed production was observed on many Gooddings willow, but not on cottonwoods. Currently no quantitative data is available for container plants; monitoring of survival, growth, density, and condition of these plants will begin in Fall 2004.

Costs

Expenses incurred by US Bureau of Reclamation and US Fish and Wildlife Service are listed in Table 8.

Discussion

This report is intended to be updated periodically as Phases 2 and 3 are completed and additional results of techniques become available. Currently, development for Beal Restoration, Phase 2 (Fig. 2, in yellow) is underway. The site has been cleared and leveled, soil samples have been collected, and irrigation has been installed and is functioning. The area was planted with a cover crop of Regreen™ during the week of 17 May 2004. In November 2004, portions of the site that were higher in salts were planted with 1500 screwbean mesquites, while other areas that had lower soil salinities were planted with 3000 cottonwoods. Planting of Phase 2 will continue in Spring 2005 and will be irrigated throughout the growing season. In Phase 3 (Fig. 3, in blue), most of the saltcedar and arrowweed has been cleared, leaving behind established mesquites. Irrigation infrastructure and leveling are in progress (February and March 2005). This area will be re-vegetated mainly with mesquites, using seeds and potted plants, with cottonwood and willow in suitable locations. Soil testing will be accomplished prior to planting.

For over 25 years, various entities have reported on the ecological, political, and economic aspects of habitat restoration on the lower Colorado River and elsewhere in the desert Southwest. Information is available regarding the ecology of southwestern riparian systems in general (Anderson and Ohmart 1976, Ohmart et al. 1977, Anderson and Ohmart 1984b, Asplund and Gooch 1988, Rosenberg et al. 1991, Busch 1992, Busch and Smith 1995, Briggs 1996; Briggs and Cornelius 1997, Stromberg 1998, Perriman and Kelly 2000,), specific requirements of southwestern riparian systems and species such as depth to water table, soil salinity, and soil textures (Anderson and Ohmart 1982, 1984b, Fenner et al. 1984, Jackson et al. 1990, Stromberg 1993, Friedman et al. 1995, Glenn et al. 1998, Scott et al. 1999, 2000, Shafroth et al. 1995, 1998, 2000, 2002) and various planting methods and restoration techniques (Johnson 1965, Swenson and Mullins 1985, Swenson 1989, Pinkney 1992, Briggs 1992, Taylor and McDaniel 1998, Raulston 2003, USBR 1992, 1998, 1999). Although many projects have been undertaken on the LCR over the years, there is still no secret recipe for success; each restoration project on the LCR presents a different set of problems to overcome.

The following are some practical lessons learned related to irrigating this type of site. Soils at the Beal site were extremely sandy, which can make a site particularly difficult and costly to irrigate. Although water not used by the plants themselves or lost to

evaporation returns to groundwater or the river eventually, the amount of water diverted is nevertheless what is subtracted from the total water entitlement associated with the site. Maintenance costs include fuel for the pump, which must operate longer due to the sandy soils, as well as the labor involved in operating the pump and managing irrigation valves. Laser leveling is strongly recommended. An inch or two rise in elevation or the accidental placement of a berm during construction can interrupt irrigation and cause problems. In order to move irrigation water over the field as quickly as possible, laser leveling the fields *after* rather than prior to infrastructure installation is recommended. This will improve water movement, but winds can still move sandy soils around enough to disrupt the even flow of water across a field, so monitoring of the irrigation during the first few weeks is recommended, especially if planting seeds or small seedlings. Air temperatures and winds can also hamper efforts to keep the surface of the soils damp for cottonwood and willow seed germination and survival. The sprinkler irrigation system at Beal was adequate for the cover crop of barley and Regreen,™ but may not have kept the surface wet enough for germination of cottonwood and willow seed. This irrigation method was also labor intensive and had to be continually monitored for problems. Because pipes were placed over the berms that separated fields, as well as within the fields, the irrigation lines were continually coming apart and creating erosion problems. In addition, sprinkler heads often became clogged and malfunctioned. Once the permanent irrigation was in place, flood irrigation was relatively free from maintenance problems but remains a time consuming activity.

Exploration of irrigation methods that keep the surface wet without disturbing seed continue. Irrigating into furrows, for example, has been used at other restoration sites (Raulston 2003) and in local farming operations, but would be difficult to maintain in sandy soils. Furrowing allows water within the furrows to saturate the berm between them, creating moist soil on the surface of the berm without the disturbance standard flood irrigation causes. If the site is planted with a cover crop that is then tilled into the soil after a few seasons, furrows may maintain their shape long enough for plants to become established. This irrigation method needs further investigation for use in restoration.

A long-term goal of Reclamation's restoration program is to lessen the re-establishment of saltcedar through preventive measures during site preparation and planting rather than through the constant maintenance of weeding. Costs of site preparation (Table 8) associated with the Beal project are closer to those of an undeveloped site (versus an agricultural conversion) i.e. site clearing and irrigation infrastructure were required. However, costs of site clearing at Beal were less than other areas because most of the vegetation to be cleared was arrowweed and sparse saltcedar rather than the dense saltcedar found in many places on the lower Colorado River. Most of the saltcedar which came in at Beal after the initial clearing was evenly distributed and of the same size, which indicates it was from seed rather than re-sprouting. These small saltcedars were disked and the areas were replanted with either cottonwood and willow seed or container plants. Container plants can successfully shade out these competitors, but it remains to be determined if cottonwood and willow established from seed will persist. When clearing saltcedar, deep root removal to at least 18" is essential to remove saltcedar root balls

below the surface (Taylor and McDaniel 1998, Taylor 1999). Re-sprouts from existing roots grow fast and can quickly shade out native container plants or seedlings.

Currently, demonstrations are being conducted in Phase 2 to reduce saltcedar establishment by planting an outer perimeter of closely planted 1 gallon container plants or pole cuttings that serve to block wind-borne seed from reaching the interior of the field. The interior is protected with a cover crop until trees in the perimeter have matured enough to seed. The interior of the field is then disked, flooded and allowed to seed more naturally. Saline areas will be seeded with native salt-tolerant shrubs such as *Atriplex spp*., which may help reduce non-natives from establishing in open areas between mesquites and in areas that are too saline for trees.

Establishing a cover crop prior to restoration has proven to be an invaluable tool for many practical reasons. Soils are held in place while irrigation problems are identified and repaired, including the movement (or lack of movement) of the water across the area to be planted. Growth patterns of the crop can be an indicator of problem areas and can help determine which native species should or should not be planted. Tilling in the cover crop adds organic matter and mulch to the soils, which helps reduce irrigation demands and conditions soils. In addition, contracting and construction delays are inevitable, irrigation problems can arise, and trees ordered from a commercial nursery may need to be delivered prior to when the site is ready. Conversely, trees ordered for a spring delivery may not be ready on time due to uncontrollable circumstances such as cool spring weather, and a fall delivery must be arranged, leaving the site vulnerable to weeds over the growing season. Most nurseries are not willing to hold plants beyond a few months after the specified delivery dates if the plants are ready, as space is needed for additional orders. However, these problems can be minimized significantly if a cover crop is in place and the site is stable. This allows for ample time to attend to the important details of actually planting the site, such as researching and ordering the appropriate species, collecting or ordering the appropriate seed, determining planting methods and equipment needs, and organizing a labor force among agencies or implementing a contract for planting. The resulting product will be better if those involved are not under pressure to plant.

High germination rates in the laboratory and an abundance of seed did not result in high sapling establishment as expected. Along with drying of the soil surface as a likely cause of low survival and densities of seedlings, storage conditions of seeds and time of harvest are other important factors. Seeds that are properly dried after collection have greater longevity and germination rates than those exposed to humid conditions during storage (Moss 1938, Wyckoff and Zasada http://ntsl.fs.fed.us/wpsm/Populus L., Zasada et al. http://ntsl.fs.fed.us/wpsm/salix.L.). Moss (1938) also mentions that despite moisture availability under controlled conditions, certain storage conditions may affect seeds that displayed a “sluggish vitality” long after the power to form normal seedlings was lost; these seeds germinated, but quickly died. Monitoring seedlings in the field is problematic; seedlings first appear as miniscule cotyledons that are very difficult to detect on the ground, while their roots can be an inch or more long (Moss 1938, Raulston pers.comm.). The ability to see seedlings was so limited that walking through fields had

the potential to affect results. Therefore, monitoring germination was delayed until seedlings were more visible, generally 6-10 weeks after planting. Irrigation following one method of hand seeding (loose seed stripped from branches and stored in cloth bags) not only resulted in seeds being washed to the end of the field furthest from the valve, but also may not have allowed for proper drying prior to dispersal. Sticking cut branches into the soil and allowing seeds to remain on the branch until they dry and disperse naturally may result in a more even dispersal followed by higher survival rate. Due to the difficulty in keeping cottonwood and willow seed from blowing away from the dispersal site, these two seeding methods often overlapped. Controlled experimentation both in the lab and on site along the LCR is needed to tease apart these variables.

The establishment of cottonwood and willow from seed in high densities will shade out saltcedar and has the potential to be a successful and less expensive method of restoration. Hydroseeding was moderately successful in that the mix used did help to keep seeds from washing away during irrigation at Beal In another test of hydroseeding near Parker, AZ, no cottonwood or willow seeds germinated at all, however, the hydroseed mix used remained where it was sprayed throughout repeated irrigations. Keeping high numbers of seeds in place and evenly distributed well past germination should lead to high densities of seedlings and less infestation of weeds, but obviously this is a problem that needs further work.

Lastly, a working definition of "successful" may be needed prior to planting so that all parties involved have the same expectations of a project. Since conditions throughout the LCR can differ from site to site, this working definition may have to be site specific. It should be discussed prior to the project so that all entities involved are aware of any limitations that the site may have toward becoming "pristine" native riparian habitat. It is unlikely that any restoration site on the LCR will remain saltcedar-free indefinitely, but steps can be taken to reduce its occurrence.

LITERATURE CITED

ANDERSON, B.W. AND R.D. OHMART. 1976. Vegetation type maps of the lower Colorado River from Davis Dam to the southerly international boundary. Final Report to U.S. Bureau of Reclamation, Boulder City, Nevada.

ANDERSON, B.W. AND R.D. OHMART. 1982. Re-vegetation for wildlife enhancement along the lower Colorado River. Report to U. S. Bureau of Reclamation, Boulder City, Nevada.

ANDERSON, B.W. AND R.D. OHMART. 1984a. Lower Colorado River riparian methods of quantifying vegetation communities to prepare type maps- final report. U.S. Bureau of Reclamation, Boulder City, Nevada.

ANDERSON, B.W. AND R.D. OHMART. 1984b. Vegetation management study for the enhancement of wildlife along the lower Colorado River. Submitted to U.S. Bureau of Reclamation, Boulder City, Nevada.

ASPLUND, K.K. AND M.T. GOOCH. 1988. Geomorphology and distributional ecology of Fremont cottonwood (*Populus Fremontii*) in a desert riparian canyon. Desert Plants:17-27.

BRIGGS, M.K. 1992. An evaluation of riparian re-vegetation efforts in Arizona. Thesis submitted to the School of Renewable Natural Resources, University of Arizona, Tucson, Arizona.

BRIGGS, M.K. 1996. Riparian ecosystem recovery in arid lands: strategies and references. University of Arizona Press. Tucson, Arizona.

BRIGGS, M. K. AND S. CORNELIUS. 1997. Opportunities for ecological improvements along the lower Colorado River and Delta, Final Report. Prepared for Defenders of Wildlife, Washington, D.C. and National Park Service, U.S. - Mexico Affairs Office, Las Cruces, New Mexico by The Sonoran Institute, Tucson, Arizona.

BUSCH, D.E. 1992. Analyses of the structure and function of lower Colorado River riparian plant communities. Dissertation submitted to the Department of Biological Sciences. University of Nevada, Las Vegas, Nevada.

BUSCH, D. E. AND S.D. SMITH. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern U.S. Ecological Monographs 65:347-370.

FENNER, P., W.W. BRADY AND D.R. PATTON. 1984. Observations on seedlings of Fremont cottonwood. Desert Plants 6:55-58.

FRIEDMAN, J. M., M. L. SCOTT AND W.M. LEWIS, JR. 1995. Restoration of riparian forest using irrigation, artificial disturbance and natural seedfall. Environmental Management 19:547-557.

GLENN, E., R. TANNER, S. MENDEZ, T. KEHRET, D. MOORE, J. GARCIA AND C. VALDES. 1998. Growth rates, salt tolerance, and water use characteristics of native and invasive riparian plants from the delta of the Colorado River, Mexico. J. Arid Envr. 40:281-294.

JACKSON, J., J.T. BALL, AND M. R. ROSE. 1990. Assessment of the salinity tolerance of eight Sonoran Desert riparian trees and shrubs. Submitted to U.S. Bureau of Reclamation, Lower Colorado Region, Yuma Projects Office, Yuma, Arizona by Biological Science Center, Desert Research Institute, University of Nevada, Reno, Nevada.

JOHNSON, R.L. 1965. Regenerating cottonwood from natural seedfall. Journal of Forestry January:33-36.

KILMER, V. J. 1982. Handbook of soils and climate in agriculture. CRC Press, Inc. Boca Raton, Florida.

LEIST, N. AND S. KRAMER. 2003. Working Sheets on Tetrazolium Testing Volume I, Agricultural, Vegetable and Horticultural Species. International Seed Testing Association, 1st Edition.

MARLER, R. J., J.C. STROMBERG AND D.T. PATTEN. 2001. Growth response of *Populus fremontii, Salix gooddingii,* and *Tamarix ramosissima* seedlings under different nitrogen and phosphorus concentrations. J. Arid Envr. 49(1):133-146.

MOSS, E.H. 1938. Longevity of seed and establishment of seedlings in species of *Populus*. Botanical Gazette 99:529-542.

OHMART, R. D., W. O. DEASON AND C. BURKE. 1977. A riparian case history: the Colorado River. Pp. 35-47 *in* R. R. Johnson and D. A. Jones (editors). Importance, preservation and management of riparian habitat: a symposium. USDA Forest Service Gen. Tech. Rep. RM-43, USDA Rocky Mountain Forest and Range Experimental Station, Ft. Collins, Colorado.

PERIMAN, R. D. AND J. F. KELLY. 2000. The dynamic environmental history of southwest Willow Flycatcher habitat: a survey of changing riparian conditions through time. Pp. 25- 42 *in* D. M. Finch and S. H. Stoleson (editors). Status, ecology, and conservation of the Southwestern Willow Flycatcher. Gen. Tech. Rep. RMRS-GTR-60. USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah

PINKNEY, F.C. 1992. Revegetation and enhancement of riparian communities along the lower Colorado River. Report submitted to Bureau of Reclamation, Boulder City, Nevada.

POPE, D.P, J.H. BROCK, AND R.A. BACKHAUS. 1990. Vegetative propagation of key southwestern wood riparian species. Desert Plants. 10(2):91-95

RAULSTON, B.E. 2003. Habitat restoration on the lower Colorado River, demonstrations projects:1995-2002. U.S. Bureau of Reclamation, Lower Colorado River Regional Office, Boulder City, NV.

ROSENBERG, K.V., R.D. OHMART, W.C. HUNTER AND B.W. ANDERSON. 1991. Birds of the lower Colorado River Valley. University of Arizona Press, Tucson, Arizona.

SCOTT, M. L., P. B. SHAFROTH AND G. T. AUBLE. 1999. Responses of riparian cottonwoods to alluvial water table declines. Environmental Management 23:347-358.

SCOTT, M.L., G.C. LINES, AND G.T. AUBLE. 2000. Channel incision and patterns of cottonwood stress and mortality along the Mojave River, California. J. Arid Envr. 44:399-414.

SHAFROTH, P. B., J. M. FRIEDMAN, AND L. S. ISCHINGER. 1995. Effects of salinity on establishment of Populus Fremontii (cottonwood) and Tamarix ramosissima (saltcedar) in southwestern United States. Great Basin Naturalist 55: 58-65.

SHAFROTH, P. B., G.T. AUBLE, J.C. STROMBERG AND D.T. PATTEN. 1998. Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona. Wetlands 18(4):577-509.

SHAFROTH, P.B., J.C. STROMBERG AND D.T. PATTEN. 2000. Woody riparian vegetation response to different alluvial water table regimes. Western North American Naturalist 60:66-75.

SHAFROTH, P.B., J. C. STROMBERG, AND D. T. PATTEN. 2002. Riparian vegetation response to altered distrubance and stress regimes. Ecol. Appl. 12(1): 107-123.

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

STROMBERG, J.C. 1998. Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (*Tamarix chinensis*) populations along the San Pedro River, Arizona. J. Arid Envr. 40:133-155.

STROMBERG, J., M. BRIGGS, C. GOURLEY, M. SCOTT, P. SHAFROTH AND L. STEVENS. 2004. Human alterations of riparian ecosystems. Pp. 99-126 *in* M.B. Baker Jr., P.F. Ffolliott, L. F. DeBano and D.G. Neary (editors). Riparian areas of the southwestern United States: hydrology, ecology and management. CRC Press.

SWENSON, E. A. 1989. Progress in the understanding of how to reestablish native riparian plants in New Mexico. Pp. 144-150 *in* K. M. Mutz, D. J. Cooper, M. L. Scott, and L. K. Miller (tech. coords). Restoration, creation, and management of wetland and riparian ecosystems in the American West. A symposium of the Rocky Mountain Chapter of the Society of Wetland Scientists, Denver, Colorado.

SWENSON, E. A. AND C. L. MULLINS. 1985. Re-vegetating riparian trees in southwestern floodplains. Pp.135-138 *in* R. R. Johnson, C. D. Ziebell, D. R. Patton, P. F. Ffolliot and R.H. Hamre (tech. coords). Ecosystems and their management: reconciling conflicting uses. USDA Forest Service Gen. Tech. Rep. RM-120, Fort Collins, Colorado.

TAYLOR, J. P. 1999. Soil disturbance, flood management, and riparian woody plant establishment in the Rio Grande floodplain. Wetlands 9(2): pp. 1-13.

Beal Lake Riparian Restoration Project

Abstract

The Beal Lake Restoration Project (the project) is located on Havasu National Wildlife Refuge in Needles, California, within the historic floodplain of the lower Colorado River. When completed, it will include over 200 acres of cottonwood, willow and mesquite riparian habitat. Prior to restoration, Beal Lake was approximately 225 acres of shallow, low quality aquatic habitat. This lake was dredged to deepen it beginning in 2001, and the dredge material was distributed over adjacent areas, to be planted at a later date with native vegetation. Container plants grown in nurseries, cuttings and seeds have been used at the site. Phase 1 of the project, which is the focus of this report, resulted in 55 acres of cottonwood (*Populus fremontii*) and willow (*Salix gooddingii, S. exigua*) along with some naturally established arrowweed (*Tessaria sericea*) and saltcedar (*Tamarix ramosissima*) . Areas that contain saline soils will be planted with salt-tolerant shrubs (*Atriplex spp*., *Baccharis spp*.) and/or wetland plants such as bulrush (*Scirpus californicus*). This report will be updated as future phases of the project are completed.

Introduction

The Beal Lake Restoration Project (the Project) began as a partnership between the U.S. Fish and Wildlife Service, Havasu National Wildlife Refuge (HNWR), Needles, California, the Bureau of Reclamation's Lower Colorado Regional Office in Boulder City, NV (USBR), and Ducks Unlimited (DU). Originally, DU's interest in the site focused on improving waterfowl habitat and creating moist soil units adjacent to the lake. Preliminary soil testing and site evaluation determined that the sandy texture of the soils in the vicinity would prevent the development of moist soil units, but would allow re-vegetation with native plants and the development of aquatic refugia for native fish in Beal Lake. The development of habitat for Southwestern Willow Flycatchers and other terrestrial and marsh species of concern is the focus of this report.
USBR is interested in quantifying conditions that result in successful habitat restoration and improving our efficiency and effectiveness in future projects under the Lower Colorado River Multi-species Plan (USBR 2004 in prep.). The re-vegetation of the site was divided into 3 phases. Phase 1, involves clearing and preparing approximately 55 acres for planting with native cottonwood, willow and various salt tolerant native shrubs and groundcovers (Figures 1 and 2). Phase 2 will restore another 48 acres of cottonwood and willow and Phase 3 will restore 100 acres of mainly honey and screwbean mesquite (*Prosopis glandulosa var. torreyana* and *P. pubescens*) (Fig.2).

The Project is located south of Needles, CA, between Topock Marsh to the northeast and Beal Lake to the southwest. Originally, the site was dominated by arrowweed and

TAYLOR, J. P. AND K. C. MCDANIEL. 1998. Restoration of saltcedar (Tamarix sp.) infested floodplains on the Bosque del Apache National Wildlife Refuge. Weed Tech.12:345-352.

WYCKOFF, G.W. AND J.C. ZASADA. http://ntsl.fs.fed.us/wpsm/populus.pdf

U.S. DEPARTMENT OF AGRICULTURE. 1996. Soil survey laboratory methods manual. U.S. Department of Agriculture, soil survey investigations report no. 42, version 3.0. Natural Resource Conservation Service, Lincoln, Nebraska.

U.S. BUREAU OF RECLAMATION. 1992. Vegetation management study, lower Colorado River, Phase 1. U. S. Bureau of Reclamation, Boulder City, Nevada.

U.S. BUREAU OF RECLAMATION. 1998. Soil survey report, lower Colorado River re-vegetation program, Cibola, Havasu, and Imperial National Wildlife Refuges. U.S. Bureau of Reclamation, Denver Technical Center, Denver, Colorado.

U.S. BUREAU OF RECLAMATION. 1999. Long-term restoration program for the historical Southwestern Willow Flycatcher (*Empidonax traillii extimus*) habitat along the lower Colorado River. U. S. Bureau of Reclamation, Boulder City, Nevada.

ZASADA, J.C., D.A. DOUGLAS AND W. BUECHLER. http://ntsl.fs.fed.us/wpsm/Salix.pdf

Use of cylindrical wedge-wire screens at Beal Lake

Background

Razorback sucker (*Xyrauchen texanus*) and bonytail chub (*Gila elegans*) are endangered fishes (federally listed) native to the Lower Colorado River. The introduction of non-native fish species is suggested to be a major factor leading to the decline of these species due to competition and predation (Minckley and Deacon 1968, Hubbard 1980, and Minckley 1983). Reclamation has a requirement to restore or create protected backwaters along the lower Colorado River to comply with the Endangered Species Act (ESA). The Term "protected backwater" implies that a restored backwater will inhibit the invasion and population of non-native fish species.

Beal Lake is a 225-acre backwater located on Havasu National Wildlife Refuge near Needles, CA. This backwater was identified as a candidate backwater to partially fulfill Reclamation's native fish protected habitat requirement. Improvements to the backwater included substantial dredging and the installation of a passive rock filtration system (hereafter referred to as: the rock structure). The system is located on an inlet canal between Topock Marsh and Beal Lake and represents the only source of water for Beal Lake and the only surface connection of Beal Lake to Topock Marsh and the lower Colorado River. This rock structure was designed to exclude all life stages of non-native fish while allowing an adequate volume of water to pass from Topock marsh into Beal Lake to balance evaporative losses in the Lake (based on studies conducted by UNLV, Love and Vizcarra 2000).

Shortly after the installation of a passive fish filtration structure at Beal Lake, Reclamation staff observed a marked head difference between the Topock Marsh and Beal Lake (Photo 1). We determined that the rock filter was at least partially clogged and was not passing an adequate volume of water to balance evaporative losses in Beal Lake. We assumed that the clogging was a result of excessive suspended solids in the water column, improper construction of the rock filter, or combination of both these factors. The poor performance of the rock filter provided the impetus for a re-evaluation of the structure and investigation of alternate technologies and/or modifications to the structure. Based on the poor flow performance of the on-site permeable barrier and a more thorough review of the literature regarding performance of this technology, we were reluctant to redesign and reconstruct a new permeable barrier. After weighing the pros and cons of other available technologies, high volume cylindrical wedge-wire (also called "v-wire) screen were selected as an alternative for the rock structure.

Screen System Description

The cylindrical wedge-wire screen system was installed in early spring 2005. It consists of four 18-inch diameter PVC pipes installed through the existing rock structure.

Cylindrical wedge-wire screens are installed on each end of three of the pipes using standard flange connections. This essentially means that each pipe and screen combination represents an independent system (Figures 1 and 2). An in-line valve is installed in each pipe to allow the pipe to be closed when necessary (ie., repair or replacement of screens, etc.). One additional pipe/valve combination is present, but capped (not fitted with screens) and may be fitted with screens in the future should it become necessary.

The screens themselves have been fabricated by Johnson Screens. The screens are approximately three feet in diameter and approximately three feet long. They are constructed of Z-Alloy, an anti-biofouling nickel-copper alloy developed by Johnson Screens and are equipped with an internal diffuser and 3-inch air backwash system. The screen slot size is 0.6 mm (0.024 inches) and each screen has a capacity of 1500 gpm (Figure 3).

Literature Cited

Hubbard, J. P. 1980. Discussion of Chapter 9. Pages 182-192 *in* Energy Development in the Southwest. Problems of water, fish, and wildlife in the upper Colorado River basin. Volume 2 (W. O. Spofford et al., eds.). Resources for the Future, Res. Pap. R-18, Washington, D. C.

Minckley, W. L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the lower Colorado River basin . The Southwestern Naturalist 28(2): 165-187.

Minckley, W. L. and J. E. Deacon. 1968. Southwestern fishes and the enigma of "endangered species." Science, 1421-1432.

Photo 1. Head difference across rock structure.

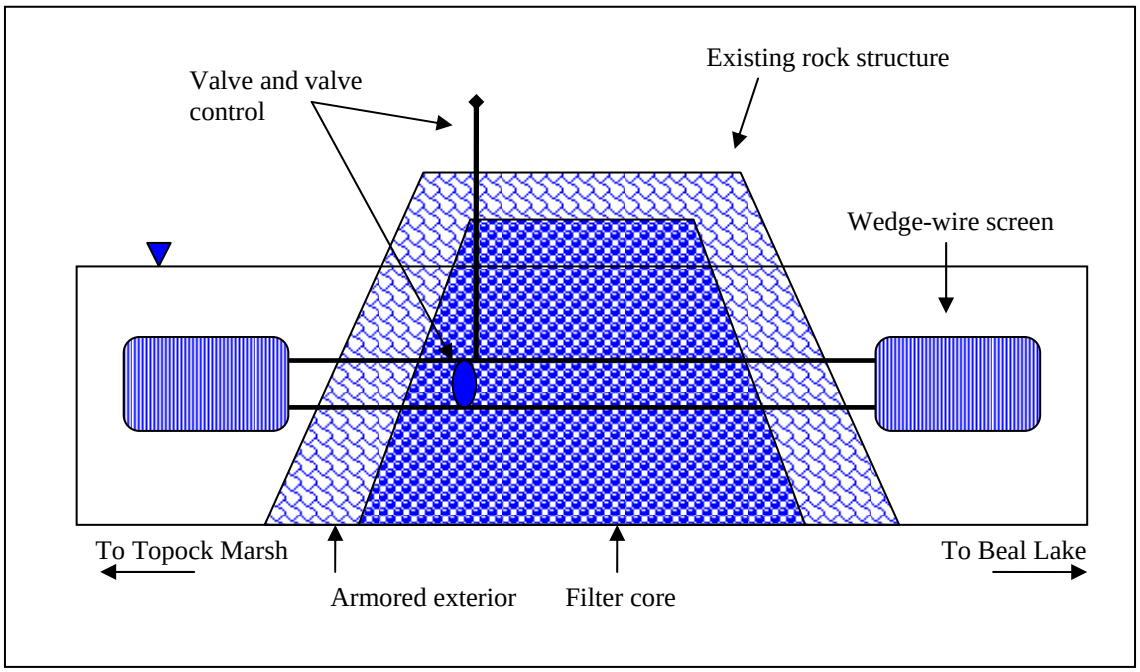


Figure 1. Cross-section of project. Rock Structure Maintenance and Improvement Activities, Reclamation, 2004. Illustrations are for informational purposes only (not to scale).

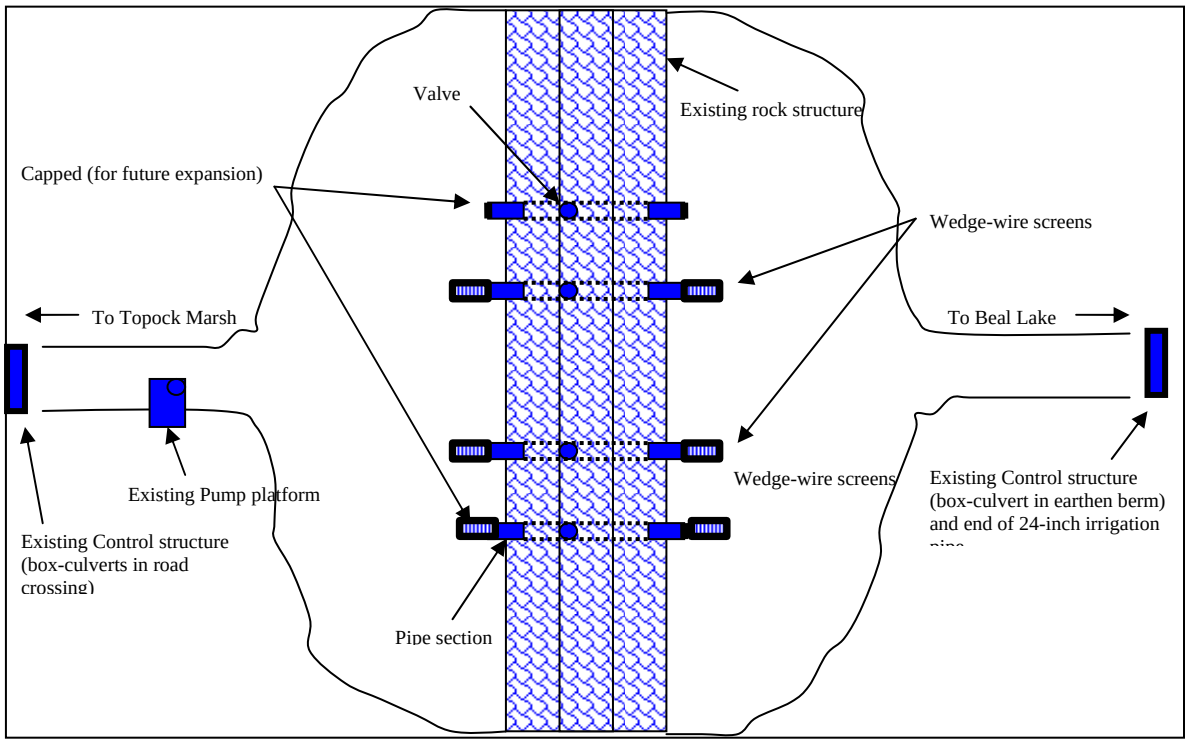


Figure 2. Plan view of project. Rock Structure Maintenance and Improvement Activities, Reclamation, 2004. NTS.

Photo 2. Site photo.

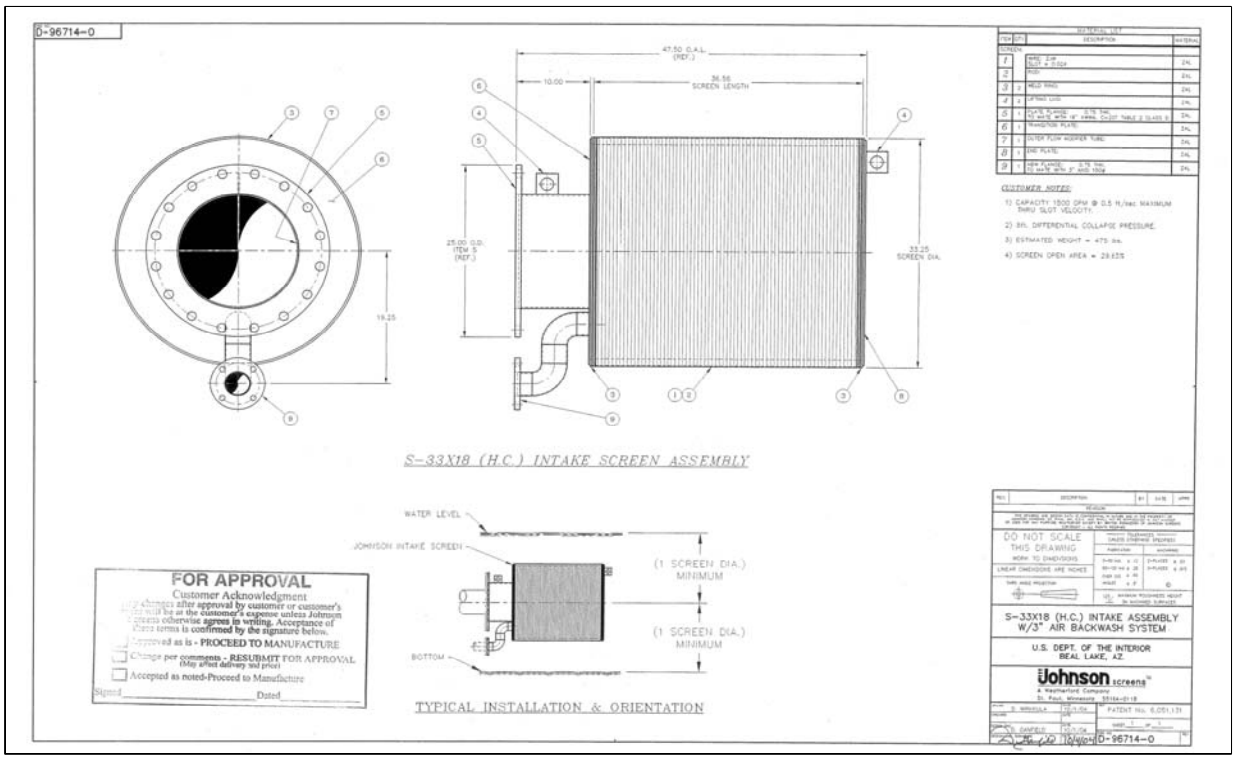
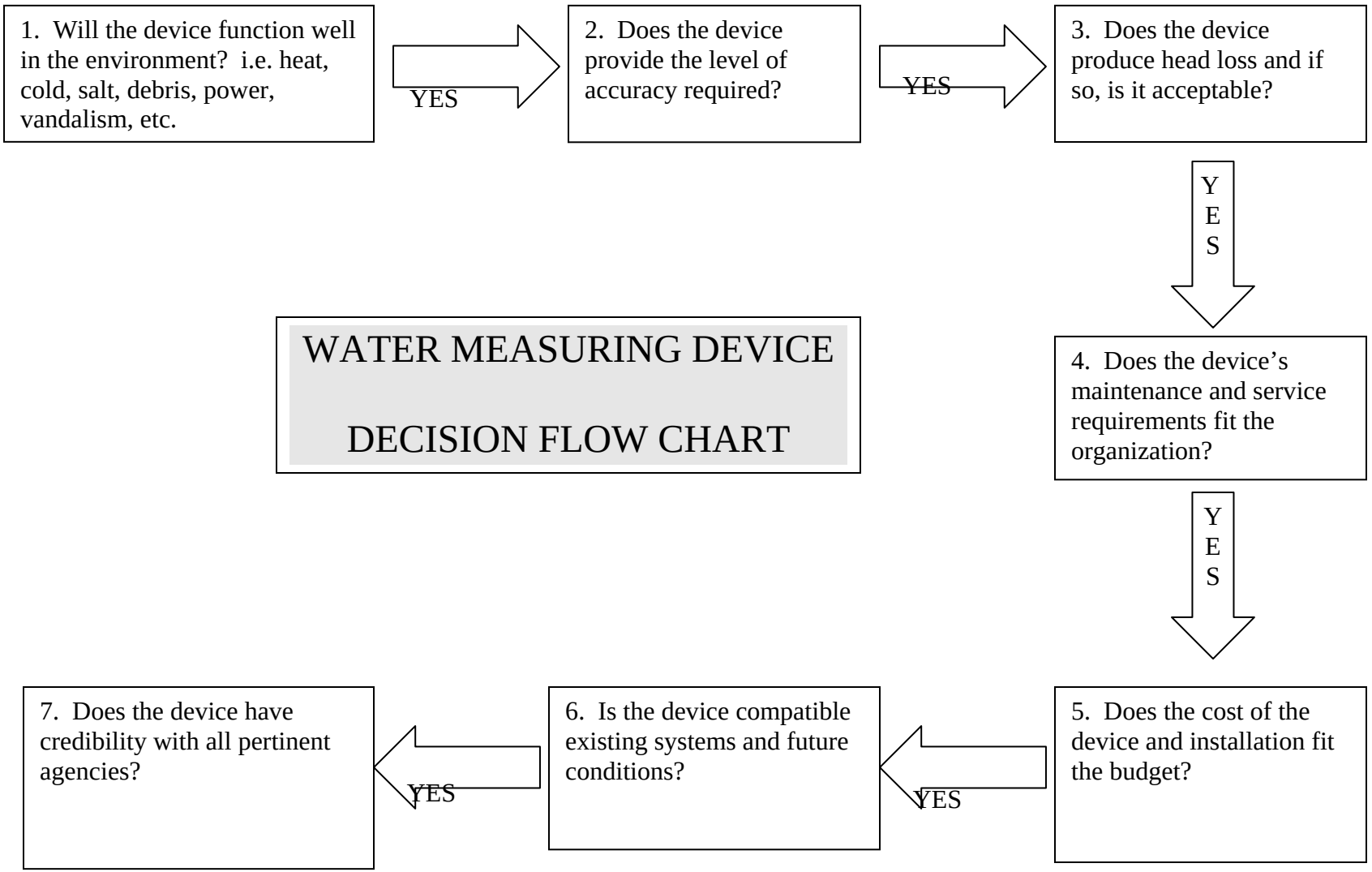


Figure 3. Cylindrical wedge-wire screen drawing and specifications.

Appendix I

Flow Measuring Selection Chart


WATER MEASURING DEVICE
DECISION FLOW CHART
1. Will the device function well in the environment? i.e. heat, cold, salt, debris, power, vandalism, etc.
YES
2. Does the device provide the level of accuracy required?
YES
3. Does the device produce head loss and if so, is it acceptable?
YES
4. Does the device's maintenance and service requirements fit the organization?
YES
5. Does the cost of the device and installation fit the budget?
YES
6. Is the device compatible existing systems and future conditions?
YES
7. Does the device have credibility with all pertinent agencies?