Carlsbad Project Water Operations and Water Supply Conservation

Final Environmental Impact Statement
APPENDICES

June 2006

U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado
Albuquerque, New Mexico

New Mexico Office of the State Engineer
Interstate Stream Commission
Santa Fe, New Mexico

Carlsbad Project Water Operations and Water Supply Conservation

Final Environmental Impact Statement
APPENDICES

June 2006

Mission Statements

Department of the Interior

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

New Mexico Office of the State Engineer and Interstate Stream Commission

To actively protect and manage the water resources of New Mexico for beneficial uses by its people, in accordance with law:

- To investigate, measure, and distribute water in accordance with water rights and interstate obligations,

- To administer a water rights system that lawfully and effectively allocates and reallocates water and adjudicates water rights to meet the needs of New Mexico's growing population, and

- To maximize use of New Mexico's renewable interstate stream apportionments in order to improve the sustainability of New Mexico's water supplies

Appendices for Carlsbad Project Water Operations and Water Supply Conservation Final Environmental Impact Statement

This volume contains six appendices that support the analyses contained in the Carlsbad Project Water Operations and Water Supply Conservation Final Environmental Impact Statement. The six appendices are as follows:

Appendix 1: Biological Opinion
Appendix 2: Water Offset Options Group Documentation Report
Appendix 3: Hydrologic and Water Resources
Appendix 4: Water Quality
Appendix 5: Estimating Regional Economic Impacts
Appendix 6: Consultation Letters

Appendix 1

Biological Opinion

United States Department of the Interior
BUREAU OF RECLAMATION
Albuquerque Area Office
555 Broadway Blvd. NE, Suite 100
Albuquerque, NM 87102-2352

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MAY 23 2006

MEMORANDUM

To: Field Supervisor, U.S. Fish and Wildlife Service,
New Mexico Ecological Services Field Office,
2105 Osuna Road NE, Albuquerque, NM 87113

From: Connie L. Rupp
Area Manager

Connie L. Rupp

Subject: Acceptance of the Biological Opinion for the Bureau of Reclamation's Proposed Carlsbad Project Water Operations and Water Supply Conservation, 2006-2016 (Cons. #22420-2006-F-0096)

Thank you for the biological opinion (BiOp) issued on May 18, 2006. Section 402.15(a) of the Endangered Species Act implementing regulations states, "Following the issuance of a biological opinion, the Federal agency shall determine whether and in what manner to proceed with the action in light of its section 7 obligations and the Service's biological opinion."

I am writing to inform you that we plan to proceed with our proposed action after the Environmental Impact Statement process and Record of Decision are complete. We accept the U.S. Fish and Wildlife Service's BiOp with the following clarifications:

1. The BiOp appropriately recognizes that through implementation of 7(a)(1) water acquisition activities to supplement the Taiban constant alternative, Reclamation's proposed action will augment base flows for the shiner and avoid river intermittency. As we implement activities to avoid intermittency, we will not target any particular flow at Acme gage but will avoid river drying at any location.

2. To fully implement the BiOp, Reclamation is dependent on the timely and/or cost-effective participation of the Service for shiner refugia and population monitoring. Reclamation is also dependent on the Service and other Pecos River stakeholders to develop partnerships to share in the cost and work involved with habitat restoration for shiner and Interior least tern. We will endeavor to implement all components of the BiOp in good faith, with the cooperation and full engagement of the Service and other organizations.

3. Regarding term and condition 1.3 for the Interior Least Tern, Reclamation shall continue its normal operation and maintenance (O&M) activities along the Brantley shoreline. Normal O&M does typically include vegetation removal but this activity may not occur each year. The O&M work may incidentally result in habitat conditions attractive to Interior Least Terns, but it would not be the specific purpose of normal O&M.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 346-2525 Fax: (505) 346-2542

May 18, 2006

Cons. # 22420-2006-F-0096

Memorandum

To: Area Manager, Albuquerque Area Office, Bureau of Reclamation, Albuquerque, New Mexico

From: Acting Field Supervisor, U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico

Subject: Biological Opinion for the Bureau of Reclamation's Proposed Carlsbad Project Water Operations and Water Supply Conservation, 2006-2016.

This document transmits the U.S. Fish and Wildlife Service's (Service) final biological opinion (BO) on the effects of the Bureau of Reclamation's (Reclamation) proposed Carlsbad Project Water Operations and Water Supply Conservation project, for a period of 10 years, beginning 30 days after a Record of Decision is signed, on the Pecos bluntnose shiner (*Notropis simus pecosensis*) (shiner) and its designated critical habitat and the interior least tern (*Sterna antillarum athalassos*) (tern) in accordance with section 7 of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq*.). The Service received Reclamation's Second Amended Biological Assessment (BA) on January 20, 2006. In addition, Reclamation provided supplemental information in several meetings, draft BAs, and other documents which are summarized under "Consultation History."

The current BO does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statute and the August 6, 2004, Ninth Circuit Court of Appeals decision in Gifford Pinchot Task Force v. USDI Fish and Wildlife Service (CIV No. 03-35279) to complete the following analysis with respect to critical habitat. This consultation analyzes the effects of the action and its relationship to the function and conservation role of shiner critical habitat to determine whether the current proposal destroys or adversely modifies critical habitat. This document and the relevant analyses from our June 18, 2003, BO represents our biological opinion for the shiner and its designated critical habitat in accordance with section 7 of the Act.

All information required for consultation was either included with your January 20, 2006 BA, was provided in subsequent memorandums and meetings, or was otherwise accessible for our consideration and reference. You determined that the proposed operations on the Pecos River "may affect, is likely to adversely affect" the shiner but will not destroy or adversely modify critical habitat. You also determined that the proposed action "may affect, is likely to adversely affect" the tern. A complete administrative record of this consultation is on file in the Service's New Mexico Ecological Services Field Office (NMESFO).

CONSULTATION HISTORY

Reclamation first initiated formal consultation with the Service in 1991 on their Pecos River operations (Reclamation 1991). On March 1, 1991, Reclamation submitted a BA which addressed impacts to the shiner, resulting from proposed Carlsbad Project operations. As part of this analysis, Reclamation included a description and analysis of the 1989 operations for filling and testing Brantley Dam and Reservoir. The 1989 operations consisted of making one large block release during the early summer months to both fill Brantley Reservoir and test it for flood control functions. After this single release, there was very little storage left in Sumner and Santa Rosa and no other water was released from Lake Sumner that calendar year, causing river intermittency. This was a one-time operation that Reclamation does not expect to repeat.

On August 5, 1991, the Service issued a BO, analyzing the effects of the proposed 1989 operations. The BO concluded that Reclamation's 1989 Pecos River Dam operations would likely jeopardize the continued existence of the shiner and adversely modify the critical habitat of the species. The jeopardy opinion was based on the fact that the prolonged continuous release of water (47 days) transported eggs, larvae, and probably adults into Brantley Reservoir and that the subsequent river drying, because of the lack of reservoir storage, also had an adverse effect on the species. Shiner population in 1991 was considered to be low, based primarily on comparisons of shiner within the shiner guild compared to historical collections (Brooks et al. 1991). Systematic collections of shiner did not begin until 1992.

There have been several subsequent consultations on Pecos River operations which are outlined in detail in the BO that covered dam operations from March 1, 2003 through February 28, 2006 (Service 2003a). The following paragraphs outline the documents and meetings that apply directly to this consultation.

On May 11, 2005 the Service received an Administrative Draft BA for the proposed project. The Service had numerous comments and met directly with Reclamation staff on June 9 and June 13, 2005, to discuss our comments. On July 13, the Service received a revised draft BA. Outstanding issues and comments were transmitted to Reclamation at a meeting on August 8, 2005. On August 11, 2005 a final BA was delivered to the Service and on September 1, the agencies met to discuss unresolved issues and plans Reclamation had to secure supplemental water for the shiner. On September 13, 2005 the Service sent a letter to Reclamation stating that formal consultation would not be initiated until there was resolution on the outstanding issues. On October 3, November 2, and November 11, 2005, the Service met with Reclamation to discuss outstanding issues related to the shiner and tern. On November 23, 2005, the Service received a final amended BA.

On December 8, 2005, an interagency meeting was held that included ornithologists and biologists from the New Mexico Department of Game and Fish, Reclamation, Bitter Lake National Wildlife Refuge, and the NMESFO to discuss the current status of terns in the Pecos River Basin and opportunities to create additional breeding habitat for terns at Brantley Reservoir. The group requested Reclamation obtain data on historic water levels at Brantley Reservoir during the May through August tern breeding season to help determine elevations within the storage space of Brantley Reservoir that would be suitable for habitat creation. It was decided that a site visit would occur prior to the 2006 tern breeding season to view the operating pool of the reservoir, the 2004 tern nesting area location, and locate potential areas for tern habitat enhancement.

On December 23, 2005, a memo was received from Reclamation outlining supplemental water sources for Pecos River operations.

On January 5, 2006, comments on the BA were faxed to Reclamation and NMESFO staff met with Reclamation to request additional information for the consultation. Reclamation was requested to provide the historic dates when block releases entered Brantley Reservoir during the tern breeding season. There was also discussion about predictive information available on the number and timing of upstream block releases, and about the salt cedar clearing that was conducted on the shoreline of Brantley Reservoir in the vicinity of the 2004 tern nesting area.

On January 19, 2006, NMESFO received a supplement to the amended BA for Pecos River Water Operations that addressed these additional requests for information on issues related to the terns at Brantley Reservoir.

On January 20, 2006. The Service received the Second Amended BA.

On April 13 and 21, 2006, Reclamation and the Service discussed details regarding supplemental water sources and scheduling for the draft BO. On April 24, 2006, the Service received a memo that outlined the details of the supplemental water.

BIOLOGICAL OPINION

I. Description of the Proposed Action

Reclamation’s proposed action is comprised of diverting water to storage, releasing water from storage, and acquiring additional water for the Carlsbad Project to conserve Project water supply and to keep the river continuous. In addition, Reclamation proposes to continue monitoring the camera on the Pecos River at the lower end of the upper section of designated critical habitat, the Taiban gage, the Dunlap gage, facilitate the weekly conference calls during the irrigation season, and organize an annual Pecos River management workshop. Implementation of proposed water operations and supplemental water activities are intended to conserve Carlsbad Project water supply and to conserve the Pecos bluntnose shiner. Reclamation’s proposed water management activities are expected to maintain continuous flow in the Pecos River from the Taiban Creek confluence to Brantley Reservoir. As an additional safeguard, Reclamation proposes to fund and assist in the capture and holding of shiner in refugia, if necessary.

Reclamation has been conducting an Environmental Impact Statement (EIS) process for long term water operations and will soon release the final EIS and issue a Record of Decision (ROD) for the Carlsbad Project Water Operations and Water Supply Conservation. Reclamation proposes to implement the “Taiban Constant” alternative (the preferred alternative identified in the EIS) for a period of 10 years, beginning 30 days after the ROD is issued.

This proposed alternative will operate the Carlsbad Project to: 1) divert water to storage when it is available and flows at the Pecos River Below Taiban Creek Near Fort Sumner, New Mexico (Taiban gage) are greater than 35 cubic feet per second (cfs); and 2) deliver Carlsbad Project water from storage as contracted for irrigation and consistent with applicable Federal and state laws.

The Carlsbad Project is presently permitted to store approximately 40,000 af of Carlsbad Project water in Lake Sumner for irrigation purposes, of which 500 af of Fish Conservation Pool (FCP) (an amount of water set aside for the conservation of the shiner) water can be used to maintain river flow. Under Reclamation’s state water right permit, Reclamation cannot store inflow in Lake Sumner or Santa Rosa Lake that the New Mexico Office of the State Engineer (NMOSE) determines Fort Sumner Irrigation District (FSID) is entitled to receive, consistent with FSID’s senior direct flow water right. Under the proposed action, Reclamation will only divert to storage inflows into Santa Rosa Lake and Lake Sumner not needed to meet FSID’s water right. Reclamation will also bypass inflows when they are available to target the downstream objective of 35 cfs at the Taiban gage.

Once water is stored, it is considered Carlsbad Project water, under contract to Carlsbad Irrigation District (CID) for delivery. If an inflow is not stored, but bypassed, that flow up to 100 cfs is considered to belong to FSID. Reclamation does not own any water rights under the Fort Sumner Project and can not impede the delivery of their water. The two-week calculations during the irrigation season are used to determine the amount of inflow, up to 100 cfs, that will be passed through Sumner Dam to meet FSID’s water right. Reclamation will bypass any remaining inflow available (potential Carlsbad Project Storage) that is above FSID’s senior water right, to maintain the target flow of 35 cfs at Taiban gage. If there is only enough available water to maintain a 20 cfs flow at Taiban gage, Reclamation will bypass that portion. If there is enough water to maintain a 45 cfs flow at Taiban gage, Reclamation will bypass only enough water to maintain the target flow of 35 cfs and store the rest. If the calculated inflow is at or below 100 cfs, Reclamation is obligated to pass such inflows at Sumner Dam to meet FSID’s diversion entitlement. FSID has the option to divert that flow or bypass that flow at the diversion dam.

Reclamation intends to secure additional water and manage supplemental water to avoid river intermittency. Reclamation’s proposed action includes operating Sumner Dam in a manner that not only seeks to avoid jeopardizing the shiner, but also to conserve and protect the species under section 7(a)(1). Consistent with these goals, Reclamation proposes the following:

A) Criteria for Diverting Water to Storage:

1) Water can be stored in Sumner and Santa Rosa Reservoirs during the irrigation season only if there is extra water after Reclamation bypasses FSID's two-week flow entitlement and the river flow target of 35 cfs at the Taiban Gage is being met, and

2) Water will be stored in Sumner and Santa Rosa Reservoirs during the non-irrigation season only if the target of 35 cfs at the Taiban Gage is being met, and

3) Water will not be diverted to storage in Sumner and Santa Rosa Reservoirs at any time when there is a danger of river intermittency.

B) Releasing Water from Storage

1) Release stored water for the beneficial purpose of irrigation in CID in a manner that does not constitute a wasteful use due to excessive losses through seepage and evaporation.

2) Manage the block release schedule from Sumner Reservoir, if possible, to alleviate any river intermittency.

3) Restrict the duration of block releases from Sumner Reservoir to a maximum of 15 days.

4) Restrict the cumulative duration of block releases from Sumner Reservoir in a calendar year to a maximum of 65 days.

5) The number of days between block releases from Sumner Reservoir shall be no less than 14.

6) To the extent possible avoid releases during a six-week period around August 1.

C) Supplemental Water (Conservation Measures)

There are two major criteria associated with Reclamation’s Pecos River operations: supplement river base flows and avoid river intermittency. These are: a) Reclamation will not store incoming water if it is needed downstream for shiner flows, and b) Reclamation will utilize its flexibilities to make block releases in a manner that will help avoid intermittency. For example, Reclamation will schedule block releases that will meet irrigation demand and will also alleviate the lowest of river flows. River intermittency has not occurred historically when Reclamation has been able to schedule multiple block releases during the irrigation season. In addition, Reclamation has and is undertaking the following proactive 7(a)(1) supplemental water activities.

Forbearance program with Fort Sumner Irrigation District

Reclamation first entered into a forbearance agreement with FSID in 2000, which made available land for fallowing. The agreement provided for the return of a percentage of FSID's water diversion right directly back into the Pecos River at the Sandgate Weir above the Taiban Gage. If the diversion is 100 cfs, then the amount of water is equal to the full percent of the forbearance. For instance, the percent of forbearance in 2006 is 11 percent. If FSID is entitled to their full diversion right, 100 cfs, then the forbearance is 11 percent or 11 cfs. Smaller diversion flows would be reduced by that amount, multiplied by the percent. If flows are 85 cfs, then the forbearance at 11 percent would be 9.35 cfs.

The total percent of forbearance is based on the number of FSID participants who have declared their intent to forbear by August 1 of the year prior to the actual year of application. All FSID members who are participating in the 2006 forbearance had to enter into the agreement by August 1, 2005. This agreement is due to expire in 2007, but Reclamation expects FSID to shift their cooperation to water banking to help avoid flow intermittency.

Fish Conservation Pool

Reclamation is permanently authorized by permit from the New Mexico Office of the State Engineer to create a Fish Conservation Pool (FCP) to store 500 af of water in Sumner and/or Santa Rosa Reservoirs for the purpose of providing riverine habitat. Flow rate from the FCP may vary by need. Water from the FCP simplifies the process of getting small flows past the FSID diversion dam. The stored water can be released downstream at any time of the year to maintain instream flows and avoid river intermittency. Reclamation must replace the water released out of Sumner Reservoir with 375 af of water in Brantley Reservoir.

Water Banking

In conjunction with the Fish Conservation Pool, Reclamation is developing a water banking/exchange program which would supply additional water from Sumner or Santa Rosa Reservoirs at critical times to avoid river intermittency and protect designated shiner critical habitat. Reclamation has discussed this option with irrigation districts and State agencies.

As original mitigation for the construction of Brantley Dam, under the Fish and Wildlife Coordination Act, Reclamation committed to irrigate 640 acres of land for small grains to attract migratory birds. Reclamation has three wells and sufficient artesian water rights at Seven Rivers to accomplish the commitment, but has never been able to successfully irrigate more than 240 acres under Reclamation's present contractual arrangement with New Mexico Department of Game and Fish (NMDGF).

Reclamation proposes to reduce its mitigation commitment to only irrigate 240 acres at Seven Rivers. Reclamation would then commit 400 acres of water rights to pumping into Brantley Reservoir to create the deposit for the water bank/exchange. Details of how much water Reclamation could pump under its rights would be determined through the State Engineer's permitting process. The two wells which Reclamation would use are capable of pumping 860 acre feet (af) in 93 days.

Reclamation would make the deposits to the bank in exchange for being able to withdraw water from Santa Rosa or Sumner Reservoir to meet the needs of the shiner. It is understood that Reclamation would need to establish a maximum size for the water bank deposits to ensure that Reclamation would not adversely impact the Carlsbad Project. Initial discussions have suggested that 2,500 af might be the appropriate size. In most years Reclamation would not need that much water, but in the abnormally dry years, it is anticipated that 2,500 af from the conservation pool in combination with some of Reclamation's other efforts would keep the river from becoming intermittent.

Reclamation also proposes that FSID operate in a way which could provide additional Carlsbad Project water in Sumner Reservoir. Because FSID has senior diversion rights, they get their entitlement before the Carlsbad Project can store water. If FSID only asks for water when they need it, then Carlsbad Project is able to store any water not called for by FSID. There are times that FSID does not need its full entitlement and the river has sufficient water to meet shiner needs. For example, when rainfall meets the irrigation need or the farmers are cutting alfalfa. In exchange for FSID agreeing to manage according to need rather than right, Reclamation proposes to stop the current leasing program.

Pumping to the River

Reclamation has an existing five-year lease (renewed in 2005 and which they intend to maintain in the future) for 1,180 af which provides for delivery of water pumped from artesian wells directly to the Pecos River through a pipeline. These wells are located approximately 10 miles upstream of the Acme Gage. Since 2001, historic annual deliveries from these wells have ranged from 200 to 650 af (1-2 cfs delivered to river). Typically, water is pumped from the wells when Acme gage flow drops below 10 cfs. Upgrades to the pipeline, which are underway, should allow for a maximum of 3 cfs to be delivered to the river.

Reclamation also proposes to enter into a lease agreement with the New Mexico Interstate Stream Commission (ISC) for approximately 1,800 af of groundwater which will be delivered through a pipeline to the Pecos River. Based on the amount of water rights being purchased, this project will provide approximately 10 cfs of water to the river for 90 days a year. This is a cooperative effort between ISC and Reclamation. The ISC is purchasing groundwater rights from a local resident of Fort Sumner, New Mexico, under the State's Strategic Water Reserve Program. The purpose of this acquisition is to augment flows of the river for riverine habitat maintenance purposes. The ISC has hired a pipeline engineer and has developed a conceptual design for a transmission pipeline that will deliver up to 10 cfs to the Pecos River. ISC expects to have the pipeline design completed before the end of June and under construction soon thereafter if a construction contractor is available. The pipeline and full amount of 1,794 af will be available for delivery by May of 2007.

D) Other proactive measures

The proposed action described above is fully expected to prevent river intermittency. As another safeguard, Reclamation will also practice adaptive management to keep the river flowing. Reclamation has formulated an Adaptive Management Plan for the Taiban Constant alternative. Communication for the Adaptive Management Plan will be carried out primarily through conference calls among the Pecos River Stakeholder Group and preparation of an Annual Adaptive Management Report. Members of the Pecos River Stakeholder Group include the Service, Reclamation, CID, FSID, NMDGF, New Mexico Office of the State Engineer, ISC, U.S. Army Corps of Engineers (Corps), and interested environmental advocacy groups. Other stakeholders, such as the U.S. Geological Survey (USGS), will be contacted when specific information or input is needed.

As a safeguard, Reclamation is also proposing to fund and assist in the capture and holding of shiner in refugia, if necessary. Reclamation proposes to meet with the Service in the Spring of each year to discuss 1) hydrologic conditions, including snowpack levels, estimated runoff, and current and estimated reservoir storage; 2) preliminary plans for irrigation season operations; 3) current condition of the shiner; 4) and if a risk of intermittency exists. If it is determined that intermittency could possibly occur, then Reclamation will proceed to assist the Service in implementing shiner refugia for that particular year. The refugia would provide a second shiner population should any unforeseen circumstances (e.g., disease, parasites) impact the wild population. It would also provide an opportunity to refine handling or develop propagation methodologies for shiner in captivity should future conditions warrant the need to expand the refugial population. The NMFRO would coordinate with the NMESFO the collection and transfer of approximately 250 shiners to the Dexter National Fish Hatchery and approximately 250 to the NMFRO. Using experienced crews supervised by the NMFRO, healthy shiner would be collected each spring when water quality (e.g., water temperature) is optimal and transferred to the Dexter facility and the NMFRO. Dexter and NMFRO would provide care and handling to maximize the survival of the translocated fish.

During the irrigation season, Reclamation will prepare weekly logs of the conference calls. Reclamation will implement the adaptive management plan within the context of the existing Pecos River water management working group, consisting of federal, state, and local agency managers and representatives, researchers, and water users. Reclamation's authority for participating in this group is described below. A successful adaptive management strategy will include interagency cooperation, long-term commitments, regular communications, and additional meetings as needed. Pecos River stakeholders have different interests, legal rights, and responsibilities with regard to river management. Likewise, there can be fundamental disagreement on flow and habitat needs and the effects of management actions. The adaptive management plan will provide a structure for making decisions, based on changing environmental conditions and will offer a forum to stakeholders to develop a consensus.

Reclamation will take the lead role in facilitating communication. During the irrigation season (March through October), Reclamation will coordinate weekly conference calls on flows and river operations and distribute weekly logs to the stakeholders. The conference calls will be the primary means of coordinating in response to changing conditions along the Pecos River. Key adaptive management indicators such as gage measurements, flows, projected irrigation use and demand, and other criteria will be discussed regularly. During the year, the indicators will be monitored regularly to keep the Reclamation river operations manager informed of changing conditions in the river. The Reclamation river operations manager will be informed as soon as possible (within 24 hours) whenever a key trigger (for instance, river flow reaches a certain level at a specific gage) has been activated. The response process will then be followed.

Reclamation will prepare an Annual Adaptive Management Report after the end of the calendar year. An annual meeting of the Pecos River Stakeholder Group will be held to discuss the status of the adaptive management plan. The focus of the meeting will be on the review of the Annual Adaptive Management Report. The status of the indicators will be discussed and needed changes to monitoring will be identified.

Reclamation will manage the documentation and reporting process for the adaptive management plan. Monitoring results will be incorporated into the Annual Adaptive Management Report. The report will describe the previous water year – January 1 through December 31. Monitoring results for each indicator will be incorporated into the report. In addition, the report will analyze trend data for indicators to determine if responses are needed to long-term changing conditions. The report could include recommendations for monitoring and river management for the next year. The annual report will be coordinated with the annual accounting process. When a trigger has been activated, it will be logged, and the response process will be initiated.

The adaptive management plan is designed to ensure compliance with the BO and the ROD for the Carlsbad Project Water Operations and Water Supply Conservation EIS. Actions currently available within Reclamation authority to change water flows in the Pecos River include (not listed in any priority order): (a) releasing bypass water: (b) releasing FCP water to prevent intermittency; (c) obtaining water from the Carlsbad Project Water Acquisition or Additional Water Acquisition options as described in the EIS; (d) coordinating with CID for block releases; or (e) initiating other similar actions within Reclamation's authority. Such actions will be initiated by Reclamation according to this adaptive management plan in conformance with the BO and ROD.

<u>Interior Least Tern</u>
As part of the proposed action, Reclamation will continue to: 1) Monitor terns to estimate the population size, nesting activity, and identify threats to the colony; 2) coordinate with the NMDGF, New Mexico State Parks, and Eddy County officials to help prevent public access to the colony; 3) erect signs to restrict public access to the area; 4) discuss water management options with the CID to avoid flooding nests; and 5) report monitoring activities and results to the NMESFO.

II. Status of the Species/Critical Habitat

Pecos Bluntnose Shiner

A. Species/Critical Habitat Description

Description of the Species

Historically, bluntnose shiner, *Notropis simus* (Cope), was found in main channel habitats of the Rio Grande, Rio Chama, and Pecos River, New Mexico and Texas (Cope and Yarrow 1875, Evermann and Kendall 1894, Koster 1957, Chernoff et al. 1982, Hatch et al. 1985, Bestgen and Platania 1990). The total range of the species, based on collected specimens, was 827 river miles (mi) (1,332 kilometers [km]) (C. Hoagstrom, Service, pers. comm. 2002). Concern for the species began in the 1970's, when it was listed as endangered by the American Fisheries Society (Deacon et al. 1979, Williams et al. 1989), and by the Texas Organization for Endangered Species (Anonymous 1987). Concern proved valid for the Rio Grande subspecies (*Notropis simus simus*) which was last collected in 1964 and determined to be extinct during the 1970's (Chernoff et al. 1982, Williams et al. 1985, Miller et al. 1989, Bestgen and Platania 1990, Sublette et al. 1990, Hubbs et al. 1991). As a result, the Pecos River subspecies (*Notropis simus pecosensis* Gilbert and Chernoff), was given formal protection by the state of New Mexico in 1976 (listed as endangered, Group 2) and the state of Texas in 1987 (chapter 68 of the Texas Parks and Wildlife Code). In 1987, the shiner was listed as threatened with critical habitat by the Service (1987).

The shiner is a relatively small, moderately deep-bodied minnow, rarely exceeding 3.1 inches (in) (80 mm) total length (TL) (Propst 1999, Hoagstrom 2003a). It has a deep, spindle-shaped silvery body and a fairly large mouth that is overhung by a bluntly rounded snout and a large subterminal mouth. The fish is pallid gray to greenish brown dorsally and whitish ventrally. Adult shiners do not exhibit sexual dimorphism except during the reproductive period, when the female's abdomen becomes noticeably distended and males develop fine tubercles on the head and pectoral fin rays. Additional details on shiner morphology can be found in the 2003 BO (Service 2003a).

The historic range of the shiner in the Pecos River was 392 river mi (631 km) from Santa Rosa, New Mexico to the New Mexico-Texas border (Delaware River confluence). At the time of listing (1987), the shiner was confined to the mainstem Pecos River from the town of Fort Sumner to Major Johnson Springs, New Mexico (roughly 202 river mi, 325 km) (Hatch et al. 1985, Service 1987). In 2003 (Service 2003a), the range of the shiner was described as from Old Fort Sumner State Park to Brantley Reservoir (194 mi, 318 km), or about 23 percent of the historical range of the species. Based on current information presented by Reclamation (Reclamation 2006) and the NMFRO (Service 2003b), the current occupied range of the shiner is from the confluence of Taiban Creek with the Pecos River to Brantley Reservoir. Shiners have not been found in the reach above Taiban Creek since 1999, even though there are no apparent barriers limiting shiner access to this area (S. Davenport, Service, electronic message, 2006).

This change in boundary, eliminating approximately 5 mi (8 km) between the Old Fort Sumner State Park and Taiban Creek, reduces the occupied range to 186 mi (298 km).

For purposes of surveys and habitat considerations, the Pecos River from Sumner Dam to Brantley Reservoir was divided into three reaches (Figure 1) (Hoagstrom 2003a,b). The first is the Tailwater reach, which extends from Sumner Dam to the confluence of the Pecos River and Taiban Creek. The second is the Rangelands reach, which extends from Taiban Creek to the Middle Tract of the Bitter Lake National Wildlife Refuge (BLNWRMT). The third reach is from the BLNWRMT to Brantley Reservoir. These reaches will be used throughout the remainder of this BO to describe the population status of the shiner and its habitat. The “stronghold” for the species occurs in the Rangelands reach (Hoagstrom 2003a). Habitat availability and suitability are the best within this reach of the river, all size classes of shiner are found, and population numbers are relatively stable (Hoagstrom 2003a,b).

Critical Habitat

Shiner critical habitat is divided into 2 separate reaches designated as upper and lower critical habitat (Figure 2) (Service 1987). Upper critical habitat is a 64 mi (103 km) reach extending from 0.6 mi (1 km) upstream from the confluence of Taiban Creek (river mi 668.9) downstream to the Crockett Draw confluence (river mi 610.4). Upper critical habitat is encompassed within the Rangelands reach (shiner stronghold), but approximately 36 mi (58 km) are contiguous with, but downstream of, upper designated critical habitat. This area is referred to as “quality habitat,” even though it is not designated as critical habitat. Lower critical habitat is a 37 mi (60 km) reach extending from Hagerman to Artesia (Service 1987). This portion of the critical habitat is located in the Farmlands reach. These two areas were chosen for critical habitat designation because both sections contained permanent flow and had relatively abundant, self-perpetuating populations of shiner. However, these two areas vary greatly in their habitat characteristics. The upper critical habitat has a wide sandy river channel with only moderately incised banks, and provides habitat suitable for all age classes. The lower critical habitat is deeply incised, has a narrow channel, and a compacted bed (Tashjian 1993). Although the lower critical habitat has permanent flow, the habitat is less suitable for shiners and only smaller size classes are common in this reach (Hatch et al. 1985, Brooks et al. 1991, Hoagstrom 2003a). Survey data indicate that most of the shiners in the Farmlands reach, including the lower critical habitat unit are young-of-the-year (YOY) and juveniles that may be washed into the area from the upstream Rangelands reach (Hoagstom 2003a). The ability of lower critical habitat to support self-sustaining populations of the shiner over the long-term is uncertain.

At the time of critical habitat designation, the 114 mi (184 km) portion of the Pecos River between the two critical habitat reaches was subject to frequent drying and therefore was not designated. The lower 36 mi (58 km) of the Rangelands reach (quality habitat) is located in this middle section, and the USGS Acme gage represents flows in this area. When flow is maintained in this middle section, as it was between 1991 and 2001, this area contains excellent habitat and supports large numbers of shiners (Hoagstrom 1997, 1999, 2000, 2003a). Reclamation has targeted flows of 35 cfs at the Acme gage during the winter, non-irrigation season (November through February) since the 1998 (Service 1998) to ensure maintenance of habitat through this reach of river. Additional irrigation season targets were specified for the Acme gage in the 2003 BO (Service 2003a). The quality habitat between the two areas of critical habitat is acknowledged as an important component for recovery of the shiner.

Primary constituent elements of the critical habitat are clean, permanent water; a main river channel with sandy substrate; and low water velocity (Service 1987). At the time of listing, sporadic water flow in the river was identified as the greatest threat to the shiner and its habitat. Water diversions, ground and river water pumping, and water storage had reduced the amount of water in the channel and altered the hydrograph with which the shiner evolved. Although block releases maintain the current channel morphology (Tetra Tech 2003), since the construction of Sumner Dam, the peak flow that can be released is much less than the historical peak flows (U.S. Geological Survey historical surface flow data). The altered hydrograph encourages the proliferation of non-native vegetation, such as salt cedar, which armors the banks and causes channel narrowing. Channel narrowing increases water velocity, reduces backwater areas, and leads to the removal of fine sediments such as sand. Consequently, in areas dominated by salt cedar, the habitat becomes less suitable or unsuitable for shiners. Lack of permanent flow and an altered hydrograph continue to be the greatest threats to the shiner and its habitat.

B. Life History

Habitat

Typical of other members of the subgenus *Alburnops* (Etnier and Starnes, 1993), the shiner inhabits big rivers (Chernoff et al. 1982, Bestgen and Platania 1990). It has survived only within perennial stretches of the middle Pecos River, New Mexico (Hatch et al. 1985, Service 1987). In conjunction with perennial flow, the shiner is found in wide river channels with a shifting sand-bed and erosive banks (Tashjian 1993, 1994, 1995, 1997; Hoagstrom 2003b). The highly erosive bed and banks allow channel configurations to change in response to flow events (Tashjian 1997, Tetra Tech 2000).

Flood inflows from numerous uncontrolled tributaries contribute to favorable river channel conditions in the Pecos River in the Rangelands reach. Although flood flows from uncontrolled tributaries occur too infrequently to maintain a wide channel, the combination of sediment and floodwater inflows are important for the maintenance of a sand-bed. Throughout the remainder of the historic bluntnose shiner range, closely spaced impoundments that control floods and block sediment transport have virtually eliminated these features (Lawson 1925, Lane 1934, Woodson and Martin 1965, Lagasse 1980, Hufstetler and Johnson 1993, Collier et al. 1996).

Although the shiner is found in the deeply incised lower river stretch that constitutes the Farmlands reach, the population there is dominated by small YOY (Hatch et al. 1985, Brooks et al. 1991, Brooks et al. 1994, Brooks and Allan 1995, Hoagstrom et al. 1995, Hoagstrom 1997, 1999, 2000, 2001, 2003a). Lack of growth, reduced survival, and reduced recruitment in this reach is attributed to poor habitat conditions related to the narrow, incised river channel and silt-armored bed. The predominance of YOY shiner in this reach is explained by periodic downstream displacement of eggs, larvae, and small juveniles (Brooks and Allan 1995, Hoagstrom et al. 1995, 1997, 1999, 2000; Platania and Altenbach 1998, Dudley and Platania 1999).

Kehmeier et al. (2004a) evaluated mesohabitat (discrete habitat types such as riffles, backwaters, runs) use and availability in the Rangelands reach between May 2002 and October 2003. While several of the minnow species they observed were described as habitat generalists, they determined that the shiner was a habitat specialist preferring mid-channel plunge-pool habitats. The research did not differentiate among age/size classes of shiner and it is assumed (based on the velocities and depths recorded) that these habitats were primarily adult habitat. Runs, flat-water areas, and pools with low or no velocity were avoided by the shiner. Based on volumetric calculations of the mesohabitats, the authors concluded that the availability of the preferred plunge habitats was less altered by low flows than other types of mesohabitats (Kehmeier et al. 2004a). The importance of maintaining a mosaic of habitat types for movement between the preferred habitat types was also noted (Kehmeier et al. 2004a).

Early studies showed that shiners avoid (or perish within) areas subjected to frequent surface flow intermittence (Hatch et al. 1985, Brooks et al. 1991). Subsequent studies found that shiners proliferate in areas that were formerly intermittent when they remained perennially wet (e.g. the quality habitat of the Pecos River between the two critical habitat segments) (Hoagstrom 1997, 1999, 2000, 2001). Favorable flow conditions between 1992 and 1999 corresponded with increased shiner density in the quality habitat (Hoagstrom 2000, 2001) and large individual size (see Age and Growth).

Velocity and Depth Preference

A habitat preference study was conducted from 1992 to 1999, to determine the effects of dam operations and variable flows on habitat availability. Velocity association varies with shiner size; larger fish are found in higher velocities (Hoagstrom 2003b). Adults most frequently utilized velocities between 0.7 and 0.9 feet/second (ft/s) (21 and 28 centimeters/s [cm/s]). These velocities were typically found in open-water runs, riffles, and shallow pools (Hoagstrom 2002). Large adults (2.1-2.5 in, 55-65 mm) were found in velocities that ranged from 0.15-1.5 ft/s (4.7 to 47 cm/s) with a mean of 1.0 ft/s (30.8 cm/s) (Hoagstrom 2003b). These large adults were primarily found in run habitats (Hoagstrom 2003b). Although Kehmeier et al. (2004a) did not specify the age class of shiner caught, the velocities they recorded in preferred mesohabitats ranged from about 0.6-0.7 ft/s (19-22 cm/s). Juveniles most frequently utilize velocities between 0.2 and 0.5 ft/s (7 and 17 cm/s), which are most commonly associated with shoreline areas (Hoagstrom 2003b). Larvae presumably utilize backwater habitats with negligible velocity, relatively high water temperature, and high water clarity (Platania and Altenbach 1998). Thus, a range of velocities is necessary to support all shiner life stages.

Adult shiners most frequently utilize depths between 9.0 and 10.6 in (23 and 27 cm) (Hoagstrom 2003b). Juvenile shiners utilize a variety of depths from 8.7 to 11 in (22 to 28 cm) (Hoagstrom 2003b). Such depths are generally associated with run, riffle, and shallow pool habitat. Use of a variety of depths may be caused by the need to avoid high velocity areas. However, shallow, low-velocity habitat may be most favorable (Platania and Altenbach 1998). Depths used most often by larvae are unknown. Kehmeier et al. (2004a) recorded average depths of approximately 9.8 in (25 cm) in mesohabitats preferred by shiner, which agrees with the preferred depths recorded for adults and juveniles by Hoagstrom (2003b).

The habitat preference study found that habitat availability varied between study sites (Hoagstrom 1999, 2000, 2002). Suitable depths and velocities were least abundant in the Farmlands reach (Hoagstrom 2002). The uniformity of the channel creates nearly constant depths and velocities across the channel at a given discharge. This lack of variability at all flows and lack of shallow depths and low velocity areas at high discharge, greatly reduces the suitability of habitat in this lower reach. In the Rangelands reach between the Taiban Creek confluence and Gasline, the wide, mobile, sand-bed channel meanders from side to side. Because a variety of depths and velocities are present over a wide range of discharges, the availability of suitable habitat is much greater in this reach.

Two studies that have examined shiner habitat preference and availability came to contrasting conclusions about the amount of flow that would best sustain the population. Hoagstrom (2003b) concluded from annual research conducted between 1992 and 1999 that more suitable habitat (preferred depths and velocities) was available at higher flows (particularly in the Rangelands reach) and that flows between 48 – 72 cfs provided the highest cumulative habitat suitability (Farmlands and Rangelands reaches combined) (Hoagstrom 2003b). In contrast, Kehmeier et al. (2004a) concluded that because shiner preferred mid-channel plunge pools, and these mesohabitats were as available at low flows (3-5 cfs) as they were at higher flows (up to 80 cfs), low flows were sufficient to maintain the population. Determining that the shiner was concentrated in specific mesohabitats contrasts with other reports that indicated that the species was found in variety of habitats (e.g., Hatch 1982, Hatch et al. 1985, Brooks et al. 1994, Hoagstrom 1997, 2002). It is possible that because Kehmeier et al. (2004a) conducted their research in the midst of two severe drought years (May 2002 to October 2003) they may have found shiner more aggregated than usual. In addition, Hoagstrom (2003b) delineated among size classes and their preferences, providing a more complete picture of the needs of all life stages. Age class of the fish captured by Kehmeier et al. (2004a) was not reported. Low flows down to 3-5 cfs may maintain the shiner during periods of limited water availability. However, flow variability, including large peak flow are necessary to support all aspects of the shiner’s life history.

Reproduction (Spawning)

The shiner is a member of the pelagic spawning minnow guild found in large plains rivers (Platania 1995a, Platania and Altenbach 1998). These minnows release non-adhesive, semi-buoyant eggs (Platania and Altenbach 1998). Because these minnow inhabit large sand bed rivers where the substrate is constantly moving, semi-buoyant eggs are a unique adaptation to prevent burial (and subsequent suffocation) and abrasion by the sand (Bestgen et al. 1989). Shiners begin spawning as one-year-olds, once they reach 1.6 in (41 mm) standard length (SL) (Hatch 1982). The spawning season extends from late April through September, with the primary period occurring from June to August (Platania 1993, 1995a). Spawning is cued by substantial increases in discharge, including flash floods and block releases of water (Platania 1993, Dudley and Platania 1999).

Fecundity varies among individuals. Platania (1993) found that females released an average of 370 eggs with each spawning event and spawn multiple times during the spawning season. Hatch et al. (1985) examined two females and found 1,049 eggs in one (57 mm standard length [SL]) and 85 eggs in the other (51 mm SL). Eggs hatch in 24 to 48 hours (Platania 1993). Because the eggs are semi-buoyant, they are carried downstream in the current (Platania 1993, 1995a, Platania and Altenbach 1998). Newly-hatched larvae float downstream for another 2 to 4 days. During this time, blood circulation begins, the yolk sac is absorbed, and the swim bladder, mouth, and fins develop (Moore 1944, Bottrell 1964, Sliger 1967, Platania 1993). As the larvae drift, they “swim up,” a behavior in which they repeat a cycle of swimming towards the surface perpendicular to the current, sink to the bottom, and upon touching substrate, propel themselves back toward the surface (Platania 1993). This behavior allows larvae to remain within the water column and avoid burial by mobile substrate (Platania and Altenbach 1998). Small juveniles are also susceptible to downstream displacement (Harvey 1987), but are better able to seek low-velocity habitats. Channel conditions that reduce downstream displacement and provide low-velocity habitats are favorable for successful shiner recruitment (Kehmeier et al. 2004b).

Historically the Pecos River had low, erosive banks, large inputs of sediment from tributaries, and uncontrolled floods. However, downstream displacement of eggs and larvae was minimal because flood peaks were of short duration and backwaters and other low velocity habitat remained abundant at high discharge (Dudley and Platania 1999). In contrast, transport of water in block releases that are part of the current water operations, sustains high flows for many days instead of several hours (Dudley and Platania 1999). In addition, where the channel is narrow and incised, backwaters and other low velocity areas are much reduced. Block releases of water stimulate the shiner to spawn (Dudley and Platania 1999), but the eggs, larvae, and small juveniles are then displaced downstream because of the lack of low velocity habitats and the sustained high discharge. Displacement from the Rangelands to the Farmlands reach accounts for the large number of YOY and juvenile fish found in this area (Brooks et al. 1994, Brooks and Allan 1995, Hoagstrom et al. 1995, Hoagstrom 1997, 1999, 2000; Platania and Altenbach 1998). Eggs, larvae, and small juveniles that are transported to Brantley Reservoir likely perish (Dudley and Platania 1999). Some shiner eggs or larvae may be able to pass through Brantley Dam, as indicated by the detection of young shiners below the dam in 2003 (Service 2003b). The ability of shiner to survive and spawn below Brantley Reserevoir is unknown.

Food Habits

A short intestine, large terminal mouth, silvery peritoneum, and pointed, hooked pharyngeal teeth indicate that the shiner is carnivorous (Hubbs and Cooper 1936, Bestgen and Platania 1990). Although Platania (1993) found both animal and vegetable matter within shiner intestines, it is possible that vegetation is ingested incidental to prey capture. It is uncertain whether vegetation can be digested in such a short intestine (Hubbs and Cooper 1936, Marshall 1947). Young shiners likely consume zooplankton primarily, while shiners of increasing size rely upon terrestrial and aquatic insects (Platania 1993, Propst 1999). In a cursory analysis of

655 shiner stomachs, Platania (1993) found terrestrial insects (ants and wasps), aquatic invertebrates (mainly fly larvae and pupae), larval fish, and plant seeds (salt cedar). Other studies have also documented *Notropis* species consuming seeds during winter (Minckley 1963, Whitaker 1977) and it could be that shiners are primarily carnivorous, but utilize less favorable forage such as seeds when animal prey is scarce or that they indiscriminately ingest anything that is of the appropriate size.

The shiner diet is indicative of drift foraging (a feeding strategy where individuals wait in a favorable position and capture potential food items as they float by) (Starrett 1950, Griffith 1974, Mendelson 1975). Drift foragers depend upon frequent delivery of food to offset the energy required to maintain a position in the current (Fausch and White 1981). Water velocity must be adequate to deliver drift (Mundie 1969, Chapman and Bjornn 1969) but low velocity refugia where the fish can rest within striking distance of target items is also necessary (Fausch and White 1981, Fausch 1984). Habitat structure that creates adjacent areas of high and low velocity (e.g., bank projections, debris, bedforms) may be important for shiner feeding. Alluvial bed forms may be the most abundant form of habitat structure in sand-bed rivers (Cross 1967) and these bedforms require a certain velocity for formation and maintenance (Simons and Richardson 1962, Task Force on Bed Forms in Alluvial Channels 1966). Thus, shiners rely upon flow both for delivering food items and for maintaining favorable habitat.

Age and Growth

Based on seine collections, shiner population structure is bimodal (two distinct length classes) from May through August (Hoagstrom 2003a). The smaller size class includes YOY and juveniles; the larger size class, adults. In the spring (January through April) the population is unimodal (one size class) as first year individuals complete a growth spurt and third year individuals decline in abundance (Hoagstrom 2003a). Large juveniles and adults dominate the population at this time. Young-of-the-year present in May and June are not collected with the seine because they are small enough to pass through the mesh.

First year and second year individuals are most common in the shiner population, comprising 97 percent of captures. Third year individuals are much less prevalent (Hatch et al. 1985). First year individuals grow rapidly, reaching 1.0 to 1.2 in (026 to 30 mm) SL within 60 days (S. Platania, University of New Mexico pers. comm. 2002). Hatch et al. (1985) reported that age-0 (first year) shiners ranged from 0.75 to 1.3 in (19.0 to 32.5 mm) SL, age-1 (second year) individuals ranged from1.28 to 1.77 in (32.6 to 45.0 mm) SL, and that age-2 (third year) individuals ranged from 1.77 to 2.22 in (45.1 to 56.5 mm) SL.

Mean length of the shiners is significantly different between the Rangeland and Farmlands reaches. In the Rangelands reach the mean length of shiners is 1.3 in (34.2 mm), with a standard deviation (SD) of 0.36 in (9.3 mm) (N=7,477). Downstream the mean length is 0.91 in (23.2 mm) with a SD of 0.28 in (7.1 mm) (N=8,876) (C. Hoagstrom, Service, pers. comm. 2002). In addition, in the Rangelands reach, all age groups are present and adults dominate the population. In contrast, in the Farmlands reach, adults are rare and YOY dominate (Hatch et al. 1985, Brooks et al. 1991, Brooks and Allan 1995, Service 2003b, Hoagstrom et al. 1995, Hoagstrom 1997, 1999, 2000, 2001). Most likely the difference in size is related to habitat quality (the downstream Farmlands reach provides less suitable habitat for the growth and survival of the shiner) and the influx of small shiners into this lower reach during high flows including those caused by block releases from Sumner Dam.

Data from 1992 to 1999 (years of high precipitation and experimental base-flow supplementation) suggest that favorable flow conditions over several years produced larger shiners (Hoagstrom 2003a). Numerous individuals captured during that period were larger than previously recorded. Abundance of record-length shiners peaked between April and July 1999 when the 16 largest shiners, ranging in size from 2.58 to 3.01 in (65.5 to 76.4 mm) SL were captured (Hoagstrom 2003a). Twenty-five percent of the longest shiners caught over an 11-year period (1992 to 2002) were caught in 1999 (Hoagstrom 2003a). The longest individual captured in 1999 was 3 in SL (76.4 mm). This specimen was 0.4 in (11.2 mm) longer than any other shiner caught during the 10-year study, 0.3 in (7.5 mm) longer than the longest reported by Platania (1993), 0.8 in (19.9 mm) longer than any reported by Hatch (1982), and 0.9 in (23 mm) longer than the longest from the historical record (Chernoff et al. 1982). Because flows were continuous and higher than normal from 1996-1999, higher velocity habitats that larger adults prefer may have been more available leading to better survival of adults (thus the larger sized individuals).

Competition and Predation

Non-native fish species, including the plains minnow (*Hybognathus placitus*) and the Arkansas River shiner (*Notropis girardi*) are now established members of the Pecos River fish community. They are also part of the guild defined as broadcast spawners to which the shiner belongs (Platania 1995a). Members of this guild spawn during high flow events in the Pecos River and have semi-buoyant eggs that are distributed downstream to colonize new areas (Bestgen et al. 1989). As a result of the non-native introductions, interspecific competition may be a factor in the reduction in shiner abundance and distribution. Young fishes of these species that also use low velocity backwater areas may compete directly with young shiner for space and food (if food is limited); however, competitive interactions among Pecos River fishes have not been studied.

Juvenile and adult shiners generally occupy flowing water of low depth (see Velocity and Depth Section). At the same time, flowing water is important for supplying food and creating habitat structure (see Food Habits). Thus, a significant reduction of velocity impacts feeding position and food availability. Under such circumstances, shiners are forced to occupy habitats with lower velocity and more variable depth, but these habitats are commonly occupied by other fish species (Hoagstrom 1999, 2000). At low discharge, competition for space and forage is likely increased (Hoagstrom 1999). Concentration of species is most severe during intermittency because fishes must congregate in remnant pools. In such cases, it is likely that fishes that commonly inhabit still and stagnant waters (e.g., red shiner [*Cyprinella lutrensis*], western mosquitofish [*Gambusia affinis*]) gain a competitive advantage over fluvial species (Cross 1967, Summerfelt and Minckley, 1969). In addition, without flows to deliver food items, species dependent upon drift, such as the shiner, are at a disadvantage (Mundie 1969).

Large-bodied piscivorous fishes in the Pecos River are uncommon in currently occupied shiner habitat between the Taiban Creek confluence and Brantley Reservoir (Hoagstrom 2000, Larson and Propst 1999). This is primarily because the majority of available habitat is shallow and unsuitable for large fish. High turbidity likely inhibits sight-oriented predators such as the sunfishes (Centrarchidae). Predators that occupy the most suitable shiner habitat include the native longnose gar (*Lepisosteus osseus*), flathead catfish (*Pylodictis olivaris*), and green sunfish (*Lepomis cyanellus*), and the non-native channel catfish (*Ictalurus punctatus*), white bass (*Morone chrysops*), and spotted bass (*Micropterus punctulatus*) (Larson and Propst 1999). When captured during surveys, the majority of these predators have been small (Larson and Propst 1999, Valdez et al. 2003). Thus, low abundance and small size suggest fish predation is not a major threat to the shiner (Larson and Propst 1999). However, the impacts of predaceous fishes within intermittent pools have not been studied and it is possible that they feed on shiner (Larson and Propst 1999). With the increase in intermittent flow days in 2002-2003 (49 days in 2002, 44 days in 2003), there may have been an increase in predation on shiner trapped in pools (Larson and Propst 2003). The reduction in intermittent flow days in 2004 to eight days, and none in 2005, may have reduced the risk of predation.

Aerial and terrestrial piscivores may also threaten the shiner. Many piscivorous birds are seasonally found at BLNWRMT and piscivorous mammals and reptiles are present along the river. Least terns are known to prey on shiner species in other rivers (Wilson et al. 1993, Schweitzer and Leslie 1996), but this has not been documented on the Pecos River. As with piscivorous fishes, impacts of non-aquatic predators (e.g. racoons, skunks, coyotes) on the shiner are likely most significant during surface flow intermittence, when fishes are confined and crowded in shallow water (Larimore et al. 1959). Larson and Propst (2004) reported that the tracks off several predators, including Great blue heron, raccoon, and coyote, were seen around isolated pools that occurred during river intermittency in 2002.

C. Population Dynamics

In 1991, Reclamation received a BO from the Service for operations on the Pecos River that included a Reasonable and Prudent Measure directing them to fund 5 years of research activities to determine the biologic and hydrologic needs of the shiner (Service 1991). To that end, in 1992, the NMFRO began a 5-year study on the shiner and its habitat. Research on the shiner population has continued, resulting in a 14-year record of population trends (1992-2005) (Fagan 2006). Population sampling has been conducted three times or more per year at 10-20 sites on the Pecos River since 1992. The timing of sampling is geared to the life history of the shiner. January-April (first trimester) is an indicator of over-winter survival. May- August (second trimester) occurs within the spawning season. Because the larval fish are too small to be caught by the seines this trimester is a reflection of the breeding population. September-December (third trimester) represents post-spawning and is when YOY are most abundant. In addition, because this time period occurs after intermittency is most likely, it is an indicator of the population’s response to this stressor.

Over the 14-year period, only 23 shiners have been caught in the Tailwaters reach. Although at the time of listing (1987) shiners were relatively common from the FSID Diversion Dam down to Taiban Creek, they have become rare in this part of the river and are infrequently collected (Hoagstrom 2003). No shiners have been caught in the Tailwaters since 1999 (S. Davenport, pers. comm., 2006). Therefore, the Tailwaters reach will not be discussed further. The remainder of this discussion will focus on the Rangelands and Farmlands reaches that remain occupied by the shiner.

From 1992-1999 shiner density within the Rangelands reach showed a gradual increase (Brooks et al. 1993, Brooks and Allan 1995, Hoagstrom et al. 1995, Hoagstrom 2003a, Fagan 2006). During these years there was a normal snow pack and spring runoff, frequent local summer precipitation, and experimental Sumner Dam operations, all of which contributed to sustaining perennial flows from Sumner Dam to Brantley Reservoir (Hoagstrom 1999, 2000). These years included base-flow supplementation and a 15-day maximum on block releases. Cooperation, brought about by a Memorandum of Understanding among the stakeholders on the Pecos River, enabled the experimental operations to occur and facilitated maintaining permanent flows throughout this period (Service 1991).

In 1999, New Mexico entered a period of sustained drought (Liles 2000a,b). By 2001, there was a reduction in reservoir storage to 60 percent of normal and river intermittency occurred (4 days) for the first time since 1991 (Table 1). Conditions in 2002 were even worse, with April 1 reservoir storage at 26 percent of normal. Intermittency was extensive that year with 49 days of no flow at the Acme gage and 63 days with flow less than 1 cfs (Table 1). Severe drought conditions persisted into 2003, with reservoir storage on April 1, 35 percent of normal, 44 days of 0 flow recorded at Acme gage, and 97 days of less than 1 cfs (Table 1).

From the long-term population surveys, it appears that the prolonged and extensive intermittency that occurred from 2002-2004, in combination with limited spawning opportunities had a negative impact on the shiner population (Figures 3 & 4 Tables 2,3,4) (NMFRO 2006, Fagan 2006). No other physical or biological factors have been identified that would lead to such a pronounced decline in population density. Both the relative abundance and shiner density dropped precipitously in the Rangelands reach, where the habitat is the best and where we would expect the population to be the most resilient. The years from 2001 to 2005 will be discussed in more detail in an effort to explain the patterns in population trend seen in this time frame. If not stated explicitly, all reference to flows in the following discussion are those recorded at the Acme gage (08386000) and all information is available on the USGS website (http://waterdata.usgs.gov/nm/nwis/uv/?site_no=08386000&PARAmeter_cd=00065,00060). All reference to shiner density and trend are displayed in Figures 3 and 4 and Tables 2-4 (S. Davenport, Service, pers. comm., 2006b).

In 2001, 4 days of intermittency occurred (Table 1) and the population trend continued upward (Figures 3 & 4). Most likely intermittency was not extensive enough to cause direct mortality of shiner and the population was still expanding, bolstered by the strong year classes produced in the proceeding years. In 2002, in the Rangelands reach, the first trimester (January to April) again showed an increase in density up to a high of about 47 fish/100 m^2, the highest density recorded from 1992-2005 (Table 3). However, in trimesters two and three, after intermittency occurred, density dropped down to 12 fish/100 m^2 and 10 fish/100 m^2, respectively (Table 3).

In contrast, density of shiner in the Farmlands reach the first trimester of 2002 began relatively low (10 fish/100 m^2) but then was extraordinarily high during the second trimester (74.4 fish/m^2), the highest value recorded in Farmlands between 1992-2005 (Table 4). Because there was only one block release that year (in March before spawning would occur), transport of larval fish into the Farmlands reach does not explain the increase in density. Four small flood events occurred in the 2002 spawning season (late April to September). The first (June 14), occurred after 24 consecutive days of intermittency and was of short duration (3 days). The second (June 21) was of greater magnitude (1830 cfs vs 672 on June 14), but also lasted only 3 days. The third (July 4), also lasted 3 days, with a peak of 420 cfs. The fourth flood (August 20) occurred between two periods of intermittency, with 21 days of 0 flow before the peak of 651 cfs and with intermittency occurring 12 days after the peak occurred. It is tempting to speculate that the high numbers of shiner found in the Rangelands reach in the first trimester moved to the Farmlands in the second. However, the fish caught in the Farmlands were nearly all less than 35 mm and the majority were caught at Brantley inflow (S. Davenport, Service, pers. comm., 2006c).

In 2003, in the Rangelands reach, shiner density for the first two trimesters was about 27 fish/100 m^2 (Table 3). Extensive drying (44 days of 0 flow, 97 days less than 1 cfs) occurred again throughout the summer of 2003 (Table 1), and in the third trimester the fish density was the lowest recorded since 1992 (Table 3). There was one peak flow event, a small block release from June 21- July 9, which was probably used by the shiner for spawning. Up until the block release, flows all spring had been very low with no peaks. Unfortunately, within 8 days of the block release flows were less than 1 cfs and within 15 days the river entered into a long period of intermittency (30 days). Most likely, this period of intermittency effectively eliminated all nursery habitat within the quality reach of river, and led to the death of many larval fish. There was another very small peak in flow (91 cfs) that occurred on August 30, but once again the flow at Acme was less than 1 cfs within 8 days and it stayed less than 1 cfs until September 22, when the river was again intermittent for several days. Consequently, reproductive success of the 2003 year class was most likely very poor. In the Farmlands reach, fish density increased in both the second and third trimesters, but the increase was very small compared to 2002, 13 and 28 fish/100 m^2, respectively (Table 4).

In 2004, initial density in the Rangelands reach was 2.9 fish/100 m^2, it increased slightly to 6.4 fish/100 m^2 in the second trimester, and declined in the third trimester to 1.5 fish/100 m^2, the lowest recorded in the third trimester since 1992 (Table 3). Because the drought was not as intense in 2004, intermittency was limited to 8 days. However, there was not a peak in flow until June 29 (240 cfs) which tailed off quickly and within 18 days, the river was intermittent. Two more small rain events occurred in August that may have prompted spawning but overall the monsoon season was very poor and probably contributed to another poor year class. Although two block releases occurred in 2004, both were outside the spawning season. One occurred in early March and the other in late September.

In 2005, density in the Rangelands reach for the first two trimesters was 1.1 and 1.0 fish/100 m^2 (Table 3). Although 2005 was a wet year and there was no intermittency, no days less than 1 cfs, and no days less than 5 cfs, there was not an immediate population response. However, in the third trimester, density numbers rose for the first time since 2003, to 4.5 fish/100 m^2 (Table 3).

Density was also up in the Farmlands reach in second and third trimesters to 2.8 and 4.0 fish/100 m^2, respectively (Table 4). These numbers are a positive sign that the wet hydrologic year of 2005 was beneficial to the population.

The combination of three years (2002-2004) with poor monsoonal rains and only one block release between 2002-2004 occurring in the spawning season, indicate the shiner had few opportunities to spawn during these three years. In addition, in 2002 and especially in 2003, very low flows (less than 1 cfs) and intermittency occurred almost immediately after small peak (spawning) flows. These conditions would have greatly limited or eliminated available nursery habitat and most likely led to a severe reduction in the survival and recruitment of two year classes. Because the shiner is short-lived (three years), it does not take long for environmental perturbations to drastically reduce its population numbers. It is our opinion that the combination of few spawning peaks and very limited, or no nursery habitat caused by river drying immediately after spawning from 2002-2004, severely impacted recruitment in the shiner population and led to its population decline.

Intermittency occurs primarily in the quality habitat located between upper and lower critical habitat. When intermittency occurs, typically upper critical habitat (64 mi, 103 km) and lower critical habitat (37 mi, 60 km) continue to have flowing water. The quality habitat between the two designated reaches of critical habit is approximately 36 mi (58 km). Observing such a drastic decline in shiner population, when intermittency is directly affecting a relatively short reach of river, leads us to two possible conclusions. First, although the quality habitat is relatively short, it is disproportionately important to shiner recruitment and reproductive success. It is possible that when this reach has flowing water that creates a variety of habitats, it supports a large number of shiner that contribute towards maintaining the entire population. In particular, if this area is critical nursery habitat, and the nursery habitat dries, the consequences are severe, especially when spawning opportunities are limited. When recruitment fails in the quality reach it has effects system-wide.

A second explanation why the shiner population declined so dramatically with two years of low flows and intermittency is that overall low flows system wide create low grade, continuous stress on the fish. Low flows may lead to increased competitive interactions, increased predation, lower fecundity, or increased susceptibility to disease. Although difficult to observe or detect, these factors could cumulatively lead to increased mortality or reduced reproductive success. Two very stressful years with limited flows could have a large impact on a species that only lives three years.

D. Status of Species and Distribution

The historic trend in shiner abundance indicates a decline since the 1940s (Hatch et al. 1985, Brooks et al. 1991, Propst 1999). For example, Koster (1957) collected 818 shiners on September 3, 1944, at the U.S. Highway 70 Bridge (University of New Mexico Museum of Southwestern Biology records). In comparison, at the same site between 1992 and 1999, the NMFRO collected a total of 815 shiners in 39 trips (Hoagstrom 2000). In pre-1950 collections the shiner achieved its greatest relative abundance, 37.5 percent of the cyprinid guild, compared to collections made from 1950-1975, 1976-1985, and 1985-1994 (Platania 1995b). It has never reached that level subsequently (Platania 1995b, Hoagstrom 2003a). The number of shiner per sample in this time frame was 1-1,492, with a mean of 433 per sample (Platania 1995b). The mean number/sample caught in Rangelands reach in 2004 and 2005, was 7.4 and 6.3, respectively with a range of 3-12 (S. Davenport, Service, pers. comm., 2006d) Collections between 1986 and 1990 indicated a further decline in abundance and a reduction in range, although the species still existed within the designated critical habitat reaches (Brooks et al. 1991). Brooks et al. (1991) found that the shiner comprised 3.7 percent of the total number of all shiners collected (5 species) from the Pecos River during 1990, compared to 22.4 percent for all collections prior to 1980 (4 species). Based on the discussion in the population dynamics section, it is clear that the status of the shiner is currently at the lowest level seen since consistent monitoring began in 1992 (NMFRO 2006, Fagan 2006).

The Service had the population monitoring data collected through 2004 peer-reviewed by Dr. Fagan, University of Maryland. He concluded that “Regardless of the spatial or temporal scales involved, the population of the Pecos bluntnose shiner has exhibited a steep, severe decline over the period 2002-2004. Measured in terms of abundance (CPUE), the database suggests the PBS was far scarcer in 2004 than it has been over the last decade, with a population structure far more similar to that of 1992 than of any other year in recent history.” He went on to say “The PBS database makes clear that the recent decline of the PBS has been system wide, affecting almost all sites, and has occurred independent of one’s choice of threshold for abundance or relative abundance.” (Fagan 2006)

In 1991, the Service came to the conclusion that Reclamation’s 1989 Pecos River Dam operations would likely jeopardize the continued existence of the shiner and adversely modify the critical habitat of the species. That opinion was based on operations that included a block release of 47 continuous days followed by river drying. Reclamation has not had a block release of that duration since that time and block releases are currently limited to a maximum of 15 days. The long duration of the block release transported eggs, larvae, and probably adults into Brantley Reservoir. Subsequent river drying, which could not be controlled because Santa Rosa and Sumner Reservoirs were at very low levels, also had an adverse affect on the species. The shiner population in 1991 was considered to be very low, based primarily on the percent of shiner within the shiner guild compared to historical collections (Brooks et al. 1991). Systematic collections of shiner did not begin until 1992. Because we now how a long term record of population trends based on systematic sampling, we can look back and confirm that population levels at that time were very low based both on density values and percent shiner within the shiner guild. The shiner population is in a very similar situation as it was in 1992, but Reclamation’s proposed action (as described in the Proposed Action section) is very different than it was in 1989.

E. Analysis of the Species/Critical Habitat Likely to be Affected

The shiner has undergone significant population declines and range contraction in the last 65 years (Service 2003a), and in particular over the last three years (NMFRO 2006, Fagan 2006). The decline is the result of various alterations to the Pecos River, including groundwater pumping, the diversion of water for irrigation, the storage of water in impoundments, and drought. The shiner is now restricted to about 186 mi (298 km) from Taiban Creek to Brantley Reservoir. The action area includes the total remaining population of shiner and its designated critical habitat.

Interior Least Tern

A. Species/Critical Habitat Description

Description of the Species

Least terns are the smallest members of the subfamily Sterninae and family Laridae of the order Charadriiformes, measuring approximately 9 in long with a wing span of 20 in. The least tern is recognized as a distinct species of tern, and the interior least tern as a subspecies, based on studies of vocalizations and behavior (American Ornithologists' Union 1957, 1983; Johnson et al. 1998). Three subspecies of least tern nest in the United States. The California least tern (*Sterna a. brownii*) nests from Baja California to the San Francisco Bay; the interior least tern (*Sterna a. athalassos*) nests along the major tributaries throughout the interior U.S. from Montana to Texas and New Mexico to Louisiana; and the eastern least tern (*Sterna a. antillarum*) nests along the coast from Texas to Maine. Breeding plumage of terns consists of a black cap, white forehead, throat and underside with a pale gray back and wings, and black-tipped yellow-orange bill. In flight, the tern is distinguished by the long, black outermost wing feathers and the short, deeply forked tail. First-year birds have a dark bill, a dark gray eye stripe, and a dusky brown cap.

Historic and Current Range-wide Distribution

Terns are long-distance migrants that breed in North America and winter in South America. Terns historically bred along the Mississippi, Missouri, Arkansas, Red, Rio Grande, and Ohio River systems (Coues 1874, Youngworth 1930, 1931; American Ornithologists' Union 1957, Hardy 1957, Burroughs 1961, Anderson 1971, Ducey 1981). Their range extended from Texas to Montana and from eastern Colorado and New Mexico to southern Indiana. This tern continues to breed in most of its historic breeding range, although its distribution is generally restricted to river segments that have not been heavily altered from historic conditions (Service 1990). It breeds along the lower Mississippi River from approximately Cairo, Illinois, south to Vicksburg, Mississippi (Service 1990). In the Great Plains, it breeds along: (1) The Missouri River and many of its major tributaries in Montana, North Dakota, South Dakota, Nebraska, and Kansas; (2) the Arkansas River in Oklahoma and Arkansas; (3) the Cimarron and Canadian Rivers in Oklahoma and Texas; and (4) the Red River and Rio Grande in Texas (Service 1990). Current wintering areas of the interior least tern remain unknown (Service 1990). Least terns of unknown subspecies are found during the winter along the Central American coast and the northern coast of South America from Venezuela to northeastern Brazil (Service 1990).

B. Life History

Reproductive Biology

Terns are present at breeding sites for 4 to 5 months, arriving from late April to early June (Youngworth 1930, Hardy 1957, Wycoff 1960, Faanes 1983, Wilson 1984, U.S. Fish and Wildlife Service 1987a). Predators and other intruders are dive-bombed by adults. Courtship can occur either at the nest site or some distance away (Tomkins 1959). It includes aerial displays involving pursuit and maneuvers, culminating in a fish transfer on the ground between two courting birds. Other courtship behaviors include nest scraping, copulation and a variety of postures and vocalizations (Hardy 1957, Wolk 1974, Ducey 1981). The nest is a shallow, inconspicuous depression in an open sandy area, gravelly patch, or exposed flat. Small stones, twigs, pieces of wood and debris usually lie near the nest. Terns nest in colonies as small as a single pair to over 100 pairs, and nests can be as close as a few feet apart or widely scattered up to hundreds of feet (Ducey 1988, Anderson 1983, Hardy 1957, Kirsch 1990, Smith and Renken 1990, Stiles 1939). Terns usually lay two to three eggs (Anderson 1983; Faanes 1983; Hardy 1957; Kirsch 1987, 1988, 1989; Sweet 1985, Smith 1985) and may renest if their nest is destroyed. Incubation generally lasts 20 to 25 days, but has ranged from 17 to 28 days (Moser 1940, Hardy 1957, Faanes 1983, Schwalbach 1988). Although the female does most of the incubation and brooding, both adults participate. Chick color varies from white to tan with black spots or streaks across back and top of head. Tern chicks hatch within 1 day of each other and stay near the nest bowl for several days. Chicks are fed small minnow-like fish until they fledge at around 20 days. Recently fledged chicks are inefficient predators and continue to receive food from adults for several weeks. Fledglings may disperse from natal colonies within 3 weeks of fledging. Departure from colonies by both adults and fledglings varies, but is usually complete by early September (Bent 1921, Stiles 1939, Hardy 1957).

Growth and Longevity

Young terns are slightly precocial and are brooded for about 6 days after hatching. At that time, they are mature enough to disperse from the nest on the ground. Chicks are able to fly by about 20 days after hatching, but do not become competent at fishing until after migrating from the breeding grounds in fall (Hardy 1957, Tomkins 1959, Massey 1972, 1974). Therefore, they depend on parental care for a short time after they have become strong fliers. Record longevity for a least tern is 24 years (Klimiewicz and Futcher 1989).

Movements/Dispersal Patterns

Annual and seasonal movements of terns between breeding sites are poorly understood, but are known to occur frequently over significant distances and may occur quickly based on abrupt changes in habitat conditions. Breeding site fidelity is affected by the ephemeral nature of the tern’s riverine environment, which prevents some sites from being used in successive years. Localized shifts observed in tern distribution likely result from the interplay of several related ecological factors, including the presence of suitable sandbars, the existence of favorable water conditions during the nesting season, and the availability of food (Hardy 1957). Changes in the microhabitat and social structure within breeding areas often leads to birds changing sites if suitable habitat of higher quality is available elsewhere (Prindiville 1986).

Food and Habitat Requirements

Terns are piscivorous, feeding on small fish in shallow waters of rivers, streams, and lakes (Service 1990). Moseley (1976) believed terns to be opportunistic feeders, exploiting any fish within a certain size range. Fishing behavior involves hovering and shallow dives over standing or flowing water.

The terns’ physical habitat requirements include lack of vegetative cover (Dirks 1990, Ziewitz et al. 1992), open expanses of sand or pebble beach within the river channel or reservoir shoreline, and proximity to stable food sources (Faanes 1983, Dugger 1997, Adolf 1998). The riverine nesting areas of terns are sparsely vegetated sand and gravel bars within a wide unobstructed river channel, or salt flats along lake shorelines. Nesting locations usually are at the higher elevations and away from the water's edge because nesting starts when the river flows are high and small amounts of sand are exposed. The size of nesting areas depends on water levels and the extent of associated sandbars. The Lower Mississippi River is very wide and carries a tremendous volume of water and sand. Sandbars form annually, are washed away, and shift position. Many sandbars are over 3.2 km long and 1.2 km wide. Nest sites are often several hundred meters from the water (Rumancik 1987, 1988). Thus, nesting areas usually are several hundred hectares in size.

Sandbar geophysiology and associated hydrology are integral components of suitable habitat. Bacon (1996) found channel bars chosen for nesting sites by least terns on the Yellowstone River were exposed above river level longer throughout the breeding season than non-nesting habitats. Similarly, Smith and Renken (1991) found that tern colonies along the lower Mississippi River were located on sand islands and sandbars that differed from unused sand islands by the length of time sites were continuously exposed above the river. Most nest colonies on the Yellowstone occurred in a section of the river where channel sinuosity began to increase. Terns prefer sites that are well-drained and well back from the water line. Terns usually nest on sites totally devoid of vegetation, but if present, vegetation is usually located well away from the colony (Hardy 1957, Anderson 1983, Rumancik 1985, Smith and Shepard 1985). Terns also nest in dike fields along the Mississippi River (Smith and Stuckey 1988, Smith and Renken 1990); at sand and gravel pits (Kirsch 1987-89); ash disposal areas of power plants (Wilson 1984, Johnson 1987, Dinsmore and Dinsmore 1988); along the shores of reservoirs (Chase and Loeffler 1978, Neck and Riskind 1981, Boyd 1987, Schwalbach 1988); and at other manmade sites (Shomo 1988). It is unknown to what extent those alternative habitats have replaced productive natural habitat.

Foraging habitat for terns includes side channels, sloughs, tributaries, shallow-water habitats adjacent to sand islands and the main channel (Dugger 1997). To successfully reproduce, productive foraging habitat must be located within a short distance of a colony (Dugger 1997). For example, terns in Nebraska generally were observed foraging within 328 feet (ft) (100 m) of the colony (Faanes 1983). Armbruster (1986) recommends that feeding areas for terns be present within 1,312 ft (400 m) of the nesting colony.

C. Range-wide Population Status and Trends

Over the past century, the number of terns has fluctuated. During the late 1800s, terns declined in numbers due to harvesting for the millinery trade. After the Migratory Bird Treaty Act was passed in 1916 to make commercial harvest illegal, tern numbers increased until the mid-1900s, when alterations of natural hydrologic patterns and urban and industrial development of shorelines led to further population declines. The interior least tern was listed as endangered on June 27, 1985 (50 FR 21784-21792), primarily due to widespread, human-caused stabilization of its normally dynamic riverine habitat. Since the taxonomic status of the interior least tern was not resolved in 1985, the interior population was defined as any least tern nesting more than 50 km from the coast, and this population was listed as endangered independent of taxonomic status (Service 1985). Barren sandbars, the tern's preferred nesting habitat, were once a common feature of the Mississippi, Missouri, Arkansas, Ohio, Red, Rio Grande, Platte, and other river systems of the central United States. Sandbars are not stable features of the natural river landscape, but are formed, enlarged, eroded, moved, or destroyed, depending on the dynamic forces of the river. Widespread stabilization of major rivers for navigation, hydropower, irrigation, and flood control significantly impaired the dynamic nature of riverine processes (Smith and Stucky 1988). Reduced flooding prevents scouring of sandy islands and shores, allowing vegetation to grow and making the habitat unsuitable for nesting terns. Many of the remaining sandbars became unsuitable for nesting because of vegetation encroachment, or were low and subject to frequent inundation. River channelization, gravel mining and human-related disturbance (i.e., foot traffic, unleashed pets, swimmers, canoeists and off-road vehicles) also contributed to the decline of this subspecies. Indirect disturbance of tern colonies can result in temporary abandonment of nests (Burger 1981), exposing adults to aerial predation and eggs and chicks to predation and inclement environmental conditions. All of these habitat changes resulted in declines in numbers and distribution of terns that led to its listing as endangered in 1985.

Kirsch and Sidle (1999) compiled tern population data from 1984 to1995 to assess the range-wide status of the population. Breeding population estimates were compiled for 35 local areas. Large population increases occurred along the middle and lower Mississippi River where approximately 52 to 79 percent of terns nest. The Platte River in Nebraska contained the second largest number of terns (6.2 to 13.6 percent). Two stretches of the Missouri River in North Dakota, South Dakota and Nebraska; Salt Plains National Wildlife Refuge in Oklahoma; Cimarron and Canadian Rivers in Oklahoma; and Falcon Reservoir on the Rio Grande in Texas all typically provided habitat for more than 100 terns annually (Kirsch and Sidle 1999).

The 1995 tern count numbered approximately 8,800 terns in 1995, and exceeded the range-wide delisting numerical recovery objective of 7,000 terns. However, the mean number of terns in 12 of 19 local areas designated in the tern recovery plan (Service 1990) did not reach corresponding recovery objectives for delisting. These recovery criteria include assuring that essential habitat is protected by removal of current threats and habitat enhancement, establishing agreed-upon management plans, and attaining a population of 7,000 birds at the following levels:

1. Adult birds in the Missouri River system will increase to 2,100 and remain stable for 10 years.
2. Current numbers of adult birds (2,200 to 2,500) on the Lower Mississippi River will remain stable for 10 years.
3. Adult birds in the Arkansas River system will increase to 1,600 and remain stable for 10 years.
4. Adult birds in the Red River system will increase to 300 and remain stable for 10 years.
5. Current number of adult birds in the Rio Grande system (500) will remain stable for 10 years, essential breeding habitat will be protected, enhanced and restored, and terns will be distributed along the Rio Grande and Pecos Rivers.

Overall tern population trends from 1986 to 1995 were positive. However, this positive trend was primarily due to increases in numbers of terns on the lower Mississippi River (Kirsch and Sidle 1999). Annual increase for the entire tern population was approximately 9 percent. When data from the lower Mississippi River were excluded, the annual increase was 2.4 percent (Kirsch and Sidle 1999). Two areas, near the Missouri River in Iowa and Optima National Wildlife Refuge in Oklahoma, had significant negative trends from 1986 to 1995.

During a recent 2005 range-wide tern survey, 4,515 river mi, 12 reservoirs, 61 sand pits, and over 14,000 ac of salt flats were covered (Lott 2006). A total of 17,587 terns were counted in association with 491 different colonies. Terns were detected on 63 out of 74 survey segments. A majority of adult terns were counted on rivers (89.9 percent), with much smaller numbers at sand pits (3.7 percent), reservoirs (2.7 percent), salt flats (2.1 percent), industrial sites (1.5 percent), and roof-tops (0.3 percent). Similarly, most colony sites were on rivers (82.5 percent) with fewer colonies occurring on reservoirs (6.8 percent), sand pits (6.0 percent), salt flats (2.5 percent), industrial sites (1.8 percent), and roof-tops (0.4 percent). Just over 62 percent of all adult terns were counted on the Lower Mississippi River (10,960 birds on over 770 river mi). Four additional river systems accounted for 33.9 percent of the remaining terns, with 12.1 percent on the Arkansas River system, 10.4 percent on the Red River system, 7.1 percent on the Missouri River system, and 4.3 percent on the Platte River system. Lesser numbers of terns were counted on the Ohio River system at natural, created, and industrial sites along the Ohio and Wabash Rivers (1.5 percent); on urban, industrial, and reservoir sites within the Trinity River system in Texas (1.5 percent); at reservoirs along the Rio Grande/Pecos river system in New Mexico and Texas (0.8 percent), or elsewhere (0.5 percent). Although nearly 63 percent of all individual adult terns were counted on the Mississippi River, the Mississippi River accounted for only 17.9 percent of all colony sites. A higher percentage of all colony sites were reported for the Arkansas (25.9 percent), Red (25.5 percent), and Missouri (19.1 percent) river systems. Less than 7 percent of all colonies were detected on the Platte River and just over 2 percent were on the Ohio and tributaries. Average colony sizes for terns were generally small, between 4 and 29 birds per colony). A strong exception to this rule was the Mississippi River, where average colony size was 119 birds and a single colony had 700 birds. The maximum colony size at any location other than the Mississippi was 130 birds at the mouth of the Canadian River at Eufaula Lake (Lott 2006).

Status and Trends in the Rio Grande/Pecos River System

In 2005, 138 terns were counted at three locations on the Pecos River (nesting on barren alkali "flats" at Bitter Lake National Wildlife Refuge, roosting but not breeding at Brantley Lake State Park in New Mexico, and at Imperial Reservoir in Texas) and at a single reservoir on the Rio Grande (Amistad National Recreation Area) (Lott 2006). During the 2005 census, water levels at Falcon Reservoir, usually an important nesting area for terns, were high, and the entire tern nesting habitat was presumed to be under water. Therefore, surveys of Falcon Reservoir were not conducted (Lott 2006). Historically, terns have nested at six reservoirs on the Rio Grande/Pecos River system and a single reservoir (O.C. Fischer) on the nearby North Concho River (Kasner et al. 2005). Habitat conditions at Lake Casa Blanca on the Rio Grande and O.C. Fischer Reservoir on the North Concho River may have declined to a point where terns would no longer nest, and no terns were recorded during the census at either of these locations (Lott 2006). The 2005 count of 85 terns at Amistad Reservoir is below average, compared to counts between 1999 and 2004. Large numbers of terns were counted at Falcon Reservoir in the late 1980s and early 1990s. However, habitat conditions have declined since then, and it is unclear how many terns still nest there (Lott 2006). The last year that all major reservoirs in this system were surveyed was 1989, when 482 birds were present. It is unclear whether numbers have actually declined from this total to the 138 reported during the 2005 census, or if this low number reflects the lack of survey data from Falcon Reservoir (Lott 2006).

D. Factors Affecting the Species Range-wide

Habitat Loss and Degradation

Remnants of tern habitat remain distributed across much of the species' historic range, although at much reduced levels. Beach habitats are increasingly used for human recreation and residential development; river sandbars have been eliminated by channelization, water diversions, impoundments, and by changes in vegetation resulting from controlled water flow below dams. Alternatively, agricultural fields, parking lots, and flat, graveled roof tops are providing occasional opportunistic nesting sites. In Nebraska, where the central Platte River no longer provides suitable habitat because of upstream diversion, terns are nesting at commercial sand and gravel pits within 0.9 mi (1.5 km) of the Platte (Sidle and Kirsch 1993). In Iowa, terns have nested on fly ash effluent at power plants (Huser 1996).

Channelization, irrigation, construction of reservoirs and pools, and managed river flows have contributed to the elimination of much of the tern's sandbar nesting habitat by engineering wide, braided rivers into a single, narrow channel (Funk and Robinson 1974, Hallberg et al. 1979, Sandheinrich and Atchison 1986). Reservoir storage and irrigation depletions of flows responsible for scouring sandbars has resulted in encroachment of vegetation onto sandbars along many rivers, further reducing tern nesting habitat (Eschner et al. 1981, Currier et al. 1985, O'Brien and Currier 1987, Stinnett et al. 1987, Lyons and Randle 1988, Sidle et al. 1989). In addition, river main stem reservoirs now trap much of the sediment load resulting in less aggradation and more degradation of the river bed, reducing formation of suitable sandbar nesting habitat. With the loss of much tern nesting habitat, predation has become a significant factor affecting tern productivity in many locations (Massey and Atwood 1979, Jenks-Jay 1982).

Human Disturbance
Human disturbance affects tern productivity in many locations (Massey and Atwood 1979, Goodrich 1982, Burger 1984, Dryer and Dryer 1985, Schwalbach et al. 1986, Dirks and Higgins 1988, Schwalbach 1988, Mayer and Dryer 1990). Many rivers have become the focus of recreational activities, and the currently reduced quantity of sandbars has become a recreational counterpart to coastal beaches. Human presence reduces reproductive success (Mayer and Dryer 1988, Smith and Renken 1990). Domestic pet disturbance and trampling by grazing cattle are other factors that have contributed to population decline.

Pollution and Contaminants
Pollutants entering waterways within and upstream of tern breeding areas can negatively impact water quality and fish populations in nearby foraging areas. Strip mining, urban and industrial pollutants, and sediments from non-point sources can all degrade water quality and fish habitat, thereby impacting small fish on which terns depend (Wilbur 1974, Erwin 1983). In addition, because terns are relatively high on the food chain, they can accumulate contaminants that can render eggs infertile or otherwise affect reproduction and chick survival (Service 1983, Dryer and Dryer 1985). Mercury residues have been found in terns from the Cheyenne River watershed in South Dakota. Organochlorines have been found in terns in South Carolina and California (U.S. Fish and Wildlife Service 1983). Elevated selenium and organochlorine concentrations were found in tern eggs collected on the Missouri River in South Dakota (Ruelle 1993). Allen and Blackford (1997) found 81 percent of 104 least tern eggs collected from the Missouri River exceeded the selenium concentration currently considered safe for avian reproductive success.

III. Environmental Baseline

The environmental baseline includes past and present impacts of all federal, state, or private actions in the action area; the anticipated impacts of all proposed federal actions in the action area that have undergone formal or early section 7 consultation; and the impact of state and private actions which are contemporaneous with the consultation process. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform to assess the effects of the action now under consultation.

Pecos Bluntnose Shiner

A. Status of the species within the action area

The current range of the shiner is wholly within the action area. Status of the species is discussed in section II. “Status of the Species.”

B. Factors affecting species environment within the action area

Based on collections, the known range of the shiner included the mainstem Pecos River from Santa Rosa, New Mexico, to the New Mexico-Texas border (Chernoff et al. 1982), but it is likely the species occurred upstream to the Pecos River-Gallinas River confluence and downstream to, at least, Live-Oak Creek confluence (near Sheffield, Texas) because the Pecos River had similar characteristics throughout (Pope 1854, Newell 1891, Freeman and Mathers 1911, Dearen 1996). These characteristics included perennial flow, a wide-erosive river channel, and shifting sand-beds (Newell 1891, Fisher 1906, Freeman and Mathers 1911, Thomas 1959, Hufstetler and Johnson 1993, Dearen 1996). The reason the full extent of the historical shiner range is not well defined is because historical fish collections were few and collectors sampled the river at easily accessible localities such as bridge crossings and villages (Sublette et al. 1990).

Within occupied habitat two reaches of the Pecos River are of poor quality. The Tailwaters reach from Sumner Dam to Taiban is armored with cobble and gravel because sediment-free releases from Sumner Dam have robbed this reach of its fine sediment (Kondolf 1997). In addition the reduction of peak flows is most acute in this reach because releases from Sumner Dam are typically 1,400 cfs (40 m^3/s)or less, leading to a more narrow and confined channel (discussed in greater detail below). Shiners have not been caught in this reach since 1999 (S. Davenport, Service, pers. comm., 2006b). The Farmlands reach from BLNWRMT to Brantley is also of poor quality. The channel is narrow, incised, and the bed silt-armored (Tashjian 1993). Smaller size-classes dominate and the ability of this reach to support self-sustaining populations without transport of individuals from the Rangelands reach is questionable (Hoagstrom 2003a,b). The lack of suitable habitat in these two reaches restricts potential population growth.

Development of irrigated agriculture began in the early 1850s with acequia diversions from headwater reaches of the mainstem Pecos River and tributaries (U.S. National Resources Planning Board 1942). Large-scale diversion and impoundment of the mainstem Pecos River began in the 1880’s (U.S. National Resources Planning Board 1942), while groundwater pumping became widespread after 1900 (Lingle and Linford 1961). By 1940, when systematic fish collections were initiated, Pecos River hydrology and geomorphology were already dramatically changed (Grover et al. 1922, U.S. National Resources Planning Board 1942, President’s Water Resources Policy Commission 1950, Campbell 1958, Thomas 1959, Grozier et al. 1966, Ashworth 1990, Hufstetler and Johnson 1993). The response of Pecos River fishes to early human developments is unknown, but it is significant that the majority of native species were decimated in areas directly impacted by irrigation projects, such as the Pecos River between Carlsbad, New Mexico and Girvin, Texas (Campbell 1958). The same pattern has been documented in other sand bed streams (Arkansas and Cimarron rivers) (Cross et al. 1985). Native fishes have survived best in reaches with fewer direct impacts, such as the Pecos River between Taiban Creek and Salt Creek confluences (Hoagstrom 2000).

In 1940, a survey of river pumps diverting water from the Pecos River found that there were 44 pumping plants from just above Dexter to about eight miles south of Artesia (Farmlands reach). At the time of the survey the pumping plants had a capacity of 189 cfs and irrigated about 7,800 acres (Miller 2006). River pumper diversions from 1956-1991 in this same area averaged 11,300 af/yr. In the early 1990s, ISC began purchasing river pumper rights to help meet Compact deliveries (discussed in more detail in Cumulative Effects section). Currently 10 river pumpers remain and are entitled to 4,785 af/yr. Six of the river pumper’s water rights, totaling 4,425 af/yr, are leased by Reclamation to supplement CID in payment for depletions that occur because of bypass water used to augment flows for the shiner (Reclamation 2005).

The construction of the dams has had many adverse effects on the Pecos River ecosystem over the last 100 years. Dams have many downstream effects on the physical and biological components of a stream ecosystem (Williams and Wolman 1984). Some of these effects include a change in water temperature, a reduction in lateral channel migration, channel scouring, blockage of fish passage, channel narrowing, changes in the riparian community, diminished peak flows, changes in the timing of high and low flows, and a loss of connectivity between the river and its flood plain (e.g., Sherrard and Erskine 1991, Power et al. 1996, Kondolf 1997, Friedman et al. 1998, Polzin and Rood 2000, Collier et al. 1996, Shields et al. 2000). Currently, six dams (Santa Rosa, Sumner, FSID Diversion Dam, Brantley, Avalon, and Black River) largely control the flow of the Pecos River in New Mexico (Figure 1). The uppermost dam, Santa Rosa (completed in 1980), is operated by the Corps for flood control and irrigation. Sumner and Brantley dams are owned and operated by Reclamation primarily for irrigation purposes and secondarily for flood control. Sumner Dam was built in 1937 and is 55 mi (88 km) downstream from the Santa Rosa Dam. The FSID Diversion Dam (owned by Reclamation) is located 14 mi (23 km) downstream of Sumner Dam and was completed in 1951. Brantley Dam was completed in 1989 and is 225 mi (360 km) downstream of Sumner Dam. Brantley Dam replaced McMillan Dam, which was completed in 1893.

The Pecos Bluntnose Shiner Recovery Plan stated that the operation of Sumner Dam had significantly altered flow regimes in the upper Pecos River (Service 1992). During the period 1913 to 1935, prior to dam operation, flows were never less than 1 cfs (0.03 m^3/s) at the Sumner Dam Gage. For the period after dam operation began, 1937 to 1990, flows less than 1 cfs (0.03 m^3/s) occurred an average of 55 days per year. After Sumner Dam was completed, it prevented all movement between the shiner population above and below the dam. Shiners were last collected above Sumner Dam in 1963 (Platania and Altenbach 1998). Sumner Dam also traps sediment that would maintain the sandy river bed that shiner prefer. The release of sediment-free water leads to channel scour below the dam, creating unsuitable habitat (Kondolf 1997).

The effect of upstream water storage and diversion on the downstream reaches of the Pecos River was to reduce the frequency and magnitude of floods (Table 5), reduce winter inflows (Table 6), and reduce summer inflows (Table 7). These Tables and the implications for the shiner and its habitat are described in detail below.

The maximum release capacity of Sumner Dam is 1,400 cfs (40 m^3/s). Prior to the completion of Sumner Dam, flows greater than 1,400 cfs (40 m^3/s) occurred an average of 7 days per year and the lowest annual peak mean daily discharge was 2,020 cfs (57 m^3/s) (Table 5). By comparison, only two of 18 post-Sumner Dam years had mean daily discharge greater than 1,400 cfs (40 m^3/s) for an average of 1 day per year. The maximum mean daily discharge in the pre-Sumner Dam years was 26,200 cfs (740 m^3/s) while the maximum of the 18 post-Sumner Dam years was 1,980 cfs (56 m^3/s). This maximum was less than the lowest annual peak of the pre-dam period.

Reduced peak discharge has caused the channel to become narrower, less braided, and to have less complex fish habitat (Tashjian 1993, 1994, 1995, 1997; Hoagstrom 2000, 2001, 2002).

Large floods are an important component of riverine ecosystems because they maintain channel width and complexity, limit colonization of non-native vegetation, maintain native riparian vegetation, recharge the alluvial aquifer, increase nutrient cycling, and maintain the connection between the aquatic and riparian ecosystems (Ward and Stanford 1995, Schiemer 1995, Power 1996, Shafroth 1999). Biological consequences of diminished peak flows could have an indirect effect on the fish community including the shiner. However, these complex ecosystem interactions have not been investigated on the Pecos River. One of the reasons that habitat in the Rangelands reach remains suitable, is the presence of tributary streams that add sediment and monsoonal flood flows to the Pecos River. Although infrequent, peak flows as high as 45,000 cfs (1941) have been recorded at Acme (USGS peak streamflow for New Mexico website, viewed April 23, 2006). However, there has not been a peak flow over 10,000 cfs at Acme since 1963 (USGS peak streamflow for New Mexico website, viewed April 23, 2006). Floods in this reach would occur more often if Sumner Dam were not in place.

Before the construction of Sumner Dam, mean daily discharge in the non-irrigation season (winter), was 97 cfs (3 m^3/s) with a minimum flow of 41 cfs (1.2 m^3/s) (Table 6). After the dam was built (1962 to 1979), mean daily discharge in the winter was 6 cfs (0.2 m^3/s), a reduction of 94 percent. The storage of winter season base flows in Sumner Reservoir reduced the amount of water and habitat available to the shiner. Beginning 1998/1999, the winter season operation of Sumner Dam was modified to divert water to storage only when not required to meet downstream flow targets at the Acme gage. Reclamation bypassed flows in the winter to target approximately 35 cfs at the Acme gage. Typically, 5 to 10 cfs were bypassed in November to supplement natural flows in the river. By February or March up to 25 - 30 cfs was bypassed, depending on the natural flows. Flows coming into Sumner Reservoir greater than the amounts bypassed to supplement natural flows were stored (Reclamation 2002). This operation continued in the winter 2006, but will be modified under the new proposed action (i.e., target flows have been moved from Acme to the Taiban gage).

During the irrigation season (March 1 to October 31), prior to Sumner Dam, the mean daily discharge flows exceeded 100 cfs (2.8 m^3/s) 147 days per year compared to 69 days per year after the completion of Sumner Dam (Table 7). Discharge adequate to overflow (greater than 100 cfs [2.8 m^3/s]) the FSID Diversion Dam during the irrigation season was recorded more than twice as often in the years prior to Sumner Dam, than in the post-Dam period. Overflow of the FSID Diversion Dam was less frequent and of greater magnitude after Sumner Dam was built because of block releases of water from Sumner Dam.

Before November 1998, all water available above FSID’s 100 cfs (2.8 m^3/s) requirement was stored in Sumner. From 1999 – 2006, Sumner Dam operations were modified to bypass water that was available above FSID’s 100 cfs (2.8 m^3/s) requirement in an attempt to keep the water flowing in the reach from Sumner Dam down to the Acme gage.

Up to 100 cfs (2.8 m^3/s) is diverted by FSID at the diversion dam for delivery to agricultural fields from March 1 through October 31. Water can also be diverted for two, eight-day periods during the winter; however, recently, this diversion has been made in the two weeks prior to the irrigation season (i.e., February 15 to March 1). Fort Sumner Irrigation District has no storage rights in the upstream reservoirs, but is entitled to water rights that predate Sumner Dam construction (1937). The water entitlement is based on a calculation made by the OSE from flow data collected every two weeks throughout the irrigation season. Reclamation releases water from Sumner Dam for FSID and the water travels 14 mi (23 km) downstream to the FSID Diversion Dam. The water is diverted into a main canal which is 15 mi (24 km) long and feeds smaller lateral canals. The system also includes a drain canal which collects seepage and runoff from the fields and carries these return flows back to the Pecos River near the confluence of Taiban Creek. The return flows to the Pecos River may be up to half of the amount diverted, but were less than 20 cfs (0.6 m^3/s) in 2002. A pumpback system, located at the lower end of the irrigation canal, pumps from 10 to 15 cfs (0.28 to 0.42 m^3/s) from the main return canal back into lateral canals. A new pump which can pump 2-3 cfs more than the old pump has further reduced the amount of water returning to the river (G. Dean, Reclamation, pers.comm. 2002). Operation of this pump continued through the 2003-2006 period.

Reclamation diverts water to storage at Sumner Reservoir for the Carlsbad Project and then releases the stored water for the CID. The release of water occurs in “blocks” where large amounts of water (usually a minimum of 1,000 cfs [28 m^3/s]) are released. Blocks of water are used because less water is lost to evaporation and groundwater seepage during transport. Sumner Dam block releases occurred between one and four times per year from 1990 to 2006 (not including the years in which block releases were modified for hydrologic studies). The average annual number of block releases per year from 1990-2001 was 2.6 (not including the years in which block releases were modified for hydrologic studies). The block release durations ranged from 7 to 30 days, with an average of 15.7 days. Since 1999, the Sumner Dam irrigation season operations have been modified to: 1) limit the block release duration to a maximum of 15 days; and 2) limit block release timing and frequency.

Block releases can provide a cue for spawning, help maintain channel morphology, and if timed correctly, can alleviate intermittency (Tetra Tech 2003, Reclamation 2006). Block releases that occur during the spawning season from May through September transport semi-buoyant shiner eggs and larvae out of the favorable habitat reach of the Rangelands, and into the less suitable Farmlands reach or Brantley Reservoir. The eggs require water velocity to remain suspended in the water column. In the reservoir, the eggs sink to the bottom and likely perish when they are covered with sediments and suffocate or are eaten by predators. Larval fish are likely eaten by predatory fish.

Eggs and larvae drift downstream for a total of 3 to 5 days; the distance they travel depends on habitat complexity, the rate of egg and larvae development, and water velocity (Platania and Altenbach 1998, Kehmeier et al. 2004b). Swifter currents and a more uniform channel carry the eggs and larvae a greater distance. Block releases exceeding 65 days per year result in the transport of many age-0 shiners into the Farmlands reach (Hoagstrom 2002). The effect on size class distribution between the Rangelands and Farmland reaches is not as pronounced when the total is less than 65 days per year. Although eggs and larvae are lost into Brantley Reservoir during natural flood events, the number is less because the peak of a flood hydrograph lasts for a very short time (several hours). In contrast, the peak flow in a block release is maintained for 10-15 days. The narrow channel and lack of slack and backwater habitat in the lower reach of critical habitat results in fewer eggs and larvae being retained in that reach, poor survival and growth of the juveniles, and greater transport of eggs and larvae into the reservoir (Hoagstrom 1997, 1999, 2000, Dudley and Platania 1999, Kehmeier et al. 2004b).

Two studies of egg transport in the Pecos River have been conducted with contrasting results (Dudley and Platania 1999, Kehmeier et al. 2004b). Both studies concluded that egg retention was greater in the Rangelands reach where complex habitats exist at higher flows leading to greater egg retention. In the Farmlands reach egg retention is much poorer. However, the studies differ greatly in their overall estimates of egg retention with Kehmeier et al. (2004b) estimating that 92 percent of shiner eggs would be retained above Brantley Lake and Dudley and Platania (1999) estimating that 40 percent would be retained.

Because the methods of the two studies were different it is difficult to evaluate which provides the better estimate. The studies used different artificial eggs which may account for part of the difference. Although both studies used eggs of appropriate density, Dudley and Platania (1999) used cylindrical nylon beads that were 2.5 mm in diameter and did not degrade. Kehmeier et al. (2004b) used gellan beads, 3-4 mm in diameter which are more delicate (Dudley and Platania 1999, Reinert et al. 2004) and may have deteriorated under the experimental conditions of river transport (leading to higher estimates of retention). Dudley and Platania (1999) tested eight different types of artificial eggs, including gellan beads, in comparison to semibuoyant fish eggs and determined that the artificial eggs they used were the optimal mimic for use in their research.

The second major difference between the studies is when the eggs were released. Kehmeier et al. (2004b) released their eggs 24 hours after the beginning of a block release (on the ascending limb of the hydrograph), whereas Dudley and Platania (1999) released midway into a block release in some trials or on the descending limb of the hydrograph in another. Kehmeier et al. (2004b) purposefully released at the beginning of the block release because they felt this best mimicked when the shiner would be spawning and the eggs would be entrained in a pattern that reflected natural conditions (i.e., higher retention). However, because of the limited numbers of adult fish and large number of juvenile fish located in the Farmlands reach, there is no doubt that large numbers of eggs and larvae are transported to this reach from upstream.

Historically, groundwater pumping has reduced Pecos River base-flow. Local pumping reduced seepage inflows from Truchas Creek, near Fort Sumner (Akin et al. 1946) and along the Pecos River between Fivemile Draw and Acme (Shomaker 1971). Inflows from the Roswell Artesian Basin (from the Pecos River near Acme to McMillan Dam) were severely reduced during the 1920s to 1950s (Fiedler and Nye 1933, Thomas 1959). At the turn of the century the natural discharge of groundwater to the river was approximately 235,000 af per year (Fiedler and Nye 1933). This equals a flow of 325 cfs entering the river. Groundwater development of the

Roswell basin aquifers reduced the amount of natural discharge into the Pecos River by 80 to 90 percent (Reynolds 1989 as cited in Reclamation 2002). In 1966, a Partial Final Decree adjudicated all groundwater rights in the Roswell artesian basin in Chaves and Eddy counties, and meters were installed on wells. Metering helped regulate use but in 2002, total pumping in the Roswell artesian basin still equaled 376,885 af (Miller 2006). In 1975, water levels in the Roswell artesian basin were at their lowest recorded levels, approximately 70 ft below their original level (Balleau 1999). By 1995, the aquifer had recovered approximately 30 ft, but is still 40 ft below its original level (Balleau 1999).

Based on historical evidence and population monitoring conducted since 1992, river intermittency is considered the primary environmental factor that has led to the recent decline of the shiner (Service 1987, Hoagstrom 2003a, NMFRO 2003, 2006). Consequently, the amount of river intermittency that has occurred and some of the factors that have contributed to it in the last three years will be discussed. The Acme gage occurs below upper critical habitat and is in the quality habitat reach of river that provides excellent shiner habitat when the river is flowing. It is also in the reach of river that is susceptible to intermittency. Annual mean runoff at the Acme gage is an indicator flow through this important reach of river (Table 1). The 2003 mean is the lowest for the period of record (1938-2003), with the 2002 mean being the 4th lowest on record. The lowest annual mean recorded prior to 2003 was in 1964 (56.5 cfs). The low annual mean runoff is reflected in the number of days of intermittency that occurred at Acme (Table 1).

In the Pecos River, flows of 5 cfs or less are indicators that intermittency is imminent. Once this sand bed river reaches these low levels, especially during hot, dry, windy weather, as is common in this part of the state, intermittency can occur very quickly. Also because the channel shifts often, there is an appreciable amount of gage error. Finally, Acme is only one point in a long reach of river that is prone to intermittency. Even though a very low flow may be recorded at this site, intermittency may have already begun at another point on the river. For these reasons, it is important to look not only at the days of 0 flow but those in which less than 1 and 5 cfs were recorded. It is clear from this record that extensive intermittency occurred in 2002 and 2003 (Table 1).

Reservoir storage (the sum of Santa Rosa, Sumner, and Brantley reservoirs) is also an indicator of the amount of water that will be available for all uses for the year (Table 1). The average amount of storage is 133,500 af. Storage in 2002 and 2003 was very low and limited the options for water management. Although storage in 2004 was even worse than on the previous two years on April 1, by the end of April storage was up to 80,700 af. In contrast, at the end of April in 2003, storage was only 36,000 af. (http://www.wcc.nrcs.usda.gov/cgibin/bor2.pl?state=nm&year=2004&month=5&format=text, viewed April 26, 2006).

In March 2002, CID moved 27,000 af of irrigation water from Santa Rosa and Sumner Reservoirs, drawing Sumner down to its minimum pool of 2,500 af and leaving only 1,000 af in Santa Rosa. The combination of low initial reservoir storage, an early season block release, and continued drought conditions led to extensive river drying throughout the summer of 2002. With no storage left in the reservoirs, alternative water operation actions to limit intermittency were precluded. The subsequent river drying dewatered approximately 38 mi (61 km), including 10 to 15 mi (16 to 24 km) of upper critical habitat from near the DeBaca County line, downstream (D. Propst, NMDGF, pers. comm. 2002, C. Hoagstrom, Service, pers. comm. 2002, USGS 2002 stream flow records as reported at: http://waterdata.usgs.gov/nm/nwis/rt). Intermittency lasted from May 20 to June 13 (25 days), July 30 to August 19 (21 days), and from September 4 to September 10.

Prior to 2002, there was always a sufficient storage in Sumner Reservoir to meet FSID's calculated water allotment. From May 30 to June 1, 2002, Sumner Reservoir dried, stopping the bypass of water to FSID for 3 days. As the reservoir was drained, silty, muddy water was released downstream affecting water quality in the Pecos River below the dam (G. Dean, Reclamation, pers. comm. 2003). Repeated releases of small blocks of water from Santa Rosa Reservoir kept Sumner Reservoir from drying again after June 1.

From May through August 2002, FSID diverted virtually the entire flow of the Pecos River (http://waterdata.usgs.gov/nm/nwis/rt viewed February 26, 2003). This caused river drying from the FSID Diversion Dam to the Taiban Creek confluence (10 mi [16 km]) and increased the probability of intermittency through upper critical habitat. Fort Sumner Irrigation District's pumpback operation further reduced the amount of water returning to the river and increased the amount and duration of intermittency downstream (G. Dean, Reclamation, pers. comm. 2002).

In 2003, Reclamation attempted to sustain flows in the Rangelands reach during the irrigation season, and provided 35 cfs at the Acme gage during the winter season. However, reservoir storage was low at the beginning of irrigation season and intermittency in the Rangelands reach occurred on 44 days with 97 days of flow less than one cfs (Table 1). Intermittency occurred from July 25 to August 26, 32 consecutive days, and again from September 21 to October 5.

On August 1, 2003, Reclamation and CID received emergency authorization from the New Mexico State Engineer to create a Fish Conservation Pool (FCP) of 500 af in Sumner or Santa Rosa Reservoir for the purpose of providing riverine habitat. The FCP does not affect the storage entitlement in Sumner Reservoir. Water from the FCP was released from August 2, 2003 to September 7, 2003. The flow rate varied from 5 to 10 cfs. The water from the FCP was diverted into the FSID's main canal and returned to the river at the nearest wasteway (Sandgate). This operation simplifies the process of getting the small flows past the diversion dam. A final permit for the FCP in Sumner Reservoir and Santa Rosa Reservoir was received in March 2004. The permit authorizes Reclamation to store and release 500 af from Sumner Reservoir to maintain riverine habitat in the upper critical habitat of the Pecos River. Reclamation must replace the water released out of Sumner Reservoir with 375 af of water in Brantley Reservoir.

In 2004, intermittency occurred 8 days, July 17 – July 24. Reclamation released water from the FCP in Sumner Reservoir to limit the extent of the intermittency. Flows reconnected due to flood inflows prior to the released water reaching the affected area (Reclamation 2006).

In 2005, there were no days of intermittency. During the winter season, flows at the Acme gage averaged 238 cfs, which is much higher than normal. The high average was caused by the delivery of water to the state of Texas and an early block release in February. In November 2005, the ISC purchased approximately 34,000 af of unused irrigation water from CID that was released to Texas (The Associated Press, November 23, 2005). The sale and delivery of this water to Texas will effectively limit water management options during the irrigation season in 2006, and also means farmers within CID will receive less than their full allotment of irrigation water (Carlsbad Current-Argus February 18, 2006).

As of April 1, 2006, the snowpack in the Pecos River Basin is at 11 percent of average, with year to date precipitation at 37 percent. The National Resources Conservation Service indicates that the basin is on track to be drier than the very dry years of 2000 and 2002 (http://www.wcc.nrcs.usda.gov/water/snow/bor2.pl?state=nm&year=2006&month=2&format=text, viewed April 11, 2006). The current snowpack in the Upper Pecos River Basin is the worst in more than 50 years and inflow to Santa Rosa Reservoir is expected to be 9 percent of normal (http://www.srh.noaa.gov/data/ABQ/ESABQ, viewed April 11, 2006). However, reservoir storage on April 1, was 118,400 af, the highest level since 2000.

Reclamation is currently operating under an interim BO for the 2006 irrigation season; however, the 10-year BO will go into affect 30 days after the ROD is signed and may include part of the 2006 irrigation season. The proposed action for the interim BO is to maintain a continuous river during the irrigation season of 2006 (Service 2006). Because of current reservoir storage and supplemental water operations, the Service expects that the river will be continuous through the irrigation season 2006, benefiting the shiner population.

Interior Least Tern

A. Status of the Species within the Action Area

The breeding population of terns in New Mexico declined from about 60 birds in the early 1960s to 3 poorly producing nesting pairs annually from 1987 to 1990. In New Mexico, terns were first recorded as nesting at Bitter Lake National Wildlife Refuge in 1949, and terns have continuously nested on or adjacent to refuge lands annually since then. Population counts over the period have been variable, ranging as high as 60 birds in 1961, but typically 20 to 30 individuals during a breeding season. For several years during the 1980s, the breeding colony was on a vegetation-free area of the Roswell Test Facility adjacent to the refuge. The colony then shifted back to barren alkali “flats” on the refuge following the growth of vegetation at the off-refuge site. A 1997 survey of potential nesting habitat on Bureau of Land Management lands by the New Mexico Natural Heritage Program located two nests at the Grace Well flats just north of the refuge.

The following list summarizes the breeding activity of the tern colony at Bitter Lake National Wildlife Refuge from 1996 through 2005 (J. Montgomery, Fish and Wildlife Service permittee, annual survey report, December 30, 2005):

	Number of pairs	Number of chicks observed	Number of chicks fledged	Number fledged per pair
1996	7	4	5	0.71
1997	7	11	3	0.43
1998	7	10	9	1.29
1999	7	1	1	0.14
2000	10	19	15	1.50
2001	11	14	9	0.82
2002	11	18	17	1.89
2003	12	15	13	1.08
2004	11	13	7	0.64
2005	14	24	23	1.64

On June 9, 2004, 5 pairs of interior least terns were first observed in a backwater area of Brantley Reservoir on the Pecos River in Eddy County. The nearest documented nesting elsewhere in New Mexico was at Bitter Lake National Wildlife Refuge, 60 mi north of Brantley Reservoir. It is unknown whether interior least terns had used areas around Brantley Reservoir for nesting in previous years. In 2004, a total of at least 14 adults were observed, with an estimated 7 nests on the lakeshore. Six juvenile terns were observed near the nesting area in late August (Bureau of Reclamation 2006; J. Montgomery, Fish and Wildlife Service permittee, electronic mail message, August 23, 2004). The nesting area used by terns in 2004 spanned approximately 28 ac.

In 2005, terns did not nest at Brantley Reservoir due to the 2004 nesting areas being inundated, vegetated, or impacted by human disturbance (J. Montgomery, Fish and Wildlife Service permittee, annual survey report, December 30, 2005). Approximately six to eight adults and up to five immature (one-year-old) terns occupied Brantley Reservoir until August. The 2005 nesting season was the most successful year at Bitter Lake National Wildlife Refuge since the mid-1980s, when observers began monitoring nesting on a regular basis, and probably back to 1937, when the refuge was established. Fourteen pairs fledged 23 juveniles (J. Montgomery, Fish and Wildlife Service permittee, electronic mail message, September 7, 2005).

B. Factors affecting the Species Environment within the Action Area

Historically, the Pecos River had similar characteristics all along its course, including perennial flow, a wide erosive river channel, and shifting sand-beds (Newell 1891, Fisher 1906, Freeman and Mathers 1911, Thomas 1959, Hufstetler and Johnson 1993, Dearen 1996). The operation of dams and human activities have had many adverse effects on the Pecos River ecosystem over the past 100 years. Upstream water storage and diversions on the downstream reaches of the Pecos River greatly reduced characteristic floods and inflows. Operation of Pecos River dams has caused reductions in lateral channel migration, channel scouring and narrowing, changes in the riparian community, diminished peak flows, and a loss of connectivity between the river and flood plain. Operation of the Santa Rosa and Sumner dams trap sediment needed for tern habitat development and alter the downstream flow regime. The depletion of groundwater, diversion of river flows, capture of sediment by tributary dams, water pollution, and salt cedar colonization also contribute to large scale changes of the Pecos River hydrograph and tern habitat. Once non-native vegetation is established, it maintains a narrower channel leading to increased water velocities and the loss of fine sediments such as sand. Downstream of Roswell, the river has become highly incised, further degrading habitat for terns. The reach from Sumner Dam to the FSID Diversion Dam has become incised and armored with gravel and cobble, and no longer provides the sand/silt habitat that terns require.

Brantley Reservoir is the southern-most, large water storage facility on the Pecos River, located in Eddy County in the southeastern portion of New Mexico. The Reservoir encompasses approximately 44,000 ac of land. The area around Brantley Reservoir is surrounded by Bureau of Land Management, State of New Mexico, and privately-owned lands. The New Mexico State Parks and Recreation Division has managed human-use of selected lands around Brantley Reservoir since 1977. Since 1994, the New Mexico Department of Game and Fish has had a 25-year lease agreement to authorize and enforce State fishing and hunting regulations at Brantley Reservoir.

In 2004, the top of conservation storage space for the Carlsbad Project in Brantley Reservoir was 3,256.05 ft for a total of 42,308 af. Tern nests were observed at elevation 3,245.71 ft in June 2004. At that time, the water was approximately one vertical foot below the tern nests at elevation 3,244.76 ft. No Reclamation block releases were expected at that time, but flood inflows due to weather-related causes were possible. No adults or chicks were affected by reservoir operations during the 2004 season while nests were occupied. Nests were located at varying distances from the water’s edge and approximately 1 to 3 ft above the water surface elevation.

Terns were again present at Brantley Reservoir in May 2005 in the Champion Cove area. This area of the Brantley Reservoir shoreline is on the south side of the North Seven Rivers inlet. At this time, the reservoir level was at an elevation of 3,248 ft, which is above the level of the 2004 breeding site at elevation 3,245.71 ft in June 2004. In response to a block release in May 2005, the reservoir’s surface level rose above 3,253 ft in elevation, inundating most of the previously exposed potential nesting substrate on the reservoir’s shoreline. Water in Brantley Reservoir was near the top of conservation storage, which in 2005 was elevation 3,256.13 ft for a total conservation storage of 42,556 af. By June 9, 2005, a large increase in water level had submerged all potential nesting habitat for the terns, with one small exception that measured approximately 100 by 75 meters to the west of the 2004 colony area, and it was becoming overgrown with sprouting kochia and cockleburr (J. Montgomery, Service permittee, annual survey report, December 30, 2005). Regular monitoring found no evidence of tern nesting during the summer months. Because block releases depend on an assortment of variables which include, but are not limited to, the annual snowpack in the upper Pecos Basin, the current volume of water stored at each of the Pecos River reservoirs, the demand by downstream irrigators, and the amount of local rainfall, Reclamation has stated that they can not predict the frequency and timing of block releases that may affect terns at Brantley Reservoir within a given year.

Terns roosting at Brantley Reservoir in 2005 were subject to disturbance, displacement, and inundation of their nesting habitat. Irrigation block releases from Sumner Dam, flood inflows from natural events, predation, and human disturbance adversely affect terns. If terns nest at elevations near or above the top of conservation storage, then the highest risk of inundation of tern nests has been from unpredictable flood inflows from upstream weather events, depending on nest locations to the existing water's edge. Such weather events may include local and regional storms that occur below Sumner Dam, causing imminent and immediate flooding or stalled weather patterns that provide large inflows of water over extended periods of time. Even if Carlsbad Irrigation District demand does not immediately require a release from Sumner, natural inflows could also inundate nests established at low elevation.

Another type of flood inflow, spring runoff, occurs upstream of Santa Rosa Dam in early spring. The Corps may initiate emergency flood operations depending on the fullness of upstream reservoirs, such as Santa Rosa and Sumner. Emergency bypasses of high spring flows may be necessary to pass water down to lower reservoirs. This event occurred in 1999 and 2005. These events have the potential to inundate tern nesting areas, but it is unlikely that nests would be active during these events in early spring.

Human recreational disturbance at this location was a likely contributing factor to the lack of tern breeding activity in 2005. In late June, a campsite was erected adjacent to the site where terns were roosting and exhibiting courtship behavior. This site is located within Seven Rivers Waterfowl Area, a designated Wildlife Management Area, where overnight camping is not permitted. Vehicle tracks were also observed in this area at different times in July.

During the winter of 2003 to 2004, Reclamation, through its Operations and Maintenance contract with CID, supported the removal of large expanses of salt cedar trees from the shoreline of Brantley Reservoir in the vicinity of the 2004 tern nesting location (L. Robertson, Reclamation, pers. comm., February 13, 2006). The salt cedar removal beneficially contributed to the creation of suitable unvegetated habitat for the tern colony in 2004. Unfortunately, clearing also resulted in the area producing dense, tall kochia and cockleburr in 2005 that caused the previously used area to become unsuitable for tern nesting and brooding (J. Montgomery, Service permittee, annual survey report, December 30, 2005).

Episodic golden algae blooms that have killed fish have been reported at Brantley Reservoir since at least 2002 (J. Lusk, NMESFO, electronic mail message, April 11, 2006). However, it is currently unknown if these fish kills are adversely affecting terns foraging at the reservoir. It has also been reported that DDT (dichloro-diphenyl-trichloroethane) levels are elevated at Brantley Reservoir when compared to other lakes across the U.S. (J. Lusk, NMESFO, electronic mail message, April 11, 2006), but it is currently unknown whether these DDT residues are adversely affecting terns feeding at Brantley Reservoir.

IV. Effects of the Action

The Service must consider the direct and indirect effects, as well as the effects of interdependent and interrelated actions to the shiner and the tern. Indirect effects are those that are caused by, or result from, the proposed action, and are later in time, but are reasonably certain to occur.

Pecos Bluntnose Shiner

As described in the environmental baseline, the natural conditions in the Pecos River have been modified due to the ongoing water management programs by Federal and non-Federal entities. These ongoing actions are, for the most part, not going to change from their current implementation except as discussed in the Cumulative Effects section of this biological opinion. The proposed action, the Taiban Constant Alternative, as amended, modifies aspects of the current operation of the Pecos River as described in the Description of the Proposed Action and the Environmental Baseline. The current operation is the No Action Alternative from the draft EIS. The effects to the shiner and its habitat from the past implementation of Pecos River management, including discretionary and non-discretionary Federal and non-Federal actions, are documented in the Environmental Baseline.

The effects section looks at the effects of the proposed action, including both new management and continuation of existing management actions by Reclamation, using the current environmental baseline as the starting point.

Block Releases

The proposed action continues the current operational program for block releases with one exception; releases, to the extent possible, will not be scheduled within a six-week period around August 1 of each year to allow larval and YOY as much time as possible to grow before another block release occurs. The larger and stronger the fish are, the greater the likelihood they will not be carried by the strong, steady current of a block release into the Farmlands reach or Brantley Reservoir. The scheduling of releases during this time period can occur if CID determines a need or if such a release would benefit the shiner by preventing intermittency; however, Reclamation would work with CID to schedule needed releases outside of this period. Otherwise, the timing of releases, flow level and duration, and total days per year for releases remains unchanged from current operations.

Continuing Effects from Unchanged and Continuing Operations

Channel maintenance:

Historically, Pecos River channel conditions were the result of the pattern of flows that formed the natural hydrograph. These natural flow patterns shaped the channel width, bed load transport, in-channel complexity, presence of riparian vegetation, and provided connections to the wider floodplain. Changes to this natural hydrograph, as described in the Environmental

Baseline, have resulted in definable changes to the river channel. Because peak flows of 1,400 cfs from Sumner Dam (the maximum amount released during a block release) are lower than the peak flows from pre-dam periods, the current channel conditions are more a reflection of the flow level and frequency of the block releases than the historic hydrograph. The current active channel is between 25 and 50 percent of the channel width in 1900 (Tetra Tech 2000). Other management actions, such as active river channelization and bank stabilization also narrow the channel width and prevent normal functioning of a wide, sand-bed river such as the Pecos. The channel conditions, including channel width, incisement, bedload stability, and bank stabilization by non-native riparian vegetation are reasonably well-defined for the Pecos River (Tashjian 1993, 1994, 1995, 1997, Tetra-Tech 2000, Hoagstrom 2003b).

Changes to river channel conditions that result from changes in flow regimes happen over a short and a long time period. When the hydrograph changes significantly, as it has on the Pecos River, a new equilibrium between physical conditions and the flows that create them is eventually reached. However, it is difficult to know when that equilibrium has been reached, and if it has not, changes to the river channel conditions will continue to occur into the future if the same management is practiced. The status of the Pecos River in this regard is uncertain; however, it is possible to discuss what these future changes may be descriptively, if not quantitatively. Current conditions as described below are from Hoagstrom (2003b).

Current channel conditions in the Tailwaters reach are severely degraded from historic conditions. This reach is incised, armored, and restrained by salt cedar thickets along the banks. The incision and armoring may become more pronounced further downstream in the reach over the next 10 years; however, the current conditions are such that significant additional change is not likely and recovery of the area to historic conditions without artificial manipulation impossible. The reach no longer appears to support shiners due to the lack of sand/silt substrates and channel stabilization that reduces channel complexity (Hoagstrom 2003b).

The Rangelands reach provides suitable shiner habitat that includes a moderately wide river channel, unstable sand substrates, and limited incisement or salt cedar bank stabilization. This reach benefits from the significant inflows of water and sediments from the tributary streams during spring runoff and seasonal rains that provide higher flows than normal base flows and contribute to channel maintenance during the year. High flows in this reach have been affected since the 1937 construction of Sumner Dam, with the 1980 construction of the larger Santa Rosa Dam causing another change in the flow pattern due to its flood control function.

Reclamation assumes that the Rangelands reach has reached equilibrium with the existing flow regime (Reclamation 2006). If so, neither significant changes to the channel conditions or effects to the shiner would be expected. However, if the reach has not come to equilibrium with the post-dam flow regime, then over the next 10-year period we would expect to see additional channel narrowing, incisement, and stabilization occur as a result of the continuation of the restricted number and extent of high flow events, further reducing the amount of suitable habitat available to the shiner. This effect is most likely to be seen at the lower end of the Rangelands reach where conditions already show a greater degree of channel narrowing. USGS gage data from the Taiban and Acme gages indicates that during spring block releases there is less attenuation of the flows reaching the downstream end of the reach than in the summer block releases. In dry years when there is less tributary inflow to support channel maintenance, the amount of channel change may be increased. The amount of change in channel characteristics that may occur cannot be determined; however, if these do occur, there will be a net loss of suitable shiner habitat, as it exists particularly in the lower portion of the Rangelands reach, over time.

In the Farmlands reach, the channel was actively channelized and retains little of its historic condition. Even with this limitation, this reach remains valuable for the shiners because it is perennially flowing. Significant changes to conditions here are not anticipated over the 10-year period without artificial management efforts to open the channel.

Timing of Releases

Block releases can be made at any time of the year but generally occur during the irrigation season. During years when reservoir storage is low, spring releases may draw down Santa Rosa and Sumner reservoirs to the point where there is insufficient storage available later in the summer for a block release. However, in years when water is not available for a block release to prevent intermittency, it is anticipated that under the proposed action as amended, Reclamation will use supplemental water to maintain a continuous river. This is an improvement over current operations.

Spawning cues

Shiners spawn beginning on the ascending limb of a flow increase and block releases provide the same cue as natural flow increases from precipitation events in triggering spawning. In years with few natural events that provide for flow increases, the block release may be particularly important in triggering spawning events. We anticipate that this effect will not change over the period for this consultation.

Transport of eggs and larvae

Because block releases are a trigger for shiners to spawn, the number of eggs and larvae in the river that are available to be carried downstream out of the Rangelands reach to the Farmlands reach and into Brantley Reservoir increases during the release event. The number of eggs and larvae so transported will vary based on a number of factors, including:

- The number of shiners capable of spawning at the time of the release. Adults (age 2) may be capable of spawning earlier in the season (late April through September) than the age 1 adults since the ability to spawn is size-dependent. The peak spawning period (June to August) would provide the greatest numbers of eggs and larvae to be displaced downstream. Since most of the peak spawning period will remain available for block releases, this factor may not significantly change.

- The distribution of adult shiners is a factor, because eggs and larvae produced in more upstream portions of the Rangelands reach may have more opportunity to be diverted onto the floodplain areas by the high flows where velocities are lower and are not as likely to be transported as far down the river (Dudley and Platania 1999, Kehmeier et al. 2004b). Those produced further downstream where the river is channelized and the distance to Brantley Reservoir is less, are more likely to be lost. Egg and larval loss may increase if channel narrowing occurs in the downstream sections of the Rangeland reach over the next 10 years.
- Even with less than 65 days of block releases per year, there is a significant transport of shiner eggs and larvae. Since the number of block releases per year will vary, as will the timing of the releases in or out of shiner spawning season, the yearly transport will vary. Generally, this variance will not change over the next 10-year period as compared to current operations.

Effects from Changed Operations

The potential to restrict block releases in the six-week period around August 1 provides a means to reduce the number of eggs and larvae displaced during a part of the peak spawning season. The extent of this reduction is not determinable because:

- Up to three block releases could occur within the June-August peak spawning season and still avoid the six-week period. This is based on a first release on June 1 for 15 days, no releases for 14 days, with a second release on July 1, and a third release the last week of August. It is not likely that this many releases would be scheduled in this period, but it is not unreasonable to expect at least one before or after the six-week period to ensure CID supplies in Brantley Reservoir.
- Depending on the needs of CID, there can be a block release within the six-week period. The commitment of Reclamation is “to the extent possible” releases would not be scheduled, so there is no absolute protection.

Changes in Flows

The 2003 BO (Service 2003a) set the target flows for the Acme Gage and represents current operations (Table 8).

Table 8. Target Flows at Acme Gage for No Action Alternative (current operations).

Season	Dry Year	Average Year	Wet Year
Winter (Nov-Feb)	35 cfs	35 cfs	35 cfs
Irrigation (Mar-Oct)	None	20 cfs	35 cfs

The proposed action, as amended, represents a potentially significant change in management of river flows between Sumner Dam and Brantley Dam. The key change in the operations is the relocation of the target flow location from Acme Gage upstream approximately 110 miles to the Taiban Gage. Acme Gage is in the quality habitat below critical habitat. Operations from 1998-

2005, provided for flows of at least 20 to 35 cfs at Acme at all times except in the summer of drought years. The new operations target 35 cfs at Taiban Gage during all seasons and hydrologic conditions. Based on USGS daily gage data for the same period, flows at Acme Gage are generally lower than those at Taiban Gage, with the exception coming after precipitation events that increase flows below the Taiban Gage.

Reclamation's modeling for the draft EIS and in the BA provides a means to compare the various alternatives to each other using the 60-year historic flow dataset as the model input. The results of this model are not predictive of actual future conditions or actual amounts of water. They do provide a comparison between effects given the same underlying set of hydrologic conditions. The model runs provided a dry year 53 percent, an average year 31percent, and a wet year 16 percent of the simulation years. The actual effects on shiner habitat in the Pecos River from the implementation of any alternative are not known since the actual future hydrology is not known. This analysis is based on the comparison of effects of the alternatives to shiner habitat based on the modeling, and thus does not indicate what actual conditions will be.

In determining the amount of supplemental water needed to meet the requirements of the EIS alternatives, Reclamation modeled Pecos River flows to assess the amounts of water needed and the resultant flows at the various gage points on the river. These model results do not completely track the effects of the proposed action as described in this BO due to changes made to the proposed action (addition of supplemental water) during the consultation period. However, the existing modeling data remains useful to compare the differences between current operations and the proposed action in terms of comparative amounts of water provided to the river.

Current operations provide for 0, 20, and 35 cfs during the summer irrigation season at the Acme Gage, depending on hydrologic year (Table 8). We have included the Dunlap Gage as a reference point for flows in the upper critical habitat area that would also change due to the proposed action. The following information is taken from Appendix A from the draft EIS (Reclamation 2005). The numbers in parentheses in the cells for the Taiban Constant (proposed action) are the net change compared to current operations at that gage. This information reflects the average for flows over the entire year and is not separated into flows expected in the summer and winter.

Reclamation determined the amount of water that would be needed to meet the flow targets for the alternatives (Reclamation 2005). For current operations, 10,700 af of water would be needed. Of this, bypass flows from Sumner Dam would provide 7,800 af. The amount of additional water needed is 2,900 af. The proposed action would only require 2,600 af, of which bypass flows provide 1,900 af and only 720 af of additional water is needed. This results in a loss of 8,100 af of water flowing through the Rangelands reach due to the proposed action. This is a reduction of 75 percent of the water needed under current operations and likely will have significant effects to the flows present throughout the year. With the change in the proposed action to maintain continuous flow in the Pecos River (at least 5 cfs at Acme Gage), the amount of water required will be higher than shown in this model scenario.

Winter Flows

For shiner to overwinter successfully, sufficient habitat based on water depth and velocity to provide complex and heterogeneous habitats with adequate cover and resistance to anchor ice (full freezing of the water column) must be available for all sizes of shiners. Very low flows that do not provide for deep waters with sufficient velocity to resist ice formation will limit the available habitat and limit overwinter survival. Even with sufficient depth available, water temperatures may be lower due to reduced flow through the area.

Reduction in habitat area available also results in an increase in the density of fish using these habitats. Shiners are only a minor component of the total fish population of the Pecos River, and the same overwinter habitats must suffice for the total population. Crowding during the winter may not be as meaningful a stressor as it can be during the warmer seasons; however, limits on available space are likely to result in higher overall mortality of fish, including the shiner.

Effects to the shiner from the reduction in winter flow focus on the reduction in the amount of habitat area available as a result of the lower flows. The amount of suitable habitat available at different flows is difficult to determine, although both Hoagstrom (2003b) and Kehmeier et al. (2004a) have provided information relative to habitat availability and use. The two primary features are water depth and velocity, with complex habitats providing greater opportunities for the combination of suitable depths and velocities preferred by different size classes. While suitable habitat may exist in areas with low flows (Kehmeier et al. 2004a), flows below 24 cfs provide less suitable habitat than higher flows (Hoagstrom 2003b). For this analysis, we will use 24 cfs as a representative flow that would support shiner habitat in the winter.

The provision for flows of at least 35 cfs at the Acme Gage during the winter as part of current operations provides a means to maintain the winter flows above 24 cfs to provide overwintering habitat. Based on average monthly flow data, this 24 cfs threshold was met in 19 of 24 months between the winter of 1998-1999 and February 2004 (Table 9). The winter of 2000-01 accounted for three of the five occurrences when 35 cfs was not met, with the remaining two events occurring in November 2001 and 2003. With the reduction in amount of flow at Acme Gage due to the change to the Taiban Gage location, and assuming a 5 cfs loss, over the same period of record, an additional two months would not have maintained 24 cfs. Because of fluctuations within each month over the period, there were considerably more days with flows below 24 cfs and if these occurred for an extended period with in a month, even a month with an average over 24 cfs may have experienced a short-term (1-10 days) period of reduced habitat availability that could have resulted in increased stress or mortality. Data from the Dunlap Gage, located within the upper critical habitat area, also show the effects of attempting to meet a 35 cfs target at the Acme Gage

Table 9. Monthly average flow data for Taiban, Dunlap, and Acme gages. Bolded letters indicate a change in comparison to the current operations. Last column only examines times when Taiban Gage is between 35-40 cfs.

Year and Month	Taiban Gage	Dunlap Gage	Acme Gage	Acme Gage over 24 cfs	With target for Taiban = 35cfs
1998-November	61.5	79.8	147	Y	
1998-December	40.6	40.0	51.4	Y	Y
1999-January	39.5	37.8	40.9	Y	Y
1999-February	35.5	30.5	37.3	Y	Y
1999-November	45.7	53.5	43.6	Y	
1999-December	41.6	43.1	32.5	Y	
2000-January	44.6	43.4	30.2	Y	
2000-February	355	315	375	Y	
2000-November	36.2	43.3	58.4	Y	Y
2000-December	25.4	28.3	23.4	N	
2001-January	20.9	25.3	23.4	N	
2001-February	21.1	19.5	15.6	N	
2001-November	36.2	34.9	21.4	N	N
2001-December	49.5	45.8	31.2	Y	
2002-January	46.2	42.2	34.1	Y	
2002-February	43.0	40.7	32.3	Y	
2002-November	39.0	40.8	31.7	Y	Y
2002-December	42.3	39.3	38.2	Y	
2003-January	42.0	38.5	35.5	Y	
2003-February	34.1	33.8	34.3	Y	Y
2003-November	29.7	27.6	19.2	N	
2003-December	39.1	35.0	26.3	Y	**N**
2004-January	40.1	37.5	28.2	Y	**N**
2004-February	40.3	41.2	34.0	Y	Y

Table 9 also provides information on what flows at Dunlap and Acme gages could look like if Taiban Gage were maintained at 35 cfs. From the information in the last column, Taiban Gage flows of approximately 35 to 40 cfs provide for flows at Acme above 24 cfs in 7 of 10 months.

This actual flow data indicates that maintaining flows of 35 cfs at the Taiban Gage for the winter may not, based on monthly average flows during this dry and average year period, have a meaningful change to flows at Acme Gage. However, as noted previously, monthly averages do not show the range or distribution of daily flows that may impact the amount of shiner habitat on a less than monthly cycle.

Reclamation provided results of modeling for flow exceedence curves (Figure 5.3, Reclamation 2006). Because these are daily flows, this information does provide an index to the change in flows that support winter habitat under the proposed action. Figure 5.3 shows that between 0 and

25 percent of the time, winter flows at the Acme Gage would be slightly higher under the proposed action than under current conditions. At 25-30 percent of the time, the proposed action flows become slightly lower and by 50 percent of the time, these flows stabilize at 20 cfs through the remaining 50 percent. Current operations stabilize at 35 cfs to meet the target, with a drop not occurring until 98 percent. Based on this information, 50 percent of the time, flows at Acme could be 4 cfs below the 24 cfs threshold and 50 percent of the time the flows would be over the threshold with the proposed action.

While the effects of the proposed action on winter flows in the Rangeland reach do not seem to be meaningful in terms of meeting the 24 cfs threshold, there are other ramifications. At low population levels for all fish, including shiners, the habitat available at 20 cfs may be sufficient to provide enough habitats without overcrowding and resultant stressors. At higher population numbers this may not be the case and crowding could adversely affect overwinter survival. We do not have explicit information to document the effects of habitat availability on overwinter survival related to population size and monthly average flows. Using changes to shiner density between the third and first trimesters and monthly average flows for those periods from the winter of 1992-93 to the winter of 2003-04, no clear picture emerges to correlate density at the beginning of the winter with density at the end of the winter and the average flows. If there is a positive relationship, then maintaining 20 cfs during the winter may compromise increases in species density that result from lower summer mortality if the river does not become intermittent. Monitoring of shiners and comparison with winter flows will be needed to assess any connections between density and amount of habitat provided.

Summer Flows

Reductions to flows through the Rangelands reach due to the proposed action are more complex to evaluate. This is because of the variable target flows for dry, normal, and wet years that are defined for current operations. In dry years, intermittency, based on zero flows at Acme Gage, were allowed under the 2003 BO. Maintaining flows through the upper critical habitat reach was the focus (Service 2003a).

Under the proposed action, the target of 35 cfs at the Taiban Gage is anticipated to provide a range of 2 to 20 cfs at the Acme Gage. Reclamation will monitor river flows on a daily basis and will implement its 7(a)(1) activities when necessary to avoid intermittency. This new target exists at all hydrologic conditions (dry, average, and wet years) and significantly reduces the flows previously targeted for average (20 cfs) and wet (35 cfs) years at the Acme Gage. However, it is an improvement over allowing intermittency to occur.

Reclamation provides an exceedence curve for the irrigation season that compares current operations to the proposed action (Figure 5.4, Reclamation 2006). For current operations, daily flows at or above 35 cfs would occur approximately 44 percent of the time. Under the proposed action, daily flows at or above 35 cfs is also expected 44 percent of the time. The proposed action does have a lower median (50 percent) flow; 21 cfs versus 29 cfs, and is lower by 2-4 cfs through to the 88th percentile. It is higher by approximately 2 cfs over the 22-49th percentiles (the figure did not provide the 0-20th percentiles). This figure does not differentiate between the dry, average and wet hydrological seasons

Figures 5.5 through 5.7 provide the exceedence curves for the three hydrologic conditions (Reclamation 2006). The dry year (Figure 5.5) curves for the two alternatives are virtually identical. The 50 percent flow level for both is 18 cfs and both reach 5 cfs at 88 percent. With the modifications to maintain 5 cfs at Acme, this lower end of the curve would improve under the proposed action to prevent flows from dipping under 5 cfs. Under current operations, Reclamation's commitment was to attempt to prevent intermittence within the upper critical habitat area and there was no target for Acme Gage. The provision for 35 cfs at Taiban Gage does not have any meaningful additional benefit at flows between 20 and 90 percent exceedence, since gage data indicates that flows of 35 cfs at Taiban generally result in higher flows at Acme, and the new Taiban target may be higher than what was needed to only support the upper critical habitat reach. Based on the model data and assumptions about the 5 cfs requirement at Acme, the proposed action provides protection for shiner habitats below the upper critical habitat in the event of very low flows but does not improve the conditions over current operations during the irrigation season over the range of flows projected. The model results provided for a dry scenario 32 years out of 60, so this scenario is the dominant one for the simulation. Shiner habitat would not go dry under the proposed action. However, it is unknown if the reduction in available habitat will be sufficient to provide for appreciable population growth. A possible outcome is recruitment at a level that maintains the existing population.

Figure 5.6 contains the exceedence curve for the average year (Reclamation 2006). The proposed action has higher flows (2-4 cfs) than current operations for flows above 30 cfs at the 46th percentile. Current operations have meaningfully higher flows, up to 10 cfs, associated with the 50 to 100th percentiles. Under the proposed action, the gain to the shiner only occurs at the highest flows that are seen less often than the lower flows that are more common. The reduction in available flows is most noticeable between 20 and 10 cfs, where current operations provide considerably more flows of 20 cfs than does the proposed action, which reaches 10 cfs over the same percentile range.

Recalling the 24 cfs figure that indicated a threshold for habitat, both alternatives provide this about 48 percent of the time. The significant difference is that current operations continue to provide 20 cfs to the 75th percentile, whereas the proposed action only reaches the median (50 percent) before dropping below 20 cfs. Summer periods without intermittency provide for the maintenance of the shiners. Summer periods with good flows provide the opportunity for greater recruitment to the population, in part because of additional habitat and lower mortality. The proposed action provides less of these higher flows than do current operations and has an adverse effect in that regard. Since average flows only make up 18 of the 60 years, and flows over 24 cfs are limited in at least half of those years, the ability of the shiner population to have meaningful increases and have less risk of stochastic event related extinction, is reduced over the current condition.

The wet year scenario shown in Figure 5.7 shows that flows in the proposed action are greater than those of current operations only 34 percent of the time (Reclamation 2006). The greatest differences are in the range of 10 to 40 cfs, where the proposed action shows a decrease of up to 16 cfs. The proposed action falls below 20 cfs at 58 percent, while current operations do not meet that level until 83 percent. Wet years provide the highest flows and depending on the correlation between flow and habitat, the largest amount of suitable habitat. The amount of habitat, particularly if shiner numbers have increased, provides for recruitment events that can increase the population size and provide enough habitat to support the expanded population. The proposed action decreases the amount of flow available for the shiner in wet years over current operations. Wet years occur in only 10 of the 60-year simulation; however, those wet years may be important in allowing the population to expand. Population expansion may be limited under the proposed action.

Summary

The block release portion of the proposed action has a limited beneficial effect for the shiner in that a portion of the peak spawning season would not generally be subject to block releases. This prohibition is not absolute, and, may under dry year scenarios, be violated to ensure that intermittency does not occur by scheduling a block release to raise flows that have reached a dangerously low level.

Reclamation has committed to maintaining continuous flow through the Pecos River as part of the proposed action. This commitment avoids the risk of intermittency that is viewed as the greatest threat to the shiner and its habitat. However, the change in targeted flow location to the Taiban Gage from the Acme Gage is generally adverse to the shiner in terms of a reduction in both summer and winter habitat availability. This loss is split between the two seasons, and serves to reduce the amount of habitat for all life stages in years where available water to support higher flows is no longer available. In dry years, low flows during the summer spawning season are not meaningfully different. While this may only lead to maintenance of population levels in dry years, avoiding intermittency is expected to prevent any further declines, an improvement over current operations.

The present status of the shiner is precarious after significant declines in population resulting from intermittency prior to 2005. Restoration of population metrics to levels seen in 2000-2002 would provide a reduced level of risk from random environmental events such as a disease outbreak or a water contamination event. The model simulations are of little use to predict the hydrologic conditions for the next 10 years. A series of dry years may further stress the population and increase risks. The benefits of increased flows in average and wet years afforded by current operations to allow for additional habitat and enhanced recruitment are less available under the proposed action, and given the current status of the species, this reduction may be meaningful in terms of population conservation.

Effects of Flow-Related Changes to Habitat on Shiners

The previous discussion addressed the changes to the amount of habitat that could be available under the current operation versus that available under the proposed action. The issue was stated in terms of habitat availability; however, the actual effect to the shiner relates to other factors in the habitat that are also related in part to the amount of habitat.

Stressors

Stressors are those conditions that affect the ability of an organism to thrive in its environment. For fish, these include water quality, habitat availability, competition with other species, predation by other species, food resources, and the presence of parasites and diseases.

For the shiner, intermittency is a significant cause for the increase in stressors, particularly water quality, competition, predation, food resources, and parasites and diseases. The biochemical effects of stressors on individuals can be insidious and lead beyond debilitation to mortality. Appendix A describes the action of stressors on parasites and disease in shiners.

Reduction in habitat availability is a consequence of the proposed action. While the stressors in winter and summer are not identical (for example, anchor ice is a winter concern, while water quality degradation due to evaporation and nutrient loading is a summer concern), the categories for the stressors remains largely the same. The literature on the interactions of various fish species and these stress categories is extensive; however, the effect analysis in this BO does not provide the degree of detail on the changes to habitat that would enable a comprehensive review of the literature to assess the significance of the effects to the shiner. Instead, the types of stressors are categorized below.

Habitat conditions include both the amount available and its quality as determined by the presence of the structure and other physical attributes identified as preferred or suitable for the species (Hoagstrom 2003b, Kehmeier et al. 2004a). For the shiner, these include factors identified by Hoagstrom (2003b) and in other papers cited previously in the Environmental Baseline, particularly defined by the complex interaction of water depth and velocity to create areas suitable for all life stages. Changes in the amount of flow will alter the depth-velocity interaction and thus the availability of a range of conditions that constitute suitable habitat. Because habitat suitability is not absolute, that is, there is not one condition that meets the needs of the shiner, the effect of overall reductions in flow may be the creation of one type of suitable habitat to the exclusion or reduction of other suitable types. The created habitat may not meet the needs of all life stages at a level needed to support the population structure. It is beneficial therefore to maintain flows that provide a variety of depth-velocity conditions that meet the needs of all life stages. The habitat needed by different life stages for the shiner is discussed in the status of the species and Environmental Baseline of this BO, and there are significant differences and needs between life stages that must be met by the flows provided under the proposed action.

Related to the amount of habitat is the effect of crowding. This is both an intra- and inter-specific issue. During times when habitat is limited, either in terms of gross area or in the structural components, the number of individuals of all species that must share the habitat becomes an issue. Crowding may be less of an issue in the winter when fish are less active and more individuals may be able to exist in the same area. Summer conditions, particularly as they affect water quality and available food resources, may be more critical and promote greater stress on individuals. Competition and predation are likely to increase in crowded conditions, as does transferal of disease and parasites (Appendix A).

Food availability may become a concern. The shiner relies largely on invertebrates produced outside of the aquatic habitat and are entrained into the river. The proximity of the river to sources of these invertebrates, and the size of the river, are both factors in how much forage will be available for the shiner. Smaller flows are likely to have less entrainment potential based solely on surface area. Such smaller wetted areas may also be farther from the riparian and upland areas that produce the invertebrate forage base. In crowded situations in small habitats, depletion of available forage by the shiners present would affect the individuals. Other food resources not normally preferred would also be limited by other species present in the habitat. The point at which food becomes limiting due to the size of the habitat is not known and likely exhibits considerable variation.

Water quality, particularly temperature, oxygen, and nutrient loading are also likely to increase in concern during times of lower flows because there is both less room and less water to refresh the system. The source of the water during the summer is also a concern for nutrient loading and increases in salinity. Drain return flows from agricultural areas or wastewater treatment have higher nutrient loads and agricultural returns are more saline. If most of the available flow is from these sources and not from clean inflows, evaporation will concentrate these chemicals and degrade water quality as the flow continues downstream. While evaporation occurs at all flow levels, lower flows have more available surface area (particularly in shallow sand-bed rivers like the Pecos River), have higher temperatures, and experience more evaporation. The effects of evaporation will be seen more downstream in the system than upstream as flows decrease.

Interior Least Tern

Operation of Pecos River dams has caused reductions in lateral channel migration, channel scouring and narrowing, changes in the riparian community, diminished peak flows, and reduction in connectivity between the river and flood plain. Operation of the Santa Rosa and Sumner dams trap sediment needed for tern habitat development and alter the downstream flow regime. The depletion of groundwater, diversion of river flows, capture of sediment by tributary dams, water pollution, and salt cedar colonization also contribute to large scale changes in the Pecos River hydrograph and tern habitat. Once non-native vegetation is established, it maintains a narrower channel leading to increased water velocities and the loss of fine sediments such as sand. Downstream of Roswell, the river has become highly incised, further degrading habitat for terns. The reach from Sumner Dam to the FSID Diversion Dam has become incised and armored with gravel and cobble, and no longer provides the sand/silt habitat that terns require.

The tern is generally restricted to river segments that have not been heavily altered from historical conditions (Service 1990). Prior to the operation of Sumner and Santa Rosa dams, maximum peak flows in the Pecos River reached 26,200 cfs. Operation of the dams reduced maximum peak flow by 92.5 percent to 1,980 cfs. Sandbar geomorphology and associated hydrology are integral components of suitable tern habitat. Those natural components necessary for successful tern nesting on the Pecos River were and likely will be eliminated by water operations that restrict maximum flows. The effect of these water operations has been the utilization of human-created habitats like Brantley Reservoir and Bitter Lakes National Wildlife Refuge that the terns have found as surrogates for the river sandbars that are no longer present.

The indirect effects of human disturbance on tern habitats at Brantley Reservoir are an important factor impacting the presence of terns and their reproductive success. The use of all-terrain and four-wheel drive vehicles and watercraft has allowed recreational users to explore areas at the reservoir previously inaccessible other than by foot. Users occasionally violate restricted Wildlife Management areas. Even brief human activity may be enough to directly or indirectly affect the breeding or nesting behavior of terns. Since tern nests consist of shallow or low depressions in the sand and their eggs are virtually indistinguishable from the substrate, nest contents can accidentally be crushed under foot or wheel without being noticed. Displaced adults may be forced to leave their nests, resulting in mortality to eggs or young. Human use of reservoirs can also result in increased predation on terns by introducing additional predators, including dogs, cats, and wild predators that increase around campsites, such as coyotes and rats.

Reclamation is authorized to store a maximum of 40,000 af of water in Brantley Reservoir for the Carlsbad Project (Reclamation 2006). Conservation storage space is comprised of this water and some sediment. Each year, the quantity of sediment increases. In 2005, the total conservation storage space was 42,556 af at an elevation of 3,256.13 ft. Reclamation makes block irrigation releases from Sumner Dam to deliver water to Brantley Reservoir to meet the irrigation requirements of the Carlsbad Irrigation District. Reclamation is authorized to fill all storage space up to the top of conservation storage. Usually, water levels are kept several hundred af below the storage limit in case of unexpected-flood inflows. Any water exceeding the top of conservation storage is remitted to the State of New Mexico and is foregone to the Carlsbad Project. Because block releases depend on an assortment of variables which include, but are not limited to, the annual snowpack in the upper Pecos Basin, the current volume of water stored at each of the Pecos River reservoirs, the demand by downstream irrigators, and the amount of local rainfall, Reclamation has stated that they can not predict, and have limited discretion over, the frequency and timing of block releases that may affect terns at Brantley Reservoir within a given year.

Reclamation moves water downstream for Project demands and may fill any or all storage space up to the top of Brantley Reservoir’s conservation storage; however, this is rarely done. Since storage space is limited in Brantley Reservoir by the State of New Mexico, and any water exceeding the top of conservation storage is remitted, or spilled, to the State, water levels are kept several hundreds of af below the storage limit in case of unexpected flood inflows. However, when water is needed in Brantley Reservoir, for either irrigation or State-line delivery, a large volume is moved to increase the efficiency of Brantley Reservoir storage. This space may be available habitat for terns, and is subject to inundation by flood inflows or upstream releases.

If terns arrive at Brantley Reservoir in spring and cannot find suitable habitat, they could lose an entire season of reproduction and recruitment, as occurred in 2005. If terns can locate suitable habitat at Brantley and nest at elevations near or above the top of conservation storage, then Reclamation's block releases would pose little risk to the terns. However, if they nest at elevations within the conservation space, then it is more likely that nests could be inundated by a block release. Adult terns would be able to easily escape this inundation, although the terns would potentially lose some reproduction and recruitment depending upon the timing. Juvenile birds could be harassed and possibly harmed by inundation of the active colony if it interfered with their dependency on parent terns and finding adequate shelter. Any eggs and very young chicks that could not move out of the way of the rising water would be killed by inundation of their nests.

There is also risk of inundation of tern nests by flood inflows from upstream weather events. Spring runoff may also occur upstream of Santa Rosa Dam in early spring. The Corps and/or Reclamation may initiate emergency flood operations depending on the fullness of upstream reservoirs, such as Santa Rosa and Sumner, or to prevent exceeding channel capacity. Such balancing of reservoir storage does not occur under normal operating conditions. Emergency bypasses of high spring flows may be necessary to pass water down to lower reservoirs. However, these events would be expected to occur early in spring, prior to tern nesting, and could inundate tern habitat, but not cause mortality to terns.

Effects to Critical Habitat

Pecos bluntnose shiner

Because continuous river flow will be maintained, the critical habitat constituent element for the shiner likely to be affected is the maintenance of a wide channel with sandy substrate. Reduced peak flows cause channel narrowing (Friedman et al. 1998) and allow non-native vegetation to encroach on the channel (Shafroth 1999, Polzin and Rood 2000, Shields et al. 2000). Once non-native vegetation is established, it maintains a narrower channel leading to increased water velocities and the loss of fine sediments such as sand. Peak flows also maintain high levels of habitat diversity through channel migration (Ward and Stanford 1995). A reduction in peak flows reduces channel migration and channel complexity (Shields et al. 2000). The result is less available habitat to the shiner. Although block releases help maintain the existing channel width, the magnitude of the block release is limited by Sumner Dam and is much less than historical peak flows leading to a reduction in shiner habitat. There is the possibility that the channel is still very slowly changing (narrowing) in response to the much lower than historical flows. It is believed that block releases are maintaining the current channel width and morphology and it is unlikely within the timeframe of this BO (10 years), an appreciable change in morphology will be detected.

Interior least tern

There is no designated critical habitat for the tern in the action area.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this BO. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act. Although many adverse effects have occurred to the shiner, it appears that river intermittency is the primary threat to the continued existence of the shiner.

Pecos Bluntnose Shiner

Cumulative effects include:

- Increased urban use of water, including municipal and private uses. Further use of surface water from the Pecos River will reduce optimal river flow and decrease available habitat for the shiner.

- The diversion of up to 100 cfs (2.8 m^3/s) from March 1 through October 31, by FSID and the pumpback operation that sends return flows back to agricultural fields. The FSID diverts 100 percent of the river onto agricultural fields when their calculated allotment is 100 cfs or less. In dry years, seldom does the calculated allotment reach 100 cfs (2.8 m^3/s). Consequently, FSID is able to divert the entire natural flow. This reduction in flow played a large role in the drying of the river in 2002 (Reclamation 2002). It is expected that the diversion will continue to have a significant impact on the amount of water available to the river in the future. Without a pumpback system as much as half the diverted water returns to the river above the Taiban gage. With the pumpback operation, less than 20 cfs (0.6 m^3/s) returned to the river in 2002 and it is expected that similar low returns have occurred since 2002 and will occur in the future. The FSID diversion reduces river flow, reduces shiner habitat, and increases the probability of river drying and subsequent mortality of shiners.

- Capture of sediment by dams on streams tributary to the Pecos River. There are many flood control dams built to protect municipalities that effectively stop the input of fine sediments into the Pecos River. The shiner prefers a silt/sand substrate. Reduction of these fine materials can alter the substrate composition over time.

- The water quality of irrigation return flows to the Pecos River is unknown. However, irrigated agriculture amounts to 84 percent of total water use in De Baca, Chaves, and Eddy counties (Department of Interior 1989). Typically, irrigation return flows are higher in salts than freshwater and may also contain pesticides, herbicides, and elevated amounts of nutrients (nitrogen and potassium) from fertilizers used on crops (http://www.fao.org/docrep/W2598E/w2598e04.htm). When irrigation return flows are diluted by natural flows water quality is not usually a problem. However, in situations where return flows provide a large portion of the total water available to the shiner (i.e., below the FSID return canal) and the pesticides, herbicides, and nutrients from fertilizers become further concentrated as the water evaporates, it is possible that water quality could negatively affect the shiners, particularly in times of very low flow.

- Oil and gas development. There is extensive development of oil and gas wells between Artesia and Carlsbad with associated roads and pipelines. Most of the pipelines are laid on top of the ground. Many pipelines cross ravines and some cross the Pecos River. Leaks and breaks in the lines have been documented (Steve Belinda, Bureau of Land Management, pers. comm. 2002). Delivery of petroleum products to the Pecos River either directly or by storm runoff, could have a negative impact on the shiner.

- On March 25, 2003, the State of New Mexico, the United States, CID, and the Pecos Valley Artesian Conservancy District reached a Settlement Agreement to settle the surface water claims of CID and the United States. Among other items, the Settlement Agreement calls for the ISC to purchase up to 6,000 water right acres in CID (2,350 acres have already been bought), up to 11,000 water right acres in the Roswell basin (2,476 acres have already been bought) and up to 1,000 acres from FSID. The water rights acquired will be transferred to augmentation wells developed and operated by the ISC. The well field will be operated to deliver water to the Pecos River to enhance the water supply of CID and to comply with the Pecos River Compact (delivery of water to Texas) (Miller 2006). Addition of water to the Pecos River from these well fields will primarily occur in the Farmlands reach or near Brantley Reservoir. In the Roswell artesian basin 6,000 af/yr and 20,000 af/yr are to be retired from the shallow and deep aquifers, respectively (McCord et al. 2005). One of the goals of the Settlement Agreement is to bring the aquifers in the basin back into hydrologic balance (McCord 2005). Although groundwater levels in the Roswell artesian basin are expected to rise through retirement of lands within Pecos Valley Artesian Conservancy District that are not part of the Settlement Agreement, the Settlement Agreement is anticipated to provide approximately 7,500 af/yr of additional baseflow to the Pecos River in the Farmlands reach by the end of 30 years (Carron 2003).

  Through the Strategic Water Reserve (State bill passed in 2005), ISC can manage water and water rights for benefit of threatened and endangered species. To that end, 1,800 af of water rights that have been retired from property in the FSID area (through the Settlement Agreement) will be used when needed for the shiner (part of the proposed action). Water from this source will be delivered to the Pecos River in the Tailwaters reach via a pipeline (most likely with a 10 cfs capacity).

- On June 9, 1949 the Pecos River Compact was approved by Congress and was signed into law. One of the major purposes of the Compact was to limit New Mexico's depletions of stream flow at the New Mexico-Texas state line. Depletions were to be limited to those occurring under conditions found in 1947. In 1974, the State of Texas filed a complaint against New Mexico alleging violations of the Compact. In 1988, the Supreme Court determined that New Mexico had under-delivered water to Texas on average, 10,000 af/year from 1950-1983. New Mexico cleared its debt with a payment of $14 million to Texas. However, the court mandated that New Mexico deliver its future water obligations to Texas on an annual basis without ever incurring a cumulative shortfall. Delivery credits are permitted to accumulate with no limits imposed. The court-appointed river master determines New Mexico's compliance with delivery obligations to Texas on the Pecos River each year. The ISC ensures that the state complies with the requirements of the Compact. Consequently, ISC monitors the flow of water in the Pecos River very closely. The New Mexico Legislature, in response to the U.S. Supreme Court order, directed the ISC to purchase and retire adequate water rights on the Pecos River to meet compact obligations. Approximately $33.8 million has been spent on the Pecos River water rights acquisition program and water leases between 1991 and 2004. The ISC estimates that the purchase and retirement of water rights has increased state-line flows by about 8,600 af/yr (NM ISC 2004).

To help meet Compact deliveries, at the beginning of each irrigation season ISC and CID sign a Miscellaneous Purposes contract which allows a certain amount of CID irrigation water (varies by year) to be used for other purposes. The CID Board of Directors decides at the beginning of each irrigation season if there is enough water in storage to provide for all the irrigation needs of their farmers, with enough left over (typically 10,000 af or more) to enter into an agreement. If there is sufficient water, they enter into a forbearance contract with ISC to deliver water to the stateline at the end of the irrigation season. In addition, if at the end of the irrigation season, CID has not used all of their allotted water, they may enter into an agreement with ISC at that time. For instance, in 2005, 34,000 af of water was purchased by ISC from CID in November and transferred to the state line. New Mexico can build a water credit and would like to do so to protect themselves against the possibility of not being able to deliver if a series of very dry years were to occur. Currently, the credit is about 30,000 af but ISC would like over the long-term, to build that credit to 115,000 af.

There are three primary consequences of ISC's requirement to deliver Pecos River water to Texas. 1) ISC competes with agencies such as Reclamation to find available water rights to lease within the basin. This makes it more difficult for Reclamation to secure sources of supplemental water. 2) Water that could be stored for future use is sent to Texas. If CID had not sold water to ISC in 2005, there would have been 34,000 af in storage that could have been used in the 2006 irrigation season and which could potentially have been used to maintain higher flows in the Pecos River for the benefit of the shiner (through block releases). 3) The transfer of water typically occurs in November and December when water transfer is most efficient. However, the amount of water released (1,000 -1,500 cfs) is much greater than the amount of water typically in the channel at that time (50-100 cfs).

In summary, human activities have had many adverse effects on the Pecos River ecosystem in the last 100 years. Although many adverse effects have occurred, it appears that lack of permanent flow and an altered hydrograph (diminished peak flows and sustained block flows) are the primary threats to the continued existence of the shiner.

Interior Least Tern

- The New Mexico State Parks and Recreation Division will continue to manage human use of selected lands around Brantley Reservoir. The NMDGF will continue their lease agreement to authorize and enforce State fishing and hunting regulations at Brantley Reservoir. State Park recreational use and other forms of human disturbance are expected to continue and can adversely affect tern breeding success. The use of all-terrain and four-wheel drive vehicles and watercraft may allow recreational users to explore areas previously inaccessible other than by foot. Occasionally, users may violate restricted Wildlife Management Areas. Even brief human activity can directly or indirectly affect the breeding or nesting behavior of terns. Displaced adults may be forced to leave their nests open, resulting in direct disturbance. Nest contents can be accidentally crushed under foot or wheel without being noticed.

- The CID will continue to call for block releases that cause the water elevation in Brantley Reservoir to rise, possibly inundating tern nests and habitat.

- Increased agricultural and urban use of Pecos River water, including municipal and private uses, will further reduce optimal river flow and decrease available habitat for terns.

- Capture of sediment by flood-control dams on tributary streams to the Pecos River will continue to decrease the input of fine sediments into the Pecos River. Terns require sand substrate for nesting. Reduction of fine sediment materials can alter substrate composition over time.

V. Conclusion

Pecos Bluntnose Shiner
After reviewing the current status of the shiner, the environmental baseline for the action area, the effects of the proposed water operations, and the cumulative effects, it is the Service's biological opinion that the proposed Carlsbad Project Water Operations and Water Supply Conservation project, is not likely to jeopardize the continued existence of the shiner, and is not likely to destroy or adversely modify designated critical habitat. We found that the proposed action is not likely to have adverse effects to designated critical habitat or alter the function and intended conservation role of shiner critical habitat.

The Service reached this conclusion because:

1) After a wet year (2005) in which the river was continuous (more than 5 cfs), there was an improvement in shiner density in both Rangeland and Farmland reaches. Evidence to

date suggests that when river flow is continuous, it has a beneficial effect on the shiner. The shiner recovered from very low densities which occurred in 1992, and we anticipate that under the appropriate conditions, it will be able to do so again.

2) Reclamation's proposed operations, including the proposed supplemental water activities, will augment base flows for the shiner and avoid river intermittency. We anticipate the river will remain whole through the use of existing reservoir storage, bypass flows, the fish conservation pool, and managing block releases in cooperation with CID. Additionally, Reclamation has verbally committed to coordinating block releases with CID such that river intermittency will be avoided.
3) The proposed action will provide less overall water to the shiner compared to current operations. Consequently, less habitat will be available for all life stages and there is the possibility that lower flows will increase stressors to the shiner, particularly in the summer. However, we have insufficient information to predict whether habitat availability for any life stage limits population growth and the degree to which this may impact the population.
4) Block releases are in part beneficial (cues for spawning, can alleviate intermittency, help maintain channel morphology) and will be managed in such a way as to minimize their impact on the shiner (15 day maximum length, 14 day minimum between releases, avoiding a 6-week period in August).
5) We do not anticipate that the proposed action will adversely affect the primary constituent elements of critical habitat; clean permanent water, a main channel with sandy substrate, and low water velocity, or alter the function of critical habitat.

Interior Least Tern

After reviewing the current status of the tern, the environmental baseline for the action area, the effects of actions associated with this amendment of the biological assessment of Reclamation's proposed Pecos River dam operations, and cumulative effects, it is the Service's biological opinion that this action, as proposed, is not likely to jeopardize the continued existence of the tern because the action area on the Pecos River represents a relatively small portion of their entire range in the interior United States. To date, no critical habitat has been designated for the tern; therefore, none will be affected.

VI. Incidental Take Statement

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of an incidental take statement. Our incidental take statement is specific to juveniles and adults which will serve as a surrogate measure of the eggs and larvae lost to Brantley Reservoir.

The measures described below are non-discretionary, and must be undertaken by Reclamation so that they become binding conditions of any grant or permit issued to any applicants, as appropriate, for the exemption in section 7(o)(2) to apply. Reclamation has a continuing duty to regulate the activity covered by this incidental take statement. If Reclamation (1) fails to assume and implement the terms and conditions, or (2) fails to require applicants to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, Reclamation must report the progress of the action and its impact on the species to the Service as specified in the incidental take statement. [50 CFR §402.14(i)(3)]

Pecos Bluntnose Shiner

Amount or Extent of Take

Based on the best available information concerning the habitat needs of this species, the project description, and information furnished by Reclamation, from the date of this final BO, take of shiner will occur in the form of harm, harassment, and kill.

It is unknown whether environmental stressors resulting from lower flows in both summer and winter will cause harm, harassment, or death of adult shiners. As a result, this biological opinion assumes, in the absence of meaningful data or research, no incidental take of adult shiners will occur as a result of lower overall flows occurring under the proposed action.

The Service anticipates that shiner eggs and larvae will be taken as a result of this proposed action. This incidental take is expected to be in the form of harm, harass, and kill as the result of block releases during the spawning season. These block releases are anticipated to transport the eggs and larvae downstream into Brantley Reservoir. This will harm many eggs and larvae by subjecting them to abnormally large and lengthy discharges that will transport them into Brantley Reservoir where death will occur, or where they will be unable to successfully develop and breed and thereby contribute offspring to the next generation. It will also harass larvae because when they are transported into the Farmlands reach there is little suitable low velocity nursery habitat available to them. Lack of suitable nursery habitat leads to poorer growth and most likely limits reproductive success of these individuals. It is anticipated that killing of larvae and eggs will occur when they reach Brantley Lake through consumption by predatory fish, by exposure to higher salinity, or by other unsuitable habitat conditions in the reservoir.

Two studies of egg transport in the Pecos River have been conducted with contrasting results (Dudley and Platania 1999, Kehmeier et al. 2004b). Both studies concluded that egg retention was greater in the Rangelands reach where complex habitats exist at higher flows leading to greater egg retention. In the Farmlands reach egg retention is much poorer. However, the studies differ greatly in their overall estimates of egg retention with Kehmeier et al. (2004b) estimating that 92 percent of shiner eggs would be retained above Brantley Lake and Dudley and Platania (1999) estimating that 40 percent would be retained. Because the methods of the two studies were different it is difficult to evaluate which provides the better estimate and so for the purposes of this incidental take statement, we will use an average of the two studies and assume 34 percent of eggs and larvae would be lost in Brantley Lake.

Loss of these individuals has an adverse effect on the population. The precise level of incidental take is difficult to identify and quantify because shiner eggs and larvae are similar in size and color to four other fish species in the Pecos River, the small size of the species' eggs and larvae, and the wide area over which take is anticipated.

Population density is used as a surrogate measure of incidental take of larvae and eggs by the impact of loss of those larvae and eggs to recruitment of adults into the population the following year. It is also useful for this purpose because there is good baseline data on that measure and it is related to the overall population size. The shiner density has been calculated by year since 1992 (S. Davenport, Service, pers.comm. 2006b). One fish/100 m^2 remains the lowest shiner population density value ever recorded. This value was recorded in the first and second trimesters in 2005 (Table 4) (S. Davenport, Service, pers.comm. 2006b).

Incidental take will be exceeded if:

1) The 2-year running average population density of shiner is less than 2.5 fish/100 m^2 between the time this biological opinion goes into effect and the first trimester of 2008 or is less than 4 fish/100 m^2 by the third trimester in 2008.

2) The 2-year running average population density of shiner is less than 3.5 fish/100 m^2 in the first trimester in 2009 or less than 5 fish/100 m^2 by the third trimester in 2009.

3) The two-year running average population density of shiner falls below 3.5 fish/100 m^2 for the first trimester or 8.0 fish/100 m^2 in the third trimester in any year beginning in 2010.

Table 10. Take schedule for shiner. All values are the two-year running average of density of shiner per 100 m². Take will be exceeded if density falls below the value listed. NA = not applicable.

Year	Trimester 1	Trimester 3	Any trimester
2006	NA	2.5	2.5
2007	2.5	2.5	2.5
2008	2.5	4	2.5
2009	3.5	5	NA
2010	3.5	8	NA
2011	3.5	8	NA
2012	3.5	8	NA
2013	3.5	8	NA
2014	3.5	8	NA
2015	3.5	8	NA
2016	3.5	8	NA

Effect of the Take

In the accompanying biological opinion, the Service determined that the level of anticipated take is not likely to result in jeopardy to the shiner or destruction or adverse modification of critical habitat.

Interior Least Tern

Amount or Extent of Take

Incidental take in the form of harm and harassment will result in actual death or injury in the form of loss of reproduction and recruitment caused by habitat loss and alteration from continued operation and maintenance of Reclamation's proposed Pecos River dam operations. This take will be difficult to detect because terns are wide-ranging and may change nesting colonies from year to year. Therefore, reduced reproductive success may be masked by annual variability in localized population numbers. However, take of terns can be anticipated by continued river operations that fail to provide habitat conditions that support self-sustaining populations of terns in the action area. The level of take is based on periodic nest inundation, erosion and/or degradation of suitable nesting and foraging habitat, and continued human-disturbance and predation of terns at Brantley Reservoir, resulting in actual death and injury to terns. The following types of losses are possible:

1. Taking of eggs and chicks by flooding or erosion;

2. Precluding nesting and renesting of terns by inundation or wetting of shoreline nesting habitat;

3. Increasing predation on nests and chicks as a result of reduced nesting habitat or changes in predatory/prey relationships;

4. Increasing susceptibility of eggs and young to disturbance and/or destruction by human activities as a result of reduced nesting habitat;

5. Continued loss of habitat due to degradation and vegetation encroachment, resulting in actual death and injury as described above.

Terns were present at Brantley Reservoir in May 2005 in the cove where terns nested in 2004. In response to a block release in May 2005, the reservoir's surface level rose above 3,253 ft in elevation, inundating most of the previously-exposed potential nesting substrate on the reservoir's shoreline. By June 9, 2005, a large increase in water level had submerged all potential nesting habitat for the terns, except for one small area that was unsuitable because it had become overgrown with sprouting kochia and cockleburr (J. Montgomery, Service permittee, annual survey report, December 30, 2005). Human recreational disturbance at this location in late June and July was a likely contributing factor to the lack of tern breeding activity later in the breeding season. Regular monitoring found no evidence of tern nesting during the summer months even though approximately six to eight adults occupied Brantley Reservoir until August. Continued lack of recruitment in future breeding seasons could lead to complete loss of the colony at Brantley Reservoir. For these reasons, ensuring availability of suitable habitat when terns are expected to arrive in 2006 is an important measure to minimize incidental take.

In 2004, a total of at least 14 adult terns nested at Brantley Reservoir, with an estimated 7 nests on the lakeshore. Six juvenile terns were observed near the nesting area in late August (Reclamation 2006; J. Montgomery, Service permittee, electronic mail message, August 23, 2004). We therefore estimate that the following numbers of adults and young may be incidentally taken during each of 10 years by implementing this proposed action: Up to 14 adult terns are authorized to be taken in the form of harassment caused by high water levels resulting from block releases and/or human recreation, and by harm and/or harassment caused by predation. The eggs and very young, immobile chicks aged 6 days or less may be incidentally taken in the form of harm caused by water levels rising as a result of block releases, human recreation and/or predation. The number of chicks taken per year may be up to 3 per pair, or a total of up to 21 eggs or immobile chicks in any combination for first nests, and the same number for renesting terns, for a combined total of 42 eggs or immobile chicks. In each of 10 years, up to 42 older, mobile young may be taken in the form of harm or harassment caused by high water levels resulting from block releases, human recreation and/or predation. Some of this age cohort could die as a result of displacement by high water levels or human recreation and others may survive displacement.

Effect of the Take

In the accompanying biological opinion, the Service determined that these levels of anticipated take are not likely to result in jeopardy to the tern.

VII. Reasonable and Prudent Measures

Pecos Bluntnose Shiner

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of the shiner.

1) Reclamation will partner with Federal, state, and private entities to participate and assist in the completion of ongoing habitat improvement projects on the Pecos River and to restore 1-1.5 miles of quality habitat within the Farmlands reach by 2009 and another 1-1.5 miles by 2014. Activities that restore and optimize the interaction of river channel and floodplain habitats with available flows will be most successful in mitigating the observed displacement of shiner eggs in severely degraded river systems (Medley et al. 2005). The reach that would provide the most benefit for the shiner is from the BLNWRMT south to Hagerman where flows are perennial due to inflow for the Roswell Basin and habitat is degraded (Tashjian, 2006).

2) In coordination with the NMESFO, Reclamation will initiate intensive monitoring whenever flows at Acme Gage drop below 10 cfs.

3) Continue to monitor the status of the shiner population using methods consistent to those used over the last 3 years (Service 2003) to ensure that incidental take of eggs and larvae is not limiting recruitment of adult shiners to an extent that will not sustain the population.

Terms and Conditions

In order to be exempt from prohibitions of section 9 of the Act, Reclamation must comply with the following terms and conditions, which implement the reasonable and prudent measures, described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

The following implements reasonable and prudent measure 1:

1.1) Reclamation will attend meetings and work with Federal, state, and private entities as a cooperating agency to support and enhance shiner habitat restoration at the Bitter Lake National Wildlife Refuge.

1.2) Reclamation will attend meetings and work with Federal, state, and private entities as a cooperating agency to support and enhance related hydrogeomorphic processes improvements to the reach of the Pecos River north of Dexter Bridge and adjacent to the Bureau of Land Management waterfowl area.

1.3) Reclamation will partner with Federal, state, and private entities to complete habitat improvement projects totaling two meander sequences 0.5-1 mile in length between Dexter and Hagerman.

1.4) Reclamation will partner with federal, state, and private entities to monitor the success of habitat restoration projects in terms of winter and summer habitat conditions through the use of color infra-red videography, at least 4 cross sections within the site, and fish population and habitat use data. Videography should be used to map riparian habitat within each restoration site including in-channel and riparian habitats.

Considerable information is available for these projects including; 1) A restoration design for the Pecos River at BLNWR based on topographic surveys, hydraulic modeling and sediment data (FLO Engineering 1999), and 2) a restoration and flood conveyance improvement design prepared for Chavez County based on topographic data, hydraulic modeling, and sediment modeling (Corps 1999).

The following implements reasonable and prudent measure 2:

2.1) Reclamation's proposed action for the Carlsbad Project Water Operations and Water Supply Conservation EIS includes a supplemental water program with the goal of utilizing water management flexibility and water acquisition options needed to keep the Pecos River continuously flowing.

Because of gage error, fluctuations in river flow, and accessibility to the river, the Service recognizes the difficulties in determining when intermittency in flow occurs on the Pecos River. Because of these difficulties, Reclamation will continuously monitor flows at numerous locations when the Taiban Gage approaches 40 cfs, and/or Acme Gage approaches 10 cfs, and/or there are other non-operational factors which cause concern over river flows. Reclamation, in coordination with the Service, shall intensively monitor the river by the best methods available at the time, including website gage readings, field site verification and surveys, flights to monitor river connectivity, monitoring the video camera, or other technology as it becomes available. Reclamation will verify as soon as sudden changes in flows in the range of the above levels occur and/or when flows approach the levels described.

The following implements reasonable and prudent measure 3:

3.1) In cooperation with the Service and NMDGF, continue population monitoring of the shiner using methods and sites that are consistent with the surveys that have been conducted over the last 3 years.

> 3.1a) Monthly monitoring will be required until the third trimester of 2010.
>
> 3.1b) Monitoring frequency will be reassessed after 2010, but will be conducted at a minimum of 6 times per year.

New sample protocols may be implemented; however, sampling consistent with methods used over the last 3 years must continue concurrently with the new method for at least 5 years so comparisons of the data sets can be made.

Interior Least Tern

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize or avoid impacts of incidental take to the tern:

1) In cooperation with other willing land managers on the Pecos River and at Brantley Reservoir, Reclamation shall fund, implement and/or assist with enhancement of tern nesting and brood-rearing habitat on the Pecos River and at Brantley Reservoir prior to the arrival of terns in May of each year, in consultation with NMESFO. This measure will ensure that suitable habitat is available when terns arrive in spring.

2) Reclamation shall survey and monitor terns throughout the action area of the proposed action and consult with NMESFO if terns are detected at new sites.

Terms and Conditions

In order to be exempt from prohibitions of section 9 of the Act, Reclamation must comply with the following terms and conditions, which implement the reasonable and prudent measures, described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

The following implements reasonable and prudent measure 1:

1.1) Reclamation shall enhance and/or maintain habitat for terns each year at least three times the size of the 28-ac 2004 tern colony at Brantley Reservoir, equaling 84 or more acres of nesting and brood-rearing habitat by 2007. This habitat shall include the 56 acres cleared in 2006. Tern habitat enhancement sites shall be based on: (1) The following NMESFO recommendations where they are applicable, (2) site analyses by NMDGF and other tern experts, (3) new or existing scientific, peer-reviewed research at this or similar sites, and (4) in consultation with NMESFO. Potential site enhancements shall incorporate important characteristics of the occupied habitat at Brantley Reservoir, as well as new or existing research on tern breeding habitat preferences, movements and establishment of territories at Brantley Reservoir and similar habitats throughout the subspecies' range.

The NMESFO requires the following physical conditions for tern nesting, brood-rearing, and foraging habitats (U.S. Fish and Wildlife Service 2000):

Nesting Habitat:

- Substrate – Nesting substrates consist of well-draining particles ranging in size from fine sand to stones < 1 in (2.5 cm) in diameter.

- Size/Shape – Nesting areas should be a minimum of 1 ac (.4 ha), preferably 10 acres (4 ha); circular to oblong in shape, maximizing interface with the lakeshore, where possible; recommended slopes of 1:25 with maximum slopes not exceeding 1:10; surface height above water to exceed 18 inches (45.7 cm) at nest initiation.
- Visibility – Smooth topography with < 10 percent early successional vegetation.

Brood Rearing Habitat:

- Substrate – Same as nesting substrate but may contain fine silts, organic detritus, and other unconsolidated fine particulate matter.
- Size/Shape – Brood-rearing areas should be 3 to 5 times larger than the nesting area; very irregular in shape where feasible, and maximizing shoreline to water interface; recommended slopes of 1:25 with maximum slopes not exceeding 1:10.
- Visibility – Vegetation can increase up to 25 percent ground coverage but should occur in a patchy pattern.
- Connectivity – Brood rearing areas must occur connected to nesting areas or immediately adjacent and separated only by shallow channels (< 1 in [2.5 cm] deep) or mud flats.

Foraging Habitat:

- Substrate –Terns require shallow, slow velocity water that provides habitat for schooling baitfish that are 0.5 to 3.0 in (1.3-7.6 cm) in length. Substrates range from large grained sand to heavy silts.
- Connectivity – Tern foraging areas should not be greater than 438 yards (400 m) from the brood-rearing areas.

Suggested management techniques for habitat creation include: (1) Replenishment or nourishment of river sandbars and islands; (2) creation of suitable nesting habitat in reservoir depositional zones; (3) creation or enhancement of shallow and backwater areas, off-channel chutes, and flats as foraging habitat; (4) removal of early successional vegetation from nesting areas; (5) peninsular cutoffs or island creations in reservoir side bays; and (6) dike construction to dewater reservoir side bays for nesting and foraging habitat.

1.2) In accordance with the physical condition requirements listed in 1.1, Reclamation shall enhance 21 or more acres as tern nesting habitat and approximately 3 or more times this amount as brood-rearing habitat, using elevated areas around Brantley Reservoir as close to the full "conservation pool" level and the 2004 colony site as feasible. Tern nesting and brood-rearing habitats shall be created and maintained in at least the following three areas: 1) Directly above and behind the 2004 colony site, 2) across the Seven Rivers inlet north of the 2004 colony site, and 3) on a suitable portion of the reservoir where human access is restricted and where predation is minimized. In areas designated for enhancement or clearing where migratory birds may be concurrently nesting, Reclamation shall survey for active nests and ensure that neither migratory bird eggs nor young will be killed while enhancing habitat for terns.

1.3) Reclamation shall continue its normal operations and maintenance activities along the Brantley shoreline annually and remove vegetation and stubble to reduce nutrient loading and algae production in the reservoir and achieve the physical conditions described in 1.1.

1.4) In accordance with the physical conditions described in 1.1, Reclamation shall incorporate tern habitat enhancements, such as creation of sandbars and removal of vegetation from nesting and brooding habitat, into the habitat improvement projects for the shiner, in consultation with NMESFO.

1.5) Because terns are sensitive to human disturbance and predation, Reclamation shall work with other willing land managers on a buffer zone of at least 1/4 mile to be maintained around areas where terns are exhibiting breeding behavior and around active colonies to protect them from potentially detrimental actions.

1.6) Reclamation shall coordinate with and update NMESFO on the implementation of these terms and conditions biweekly during April and May of each year. Reclamation shall again meet with NMESFO if terns establish nests that could be subject to take. If terns do not successfully nest in habitat enhancements areas, Reclamation, in consultation with NMESFO, shall use adaptive management methodology to annually modify habitat enhancement locations and/or techniques until a stable colony of terns is established.

The following implements reasonable and prudent measure 2:

2.1) Reclamation shall survey and monitor terns throughout the action area, and consult with NMESFO if terns are detected at new sites. Reclamation shall submit interim update reports to NMESFO at biweekly intervals from June through August. A final report shall be submitted to NMESFO by December 15 of each year.

VIII. Conservation Recommendations

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

Pecos Bluntnose Shiner

1. Determine the effective population size of shiners.

2. Determine the extent of shiner movement between reaches.

3. Reclamation should monitor fish health to ensure proposed flow regime is not having adverse physiological consequences for the shiner.

4. Reclamation should cooperate with the Corps, CID and FSID in developing river restoration projects to benefit the shiner. These could include the removal of salt cedar, destabilizing the banks and widening of the channel, especially in the reach below BLNWR.

5. The New Mexico Department of Agriculture (NMDA) is currently administering the New Mexico Saltcedar Control Project through local soil and water conservation districts along the Pecos River. To improve habitat for shiner, Reclamation should collaborate with NMDA to investigate the possibility of removing stands of dead salt cedar and destabilizing the river banks so that the river can become reconnected with the flood plain.

6. Reclamation should continue to pursue opportunities for leasing water to provide supplemental water to the shiner consistent with state and federal law.

7. Determine water quality impacts on the shiner.

8. Examine competitive interactions among the Pecos River fishes to determine the extent that non-native fish or the red shiner may affect the shiner population.

9. Investigate the possibility of modifying outlet structures at Sumner Dam so that releases greater than 1,400 cfs could be made.

10. Conduct a watershed analysis of check dams. Prioritize for removal those structures that have the greatest potential for providing additional sediment into the Pecos River.

11. Color infra-red videography, cross sectional information, and fish monitoring should be used to assess habitat suitability during winter and summer base flow conditions for occupied shiner habitat.

12. In coordination with the Service, Reclamation will pursue Section 10 coverage for FSID.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations. These accomplishments may be reported in the weekly conference calls and notes.

Interior Least Tern

13. Reclamation should work with the State, CID, FSID, and the Service to investigate ways to manage water levels in Brantley Reservoir to benefit terns without impacting the shiner or water deliveries.

14. Reclamation should continue to work with CID and others to clear areas of salt cedar and early successional vegetation from areas around and in proximity to Brantley Reservoir that will create additional nesting and brood-rearing habitat for terns.

15. Reclamation should investigate ways to enhance foraging habitat for terns, using the habitat recommendations listed in Term and Condition 1.1.

16. Reclamation should investigate management opportunities, including protection of peninsular habitat, overburden removal, island construction, and water-control structures to provide long-term habitat to support terns on Pecos River reservoirs.

17. Determine whether water quality is directly or indirectly affecting the tern through effects to prey base quality, abundance, and/or availability, and if so, determine available remedies.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefiting terns, the Service requests notification of the implementation of any conservation recommendations by notifying the lead biologist for the tern at the NMESFO.

Reporting Requirements

The nearest Service Law Enforcement Office must be notified within 24 hours in writing should any listed species be found dead, injured, or sick. Notification must include the date, time, and location of the carcass, cause of injury or death (if known), and any pertinent information. Care should be taken in handling sick or injured individuals and in the preservation of specimens in the best possible state for later analysis of cause of death. In conjunction with the care of sick or injured endangered species or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed. If necessary, the Service will provide a protocol for the handling of dead or injured listed animals. In the event Reclamation suspects that a species has been taken in violation of Federal, State, or local law, all relevant information should be reported in writing within 24 hours to the Service's New Mexico Law Enforcement Office (505/883-7814) or the New Mexico Ecological Services Field Office (505/346-2525).

IX. Reinitiation Notice

This concludes formal consultation on the action(s) outlined in the January 20, 2006, request. As provided in 50 CFR § 402.16, reinitiation of formal consultation is required where 42 discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) The amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this BO; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this BO; or (4) a new species is listed or critical habitat designated that may be affected by the action. This consultation is only valid for a period of 10 years beginning 30 days after the Record of Decision is issued for the Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement and therefore consultation must be reinitiated prior to the expiration of this BO to ensure continued compliance with section 7 and 9 of the Act.

Updates of any environmental commitments may require reinitiation of consultation. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation. Any questions regarding this BO should be directed to Lyle Lewis (505) 761-4714, Marilyn Myers (505) 761-4754, or Patricia Zenone (505) 761-4718.

Lyle Lewis
for Brian Hanson

cc:
Assistant Regional Director, U.S. Fish and Wildlife Service, Region 2 (ES), Albuquerque, New Mexico
Regional Section 7 Coordinator, U.S. Fish and Wildlife Service, Region 2 (ES), Albuquerque, New Mexico

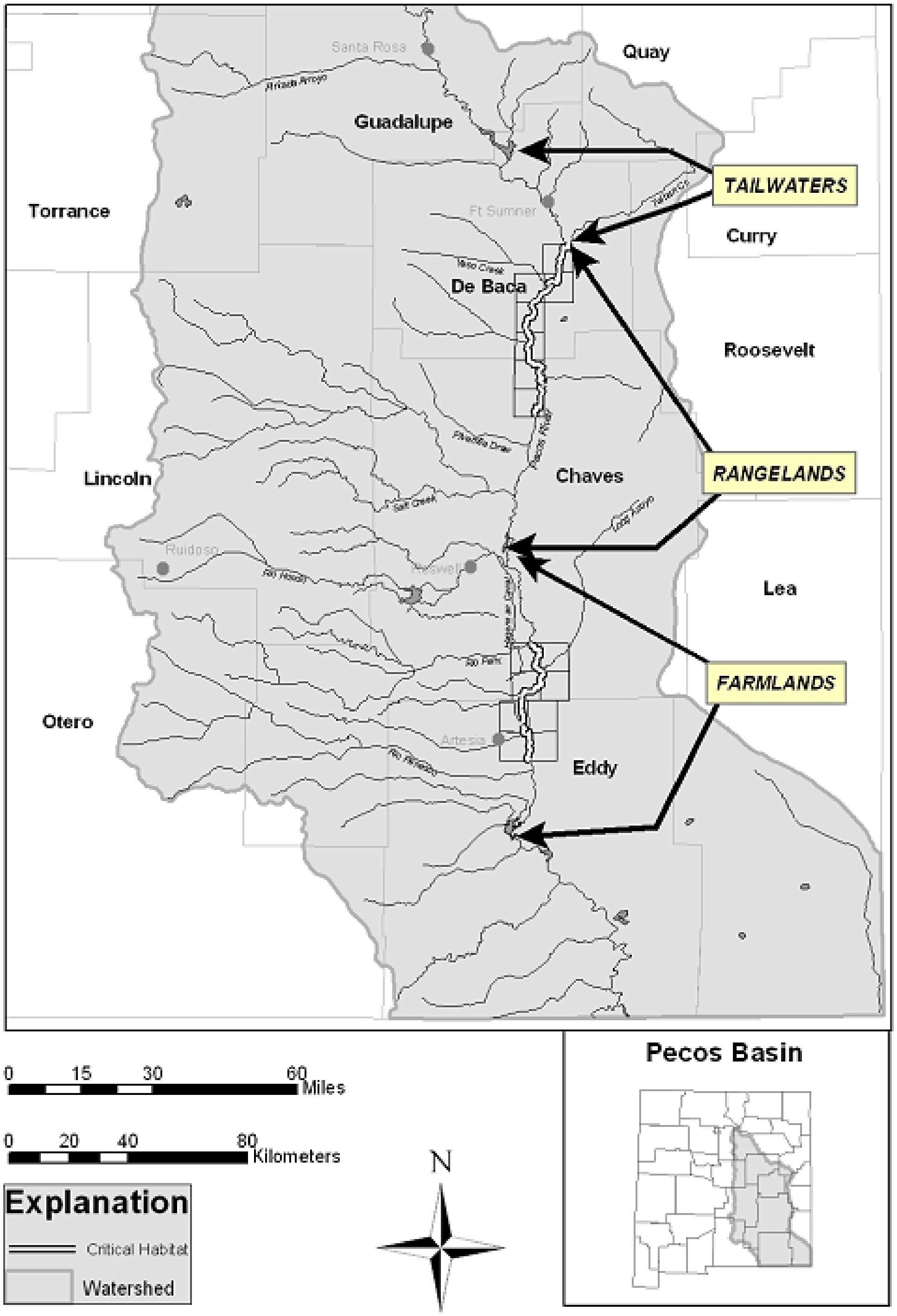


Figure 1. River reaches of similar character designated for Pecos bluntnose shiner research.

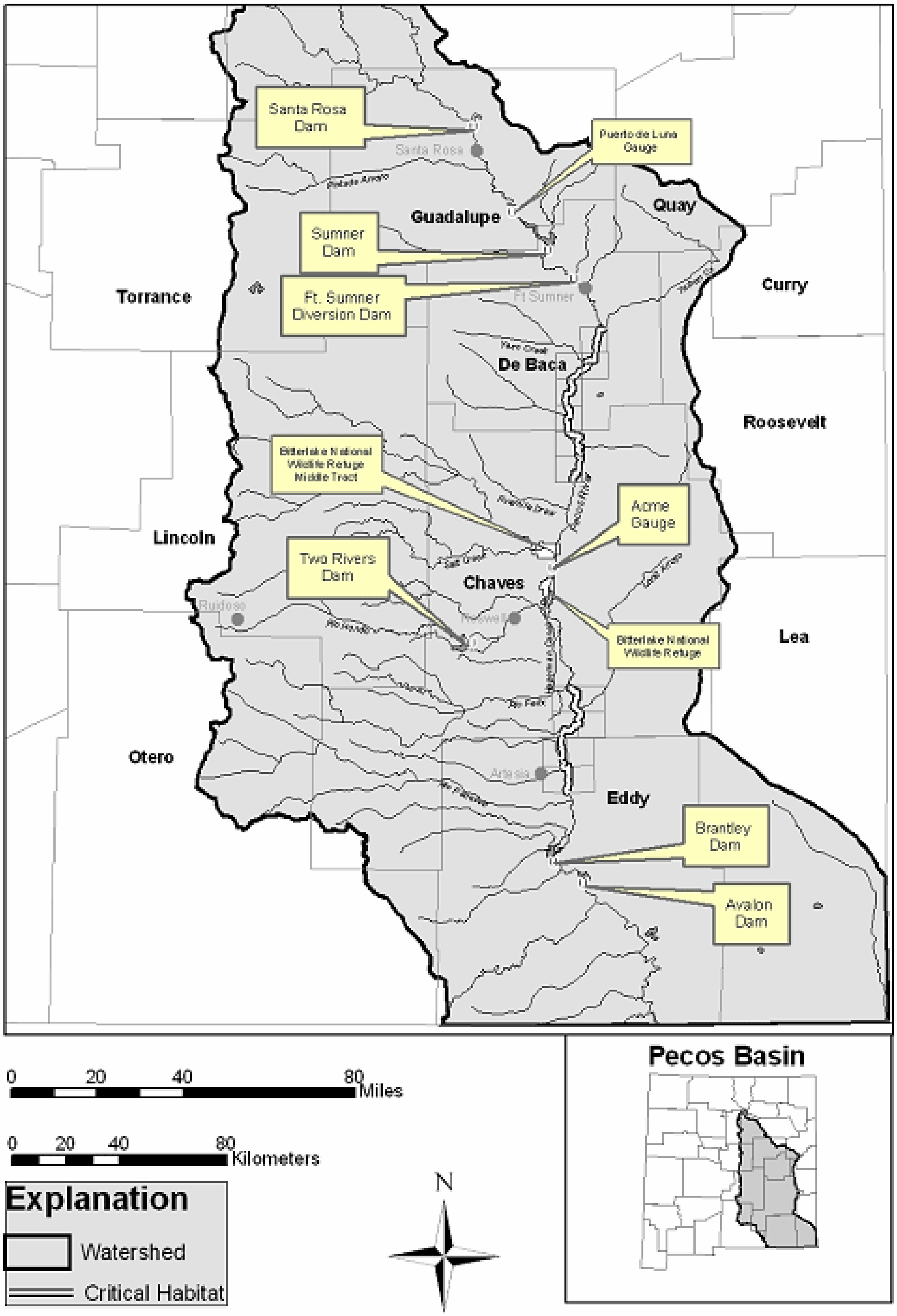
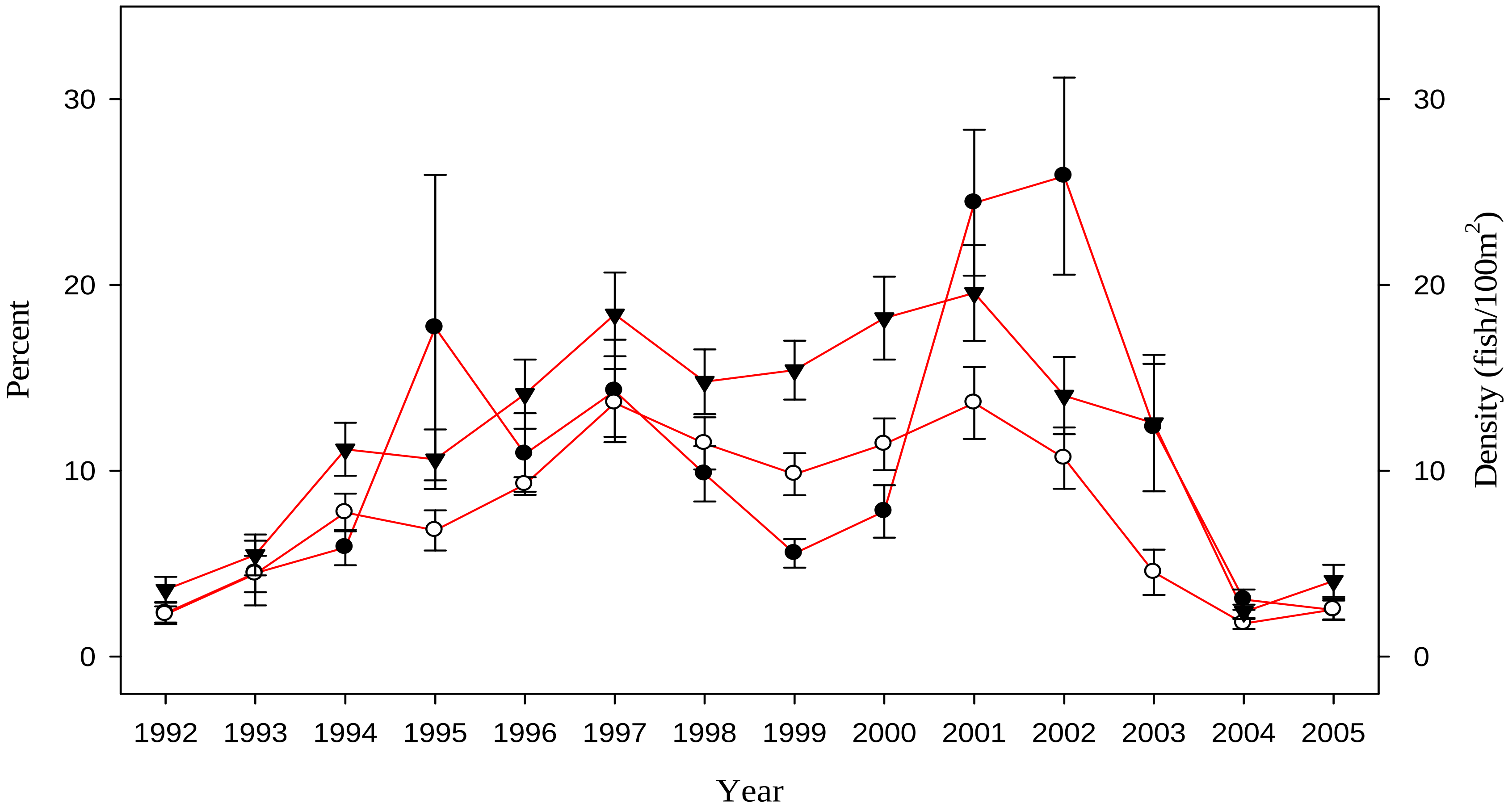


Figure 2. Pecos bluntnose shiner critical habitat, dams and two gauging stations on the Pecos River, New Mexico.

Figure 3. All abundance metrics used to track status and trends of Pecos bluntnose shiner including: density, percent of total fish community, and percent of shiner guild for the years 1992 through 2005. All river sections and trimesters are combined and data is presented with ± one standard error. Filled in circles = density (fish/100m2), open circles = percent shiner within the total fish community, filled in triangles = percent shiner within the shiner guild. Source: New Mexico Fishery Resources Office 2006.

Figure 4. All abundance metrics used to track status and trends of Pecos bluntnose shiner including: density, percent of total fish community, and percent of shiner guild for the years 1992 through 2005. All river sections and trimesters are combined and data is presented with ± one standard error, and data is log transformed. Filled in circles = density (fish/100m2), open circles = percent shiner within the total fish community, filled in triangles = percent shiner within the shiner guild. Source: New Mexico Fishery Resources Office 2006.

Figure 3


30
20
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Percent
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Density (fish/100m^2)
1992
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1994
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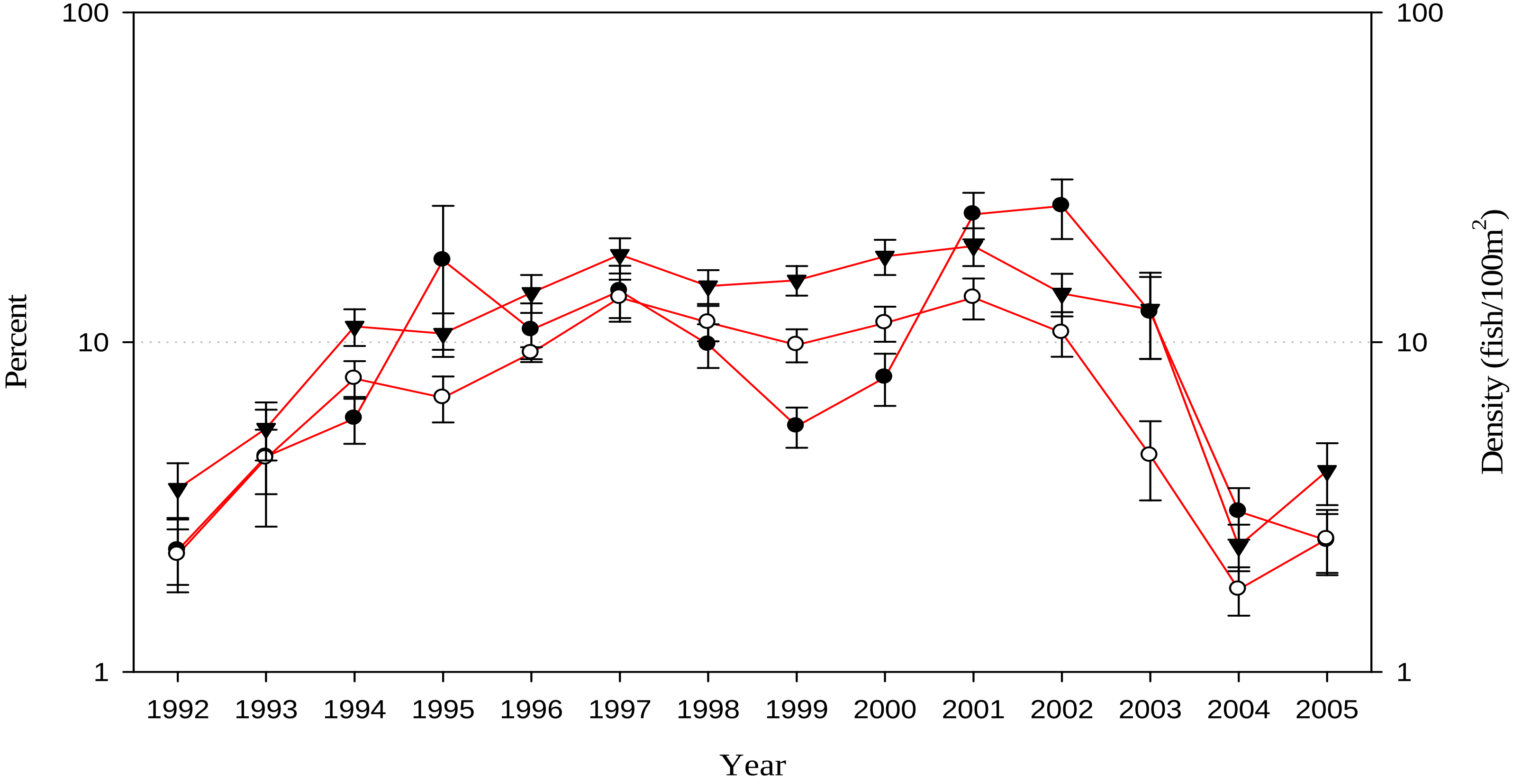
Year

Figure 4



100
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1992
1993
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Year
Percent
Density (fish/100m^2)

Table 1. Annual mean flow (calendar year), days of intermittency (0 flow), days less than one cfs, and days less than 5 cfs as recorded at the Acme gage, New Mexico and total reservoir storage as of April 1 of each year (summarized from U.S. Geological Survey records and Natural Resources Conservation Services, State Basin Outlook Reports).

	2000	2001	2002	2003	2004	2005
Annual mean flow	173	92	72	51	141*	146*
Days of intermittency	0	4	49	44	8	0
Days less than one cfs	0	13	63	97	15	0
Days less than 5 cfs	14	21	75	110	26	0
April 1 reservoir storage	136,600	79,500	35,200	47,100	29,200	115,000

* Provisional

Table 2. Total abundance of Pecos bluntnose shiner (n), seining effort (effort), and mean Pecos bluntnose shiner density (mean density = mean number of Pecos bluntnose shiner divided by area seined x 100). Data presented by four month trimester; Tri 1 = Jan-Apr, Tri 2 = May-Aug, Tri 3 = Sep-Dec for 1992 through 2005. **All three river sections (Tail-water, Rangeland and Farmland) are combined.**

		n				effort						mean density				
	Tri 1	Tri 2	Tri 3	**Total**	Tri 1	Tri 2	Tri 3	**Total**	Tri 1	se	Tri 2	se	Tri 3	se	**Total**	**se**
1992	32	83	218	**333**	3,156	6,828	6,123	**16,107**	1.26	0.9	1.3	0.4	3.6	1.2	**2.3**	**0.6**
1993	103	149	384	**636**	4,712	8,530	3,128	**16,370**	1.75	1.0	1.9	0.5	14.6	7.8	**4.5**	**1.7**
1994	105	238	473	**816**	5,543	5,772	6,314	**17,629**	2.54	0.8	5.3	1.4	8.8	2.0	**5.8**	**0.9**
1995	96	1,534	657	**2,287**	4,361	9,103	6,128	**19,592**	2.37	1.3	28.7	18.9	14.1	3.8	**17.7**	**8.2**
1996	338	384	1,110	**1,832**	5,034	7,040	6,905	**18,979**	9.45	4.9	5.7	1.6	16.4	4.2	**10.9**	**2.2**
1997	381	346	1,224	**1,951**	2,307	3,875	8,034	**14,216**	19.1	9.8	9.1	1.7	15.6	3.4	**14.3**	**2.7**
1998	302	613	866	**1,781**	3,201	6,732	9,558	**19,491**	9.5	2.9	11.1	3.0	8.9	2.0	**9.8**	**1.5**
1999	411	471	999	**1,881**	11,730	9,684	11,082	**32,496**	3.2	0.8	5.2	1.3	8.9	1.7	**5.5**	**0.7**
2000	445	415	1,527	**2,387**	9,417	11,340	11,163	**31,920**	4.7	1.5	3.5	0.7	14.5	3.3	**7.8**	**1.4**
2001	931	1,102	1,241	**3,274**	9,379	2,868	3,390	**15,637**	12.5	4.6	38.7	7.2	35.9	8.7	**25.9**	**4.1**
2002	1,843	504	585	**2,932**	8,056	1,960	3,780	**13,796**	27.4	7.2	31.7	15.6	17.6	5.3	**25.8**	**5.3**
2003	379	286	151	**828**	1,947	1,798	1,708	**5,453**	19.7	7.7	19.5	7.0	12.5	9.9	**17.4**	**4.6**
2004	114	248	118	**480**	4,718	5,709	6,011	**16,438**	2.4	0.8	4.8	1.1	2.3	0.9	**3.2**	**0.6**
2005	90	117	174	**381**	7,648	8,059	4,388	**20,095**	1.2	0.4	1.7	0.6	4.2	1.0	**2.3**	**0.4**
Total	**5,570**	**6,490**	**9,899**	**21,935**	**81,209**	**89,338**	**87,712**	**258,219**	**8.36**	**2.2**	**12.01**	**3.3**	**12.8**	**2.2**	**10.8**	**2.2**

Table 3. Total abundance of Pecos bluntnose shiner (n), seining effort (effort), and mean Pecos bluntnose shiner density (mean density = mean number of Pecos bluntnose shiner divided by area seined x 100). Data presented by four month trimester; Tri 1 = Jan-Apr, Tri 2 = May-Aug, Tri 3 = Sep-Dec for 1992 through 2005. **Rangeland River Section only**.

		n				effort						mean density				
	Tri 1	Tri 2	Tri 3	**Total**	Tri 1	Tri 2	Tri 3	**Total**	Tri 1	se	Tri 2	se	Tri 3	se	**Total**	**se**
1992	12	54	64	**130**	1,391	2,616	2,823	**6,830**	0.7	0.7	2.0	0.4	2.3	5.8	**1.9**	**0.3**
1993	21	65	76	**162**	1,932	2,623	583	**5,138**	1.1	0.5	2.6	0.6	13.0	0.8	**3.4**	**0.9**
1994	60	116	85	**261**	2,109	1,602	2,117	**5,828**	3.2	1.0	7.5	1.3	4.8	1.9	**5.1**	**0.9**
1995	62	148	56	**266**	1,484	3,162	1,635	**6,281**	5.1	4.1	4.7	0.8	4.0	0.9	**4.6**	**1.1**
1996	117	161	364	**642**	1,546	2,223	2,382	**6,151**	10.1	3.3	7.9	3.2	15.7	5.2	**11.8**	**2.6**
1997	110	272	850	**1,232**	1,002	1,862	3,795	**6,659**	15.4	5.4	14.3	2.3	23.6	5.8	**18.6**	**2.1**
1998	237	392	574	**1,203**	1,692	3,444	6,012	**11,148**	14.3	3.5	15.6	5.1	10.2	2.2	**12.8**	**1.6**
1999	385	246	505	**1,136**	8,346	4,689	6,066	**19,101**	4.3	1.1	5.6	1.4	8.5	2.0	**5.8**	**0.9**
2000	232	279	585	**1,096**	5,061	5,565	5,985	**16,611**	4.8	1.7	5.0	1.0	10.9	2.4	**7.1**	**1.1**
2001	560	456	413	**1,429**	4,083	1,561	1,389	**7,033**	18.0	8.2	30.4	7.5	30.8	8.3	**24.8**	**4.8**
2002	1,541	127	219	**1,887**	3,405	1,116	2,319	**6,840**	46.6	11.2	11.8	3.4	9.6	1.9	**28.0**	**6.4**
2003	352	206	22	**580**	1,245	896	912	**3,053**	29.1	10.1	25.7	10.4	2.4	0.6	**20.2**	**5.8**
2004	79	190	57	**326**	2,936	3,306	3,855	**10,097**	2.9	1.1	6.4	1.3	1.5	0.3	**3.6**	**0.6**
2005	65	48	121	**234**	4,809	5,115	2,960	**12,884**	1.1	0.5	1.0	0.2	4.5	2.4	**2.2**	**0.6**
Total	**3,833**	**2,760**	**3,991**	**10,584**	**41,041**	**39,780**	**41,398**	**123,654**	**11.2**	**3.5**	**10.0**	**2.4**	**10.3**	**2.4**	**10.7**	**2.3**

Table 4. Total abundance of Pecos bluntnose shiner (n), seining effort (effort), and mean Pecos bluntnose shiner density (mean density = mean number of Pecos bluntnose shiner divided by area seined x 100). Data presented by four month trimester; Tri 1 = Jan-Apr, Tri 2 = May-Aug, Tri 3 = Sep-Dec for 1992 through 2005. **Farmland River Section only**.

	n				effort				mean density							
	Tri 1	Tri 2	Tri 3	**Total**	Tri 1	Tri 2	Tri 3	**Total**	Tri 1	se	Tri 2	se	Tri 3	se	**Total**	**se**
1992	20	27	154	**201**	971	2,853	2,344	**6,168**	2.7	2.6	1.3	0.8	6.5	2.8	**4.0**	**1.5**
1993	82	70	308	**460**	2,422	4,518	1,619	**8,559**	2.5	1.9	1.8	0.8	20.7	13.5	**6.1**	**3.1**
1994	45	112	388	**545**	2,342	3,262	3,081	**8,684**	2.8	1.5	5.1	2.2	13.6	3.0	**7.8**	**1.6**
1995	34	1385	601	**2,020**	2,184	4,077	3,401	**9,663**	1.5	0.7	54.7	37.4	21.5	5.7	**29.9**	**14.7**
1996	221	223	746	**1,190**	2,358	3,209	3,496	**9,063**	13.0	9.2	7.1	2.5	22.0	7.2	**14.5**	**3.8**
1997	271	74	374	**719**	1,074	1,713	3,423	**6,210**	28.0	22.8	4.4	2.1	11.2	4.3	**13.2**	**5.8**
1998	65	221	292	**578**	1,254	2,796	2,817	**6,867**	5.5	5.5	7.7	3.1	9.6	4.8	**7.9**	**2.4**
1999	26	225	492	**743**	2,697	3,954	4,083	**10,734**	1.1	0.6	6.2	2.5	11.9	3.5	**6.7**	**1.7**
2000	213	136	942	**1,291**	3,990	4,734	4,182	**12,906**	5.1	2.8	2.7	1.0	22.7	7.0	**10.3**	**3.0**
2001	371	646	828	**1,845**	4,558	1,084	1,860	**7,503**	9.1	5.5	58.1	9.5	45.3	15.2	**31.7**	**7.2**
2002	302	377	366	**1,045**	4,030	541	1,461	**6,033**	9.3	6.3	74.4	41.5	27.0	10.4	**26.8**	**9.8**
2003	27	80	129	**236**	701	671	570	**1,944**	4.0	3.4	13.4	10.2	28.4	24.5	**16.0**	**8.9**
2004	35	58	61	**154**	1,233	1,829	1,773	**4,835**	2.4	1.4	3.5	2.2	4.1	2.4	**3.4**	**1.2**
2005	25	69	53	**147**	2,554	2,700	1,287	**6,541**	1.5	0.9	2.8	1.3	4.0	2.2	**2.7**	**0.7**
Total	**1,737**	**3,703**	**5,896**	**11,351**	32,368	37,940	35,398	105,710	**6.3**	**1.9**	**17.3**	**6.6**	**17.7**	**3.0**	**12.9**	**2.6**

Table 5. Summary of change in frequency and magnitude of flows > 1400 ft^3/s (maximum Sumner Dam release) at the Pecos River Below Sumner Dam Gage. The Fort Sumner gage represents inflow into the Pecos bluntnose shiner range. The pre-Dam summary was completed using mean daily discharge data for the 18 calendar years with complete records. The post-Dam summary was completed using the calendar years 1962 through 1979 (18 years). This period was chosen because it represented flow conditions after the 1950s drought, pre-Santa Rosa Dam, and pre-1980s and 1990s wet years. In other words, this 18-year period was the most 'normal' for the post-Sumner Dam period.

Period	Days	Days > 1400 ft^3/s	Mean Days per Year > 1400 ft^3/s	Years With Flows > 1400 ft^3/s	Maximum Discharge (ft^3/s)
Pre-Dam	6574	128	7.1	18	26200
Post-Dam	6574	18	1.0	2	1980

Table 6. Summary of winter flows (i.e., flows reported for the typical FSID non-irrigation season, 1 November to 14 February) at the Pecos River Below Sumner Dam Gage. The Fort Sumner gage represents inflow into the Pecos bluntnose shiner range. The same records were used in this Table as described in Table 5.

Period	Days	Mean ft^3/s	Minimum ft^3/s	Maximum ft^3/s
Pre-Dam	1908	97.3	41	265
Post-Dam	1908	6.0	0	99

Table 7. Summary of flows at the Pecos River Below Sumner Dam Gage during the FSID irrigation season (March through October). The same records were used in this Table as described in Table 5.

Period	Days	Days > 100 ft^3/s	Mean Days per Year > 100 ft^3/s	Mean Overflow (ft^3/s)
Pre-Dam	4666	2649	147.2	355.7
Post-Dam	4666	1238	68.8	594.2

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APPENDIX A

April 25, 2006

Memorandum

To:	Lead Pecos Bluntnose Shiner Biologist, New Mexico Ecological Services Field Office, Albuquerque, New Mexico
From:	Senior Environmental Contaminants Specialist, New Mexico Ecological Services Field Office, Albuquerque, New Mexico
Subject:	Potential Health Effects to the Bluntnose Shiner from Environmental Stressors

Confining riverine fish to pools or to intermittent conditions during low flow has been identified as an environmental stressor of concern to the health of fish in the Rio Grande Basin (U.S. Fish and Wildlife Service [USFWS] 1994, Caldwell 2005). In 2005, river intermittency isolated Rio Grande silvery minnow in large pools throughout several miles of the Middle Rio Grande Valley (Caldwell 2005). During this time, Rio Grande silvery minnow were rescued from these pools by the USFWS and placed in bags for transport. Subsamples of the rescued fish were sent to the USFWS Fish Health Center for diagnostic examination. Of the fish examined, gill tissue was found to be infested with flagellated protozoan parasites and kidney tissue was infected with many species of bacteria (P. Hines, USFWS, written comm. October 13, 2005). Hines (USFWS, written comm. October 13, 2005) reported that the Rio Grande silvery minnow collected from these intermittent pools were in poor health and any additional stressors could lead to high rates of mortality or these fish could experience delayed mortality up to a week or more after fish were relocated. Low flow conditions could be expected to similarly stress Pecos bluntnose shiner.

Changes in environmental conditions of a fishes habitat (i.e., reduced water flow resulting in elevated water temperature, low dissolved oxygen concentrations, and degraded water quality) can contribute to excess parasitism and pathogen burdens in fish. Long term environmental stressors will ultimately reduce a fish’s immunity and the survival of local fish populations, including the bluntnose shiner. Physiological responses to stress include measurable changes in blood cortisol levels that can lead to changes in metabolism, hydromineral balance, cardiovascular, respiratory and immune functions, behavior, food intake, feed efficiency, growth and even survivorship (Anderson 1990). Elevated blood cortisol levels may compromise an immune response in fish by inhibiting inflammatory reactions and phagocytosis (i.e., reduced lymphocytes and macrophages) and retarding healing processes (Pickering 1987; Ellasaesser and Clem 1986). Malnutrition, metabolic disorders, and environmental stressors such as rapid changes in water quality will result in decreased food intake, decreased feed efficiency, growth retardation, or adversely affect the immune response (Anderson 1990). The final result will be increased susceptibility to disease (MacArthur et al. 1984; Woo et al. 1987).

However, disease in fish is not the result of a single event, but the result of multiple interactions between the fish, the pathogen and the aquatic environment. Most often, stress-mediated diseases are those associated with pathogens and parasites that are widespread, continuously present in the environment and opportunistic (i.e., these diseases are not manifested unless stress results in increased susceptibility) (Wedemeyer and Wood 1974). The presence of most pathogens do not result in disease unless unfavorable conditions compromise the fish's defense system. Different fish species display a wide variation in their physiological responses to stress, with elevated circulating cortisol after an acute disturbance. Species differences and genetic history will account for much of this variation. An appreciation of the factors that affect the magnitude, duration and recovery of cortisol and other physiological changes caused by stress in the bluntnose shiner would be important for proper interpretation of effective biological monitoring programs. Monitoring the longterm health of the bluntnose shiner population over time would be one means to obtain biologically-relevant information about the potential effects of changes the environment will have on the bluntnose shiner.

If a fish is healthy, both the fish and its protozoan parasites can exist in a symbiotic relationship. However, this relationship changes quickly to pathogenic if the fish host becomes stressed. The reproductive potential of the protozoans and bacteria increases exponentially if there is also a change in the environmental conditions that favor these pathogens (e.g., increased temperature, nutrients) or conditions that stress the fish or compromise its immune system (e.g., low dissolved oxygen, crowding, elevated blood cortisol, elevated ammonia, poor nutritional status, genetic fitness), which can favor the rapid reproduction of these pathogens or increase the susceptibility of the fish to disease (Caldwell 2005 citing Post 1983) and result in fish mortalities. Fish in all environments sometimes die because of stressful conditions (Anderson 1990). Although fish may appear healthy before, during and immediately after a period of stress, a disease outbreak can occur afterwards. Chronic mortality in those populations has been tied to a specific pathogen (Anderson 1990). In many cases, pathogens are already present in the environment or carried by the fish and a compromised immune system will make the fish more susceptible to these agents. Therefore, impairment of immune mechanisms in fish may lead to reduced resistance against opportunistic pathogens in the wild.

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Appendix 2

Water Offset Options Group Documentation Report

Water Offset Options Group (WOOG) Documentation Report

Report on Research and Evaluation Efforts
by the Water Offset Options Group for
the Carlsbad Project Water Operations
and Water Supply Conservation NEPA Process

July 2005 Final Draft

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1. Introduction

This work plan was developed to document past efforts by the Water Offset Options Group (WOOG) for the ongoing Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement (Carlsbad Project EIS). The purpose of and need for the Carlsbad Project EIS as stated in the Federal Register Notice of Intent was "The purpose of Reclamation's proposed federal action is to conserve the Pecos Bluntnose shiner, a federally threatened fish species, and to conserve the Carlsbad Project water supply. The underlying need for Reclamation action is compliance with the Endangered Species Act and Reclamation's responsibility to conserve the Carlsbad Project water supply."

The WOOG's role in impact analysis for this EIS is limited; although given the variety and complexity of proposed offset and supplemental water sources, a thorough documentation of past efforts and planning for future efforts in the WOOG is warranted. Sections 1 through 10 of this document outline analyses and actions taken by the WOOG.

1.1. WOOG Purposes

The WOOG's primary purpose was to gather information and evaluate possible offset options to projected depletions to the Carlsbad Project Water Supply. These depletions are expected to arise from the modified operations at Sumner Dam of bypassing inflows to augment stream-flow for the Pecos Bluntnose Shiner (PBNS). The bypassing of inflows through Sumner Reservoir is expected to generate additional or "net" depletion components. The first component arises from the reduced transmission efficiency of low-flow bypasses through the reservoir as opposed to high-flow block releases. The second component arises from block release durations limited to 15-days, which also decreases the efficiency of water transmission in the Pecos River.

A recent secondary purpose identified by the EIS team is direct water acquisition for augmenting river flows to benefit the PBNS. Currently, when water is needed for augmenting stream flow, inflows are bypassed through the reservoir. However, inflow water is not always available for bypass since the supply is dependent on upstream conditions. Since instream flow demands may not coincide with the availability of inflow water for bypass, additional water supplies may be required to conserve the shiner. These supplies are termed additional water acquisition (AWA).

Finally, the WOOG is responsible for providing guidance in the selection process for offset and direct water acquisition choices. Because purely objective analyses of each offset option is difficult, the WOOG attempted to fairly and equitably evaluate options with several evaluation tools.

1.2. WOOG Carlsbad Project Supply Offset Options

Twenty-four possible water sources were suggested as offset options prior to WOOG research and evaluation, and two options were added during the research process. The options, along with a brief description of each option, are shown in Table 1.

Table 1. Water Offset Options for Depletions to Carlsbad Project Supply

Option Desig.	Option Name	Option Description
A	On-Farm Conservation	Improve irrigation efficiency and subsequently reduce diversions in the three major districts: FSID, PVACD or CID. Anticipates agreements with irrigation districts or land owners to release saved water to the river or CID in exchange for USBR payment for conservation measures.
B	Drain Construction/Renovation	Renovate drains in PVACD to augment return flows. Probably would only produce a one-time volume of drain water.

Table 1. Water Offset Options for Depletions to Carlsbad Project Supply

Option Desig.	Option Name	Option Description
C	Hernandez Idea/Plan	Recirculate water between mouth of Hondo and Acme.
D	Water Right Purchases	Buy water rights and retire in place: FSID, PVACD, or CID.
E	Water Right Leases	Lease water rights (fallow land) in FSID, PVACD, or CID.
F	Riparian Vegetation Control	Eradicate and control exotic vegetation growth, such as Salt Cedar and Russian Olive, in the riparian corridor.
G	Acequia Improvements	Improve acequia irrigation efficiency (such as Puerto de Luna and Anton Chico acequias)
H	Pump Supplemental Wells	Pump CID supplemental wells for offset water
I	Import Canadian River Water	Import Canadian River water by building a trans-basin diversion between Conchas and Santa Rosa. Water would be supplied by saved irrigation losses from lining the Arch-Hurley canal. Contract with district for transport of saved water form Canadian Basin
J	Reservoir Entitlement Storage	Increase upstream reservoir (Santa Rosa and Sumner) conservation storage limits to save on evaporation.
K	Desalination	Build desalination plant with new technology (reverse osmosis and ion exchange) to convert brackish groundwater supplies and augment river flows.
L	Change Cropping Patterns	Change cropping patterns to crops that use less water in exchange for crop subsidy. Agree with water district or landowner for payments in lieu of crop revenue and releases of saved water
M	Lower Groundwater Levels	Lower groundwater levels in the old McMillan delta area to reduce evaporation through capillary rise and plant transpiration which in turn will augment streamflow.
N	Range and Watershed Management	Eradicate mesquite and juniper from range areas tributary to river to increase river base flows. Also, thin upland forest areas (in the Sacramento Mountains) to increase mountain front recharge.
O	Cloud Seeding	Seed clouds in the Sacramento or Sangre de Cristo mountain ranges to augment precipitation.
P	Groundwater Recharge/Conjunctive Use	Use groundwater and surface water conjunctively to increase river flows over the short-term, and increase aquifer storage to supplement river base flows over the long-term.
Q	Well Field Development	Develop well field in aquifer to augment river flows.
R	Rio Hondo Flood Control	Route flood flows on the Rio Hondo to augment surface water supply.
S	Additional Metering	Additional enforcement of water right limitations on diversions and pumping to discourage over-use.
T	Evaporation Suppression	Suppress evaporation on the major reservoirs.

Table 1. Water Offset Options for Depletions to Carlsbad Project Supply

Option Desig.	Option Name	Option Description
U	Fort Sumner Area-Gravel Pit Pumping	Pump water to the Pecos River from abandoned gravel pits in the Fort Sumner area.
V	Kaiser Channel Lining	Line the Kaiser channel to save on seepage losses through the reach from Artesia to Kaiser.
W	Import Salt Basin or Capitan Reef Water	Import water from the Salt Basin or from the Capitan Reef.
X	Flash Distillation (Desalination) Power Plant	Build a flash distillation (gas-fired) power plant to desalinate brackish water; use electric sales to offset cost of distilling water.
Y	Treat Oil Field Waste Water	Treat brackish by-product water as a result of oil production; pump to river to augment supply.
Z	Renegotiate Compact-Forbearance	Renegotiate compact terms to enable purchase of water rights from farmers in the Red Bluff Irrigation District.

1.3. WOOG Evaluation Tools – A Brief Overview

WOOG evaluation tools discretized quantitative parameters, such as cost and amounts available, from qualitative, more subjective parameters such as sustainability or risk. The evaluation tools were centered on evaluation parameters. Evaluation parameters considered to evaluate offsets for CID project supply include cost, supply flexibility, salvage risk, political/social/institutional risk, amount available, proximity to CID, sustainability, time to implement, time to realize, and state-line effects. Evaluation parameters for additional water acquisition are identical except proximity to CID is replaced with proximity to the upper critical habitat for the PBNS. These evaluation parameters evolved from iterations between development of the tools and input from WOOG group members.

1.3.1. Documentation Matrices

Qualitative evaluation parameters, which include cost, variable supply, amount available, proximity, time to implement, and time to realize, are tracked in *documentation matrices*. The matrices contain both the quantitative data and cost estimates derived from report research by WOOG members. Parameters and calculations in the documentation matrix for the offset of Carlsbad Project Supply are discussed in detail in Section 3. Parameters and calculations in the documentation matrix for additional water acquisition to augment instream flows are discussed in detail in Section 8.

1.3.2. Ranking Matrices

Ranking matrices contain both qualitative evaluation parameters, which include salvage risk, political/social/institutional risk, sustainability, and state-line effects, and quantitative parameters. Quantitative parameters are ranked indirectly through *ranking criteria*, which translate quantitative ranges in the documentation matrix to ranking values on a 0 through 5 scale in the ranking matrix. Qualitative parameters are ranked directly on a 0 through 5 scale using the ranking criteria for each evaluation parameter as a framework. Ranking criteria and the ranking matrices are also discussed in detail in Section 3.

1.3.3. Option Forms

Option forms were later added to the documentation process, and provided an extension to the documentation. Most reports contained sufficient information about possible water sources to formulate an estimate for the more quantitative parameters, but assumptions were needed to properly evaluate the options. One sheet in each option form tracks these economic assumptions. Also included in the option form is a second sheet providing a brief synopsis of how the option would be implemented and any assumptions associated with that implementation. Assumptions for implementation assisted evaluation and ranking, which is also documented on the synopsis sheet. Additional discussion on option form sheets as they relate to documentation and ranking matrices for offset and additional water acquisition is found in Sections 3, 4, 8, and 9.

2. Economic Equivalence Considerations

In order to properly evaluate the cost of water for offset or additional acquisition options that have different service lives, different capital investments, and different annual operation costs, the time-value-of-money or *engineering economy* of the options must be analyzed. Engineering economy assumes that the option will be paid for by securing debt, which is a mechanism for spreading the cost of a large capital investment. Within the subject of engineering economy is the notion of *equivalence*. Steiner defines equivalence as, "…the equality of different sums considered at different times.(1996)"

2.1. Engineering Economy Calculations

Primarily, four time-value of money formulas were used to translate present and future costs into equivalent uniform annual costs. These formulas included: the single payment compound amount factor, the single payment present worth factor, the uniform series present worth factor, and the capital recovery factor. The equations are presented below:

$$F = P(1+i)^N$$ Eq. 1 Single Payment Compound Amount Factor

$$P = F\left(\frac{1}{1+i}\right)^N$$ Eq. 2 Single Payment Present Worth Factor

$$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right]$$ Eq. 3 Uniform Series Present Worth Factor

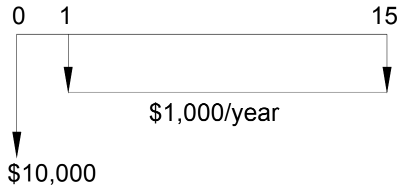
$$A = P\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right]$$ Eq. 4 Capital Recovery Factor

In the preceding formulas, *P* represents present worth in year 0 (the end of the payment period preceding the first accounting period for the investment), *F* stands for future worth of an investment, *A* represents uniform series payments per period for the life of the investment, *i* represents the interest or planning rate for financing the investment, and *N* represents the number of payment periods or the time in between present and future worth.

2.2. Equivalent Uniform Annual Series for a WOOG Option Single Life-Cycle

Each water option is investigated initially on a single life-cycle basis. For the purpose of simplicity, all payment periods are assumed to be annual, and project life is the number of payments over the life of the investment. Using equations 2 and 3, future payments, whether lump-sum or uniform annual, are translated back to present worth dollars and then summed into a total present worth. This total present worth was then converted into an *equivalent uniform annual cost*, EUAC, using the capital recovery factor (Eq. 4). One series of future lump-sum and annual payments translated into EUAC, using annual payment periods and the project life, comprises one project life cycle. A brief example for a hypothetical water option, water option A, follows.

Water option A is a 15-year investment that costs $10,000 upfront capital and $1,000/year operation and maintenance costs. The disbursements in a single life-cycle for Option A are shown graphically in Figure 1.



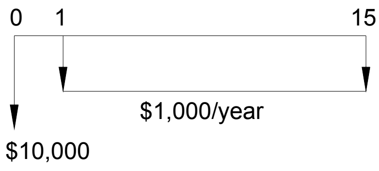
Water Option A

Figure 1. Disbursement Schedule for Water Option A.

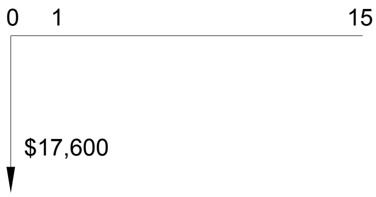
The large arrow pointing down represents the initial capital investment. Initial capital investments are typically made before any other payments on the project are made. An initial capital investment is analogous to the down payment on a car or a house. Within the timeline, the initial capital investment is represented in *year 0*, which is a distinction arising from the payments being made at the end of the payment period rather than the beginning. Year 0 is the end of the year *before* the year the first payment is made on the investment (year 1). The two arrows pointing down with the line drawn in between the points of the arrows represents the annual operation and maintenance costs at $1,000/year. The horizontal line connecting all the arrows represents time over the life of the investment from year zero to year fifteen.

In order to convert this disbursement schedule into an EUAC, we must use one of the formulas in the previous section. The interest (or planning) rate of 10% completes the needed unknowns. Since there are two different approaches to computing EUAC for the given project life-cycle, this example will demonstrate them both.

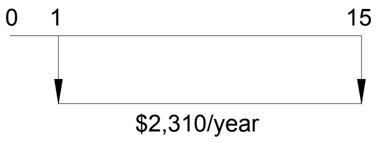
The first method converts the annual series to present worth, and then sums that value with the initial capital investment to compute the *total net present value* of the investment. Finally, the total net present value is then converted to an equivalent annual series. For the first calculation, Eq. 3, the uniform series present worth factor, is used. The total net present value is equal to $10,000 + $1,000 (1.1^15-1)/(.1*1.1^15) = $17,600. For the second calculation, converting the total net present value to an equivalent annual series, Eq. 4, which is the capital recovery factor, is used. The equivalent uniform annual series for this investment is equal to $17,600*(.1*1.1^15)/(1.1^15-1) = $2,310. The graphical depiction of the conversion from the original investment schedule is shown in Figure 2.



Water Option A - Original
Investment Schedule



Water Option A - Total
Net Present Value



Water Option A -
Equivalent Uniform
Annual Series

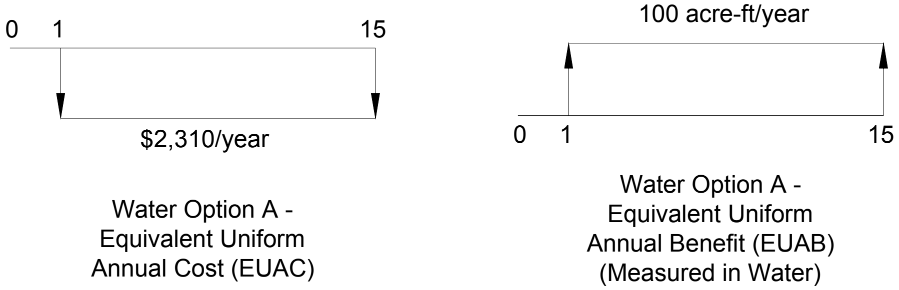
Figure 2. Converting Water Option A's Investment Schedule to an Equivalent Uniform Annual Series using Total Net Present Value.

Alternatively, the initial capital investment could be directly converted to an annual series and then combined with the two annual series. The equivalent uniform annual cost of the $10,000 capital investment is computed using Equation 4, the capital recovery factor. The calculation follows as $1,000 + $10,000*(.1*1.1^15)/(1.1^15-1) = $2,310 (per year).

2.3. Equivalent Project Life vs. EUAC

Originally, water offset options were to be compared using "equivalent project life" (USBR, 2003). After consideration for infinite replacement of a given water offset option, "equivalent uniform annual cost" or EUAC was used instead of equivalent project life (Piper, 2003).

Consider the following example. Option A produces 100 acre-ft/year. In other words, Option A has an equivalent uniform annual benefit of 100 acre-ft/year. Figure 3 shows the equivalent uniform annual cost and benefit diagrams for the life-cycle of Option A.

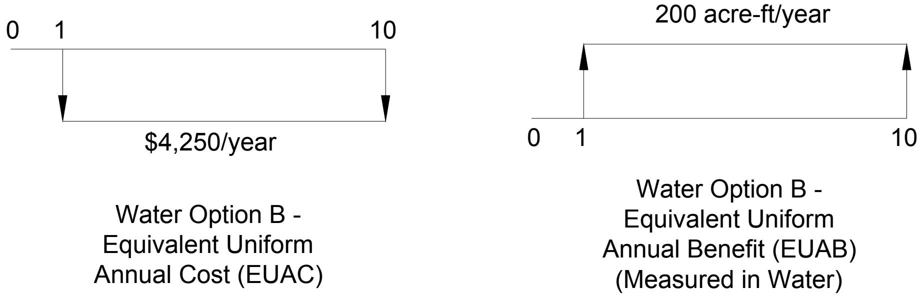


Water Option A - Equivalent Uniform Annual Cost (EUAC)

Water Option A - Equivalent Uniform Annual Benefit (EUAB) (Measured in Water)

Figure 3. Equivalent Uniform Annual Costs and Benefits for Water Option A.

Water Option B produces 200 acre-ft/year, while costing $20,000 of initial capital with $1,000 per year of operation and maintenance costs. Option B has a service life of 10 years. Calculating the EUAC, again with Equation 4—the capital recovery factor, yields $1,000 + $20,000*(.1*1.1^10)/(1.1^10-1) = $4,250 (per year). Figure 4 shows the equivalent uniform annual cost and benefit diagrams for the life-cycle of Option B.



Water Option B - Equivalent Uniform Annual Cost (EUAC)

Water Option B - Equivalent Uniform Annual Benefit (EUAB) (Measured in Water)

Figure 4. Equivalent Uniform Annual Costs and Benefits for Water Option B.

Given the two options and their various parameters, which option is the most economical? First, equivalent project life will be used to show which option is the most economical. 10-years will be the equivalent project life. This means that Option A must be translated into a 10-year project life. First, the annual series is converted to present worth using the uniform series present worth factor—Equation 3. The previous result was $17,600. Converting this to a 10-year annual series requires Equation 4, which yields $17,600*(.1*1.1^10)/(1.1^10-1) = $2,860 (per year). The benefit must also be translated to be equivalent to the 10-year project life. This requires assigning an arbitrary dollar value for the benefit of water. For this exercise, the benefit will be \$100/acre-ft. Multiplying \$100/acre-ft by the amount of water (100 acre-ft/year) yields an equivalent uniform annual benefit (EUAB) of \$10,000/year. Converting the uniform annual benefit to a total net present benefit requires the uniform series present worth factor, and yields \$10,000*(1.1^15-1)/(.1*1.1^15) = \$76,100. Converting the total net present benefit to the equivalent project life, using the capital recovery factor, yields \$76,100* (.1*1.1^10)/(1.1^10-1) = \$12,400 (per year). The benefits of Option B must still be converted to dollars. Using the assignment of \$100/acre-ft, Option B has an EUAB of \$20,000.   Figure 5 graphically depicts the conversion of Option A's 15-year cost life-cycle to a 10-year cost life cycle. Figure 6 shows the transformation of Option A's 15-year benefit life-cycle to a 10-year benefit life-cycle.

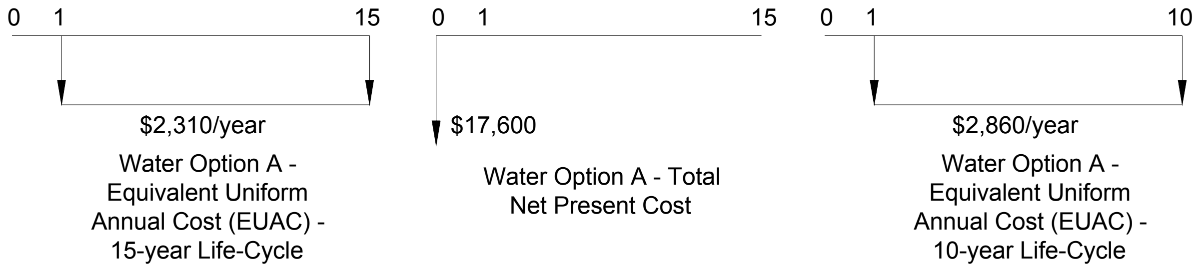


Figure 5. Conversion of Option A's 15-year cost schedule to a 10-year schedule.

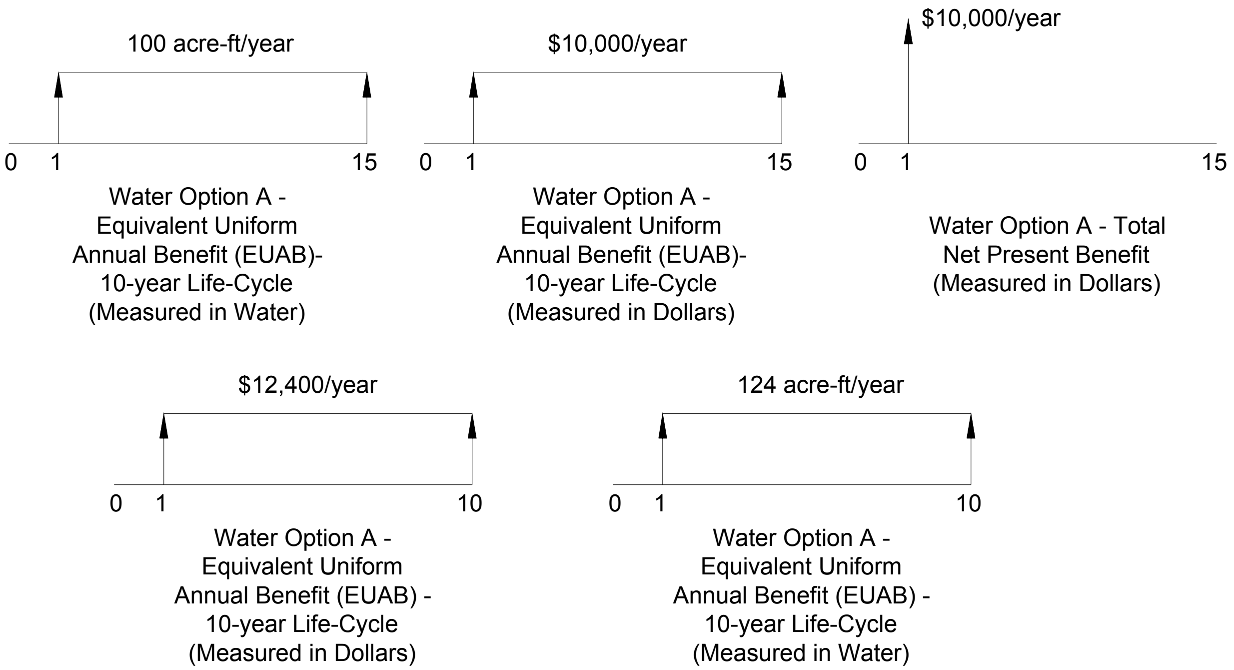


Figure 6. Conversion of Option A's 15-year benefit schedule to a 10-year schedule.

Since both series' costs and benefits are now in a 10-year cycle they can be directly compared. Figure 7 shows the 10-year life-cycle costs and benefits of Options A and B with final annual costs reduced to dollars per acre-ft.

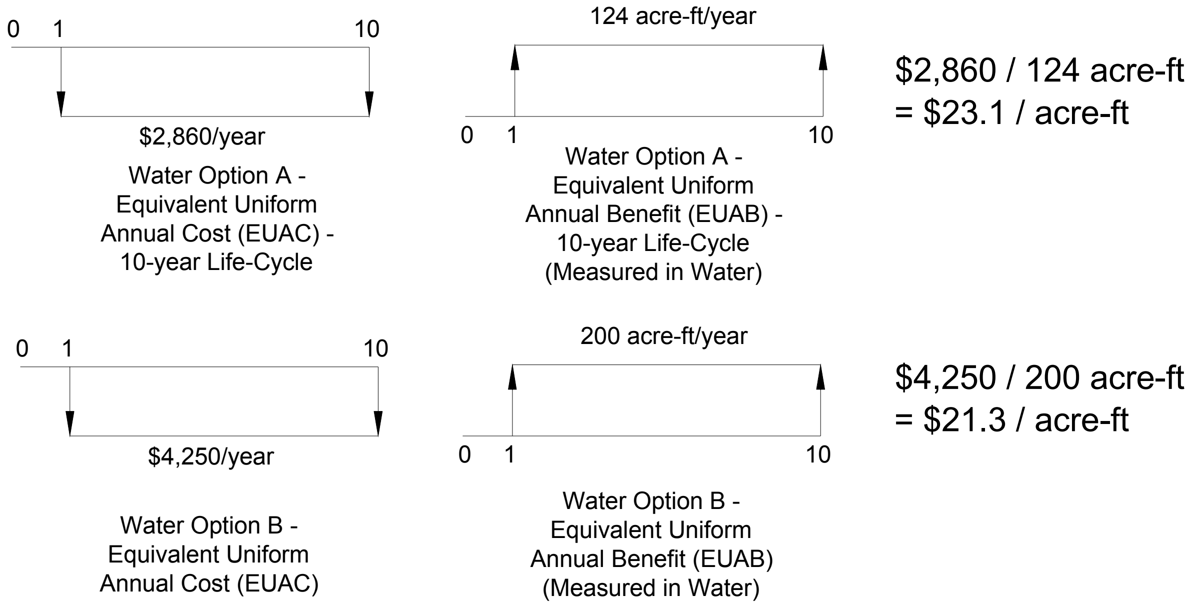


Figure 7. Comparison of Water Options A and B, with final dollar per acre-ft unit costs.

An alternative methodology to using equivalent project life, is direct use of unit costs developed from EUAC. Returning to Figures 3 and 4, and computing the final per-unit cost of Option's A and B arrives at the same result as shown in Figure 7. Option A, from figure 3, has and EUAC of $2,310/year, a benefit of 100 acre-ft/year; and a unit cost of $23.1 per acre-ft; precisely what is shown in Figure 7. Similarly, from Figure 4, Option B has an EUAC of $4,250/year with a benefit of 200 acre-ft/year. The unit cost for Option B is $21.3/acre-ft, which is equal to the amount shown in Figure 7. From this demonstration, it is clear that the concept of equivalent uniform annual cost serves to determine the unit cost of the water resource, and does not require additional economic considerations for project life. From an analytical standpoint, conversions using an equivalent project life can distort benefits. Option A yields 100 acre-ft/year; however, when Option A is translated to a 10-year cost cycle its *representative* benefit is 124 acre-ft/year. This does not mean that Option A can produce 124 acre-ft/year.

2.4. Infinite Replacement

Considering the purposes and needs of this EIS, it is probable that water offsets must be permanent solutions. This permanent solution implies infinite replacement will be needed for any type of water option. Since it was demonstrated that EUAC is just as resilient as alternative methods in determining the final unit cost of water, EUAC will be used again for infinite replacement. Consider the diagram shown in Figure 8. Option A's life-cycle is now repeating through time.

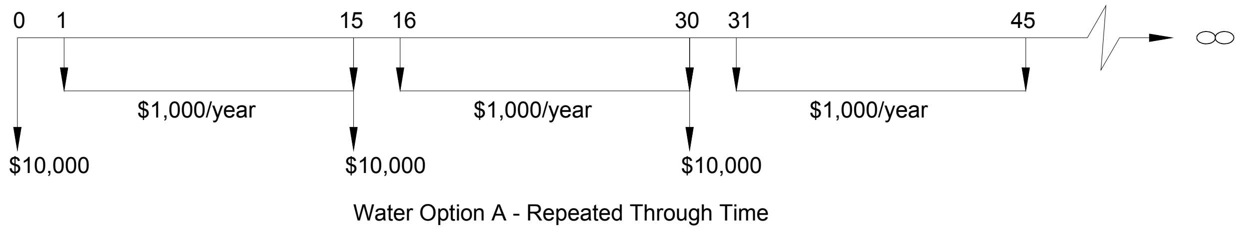


Figure 8. Water Option A costs repeated through time.

The total net present cost of the first life-cycle of Option A in year zero is $17,600. What about the cost of the second life cycle at the beginning of year 16? Again using the uniform series present worth factor, the second life cycle cost at the beginning of year 16 is equal to $10,000 + $1,000*(1.1^(30-15)-1)/(.1*1.1^(30-15)) = $17,600. The second life-cycle cost at the beginning of year 16 is equal to the first life-cycle cost in year zero. The third life-cycle cost at the beginning of year 31 is also equal to the first life-cycle cost in year zero. Figure 9 shows the repeating life-cycle costs for Option A with the costs transformed into equivalent uniform annual costs. Figure 10 shows the repeating life-cycle benefits for Option A, which are already an equivalent uniform series.

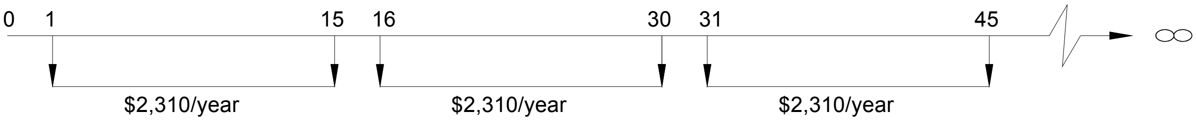


Figure 9. Water Option A – EUAC Repeated Through Time.

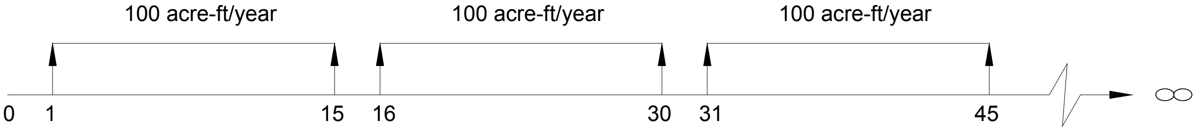


Figure 10. Water Option A –EUAB Repeated Through Time

Looking at both figures, it is apparent that in any given year the cost of the option is $2,310 and the benefit is 100 acre-ft/year. Again, the unit cost is $23.1/acre-ft.

The preceding sections both demonstrate that simply calculating the unit-cost of water from the equivalent uniform annual cost, which is derived from the original disbursement schedule for the option, will account for both the unequal service lives of different options and the infinite replacement of those options.

2.5. Inflation

Inflation is considered in the formulation of the government planning rate for water projects. Classical economic analysis implementing the inflation rate with the current interest rate for investment was not performed for this reason.

3. WOOG Documentation Matrix for Offsetting Depletions to Carlsbad Project Supply

The matrix is the primary tool utilized by the WOOG in their evaluation of alternative water sources. The WOOG utilizes four matrices for their documentation, screening and sorting efforts. Two matrices are for documentation, screening and sorting of CID offset options and two matrices are used for looking at additional water acquisition options. This section covers the CID offset option elements and economic analyses as documented in the *CID Offset Documentation Matrix*. This matrix is shown in Appendix A as Table 1.

3.1. Research, Investigation, and Central Documentation of Offset Options

The first step in the WOOG's ranking of offset options was research by group members. Research tasks addressing each of the options shown in Table 1 were assigned to WOOG group members. Most group members wrote summary reports or memoranda presenting pertinent information concerning each option.

Alternatively, some group members assembled the research and provided it directly to the WOOG to formulate estimates and document the information. Report parameters were assembled and centrally documented in the CID Offset Documentation Matrix, which is discussed in the next section.

3.2. CID Offset Documentation Matrix Parameter Summary

The CID Offset Documentation Matrix contains several different parameters. Some of the parameters were merely used for documentation while other parameters are used throughout the ranking process. Occasionally parameters were listed on the documentation matrix but were not used since they were less quantitative in nature. These parameters were retained for completeness and as a placeholder for any quantitative information that became available. Parameters contained in the WOOG ranking matrix include:

- **ID:** Arbitrary identification code for each primary option set (letters) and subsets (numbers).
- **Description:** Short descriptive name for the option.
- **Lead Reviewer:** Lead researcher for exploring logistics of options. Responsible for getting sufficient information to the WOOG for the option to be ranked or eliminated.
- **EUAC:** Equivalent Uniform Annual Cost ($/year) for the given option. Derived from upfront capital cost, operation and maintenance cost, government planning rate (interest rate), project life, and amount available.
- **Supply flexibility:** Qualitative parameter; column in documentation matrix was left as placeholder for completeness. Actual timing ranking is performed in the ranking matrix.
- **Salvage Risk:** Qualitative parameter; column in documentation matrix was left as placeholder for completeness. Actual salvage risk ranking is performed in ranking matrix.
- **Political, Social, Legal, and Institutional Risk:** Qualitative parameter; column in documentation matrix was left as placeholder for completeness. Actual political risk ranking is performed in the ranking matrix.
- **Amount Available:** Estimated volume amount per year (acre-ft/year), at the source, that the offset option is projected to generate.
- **Proximity to CID:** Documents river distance (by total river mile) from CID.
- **Sustainability:** Qualitative parameter; column in documentation matrix was left as placeholder for completeness. Actual sustainability ranking is performed in the ranking matrix.
- **Time to Implement:** Amount of time needed (years) to resolve all legal, financial, and infrastructure related issues.
- **Time to Realize:** Time between completion of the project (end of time to implement) and the actual realization of offset water.
- **Willing Seller:** Originally derived for water right purchases and land retirement; willing seller indicates that the water rights were not condemned by a governmental entity. Since it was determined that only willing sellers would be considered this categorization became moot. WOOG options with a “NO” entry for willing seller are not viable options.
- **Upfront Capital Cost:** The amount of money needed at the start of the investment ($). All initial capital investments are considered to start at the beginning of the first year (also termed year zero). Used to compute total net present value of options, and subsequently used to compute EUAC. See Section 2 for further information on engineering economy calculations.
- **Operation & Maintenance:** Annual investment costs ($/year) for the option. Includes more than O&M for some options such as power generation and tax credits. Used to compute total net present value of options, and subsequently used to compute EUAC. See Section 2 for further information on engineering economy calculations.
- **Project Life:** The life of the project (years) before replacement is needed.
- **Total Cost (NPV):** The total net present value (in year zero) of the option including all upfront capital costs, annual maintenance costs, and any other costs or benefits associated with the option. See Section 2 for further information on engineering economy calculations.
- **Parameter Comments:** Used to note variations of some parameters, pertinent assumptions made about the option, or notes concerning elimination of the option.

In addition to the parameters categories, the documentation matrix also contains some parameter color coding. Table 2 shows the final color coding for the parameter entries of the CID Offset Documentation Matrix. Mr. Phil Soice of Southwest Water Consultants, and Mr. Tomas Stockton of Tetra Tech, Inc. were responsible for assembly, analysis and estimation of any parameters for the CID Offset Documentation Matrix; subsequently, their names are reflected in the color legend for estimated parameters.

Table 2. CID Offset Documentation Matrix - Color Legend

⬜ -Base Parameter from report/investigation/or derived from alternative source
🟥 -Parameter estimated by Stockton
🟩 -Original costs annualized with 5.875% planning rate to reflect time value of money by Stockton
🟪 -Options eliminated
▨ -Subjective parameter-not determined in this matrix.
🟦 -Parameter estimated by Soice

In addition to the color coding for parameter estimation, option elimination, or engineering economy calculation, coding was established for the more qualitative parameters that were not used in the matrix, but were left in for consistency.

3.3. Sub-categories of Offset Options

Original offset options were divided into sub-categories to evaluate different input parameters that are associated with the option. For example, on farm conservation could be implemented in a number of places including the Fort Sumner Irrigation District (FSID), the Pecos Valley Artesian Conservancy District (PVACD), or CID itself. Each of these inputs was divided into sub-categories since differing irrigation districts would affect input parameters such as proximity to CID and amount available. A brief description of options containing sub-category options and why they were divided follows:

- **On Farm Conservation (A):** Differing irrigation districts have different proximities to CID and also have different amounts available based on irrigated acreage.
- **Canal Refurbishing (B):** Two irrigation districts have canals. Multiple input parameters include proximity to CID and amount available.
- **Hernandez Idea (C):** Multiple flow rates for pump operation leads to different costs and amounts to recirculate.
- **Water Right Purchase (D):** Water right purchase options contain two tiers of sub-categories. The first tier is options that have projected prices based on time regression of prices from the 1990's. The second tier are options that are additionally inflated (after the time regression) by 40%; these options are indicated with an "X" following their designation. Also, water right purchase options are divided by district, and type (surface, shallow groundwater, and artesian groundwater), which affects the amount available for each sub-category option.
- **Water Right Lease (E):** Water right lease options are divided by district and type (surface, shallow groundwater, and artesian groundwater), which affects the amount available for each sub-category option.
- **Riparian Vegetation Control (F):** Three subsets were studied including removing Salt Cedar, replacing Russian Olive trees with Cottonwood trees, and replacing Kochia weed on the old McMillan delta with rye grasses. All of these sub-categories contained variations in almost every category.
- **Desalination (K):** This option contained two different assumptions for feed water total dissolved solids. The first sub-category assumes normal brackish range TDS (~10,000 mg/L) while the second assumes feed water closer to the salinity of ocean water TDS (~35,000 mg/L).
- **Change Cropping Patterns (L):** Cropping pattern changes were all applied to the CID, but were split into different sub-categories using the input parameters from three different replacement crops or the average cost of all three replacement crops. The available amounts for these crops types were later revised since original saved amounts used a large total farm diversion per acre (4.5'/acre) that included water stacking practices within the CID. It was anticipated that these stacked water amounts over the full allotment (3.7'/acre) would not be available as saved water. Subsequently, the numbers

were reduced and the crop names were relabeled to relative crop water use amounts. This change is only reflected in the final WOOG lists developed for ranking. Other related WOOG media including the ranking process itself were not revised to reflect this change since it was considered inconsequential to the ranking process.

- **Range and Watershed Management (N):** This option was split into two tiers of sub-categories. The first tier distinguished range and watershed management in the lower watershed, such as management of vegetation in the adjacent uplands to the Pecos River, from upper watershed management, which is the management of the forest in the headwaters of the Pecos River or the headwaters of the Rio Hondo. The second tier divisions depend on the sub-category for the first tier. Lower watershed management recognized range divisions indicated by the researcher for salvage (upper, lower, and average amounts available) and upper watershed management was split into the range of costs associated with it (upper limit costs, lower limit costs, and average costs).
- **Develop Well Field (Q):** Well field development was split into two sub-categories depending on the location of the well field, which ultimately affected cost parameters.
- **Evaporation Suppression (T):** This option was also divided into two tiers of sub-categories. The first tier divided new evaporation suppression methods from old evaporation suppression methods, which varied in cost. Additional sub-categories were then created for the aggregate of all the reservoirs, and for the individual reservoirs: Santa Rosa, Sumner, and Brantley.
- **Desalination/Cogeneration Power Plant:** This option was divided into nine categories with three tiers to provide adequate perspective on the energy prices inherent with the option. The first tier analyzed water production without any power sales, the second tier examined water production coupled with power sales to the industrial sector, and finally the third tier examined water production coupled with power sales to all sectors. Each tier contains three sub-categories. The first sub-category uses energy prices from 2002. The second sub-category uses energy prices from the past three years and the third sub-category uses energy prices from the last 10-years.
- **Oil Field Production Well Wastewater:** This option contained two sub-categories for finished (product) water TDS. One assumes more rigorous treatment of the water with product water TDS less than 500 mg/L while the other assumes product water TDS less than 5000 mg/L.

The WOOG investigated a total of 80 combined categories and sub-categories of options.

3.4. Quantitative Data in the Offset Option Forms

In addition to storing summary quantitative data in the documentation matrix, detailed quantitative data are also stored in the option forms. The second sheet in the each option form is the EUAC computation sheet which lists data from the original research report along with any assumptions in the analysis. Figure 1 is a copy of the second page of the option form showing the different elements incorporated. The following fields are included on the EUAC computation sheet of the options forms:

- **Option Designation:** Option letter and sub-category number of the option.
- **Option Name:** Short descriptive name for option (same as “description” in documentation matrix).
- **Principle Investigator:** WOOG member responsible for memorandum or research concerning option.
- **EUAC:** Equivalent uniform annual cost (in dollars per acre-ft) of the option as calculated using the engineering economy principles discussed in Section 2.
- **Initial Capital Cost in year 0:** Initial capital cost (in dollars) of the option at the beginning of the first year (year 0).
- **O & M Costs:** Any annually recurring costs (in dollars) associated with the option.
- **Project Life:** The total time (years) the project will last before it requires complete replacement (new capital investment).
- **Discount Rate:** The planning rate used by the Bureau of Reclamation for water projects; currently the rate is 5.875%.
- **Total Present Worth:** The total amount of money the project is worth (in dollars) if all of the investment is considered in year zero.
- **Notes and Reference Numbers:** Contains data from research and reports along with any assumptions made for EUAC calculation.

Water Offset Options Group (WOOG) Option Processing Form

Option Designation: Y-2
Option Name: Oil Field Production Well Waste Water-High TDS

Principle Investigator: Sims

General Location: Vicinity of Brantley Reservoir
River Mile Location: close to 469

Water Salvage Amount (acre-ft/year): 9030

EUAC ($/acre-ft): $1,687.17

Initial Capital Cost in year 0: $ 31,599,000

O & M costs: ($ each year-over project life) $ 7,879,000

Project Life: (years) (before replacement is needed) 10

Discount Rate: (fixed for all options) 0.05875

Total Present Worth: ($ in year 0) $89,934,105.94

Notes and Reference Numbers:

Total Capital Cost: $14,315,000 raw water pumping and piping; $5,646,000 residual disposal; $11,638,000 delivery system to Pecos below Brantley Dam

Annual O&M: $480,000 raw water pumping and piping; $6,429,000 residual disposal; $970,000 delivery system operation costs

Additional $1342/acre-ft treatment cost.
$1000/acre-ft tax credit

Figure 11. WOOG Option Processing Form—EUAC Computation Sheet

4. WOOG Ranking Matrix for Offsetting Depletions to Carlsbad Project Supply

The CID Offset Ranking Matrix is the final tool in the documentation and ranking process. Certain Offset Options were truncated prior to ranking due to a need and desire to limit the analysis to those options that reasonably provide the needed offsets. Quantitative parameters are translated into ranks from the documentation matrix using ranking criteria. Qualitative parameters are ranked directly using the guidance of the ranking criteria. The following sections explain the CID Offset Ranking Matrix and its components, including truncated option and both qualitative and quantitative ranking criteria. In addition, the following sections give a history for the ranking process of CID offset options along with a description of the ranking sheet portion of the option forms.

4.1. Truncated Options

Ten Offset Options were truncated after preliminary investigation of their merits and were not further analyzed. These options were duplicates of other options, options without offset capabilities or options that did not meet offset needs. Options B, C-1, C-2, C-3, C-4, G, J, M, P and R were truncated from receiving further analysis. Option B, renovation of drains in the Roswell Area, was eliminated from further consideration because private water rights to drain water exist, and it is questionable if the supply could be sustained. It appeared that the water supply may have been a relatively small one-time volume of water and that the water source may not be continuous. Option C-1, C-2, C-3 and C-4 were variations on an option to re-circulate water in the Pecos River to create flow for the shiner. This option actually causes depletion of Pecos River flows and does not offset depletions. These options were forwarded to the Alternative Development Group for possible consideration as an alternative method of providing water for the shiner. Options M and P included development of groundwater resources as a buffer to the variability of surface water, and were considered duplicative of Options Q-BV and Q-SR which also developed groundwater supplies. Options G and R were projects by the Corps of Engineers that were completed before the end of the EIS and whatever offset benefits that were created were no longer available for implementation. Finally, option J envisioned moving Carlsbad Project storage upstream to benefit from the reduced evaporation at higher elevations. However, it was concluded that permitting new conservation storage was not likely because of compact restraints, and transferring conservation storage upstream caused the lower reservoirs to spill more often because of side inflows to the Pecos River. Losses to spills more than offset the reduced evaporative losses. For these reasons ten,offset options were truncated without further analysis.

4.2. Quantitative Parameters and Ranking Criteria for Offset Options

Quantitative parameters in the ranking process include equivalent uniform annual cost (EUAC), amount available, proximity to CID, time to implement, and time to realize. Each qualitative parameter is also linked to the ranking matrix with ranking criteria. The ranking criteria translate the quantitative numbers from the documentation to a 0 through 5 scale to be inserted in the ranking matrix.

The following tables, Tables 3-7, detail the ranking criteria for the quantitative parameters. Included with the tables is a brief description of how the ranking criteria are applied to the parameters in the documentation matrix in order to translate values into ranks.

Table 3. Cost Ranking Criteria Table

Annual uniform cost per acre-ft available each year.	
Rank	EUAC ($/acre-ft/year), less than or equal to dollar amount:
5	50
4	100
3	500
2	1000
1	2000
0	10000

Table 4. Amount Available Ranking Criteria Table

Greater than or equal to acre-ft/year:	
Rank	Amount (acre-ft/year)
5	20000
4	15000
3	10000
2	5000
1	1000
0	0

Table 5. River Mile Ranking Criteria Table

Based on where on the river the water would be realized or where the outfall would be located if the offset source is not adjacent to the river. Additional criteria addresses effected compact calculations or a downstream location from Avalon Reservoir.		
Rank	River Mile	Description/Other Conditions
5	≤479	Less than or equal to RM 479, on CID, or very near CID lands.
4	≤586	Less than or equal to RM 586 (below Acme)
3	≤709	Less than or equal to RM 709 (below Sumner)
2	≥709	Greater than RM 709 (above Sumner) not subject to compact calculations.
1	≥709	Greater than RM 709 subject to compact calculations.
0	N/A	Below Avalon

Table 6. Time to Implement Ranking Criteria Table

Based on time to resolve all legal, financial, and infrastructure related issues to implement option.	
Rank	Less than or equal to (years):
5	1
4	2
3	5
2	7
1	9
0	Greater than 9

Table 7. Time to Realize Ranking Criteria Table

Time before water is physically realized after offset option is implemented. Measured from end of time to implement.	
Rank	Less than or equal to (years):
5	1
4	5
3	10
2	15
1	20
0	Greater than 20

4.3. Qualitative Parameters and Ranking Criteria for Offset Options

Some ranking parameters were more qualitative. These parameters included supply flexibility; salvage risk; political, legal, social, and institutional risk; sustainability, along with stateline effects. The WOOG structured ranking criteria for these parameters to be as objective as possible; however, the qualitative parameters still were partially subjective.

Tables 8-12 detail the qualitative ranking criteria. Also included with the table is a short description of the purpose of the parameter and how it applies to the ranking of offset options.

Table 8. Supply Flexibility Ranking Criteria Table

Using average offset = 5000 acre-ft or average yield (of the given amount available) and additional merit achieved by having the ability to take 3 times that amount on a planned basis. Based on how much water is available consistently.	
Rank	Timing
5	Provides 3x the average offset amount consistently from year to year.
4	Provides 3x the average offset amount with random yearly timing.
3	Provides average offset amount consistently from year to year.
2	Provides average offset amount with random yearly timing.
1	Provides below-average offset amount consistently from year to year.
0	Provides below-average offset amount with random yearly timing.

Table 9. Salvage Risk Ranking Criteria Table

Evaluated by the probability of whether salvage will occur.	
Rank	Relative degree of risk:
5	Certain salvage will occur (very low risk)
4	
3	
2	
1	
0	Salvage very uncertain (very high risk)

Table 10. Political, Legal, Social, and Institutional Risk Ranking Criteria Table

Encompasses risks associated with funding, popular opinion (public approval), permitting, political climate, and administration.	
Rank	Relative degree of risk:
5	Very low risk
4	
3	
2	
1	
0	Very high risk

Table 11. Stateline Effects Ranking Criteria Table

Ranked by whether offset option will have a negative, positive, or no effect on state-line compact deliveries.	
Rank	Effect
5	Positive effect to stateline
2.5	No Effect
0	Negative Effect

Table 12. Sustainability Ranking Criteria Table

Evaluated by the probability of whether salvage is sustainable.	
Rank	Relative degree of sustainability:
5	Infinitely sustainable resources
4	Somewhat sustainable over the long-term
3	Somewhat sustainable over the short-term, random periodic availability over the long-term
2	No short-term sustainability, random periodic availability over the long term
1	No short-term sustainability, will not be available again over the long term
0	One use – cannot be renewed

4.4. Ranking of Offset Options

Ranking of offset options was first accomplished by a trial run with the entire WOOG. After ranking three options, the WOOG group elected to have *ranking officers*. The ranking officers that were chosen by the group were Mr. Phil Soice of Southwest Water Consultants, and Mr. Tomas Stockton of Tetra Tech, Inc. Mr. Stockton made the first analysis using the ranking process and returned to the group with his results. Mr. Stockton showed the initial results to the WOOG, suggesting some minor modifications to the ranking criteria. At that time, the New Mexico Interstate Commission requested adding an additional criterion to cover “state-line effects” and for completeness the effects on the shiner were included as “PBNS effects”. After the final ranking by the ranking officers, the criteria were once again revised and the “PBNS effects” criteria were eliminated because a separate analysis for additional water for the shiner was instituted. The preceding section represents the final criteria recommended by the WOOG for the ranking of offset options.

Ranking by the officers was accomplished independently although some revisions occurred following the review of the ranking exercises accomplished by both officers. Mr. Soice had the benefit of seeing Mr. Stockton’s initial ranking, and Mr. Stockton had the benefit of seeing Mr. Soice’s initial ranking before finalizing their rankings. Given some of the remaining ambiguity in the qualitative ranking criteria, ranking officers were still left with some judgment calls. The completed ranking matrices, two from each officer (one for offset options and one for AWA), are shown as Tables A.2 ,A.3, A.5, and A.6 in the Appendix. Final ranking tallies were summed together and then sorted by score. The ranking matrices also allowed for “weighting” factors, which are discussed in Section 6. Options with equal scores are then ranked by EUAC, with the lower cost option receiving the higher rank. The final results of the ranking of CID offset options, without weighting factors applied, are shown in Table 13.

Table 13. Final Standings for Equally Weighted Ranking of CID Offset Options – Combined Ranking from both Officers

Rank	Desig-nation	Option Name/Description	Combined Total Score (unitless)	EUAC ($/acre-ft/year)
1	Q1-SR	Develop Well Field Seven Rivers	77.0	290
2	Q1-BV	Develop Well Field Buffalo Valley	76.0	264
3	D-1B	Water Right Purch Sur Roswell Area	74.0	99
4	W	Water imprt. From Salt Bas. or Cap. Reef	74.0	620
5	E-1B	Water Right Lease Sur Roswell Area	73.0	91
6	D-2A	Water Right Purch Shallow PVACD	72.0	67
7	D-2AX	Water Right Purch Shallow PVACD	72.0	94
8	D-1A	Water Right Purch Sur FSID	72.0	99
9	D-1BX	Water Right Purch Sur Roswell Area	72.0	139
10	L-3	Change Cropping Patterns (CID)-Small Grain	71.5	128
11	E-2A	Water Right Lease Shallow PVACD	71.0	69
12	E-1A	Water Right Lease Sur FSID	71.0	91
13	D-1C	Water Right Purch Sur CID	71.0	99
14	X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	70.0	-1164
15	N-6	Range and (Upper) Watershed Management-no cost	70.0	-378
16	X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale)	70.0	-236
17	D-3A	Water Right Purch Artesian PVACD	70.0	84
18	E-1C	Water Right Lease Sur CID	70.0	91
19	D-1AX	Water Right Purch Sur FSID	70.0	139
20	D-3AX	Water Right Purch Artesian PVACD	69.0	118
21	D-1CX	Water Right Purch Sur CID	69.0	139

Table 13. Final Standings for Equally Weighted Ranking of CID Offset Options – Combined Ranking from both Officers

Rank	Desig-nation	Option Name/Description	Combined Total Score (unitless)	EUAC ($/acre-ft/year)
22	F-1	Rip. Veg. Control-Salt Cedar	68.0	27
23	E-3A	Water Right Lease Artesian PVACD	68.0	106
24	F-2	Veg. Control-Kochia Eradication	67.0	13
25	E-2B	Water Right Lease Shallow CID	66.5	69
26	L-2	Change Cropping Patterns (CID)-Cotton	66.5	175
27	S	Additional Metering	66.0	16
28	A-5	Canal Refurbishing-CID	66.0	44
29	N-5	Range and (Upper) Watershed Management-prob. cost	66.0	482
30	K-1	Desalinization-Lower Limit Cost	66.0	652
31	D-2B	Water Right Purch Shallow CID	65.5	67
32	D-3B	Water Right Purch Reef CID	65.5	84
33	D-2BX	Water Right Purch Shallow CID	65.5	94
34	D-3BX	Water Right Purch Reef CID	65.5	118
35	L-1	Change Cropping Patterns (CID)-Ave. All Crops	65.5	144
36	I	Import Canadian River Water	65.5	285
37	A-3	On Farm Conservation-CID	65.0	50
38	Y-2	Oil Field Production Well Waste Water-High FW TDS	65.0	1687
39	E-3B	Water Right Lease Reef CID	64.5	106
40	L-4	Change Cropping Patterns (CID)-Corn	64.5	147
41	X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	64.0	862
42	K-2	Desalinization-Upper Limit Cost	64.0	1639
43	V	Kaiser Channel Lining	63.0	180
44	Y-1	Oil Field Production Well Waste Water-Low FW TDS	63.0	3188
45	T-1	Evaporation Suppresion-Old Methods	62.3	100
46	A-4	Canal Refurbishing-FSID	62.0	3
47	N-1	Rng. And Watershed Management-Upper Limit	62.0	6
48	U	FS Area Gravel Pit Pumping	62.0	9.5
49	N-2	Rng. And Watershed Management-Average	62.0	10.1
50	Z	Renegotiate Compact-Forebearance	62.0	145
51	N-4	Range and (Upper) Watershed Management-high cost	62.0	1134
52	X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	62.0	1484
53	O	Cloud Seeding	61.0	1
54	A-1	On Farm Conservation-FSID	60.0	96
55	X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	60.0	2222
56	X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	60.0	3082
57	X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	60.0	7026
58	X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	60.0	7884
59	X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	60.0	8965
60	T-1C	Evaporation Suppresion-Old Methods (Brantley)	59.0	100
61	F-3	Replace Russian Olive trees with Cottonwood trees	58.0	51
62	N-3	Rng. And Watershed Management-Lower Limit	56.0	57
63	A-2	On Farm Conservation-PVACD	54.0	216
64	T-1B	Evaporation Suppresion-Old Methods (Sumner)	51.0	100

Table 13. Final Standings for Equally Weighted Ranking of CID Offset Options – Combined Ranking from both Officers

Rank	Desig-nation	Option Name/Description	Combined Total Score (unitless)	EUAC ($/acre-ft/year)
65	T-1A	Evaporation Suppresion-Old Methods (Santa Rosa)	49.0	100
66	T-2	Evaporation Suppresion-New Research	47.3	3
67	T-2C	Evaporation Suppresion-New Methods (Brantley)	44.0	3
68	T-2B	Evaporation Suppresion-New Methods (Sumner)	36.0	3
69	T-2A	Evaporation Suppresion-New Methods (Santa Rosa)	32.0	3
70	B	Drain Construction	Elim.	0
71	C-1	Hernandez Idea-10 cfs	Elim.	3516
72	C-2	Hernandez Idea-25 cfs	Elim.	2198
73	C-3	Hernandez Idea-50 cfs	Elim.	1403
74	C-4	Hernandez Idea-90 cfs	Elim.	1000
75	G	Acequia Improvements	Elim.	28
76	H	Pump Supplemental Wells	Elim.	0
77	J	Res. Entitlement Storage Flexibility	Elim.	0
78	M	Lower Groundwater Levels	Elim.	0
79	P	GW recharge/conjunctive use	Elim.	0
80	R	Rio Hondo Flood Control	Elim.	0

4.5. Qualitative Ranking for Offset Options in the Option Forms

In addition to the documentation in the ranking matrices, option forms also contain a ranking sheet. The ranking sheet gives a brief synopsis of how the ranking officers assumed the option would be implemented. Also contained on the ranking sheet are ranking columns showing the assigned ranks and reasoning the ranking officers had for assigning the ranks. The ranking sheet also contained listings of the technical researcher/report writer, the unanimous agreement of the WOOG, dissenting opinions, and general comments. This sheet is shown in Figure 12.

Commentary concerning the ranking is listed in black if both officers had the same conclusion concerning the ranking of that particular parameter for the option in question. Otherwise, Mr. Soice's comments and ranking numbers are all listed in blue font and Mr. Stockton's comments and ranking numbers are all listed in green font.

Water Offset Option V

Description of Option:

Line Kaiser Canal

The Kaiser Channel is an artificial, unlined canal traversing the old McMillan lakebed delta for 13 miles. Losses through this section of the Pecos river were estimated at 10,600 acre-feet during 1998. Adjusting the loss calculation for surface evaporation which would continue even with lining, the net loss from the Kaiser Channel for this 13 mile section was 9,600 acre feet per year. Some of this seepage may reappear in the Pecos river, but for this analysis all seepage was considered consumed. This option would line this 13-mile reach of the channel, making the salvaged water available for CID.

Technical Report Available? Yes
Author of Technical Report? Stockton
Unanimous Agreement of WOOG?
Dissenting Opinion?

Important Comments:

Ranking Criteria			Phil Soice WOOG Criteria Rank	Tom Stockton WOOG Criteria Rank
1)	Cost		3	3
	See Option Processing Form			
2)	Timing		3	2
	Consistent			
	Average assumed offset amount provided inconsistently (varies with streamflow)			
3)	Offset Risk		4	5
	Seepage may have reached Pecos river anyway			
	Seepage most likely consumed on McMillan Delta and old lakebed			
4)	Political Risk		2	0
	Capital intensive			
	Capital intensive and environmentally unpopular ("river paving")			
5)	Amount Available		2	2
	9600 afy			
6)	Close to CID		5	5
	River Mile 479			
	Concur, one end is at RM479			
7)	Sustainable		5	4
	Indefinitely			
	Concrete channel will require maintenance, sediment may become a problem			
8)	Time to Implement		3	0
	Less than 5 years			
	Greater than 9 years			
9)	Time to Realize		5	5
	Savings realized in same year			
10)	Benefit to State Line		2.5	2.5
	Little or no effect on state line			
	Equivalent Uniform Annual Cost	$180/afy		
	Total Score		34.5	28.5

Figure 12. The Ranking Sheet portion of the Option Form.

5. WOOG Maximum Offset with Respect to Alternative Screening

The WOOG addressed another work item that pertained to the screening of alternatives developed in this EIS. The Alternative Development Group for the ongoing Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement requested WOOG to provide a value for a maximum offset amount. This request would be used by the Alternative Development Group for the purpose of screening options based on water available for offset.

The WOOG responded with the following, which is quoted from their memorandum to the Alternative Development Group:

> "The WOOG did not determine *maximum offset amounts* for the following reasons:
>
> - the WOOG's members were reluctant to set arbitrary limits on the amount of water that is available to offset options for the PBNS,
> - the WOOG does not know the availability of funds or the reasonableness of their expenditure for offset options,
> - the WOOG's members all share the same perspective that instream flow requirements for the PBNS should be determined initially based on biological considerations, followed by a determination of depletions from hydrologic considerations. WOOG can then effectively determine options to offset those depletions" (2003).

In addition to the points above, the WOOG formulated conclusions summarizing their decision to not put a limit on the maximum offset. The conclusion is quoted from the same memorandum to the Alternative Development Group:

> "Two main points form the basis and conclusions of this memorandum. First, the WOOG does not believe that there is a practical *maximum offset amount* that limits the amount of offsets that can be obtained in the Pecos River Basin. Offset options amounting to several hundred thousand acre feet per year have been identified although the desirability of many offsets from cost and other perspectives is marginal at best. The economic viability of, or reasonableness of, the various WOOG offset options are a matter for management to determine. Second, not only should the required offset be determined, but the computation of that amount should consider the water right administration involved with the option. WOOG suggests that the most efficient method of developing viable alternatives is for the Biology Work Group (BWG) to devise the required instream flow(s), the Hydrology/Water Operations Work Group (HWG) to determine the net depletion to CID's supply given the instream flow requirements that the BWG has set, management to decide the reasonableness of expending funds on facilitating the goals of this EIS, and the WOOG to select an appropriate offset option" (2003).

The second point in the conclusion applies to the administration of water rights associated with certain options. Groundwater retirement options may require less total acquisition considering the right may be pumped in excess of the average yield as long as it does not exceed the total allotment for any given 5-year period.

6. Application of WOOG Tools for Formulation of Preferred Offset Options

The following sections contain: sample assignments of offset options to operational alternatives including a review of WOOG tools; formulation of "A" and "B" lists; additional water acquisition discussion and options; WOOG tools for evaluating additional water acquisition options; and WOOG suggestions for water offset options and additional water acquisition options.

6.1. Alternative Offset Demands

The screened list of alternatives for the reoperation of Sumner Dam is shown in Table A-3, located in the Appendix. This is the list of final alternatives to be analyzed in the impact analysis portion of this EIS. The WOOG role in this analysis of options is limited since all of the WOOG options were carried forward through this EIS. The WOOG examined options for the best match with certain operational alternatives. In order to accomplish this, first the offset *demands* of the alternatives should be examined.

The need for offset water is the primary output of the alternatives, as far as the WOOG is concerned. The Hydrology/Water Operations Group for the Carlsbad Water Supply and Conservation EIS (HWG) completed preliminary modeling results predicting net depletions caused by each alternative (Briggs et al., 2004). This net depletion is the primary demand for water. A secondary demand is for additional water supplies acquired for periods when CID reoperations are not sufficient to meet the needs of the shiner. Considering the purpose and need of this EIS, all net-depletions to CID due to reoperation of Sumner Dam will be offset. Whether these depletions will be offset on an average basis or discretely on an annual basis has yet to be determined; however, the conservative assumption would be that the depletions require full offsets in the year which they occur. Equation 5 equates the “average annual corrected reoperation net depletion (Tetra Tech, 2003)” with the “average annual alternative offset demand”. Equation 6 determines the additional amount required on an annual basis to offset the variability of the maximum or annual depletions exceeding the average. Amounts of offset required over and above the average would be facilitated best by options that can be implemented (or not implemented) on a year-by-year basis, such as surface water retirement leases or pumped well field rights. Additional information on alternative offset demands can be located in Hydrology Work Group documentation.

$$\begin{array}{l}\textit{Average Annual}\\ \textit{Reoperation Alternative}\\ \textit{Offset Demand}\end{array} = \begin{array}{l}\textit{Average Annual Corrected}\\ \textit{Reoperation Net Depletion}\\ \textit{to CID Supply}\end{array} \qquad \text{Eq. 5}$$

$$\begin{array}{l}\textit{Maximum Required}\\ \textit{Variable Offset}\\ \textit{Demand}\end{array} = \begin{array}{l}\textit{60-Year Maximum Transmission}\\ \textit{Loss between Sumner and Brantley} -\\ \textit{Due to Bypass Operations}\end{array} \begin{array}{l}\textit{Average Annual Corrected}\\ \textit{Reoperation Net Depletion}\\ \textit{to CID Supply}\end{array} \qquad \text{Eq. 6}$$

Table 14 shows the average annual reoperation alternative offset demand and the annual required variable offset for the alternatives currently selected in this EIS. The values shown in the table were derived using the equations above from the final planning model amounts for reoperating Sumner Dam as predicted by the Hydrology/Water Operations Group (Stockton, Personal Communication, 2005).

Table 14. Estimated Average and Maximum Annual Net Depletions due to the Reoperation of Sumner Dam

Alternative Designation	Average Annual Reoperation Alternative Offset Demand (acre-ft)[1]	Maximum Required Variable Offset Demand (acre-ft)[1 2]
Taiban Constant	1,200	500
Taiban Variable	1,200 to 1,700	700 to 2,000
Acme Constant	3,900	3,000
Acme Variable	3,000	2,900

Table 14. Estimated Average and Maximum Annual Net Depletions due to the Reoperation of Sumner Dam

Alternative Designation	Average Annual Reoperation Alternative Offset Demand (acre-ft)[1]	Maximum Required Variable Offset Demand (acre-ft)[1 2]
Critical Habitat	1,200	200
No Action (Current BO)	1,600	3,800[3]

[1] Uses final reoperation modeling HWG results.

[2] Uses estimated maximum additional transmission loss between Sumner and Brantley due to bypass operations.

[3] The No Action maximum variable amount does not compare directly with other variable amounts since this alternative was not modeled with the 6-week no-release restriction which tends to increase (due to spill trend changes) the average total net depletion and subsequently the average annual offset demand used in equation 6.

It is apparent that a minimum required offset will need to be offset with a constant amount that is available every year. Other than the minimum, the required annual amount, and the frequency with which that amount must be obtained, is variable. WOOG members expressed that an added factor of safety would be to simply use the average offset amount (as opposed to the minimum offset amount) as the lower bound of offset water to be obtained on an annual basis. For this reason, minimum offset amounts were not presented here.

6.2. Option Results Weighting the Ranking Matrix

Built into the ranking matrix is the ability to prioritize some of the ranking criteria by assigning more weight to certain criteria. From the beginning of the ranking process, emphasis was placed on the feasibility of the water offset options more than the cost of those options. The weighted percentage that each ranking criterion holds within the matrix, not examining the interdependencies of criterion such as cost, is 1/10 or 10%. This means that 90% of the ranking criteria do not consider cost. 90% of the criteria, not counting the interdependency of EUAC on amount available, do not consider the amount. In fact, 80% of the criteria emphasize obtaining wet-water in Brantley reservoir in a timely fashion.

In order to devise a weighting scheme for the selection of options, important criteria for offset must be defined and ordered. From Table 13, the average required offset each year is known. This average offset should be sustainable. In addition, this amount should be available in a timely manner since depletions will occur as soon as operations are changed. Further, options that satisfy the average depletion should have minimal risk. In addition, options can be stacked to form the minimum amount needed every year, provided they are sustainable. Table 14 proposes a weighting strategy for the ranking of options meeting all of the aforementioned priorities.

Justification of the weighting strategy for offset of net depletions above the average and up to the maximum is somewhat different. The supply flexibility category is very important since an increased supply of water upon demand is vital. In addition, the source would have to be sustainable even though it would only be needed periodically. An additional desirable requisite is that the source be flexible in terms of its available amount and its administration, without committing large amounts of capital. Table 15 reflects weights for timing and sustainability ranking criteria. Tables 16 and 17 show the respective standing results for an average offset weighting strategy and a maximum offset weighting strategy.

Table 15. Weighting Strategies for Offsetting Average and Maximum Net Depletions.

WOOG Ranking Criteria:	Approximate Original Weights	Weights for Prioritization of Average Offset	Weights for Prioritization of Additional Offset Needed (above average) to Meet Maximum
EUAC ($/acre-ft/year)	1	0.5	0.75
Timing	1	0.5	2.0
Salvage Risk	1	1.25	0.75
Political, Legal, Social, and Institutional Risk	1	1.25	0.75
Amount Available (acre-ft)	1	0.5	0.75
Proximity to CID (river miles)	1	0.5	0.75
Sustainability	1	2.0	2.0
Time to Implement	1	1.5	0.75
Time to Realize	1	1.5	0.75
State-line Effects	1	0.5	0.75
Total	10	10	10

Table 16. Weighted Standings for Offset of Average Net Depletions

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
1	D-1B	Water Right Purch/Land Retirement-Surface (Roswell Area)	84.3	99
2	D-1A	Water Right Purch/Land Retirement-Surface (FSID)	83.3	99
3	D-1BX	Water Right Purch/Land Retirement-Surface (Roswell Area)	83.3	139
4	D-1C	Water Right Purch/Land Retirement-Surface (CID)	82.8	99
5	D-1AX	Water Right Purch/Land Retirement-Surface (FSID)	82.3	139
6	D-1CX	Water Right Purch/Land Retirement-Surface (CID)	81.8	139
7	E-1B	Water Right Lease/Land Fallowing-Surface (Roswell Area)	81.0	91
8	Q1-SR	Develop Well Field-Seven Rivers	81.0	290
9	Q1-BV	Develop Well Field-Buffalo Valley	80.5	264
10	E-1A	Water Right Lease/Land Fallowing-Surface (FSID)	80.0	91
11	E-1C	Water Right Lease/Land Fallowing-Surface (CID)	79.5	91
12	D-2A	Water Right Purch/Land Ret.-Shallow GW (PVACD)	77.8	67
13	D-2AX	Water Right Purch/Land Ret.-Shallow GW (PVACD)	77.8	94
14	D-3BX	Water Right Purch/Land Ret.-Reef GW (CID)	75.3	118
15	D-3AX	Water Right Purch/Land Ret.-Artesian GW (PVACD)	75.0	118
16	D-3A	Water Right Purch/Land Ret.-Artesian GW (PVACD)	74.8	84
17	D-2B	Water Right Purch/Land Ret.-Shallow GW (CID)	74.5	67
18	E-2A	Water Right Lease/Land Flw.-Shallow GW (PVACD)	74.5	69
19	D-3B	Water Right Purch/Land Ret.-Reef GW (CID)	74.5	84
20	D-2BX	Water Right Purch/Land Ret.-Shallow GW (CID)	74.5	94

Table 16. Weighted Standings for Offset of Average Net Depletions

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
21	E-2B	Water Right Lease/Land Flw.-Shallow GW (CID)	74.3	69
22	E-3B	Water Right Lease/Land Fallowing-Reef GW (CID)	73.3	106
23	E-3A	Water Right Lease/Land Flw.-Artesian GW (PVACD)	72.0	106
24	L-3	Change Cropping Patterns (CID)-Small Grain	72.0	128
25	Y-2	Oil Field Production Well Waste Water-High FW TDS	71.0	1687
26	W	Water imprt. From Salt Bas. or Cap. Reef	70.5	620
27	S	Additional Metering	70.3	16
28	K-1	Desalinization-Lower Limit Cost	70.0	652
29	Y-1	Oil Field Production Well Waste Water-Low FW TDS	70.0	3188
30	A-3	On Farm Conservation-CID	69.5	50
31	L-2	Change Cropping Patterns (CID)-Cotton	69.5	175
32	A-5	Canal Refurbishing-CID	69.3	44
33	F-2	Veg. Control-Kochia Eradication	69.0	13
34	L-1	Change Cropping Patterns (CID)-Ave. All Crops	69.0	144
35	K-2	Desalinization-Upper Limit Cost	69.0	1639
36	L-4	Change Cropping Patterns (CID)-Corn	68.5	147
37	F-1	Rip. Veg. Control-Salt Cedar	68.0	27
38	U	FS Area Gravel Pit Pumping	66.3	10
39	V	Kaiser Channel Lining	66.3	180
40	N-6	Rng. and (Upper) Watershed Mng.-Lower Limit Cost	65.0	-378
41	A-4	Canal Refurbishing-FSID	65.0	3
42	X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	64.5	-1164
43	X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale)	64.5	-236
44	I	Import Canadian River Water	64.5	285
45	A-1	On Farm Conservation-FSID	64.0	96
46	Z	Renegotiate Compact-Forebearance	63.5	145
47	N-5	Rng. and (Upper) Watershed Mng.-Average Cost	63.0	482
48	O	Cloud Seeding	62.0	1
49	N-2	Rng. and (Lower) Watershed Mng.-Average Slvg.	62.0	10
50	F-3	Replace Russian Olive trees with Cottonwood trees	61.5	51
51	X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	61.5	862
52	N-4	Rng. and (Upper) Watershed Mng.-Upper Limit Cost	61.0	1134
53	X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	60.5	1484
54	T-1	Evap. Suppresion-Old Methods (All Major)	60.2	100
55	N-1	Rng. and (Lower) Watershed Mng.-Upper Limit Slvg.	60.0	6
56	X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	59.5	2222
57	X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	59.5	3082
58	X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	59.5	7026
59	X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	59.5	7884
60	X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	59.5	8965
61	N-3	Rng. and (Lower) Watershed Mng.-Lower Limit Slvg.	59.0	57
62	T-1C	Evap. Suppresion-Old Methods (Brantley)	58.5	100
63	A-2	On Farm Conservation-PVACD	55.0	216
64	T-1B	Evap. Suppresion-Old Methods (Sumner)	54.5	100
65	T-1A	Evap. Suppresion-Old Methods (Santa Rosa)	53.5	100

Table 16. Weighted Standings for Offset of Average Net Depletions

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre -ft)
66	T-2	Evap. Suppresion-New Rsrch. (All Major)	33.7	3
67	T-2C	Evap. Suppresion-New Rsrch. (Brantley)	32.0	3
68	T-2B	Evap. Suppresion-New Rsrch. (Sumner)	28.0	3
69	T-2A	Evap. Suppresion-New Rsrch. (Santa Rosa)	26.0	3

Table 17. Weighted Standings for Offset of Maximum Net Depletions

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
1	Q1-SR	Develop Well Field-Seven Rivers	76.5	290
2	Q1-BV	Develop Well Field-Buffalo Valley	75.8	264
3	W	Water imprt. From Salt Bas. or Cap. Reef	75.5	620
4	D-2A	Water Right Purch/Land Ret.-Shallow GW (PVACD)	74.0	67
5	D-2AX	Water Right Purch/Land Ret.-Shallow GW (PVACD)	74.0	94
6	D-1B	Water Right Purch/Land Retirement-Surface (Roswell Area)	73.0	99
7	X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	72.5	-1164
8	N-6	Rng. and (Upper) Watershed Mng.-Lower Limit Cost	72.5	-378
9	X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale)	72.5	-236
10	D-3A	Water Right Purch/Land Ret.-Artesian GW (PVACD)	72.5	84
11	L-3	Change Cropping Patterns (CID)-Small Grain	72.4	128
12	D-3AX	Water Right Purch/Land Ret.-Artesian GW (PVACD)	71.8	118
13	D-1A	Water Right Purch/Land Retirement-Surface (FSID)	71.5	99
14	D-1BX	Water Right Purch/Land Retirement-Surface (Roswell Area)	71.5	139
15	D-1C	Water Right Purch/Land Retirement-Surface (CID)	70.8	99
16	D-1AX	Water Right Purch/Land Retirement-Surface (FSID)	70.0	139
17	E-2A	Water Right Lease/Land Flw.-Shallow GW (PVACD)	69.5	69
18	N-5	Rng. and (Upper) Watershed Mng.-Average Cost	69.5	482
19	D-1CX	Water Right Purch/Land Retirement-Surface (CID)	69.3	139
20	I	Import Canadian River Water	69.1	285
21	Z	Renegotiate Compact-Forebearance	69.0	145
22	F-1	Rip. Veg. Control-Salt Cedar	68.5	27
23	E-1B	Water Right Lease/Land Fallowing-Surface (Roswell Area)	68.5	91
24	A-5	Canal Refurbishing-CID	68.3	44
25	X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	68.0	862
26	A-3	On Farm Conservation-CID	67.5	50
27	E-3A	Water Right Lease/Land Flw.-Artesian GW (PVACD)	67.3	106
28	S	Additional Metering	67.0	16
29	E-1A	Water Right Lease/Land Fallowing-Surface (FSID)	67.0	91
30	K-1	Desalinization-Lower Limit Cost	67.0	652
31	D-2B	Water Right Purch/Land Ret.-Shallow GW (CID)	66.6	67
32	D-3B	Water Right Purch/Land Ret.-Reef GW (CID)	66.6	84
33	D-2BX	Water Right Purch/Land Ret.-Shallow GW (CID)	66.6	94

Table 17. Weighted Standings for Offset of Maximum Net Depletions

Rank	Desig- nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
34	D-3BX	Water Right Purch/Land Ret.-Reef GW (CID)	66.6	118
35	F-2	Veg. Control-Kochia Eradication	66.5	13
36	N-4	Rng. and (Upper) Watershed Mng.-Upper Limit Cost	66.5	1134
37	X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	66.5	1484
38	E-1C	Water Right Lease/Land Fallowing-Surface (CID)	66.3	91
39	Y-2	Oil Field Production Well Waste Water-High FW TDS	66.3	1687
40	L-2	Change Cropping Patterns (CID)-Cotton	66.1	175
41	K-2	Desalinization-Upper Limit Cost	65.5	1639
42	L-1	Change Cropping Patterns (CID)-Ave. All Crops	65.4	144
43	A-4	Canal Refurbishing-FSID	65.3	3
44	X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	65.0	2222
45	X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	65.0	3082
46	X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	65.0	7026
47	X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	65.0	7884
48	X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	65.0	8965
49	V	Kaiser Channel Lining	64.8	180
50	Y-1	Oil Field Production Well Waste Water-Low FW TDS	64.8	3188
51	L-4	Change Cropping Patterns (CID)-Corn	64.6	147
52	N-1	Rng. and (Lower) Watershed Mng.-Upper Limit Slvg.	64.0	6
53	N-2	Rng. and (Lower) Watershed Mng.-Average Slvg.	64.0	10
54	A-1	On Farm Conservation-FSID	63.8	96
55	E-2B	Water Right Lease/Land Flw.-Shallow GW (CID)	63.6	69
56	T-1	Evap. Suppresion-Old Methods (All Major)	63.0	100
57	E-3B	Water Right Lease/Land Fallowing-Reef GW (CID)	62.1	106
58	F-3	Replace Russian Olive with Cottonwood	61.0	51
59	O	Cloud Seeding	60.8	1
60	A-2	On Farm Conservation-PVACD	59.3	216
61	T-1C	Evap. Suppresion-Old Methods (Brantley)	58.0	100
62	N-3	Rng. and (Lower) Watershed Mng.-Lower Limit Slvg.	57.0	57
63	U	FS Area Gravel Pit Pumping	56.5	10
64	T-1B	Evap. Suppresion-Old Methods (Sumner)	52.0	100
65	T-1A	Evap. Suppresion-Old Methods (Santa Rosa)	50.5	100
66	T-2	Evap. Suppresion-New Rsrch. (All Major)	44.2	3.3
67	T-2C	Evap. Suppresion-New Rsrch. (Brantley)	39.3	3
68	T-2B	Evap. Suppresion-New Rsrch. (Sumner)	33.3	3
69	T-2A	Evap. Suppresion-New Rsrch. (Santa Rosa)	27.8	3

Comparing the results of Tables 16 and 17 with Table 13, it is evident that the weighting schemes worked as intended. For offset of the average depletion, options that are sustainable and also implemented fairly quickly rose to the top of the list. Practically, lease or purchase of surface water options will be vital to having a sustainable supply with very little risk involved. For offsets of the maximum depletion, expected results included more groundwater options dominating the top of the list. This is reasonable since the five-year accounting period for groundwater rights in the basin provides greater flexibility of supply than that associated with surface rights. Weighting of the options considering the type of offset being met is a refinement of the un-weighted ranking of offset options. The next step is sorting of the lists to determine “A” and “B” lists.

6.3. Preferred Offset Options – “A” List

Since the WOOG list of options is too extensive for analysis of all options in the impact analysis portion of this NEPA process, three “A” lists, one for un-weighted option ranking and two for weighted option ranking, including average and maximum offsets, were developed to narrow the options to be analyzed. Time to implement and time to realize were considered the most appropriate screening choices to narrow the options shown in tables 13, 16 and 17. In addition, some options are beyond the scope of this NEPA process in terms of the environmental evaluation of their effects, and would in fact require their own Environmental Impact Statement to be built. These two screening filters were used in combination to develop the “A” lists for un-weighted options and weighted average and maximum offsets.

Three years was the maximum amount of time lapse acceptable for an option to provide water to the Pecos River. The combination of time to implement the option and time to realize water in the river was limited to three years as the maximum amount of time acceptable for an option to be on the “A” list. In terms of ranking for an option to be on the “A” list, it must have at least a “4” for time to implement and it must also have a “5” for time to realize (See Tables 6 & 7).

For the EIS filter, complex options that required planning beyond the scope of this NEPA process were also cut from the “A” lists. The flash distillation power plant (Option X) was one such complex project whose planning and environmental permitting would likely exceed three years to implement. It was assumed that private investment would drive this option with possible tax incentives by the Federal, State, and local governments to offset the decreased power generating ability from the added benefit of flash distillation (i.e. pay for the water that is generated). It may be possible that it could be built privately with the EIS work required in less than the 3-year cutoff window, but Reclamation involvement would likely invoke environmental analyses. Table 18 shows the “A” list for equally weighted offset options, Table 19 shows the “A” list for average weighted offset options, and Table 20 shows the “A” list for maximu weighted offset options. Figures 13, 14, and 15 illustrate the respective equally weighted, average weighted, and maximum weighted A-lists. Since the same filter criteria were used for all offset options, all “A” lists contain the same options; however, the most suitable options are still ordered by overall combined score.

It should be noted that offset amounts are for delivery of offset water to the Pecos River in the amounts determined by the WOOG. Losses incurred to these amounts by delivery to the Carlsbad Project were left for determination by the Hydrology Group through modeling of the stream system (Tetra Tech, 2005). Average efficiencies for water offset options, which take into account transit delivery losses to Brantley reservoir from the offset source, are shown on Table 18 for use in example calculations. The WOOG did not attempt to incorporate the efficiency factor into the ultimate cost of all of the offset options; adjusted EUAC is only shown for A-list options.

Table 18 "A" List – Equally Weighted Ranking of Water Offset Options with Estimated Offset Efficiencies, Effective Offset, and EUAC Adjusted for Efficiency

Rank	Desig-nation	Option Name/Description	Amount Available acre-feet/ year[1]	Transit Efficiency from Offset Source to Brantley Reservoir	Average Effective Offset[3]	Combined Total Score (unitless)	Adjusted EUAC ($/acre-ft/year)[5]
1	Q1-SR	Develop well field (Seven Rivers)	10,000	67%	6,700	77.0	433
2	Q1-BV	Develop well field: Buffalo Valley	10,000	58%	5,800	76.0	455
3	D-1B	Water right purchase: Roswell area	1,600	55%	1,300	74.0	180
4	E-1B	Water right lease: Roswell area	1,600	55%	1,300	73.0	165
5	D-1A	Water right purchase: FSID	1,000	23%	300	72.0	431
6	D-1BX	Water right purchase: Roswell area	1,600	55%	1,300	72.0	252
7	L-3[2]	Change cropping patterns (CID): very low water use crop	10,500	100%[4]	10,500	71.5	182
8	E-1A	Water right lease: FSID	1,000	23%	300	71.0	396
9	D-1C	Water right purchase: CID	3,150	100%[4]	3,150	71.0	99
10	E-1C	Water right lease: CID	3,150	100%[4]	3,150	70.0	91
11	D-1AX	Water right purchase: FSID	1,000	23%	300	70.0	603
12	D-1CX	Water right purchase: CID	3,150	100%[4]	3,150	69.0	139
13	L-2[2]	Change cropping patterns (CID): low water use crop	8,800	100%[4]	8,800	66.5	249
14	L-1[2]	Change cropping patterns (CID): ave. water use	8,900	100%[4]	8,900	65.5	206
15	L-4[2]	Change cropping patterns (CID): med. water use crop	6,000	100%[4]	6,000	64.5	209
16	U	FSID gravel pit pumping	300	74%	222	62.0	13

[1] Options designated with an "X" do not represent a unique amount of water, only an escalated cost for another listed option. CIR amount presented for options involving water rights retirement.
[2] The Change of Cropping Patterns is based on conversion of 5,000 acres of alfalfa to the indicated water use; the acreage conversion is available only once. Amount available reflects 2005 revision accounting for water stacking (See section 3.3).

[3] Note that “amount available” column multiplied by efficiency in this column does not yield effective offset for non-project offsets. Only diverted amounts (convert from CIR amount by multiplying by 3 AF/acre and dividing by 2.1 AF/acre) can be multiplied by efficiencies in this column to determine effective offset.
[4] Project (CID) derived offset efficiencies don’t apply to diverted amounts as do other efficiencies. Multiplication for average effective offset is direct (no conversion to diverted amount is necessary).

[5] EUAC was “adjusted” to account for offset option efficiencies.

Table 19. Average Offset - "A" List Water Offset Options

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
1	D-1B	Water Right Purch/Land Retirement-Surface (Roswell Area)	84.3	99
2	D-1A	Water Right Purch/Land Retirement-Surface (FSID)	83.3	99
3	D-1BX	Water Right Purch/Land Retirement-Surface (Roswell Area)	83.3	139
4	D-1C	Water Right Purch/Land Retirement-Surface (CID)	82.8	99
5	D-1AX	Water Right Purch/Land Retirement-Surface (FSID)	82.3	139
6	D-1CX	Water Right Purch/Land Retirement-Surface (CID)	81.8	139
7	E-1B	Water Right Lease/Land Fallowing-Surface (Roswell Area)	81.0	91
8	Q1-SR	Develop Well Field-Seven Rivers	81.0	290
9	Q1-BV	Develop Well Field-Buffalo Valley	80.5	264
10	E-1A	Water Right Lease/Land Fallowing-Surface (FSID)	80.0	91
11	E-1C	Water Right Lease/Land Fallowing-Surface (CID)	79.5	91
12	L-3	Change Cropping Patterns (CID)-Small Grain	72.0	128
13	L-2	Change Cropping Patterns (CID)-Cotton	69.5	175
14	L-1	Change Cropping Patterns (CID)-Ave. All Crops	69.0	144
15	L-4	Change Cropping Patterns (CID)-Corn	68.5	147
16	U	FS Area Gravel Pit Pumping	66.3	10

Table 20. Maximum Offset - "A" List Water Offset Options

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
1	Q1-SR	Develop Well Field-Seven Rivers	76.5	290
2	Q1-BV	Develop Well Field-Buffalo Valley	75.8	264
3	D-1B	Water Right Purch/Land Retirement-Surface (Roswell Area)	73.0	99
4	L-3	Change Cropping Patterns (CID)-Small Grain	72.4	128
5	D-1A	Water Right Purch/Land Retirement-Surface (FSID)	71.5	99
6	D-1BX	Water Right Purch/Land Retirement-Surface (Roswell Area)	71.5	139
7	D-1C	Water Right Purch/Land Retirement-Surface (CID)	70.8	99
8	D-1AX	Water Right Purch/Land Retirement-Surface (FSID)	70.0	139
9	D-1CX	Water Right Purch/Land Retirement-Surface (CID)	69.3	139
10	E-1B	Water Right Lease/Land Fallowing-Surface (Roswell Area)	68.5	91
11	E-1A	Water Right Lease/Land Fallowing-Surface (FSID)	67.0	91
12	E-1C	Water Right Lease/Land Fallowing-Surface (CID)	66.3	91
13	L-2	Change Cropping Patterns (CID)-Cotton	66.1	175
14	L-1	Change Cropping Patterns (CID)-Ave. All Crops	65.4	144
15	L-4	Change Cropping Patterns (CID)-Corn	64.6	147
16	U	FS Area Gravel Pit Pumping	56.5	10

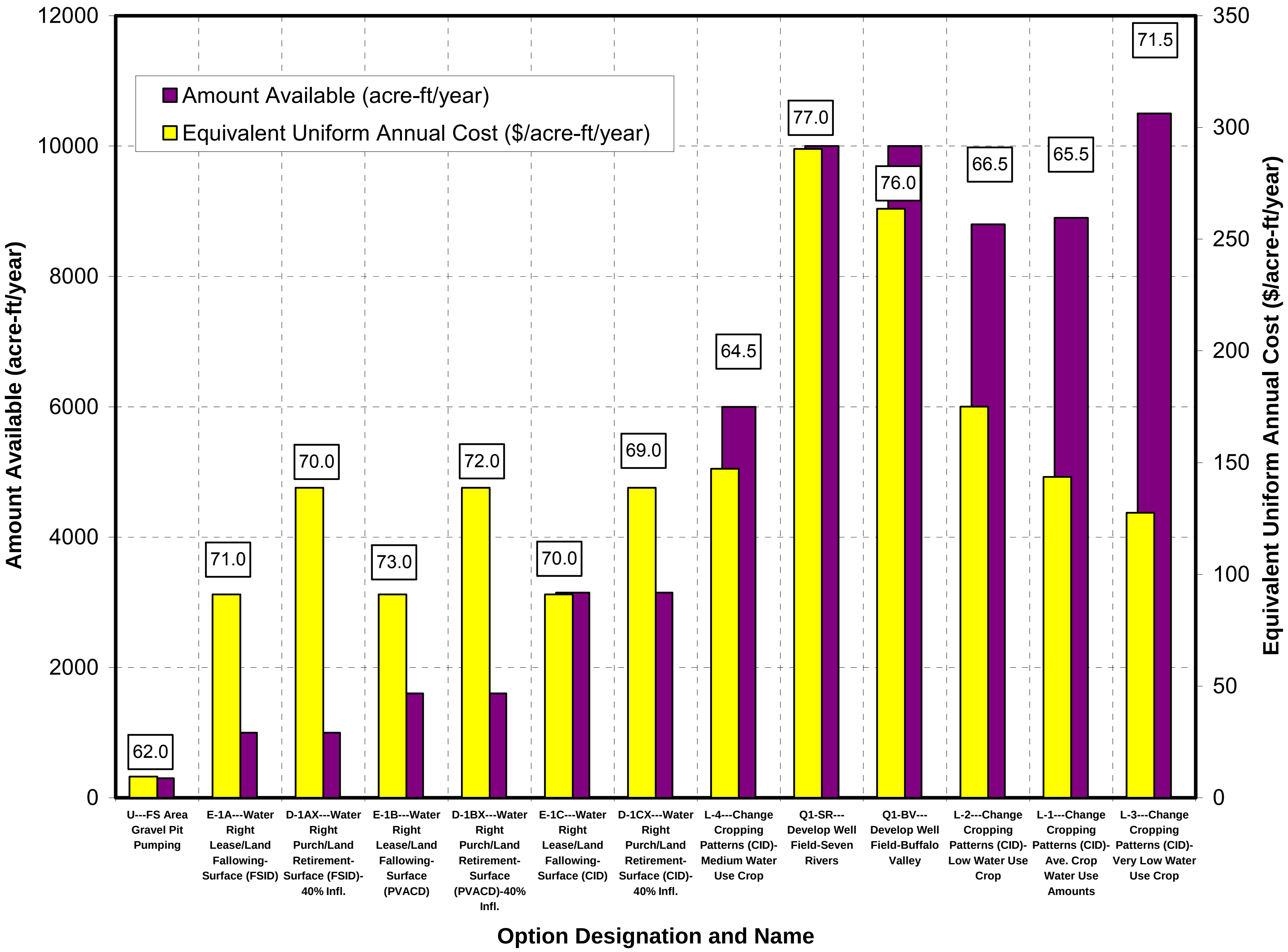


Figure 13. Equally Weighted “A” List - Depicted Graphically with Equivalent Uniform Annual Cost, Amount Available, and Score.

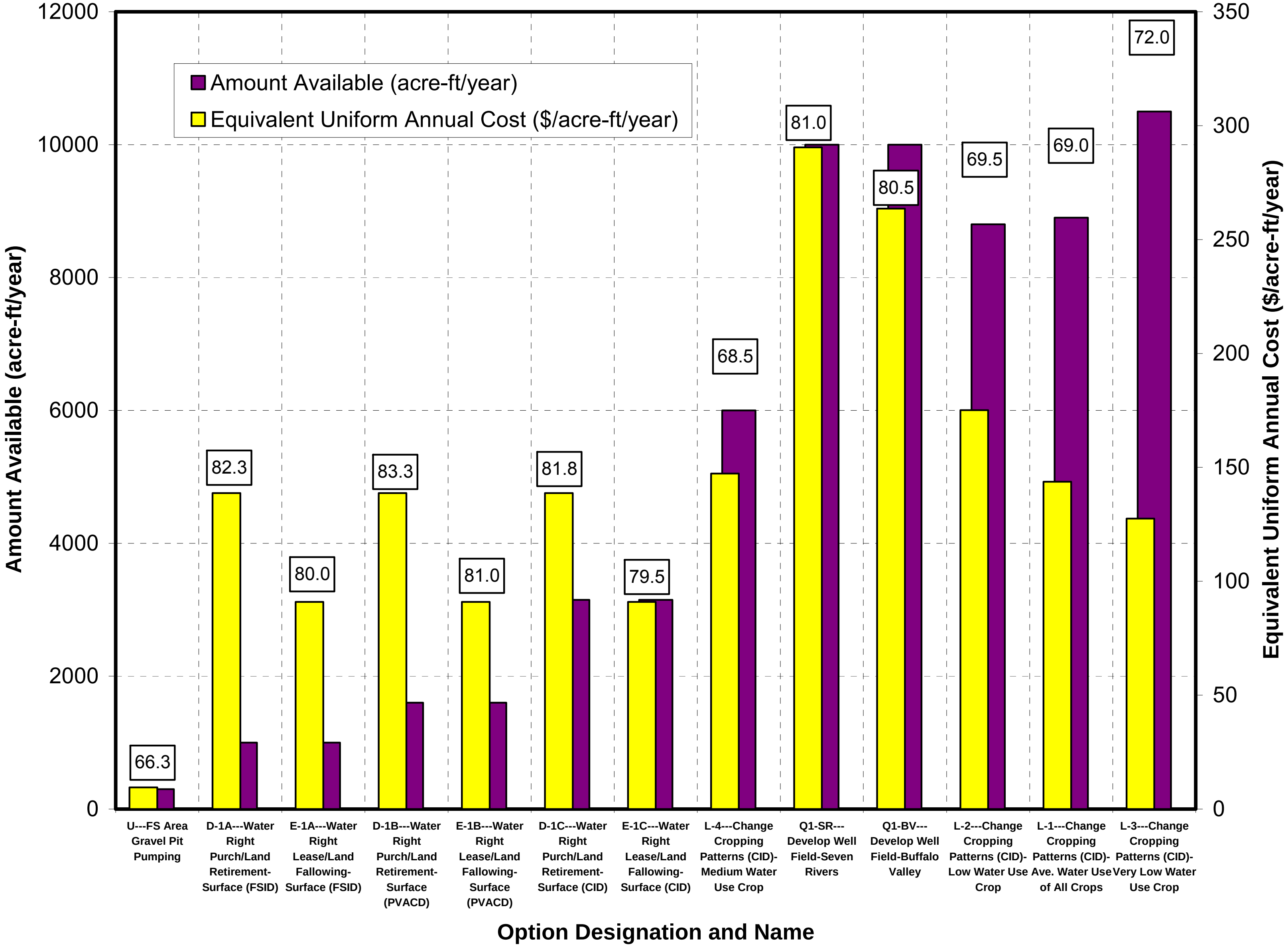


Figure 14. “A” List for Average Offsets - Depicted Graphically with Equivalent Uniform Annual Cost, Amount Available, and Score.

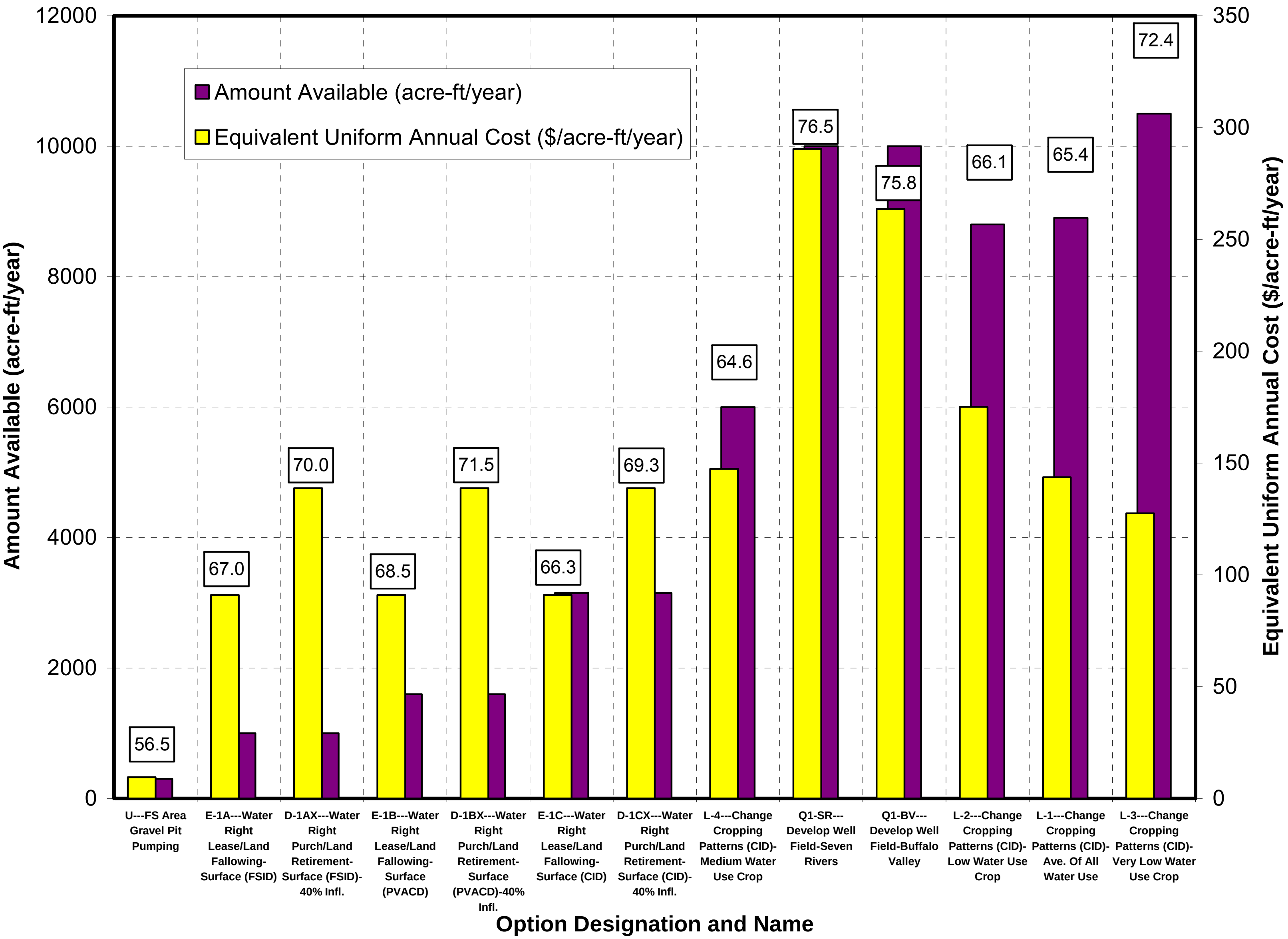


Figure 15. "A" List for Maximum Offsets - Depicted Graphically with Equivalent Uniform Annual Cost, Amount Available, and Score.

6.4. Remaining Offset Options – “B” List

Those Offset Options that were not on the “A” list were ranked and listed on the “B” list. These options were not considered likely to be timely in providing offset water for depletions in the near term but may be viable in the long term. There may be offset options on the “B**” list that can become viable offsets with additional research and development.** Indeed, many of the “B” list options are cost effective if they can be shown to provide the needed water supplies. Tables 21, 22 and 23 indicate the “B” list for un-weighted options and weighted options for average and maximum depletions.

Table 21 "B" List – Equally Weighted Ranking of Water Offset Options

Rank	Desig-nation	Option Name/Description	Amount Available (acre-ft / year)	Combined Total Score (unitless)	EUAC ($/acre-ft/year)
1	W	Water imprt. From Salt Bas. or Capitan Reef	20,000	74.0	620
2	D-2A	Water Right Purch Shallow (Roswell Area)	7,000	72.0	67
3	D-2AX	Water Right Purch Shallow (Roswell Area)	7,000	72.0	94
4	E-2A	Water Right Lease Shallow (Roswell Area)	7,000	71.0	69
5	X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	22,000	70.0	-1164
6	N-6	Range and (Upper) Watershed Management-no cost	25,400	70.0	-378
7	X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale)	22,000	70.0	-236
8	D-3A	Water Right Purch Artesian (Roswell Area)	7,000	70.0	84
9	D-3AX	Water Right Purch Artesian (Roswell Area)	7,000	69.0	118
10	F-1	Rip. Veg. Control-Salt Cedar	12,500	68.0	27
11	E-3A	Water Right Lease Artesian (Roswell Area)	7,000	68.0	106
12	F-2	Veg. Control-Kochia Eradication	3,600	67.0	13
13	E-2B	Water Right Lease Shallow (CID)	400	66.5	69
14	A-5	Canal Refurbishing (CID)	10,000	66.0	44
15	N-5	Range and (Upper) Watershed Management-average cost	25,400	66.0	482
16	K-1	Desalinization-Lower Limit Cost	10,000	66.0	652
17	D-2B	Water Right Purch Shallow (CID)	400	65.5	67
18	D-3B	Water Right Purch Reef (CID)	400	65.5	84
19	D-2BX	Water Right Purch Shallow (CID)	400	65.5	94
20	D-3BX	Water Right Purch Reef (CID)	400	65.5	118
21	I	Import Canadian River Water	20,000	65.5	285
22	A-3	On Farm Conservation (CID)	4,000	65.0	50
23	Y-2	Oil Field Production Well Waste Water-High FW TDS	9,030	65.0	1687
24	E-3B	Water Right Lease Reef (CID)	400	64.5	106
25	X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	22,000	64.0	862
26	K-2	Desalinization-Upper Limit Cost	10,000	64.0	1639
27	V	Kaiser Channel Lining	990	63.0	180
28	Y-1	Oil Field Production Well Waste Water-Low FW TDS	8,815	63.0	3188
29	T-1	Evaporation Suppression-Old Methods	17,500	62.3	100
30	A-4	Canal Refurbishing (FSID)	9,000	62.0	3
31	N-1	Rng. And Watershed Management-Upper Limit	13,271	62.0	6
32	N-2	Rng. And Watershed Management-Average	7,300	62.0	10.1
33	Z	Renegotiate Compact-Forbearance	18,500	62.0	145

Table 21 "B" List – Equally Weighted Ranking of Water Offset Options

34	N-4	Range and (Upper) Watershed Management-high cost	25,400	62.0	1134
35	X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	22,000	62.0	1484
36	O	Cloud Seeding	43,000	61.0	1
37	A-1	On Farm Conservation (FSID)	5,400	60.0	96
38	X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	22,000	60.0	2222
39	X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	22,000	60.0	3082
40	X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	22,000	60.0	7026
41	X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	22,000	60.0	7884
42	X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	22,000	60.0	8965
43	T-1C	Evaporation Suppression-Old Methods (Brantley)	6,500	59.0	100
44	F-3	Replace Russian Olive trees with Cottonwood trees	4,000	58.0	51
45	S	Additional Metering	6,250	66.0	55
46	N-3	Range And Watershed Management-Lower Limit	1,296	56.0	57
47	A-2	On Farm Conservation (PVACD)	8,000	54.0	216
48	T-1B	Evaporation Suppression-Old Methods (Sumner)	6,100	51.0	100
49	T-1A	Evaporation Suppression-Old Methods (Santa Rosa)	4,900	49.0	100
50	T-2	Evaporation Suppression-New Research	17,500	47.3	3
51	T-2C	Evaporation Suppression-New Methods (Brantley)	6,500	44.0	3
52	T-2B	Evaporation Suppression-New Methods (Sumner)	6,100	36.0	3
53	T-2A	Evaporation Suppression-New Methods (Santa Rosa)	4,900	32.0	3

Table 22. Average Offset - "B" List Water Offset Options

Rank	**Desig-nation**	**Option Name**	**Combined Total Score**	**EUAC ($/acre-ft)**
1	D-2A	Water Right Purch/Land Ret.-Shallow GW (PVACD)	77.8	67
2	D-2AX	Water Right Purch/Land Ret.-Shallow GW (PVACD)	77.8	94
3	D-3BX	Water Right Purch/Land Ret.-Reef GW (CID)	75.3	118
4	D-3AX	Water Right Purch/Land Ret.-Artesian GW (PVACD)	75.0	118
5	D-3A	Water Right Purch/Land Ret.-Artesian GW (PVACD)	74.8	84
6	D-2B	Water Right Purch/Land Ret.-Shallow GW (CID)	74.5	67
7	E-2A	Water Right Lease/Land Flw.-Shallow GW (PVACD)	74.5	69
8	D-3B	Water Right Purch/Land Ret.-Reef GW (CID)	74.5	84
9	D-2BX	Water Right Purch/Land Ret.-Shallow GW (CID)	74.5	94
10	E-2B	Water Right Lease/Land Flw.-Shallow GW (CID)	74.3	69
11	E-3B	Water Right Lease/Land Fallowing-Reef GW (CID)	73.3	106
12	E-3A	Water Right Lease/Land Flw.-Artesian GW (PVACD)	72.0	106
13	Y-2	Oil Field Production Well Waste Water-High FW TDS	71.0	1687
14	W	Water imprt. From Salt Bas. or Cap. Reef	70.5	620
15	K-1	Desalinization-Lower Limit Cost	70.0	652
16	Y-1	Oil Field Production Well Waste Water-Low FW TDS	70.0	3188
17	A-3	On Farm Conservation-CID	69.5	50
18	A-5	Canal Refurbishing-CID	69.3	44
19	F-2	Veg. Control-Kochia Eradication	69.0	13
20	K-2	Desalinization-Upper Limit Cost	69.0	1639
21	F-1	Rip. Veg. Control-Salt Cedar	68.0	27
22	V	Kaiser Channel Lining	66.3	180

Table 22. Average Offset - "B" List Water Offset Options

23	N-6	Rng. and (Upper) Watershed Mng.-Lower Limit Cost	65.0	-378
24	A-4	Canal Refurbishing-FSID	65.0	3
25	X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	64.5	-1164
26	X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale)	64.5	-236
27	I	Import Canadian River Water	64.5	285
28	A-1	On Farm Conservation-FSID	64.0	96
29	Z	Renegotiate Compact-Forbearance	63.5	145
30	N-5	Rng. and (Upper) Watershed Mng.-Average Cost	63.0	482
31	O	Cloud Seeding	62.0	1
32	N-2	Rng. and (Lower) Watershed Mng.-Average Slvg.	62.0	10
33	F-3	Replace Russian Olive trees with Cottonwood trees	61.5	51
34	X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	61.5	862
35	N-4	Rng. and (Upper) Watershed Mng.-Upper Limit Cost	61.0	1134
36	X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	60.5	1484
37	T-1	Evap. Suppresion-Old Methods (All Major)	60.2	100
38	N-1	Rng. and (Lower) Watershed Mng.-Upper Limit Slvg.	60.0	6
39	X-4	Dsl. Pwr. Plant-2002 Energy Prices (Ind. Elec. Sale)	59.5	2222
40	X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	59.5	3082
41	X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	59.5	7026
42	X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	59.5	7884
43	X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	59.5	8965
44	S	Additional Metering	70.3	16
45	N-3	Rng. and (Lower) Watershed Mng.-Lower Limit Slvg.	59.0	57
46	T-1C	Evap. Suppresion-Old Methods (Brantley)	58.5	100
47	A-2	On Farm Conservation-PVACD	55.0	216
48	T-1B	Evap. Suppresion-Old Methods (Sumner)	54.5	100
49	T-1A	Evap. Suppresion-Old Methods (Santa Rosa)	53.5	100
50	T-2	Evap. Suppresion-New Rsrch. (All Major)	33.7	3
51	T-2C	Evap. Suppresion-New Rsrch. (Brantley)	32.0	3
52	T-2B	Evap. Suppresion-New Rsrch. (Sumner)	28.0	3
53	T-2A	Evap. Suppresion-New Rsrch. (Santa Rosa)	26.0	3

Table 23. Maximum Offset - "B" List WOOG Options

Rank	Desig-nation	Option Name	Combined Total Score	EUAC ($/acre-ft)
1	W	Water imprt. From Salt Bas. or Cap. Reef	75.5	620
2	D-2A	Water Right Purch/Land Ret.-Shallow GW (PVACD)	74.0	67
3	D-2AX	Water Right Purch/Land Ret.-Shallow GW (PVACD)	74.0	94
4	X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	72.5	-1164
5	N-6	Rng. and (Upper) Watershed Mng.-Lower Limit Cost	72.5	-378
6	X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector ES)	72.5	-236
7	D-3A	Water Right Purch/Land Ret.-Artesian GW (PVACD)	72.5	84
8	D-3AX	Water Right Purch/Land Ret.-Artesian GW (PVACD)	71.8	118
9	E-2A	Water Right Lease/Land Flw.-Shallow GW (PVACD)	69.5	69
10	N-5	Rng. and (Upper) Watershed Mng.-Average Cost	69.5	482
11	I	Import Canadian River Water	69.1	285

Table 23. Maximum Offset - "B" List WOOG Options

12	Z	Renegotiate Compact-Forebearance	69.0	145
13	F-1	Rip. Veg. Control-Salt Cedar	68.5	27
14	A-5	Canal Refurbishing-CID	68.3	44
15	X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	68.0	862
16	A-3	On Farm Conservation-CID	67.5	50
17	E-3A	Water Right Lease/Land Flw.-Artesian GW (PVACD)	67.3	106
18	K-1	Desalinization-Lower Limit Cost	67.0	652
19	D-2B	Water Right Purch/Land Ret.-Shallow GW (CID)	66.6	67
20	D-3B	Water Right Purch/Land Ret.-Reef GW (CID)	66.6	84
21	D-2BX	Water Right Purch/Land Ret.-Shallow GW (CID)	66.6	94
22	D-3BX	Water Right Purch/Land Ret.-Reef GW (CID)	66.6	118
23	F-2	Veg. Control-Kochia Eradication	66.5	13
24	N-4	Rng. and (Upper) Watershed Mng.-Upper Limit Cost	66.5	1134
25	X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	66.5	1484
26	Y-2	Oil Field Production Well Waste Water-High FW TDS	66.3	1687
27	K-2	Desalinization-Upper Limit Cost	65.5	1639
28	A-4	Canal Refurbishing-FSID	65.3	3
29	X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	65.0	2222
30	X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	65.0	3082
31	X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	65.0	7026
32	X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	65.0	7884
33	X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	65.0	8965
34	V	Kaiser Channel Lining	64.8	180
35	Y-1	Oil Field Production Well Waste Water-Low FW TDS	64.8	3188
36	N-1	Rng. and (Lower) Watershed Mng.-Upper Limit Slvg.	64.0	6
37	N-2	Rng. and (Lower) Watershed Mng.-Average Slvg.	64.0	10
38	A-1	On Farm Conservation-FSID	63.8	96
39	E-2B	Water Right Lease/Land Flw.-Shallow GW (CID)	63.6	69
40	T-1	Evap. Suppresion-Old Methods (All Major)	63.0	100
41	E-3B	Water Right Lease/Land Fallowing-Reef GW (CID)	62.1	106
42	F-3	Replace Russian Olive trees with Cottonwood trees	61.0	51
43	S	Additional Metering	67.0	16
44	O	Cloud Seeding	60.8	1
45	A-2	On Farm Conservation-PVACD	59.3	216
46	T-1C	Evap. Suppresion-Old Methods (Brantley)	58.0	100
47	N-3	Rng. and (Lower) Watershed Mng.-Lower Limit Slvg.	57.0	57
48	T-1B	Evap. Suppresion-Old Methods (Sumner)	52.0	100
49	T-1A	Evap. Suppresion-Old Methods (Santa Rosa)	50.5	100
50	T-2	Evap. Suppresion-New Rsrch. (All Major)	44.2	3
51	T-2C	Evap. Suppresion-New Rsrch. (Brantley)	39.3	3
52	T-2B	Evap. Suppresion-New Rsrch. (Sumner)	33.3	3
53	T-2A	Evap. Suppresion-New Rsrch. (Santa Rosa)	27.8	3

6.5 Example Coupling of Offset Options with Alternatives

Selection of appropriate WOOG options to offset depletions is left to those who are charged with implementing this EIS, but two approaches are suggested here to effectively utilize WOOG results. Possible approaches to implement these options include selection of the highest ranked options that sum incrementally to the amount needed, or in the alternative, selection of a portion of options with the highest WOOG ranking.

6.5.1 Selection by Incremental Amount

The first perspective would be to minimize the securing of water in excess of offset needs through incremental acquisitions of offset amounts. The offset demands are directly taken from Table 14, indicating depletions associated with various EIS Alternatives. Using the “Acme Variable” alternative as an example, the offset demands are estimated to be 3,000 acre-ft/year for the average and an additional 2,900 acre-ft/year to be able to offset the maximum. The following example uses only escalated water right purchase prices (the “X” options) from the A-list and various other A-list options. The example also uses ranking scores from the equally weighted A-list (See table 18 and figure 13). Minimizing water acquisitions leads to selection of the following sequence of decisions to offset an average net depletion of 3,000 acre feet/year:

1) The first option selected is the one with the highest score with an amount available less than the average offset demand, “E-1B---Water Right Lease Surface – Roswell Area”; this option provides an effective offset of 1,300 acre-ft/year, leaving 1,700 acre-ft/year to still be offset.
2) The next option selected is “D-1BX---Water Right Purchase Surface – Roswell Area, which provides another 1,300 acre-ft/year, leaving 400 acre-ft/year to still be offset.
3) The third highest ranking option with offset amounts less than 400 acre-ft/year is “E-1A---Water Right Lease Surface - FSID”, which provides another 300 acre-ft/year, leaving 100 acre-ft/year to be offset.
4) The last option selected for offsetting the average demand is the option with least effective offset amount of all the remaining options (in order to minimize the amount of effective offset acquisition), “U – FSID Gravel Pit Pumping”; this option provides 200 acre-ft/year, creating 100 acre-ft/year of surplus.

The maximum required variable offset demands follow the same selection process, but now only 2,800 acre-ft is needed to meet the maximum demand since there was a surplus generated in offsetting the average demand. As a result of selecting offsets to meet the average depletions of the “Acme Variable” alternative, four options have now been consumed from the “A” list of offset options. These options cannot be selected for meeting the maximum offset demand. Again, using the rule of selecting the highest scoring option that is less than or equal to (or nearest greater than in this example) the remaining 2,800 acre-ft yields two options: “D-1AX- Water Right Purchase - FSID” and “D-1CX---Water Right Lease Surface – CID”. Since the FSID purchase won’t cover the entire needed offset amount but the CID lease will, it is logical to only choose the CID lease option for 3,150 acre-ft/year of effective offset. This option will provide 350 acre-ft/year more than required, which will be excess to the total offset requirement. Note that suitability of options to meet either average or maximum offset demands wasn’t considered.

The last remaining step is to establish a total annual maximum cost for the alternative. Table 24 lists the example offsets for the “Acme Variable” alternative and their annual costs. Also shown is the annual cost sum, which represents the maximum cost for this alternative (occurring some years).

Table 24 Hypothetical Coupling of Offset Options by Amount Available with the "Acme Variable" Alternative.

Offset Option	Demand Type	Adjusted EUAC ($/acre-ft/year)	Effective Offset Amount (acre-ft/year)	Maximum Total Annual Cost ($/year)
E-1B---Water Right Lease Surface – Roswell Area	Avg.	165	1,300	214,500
D-1BX---Water Right Purchase Surface – Roswell Area	Avg.	252	1,300	327,600
E-1A---Water Right Lease Surface - FSID	Avg.	396	300	118,800
U---Fort Sumner Area Gravel Pit Pumping	Avg.	13	200	2,600
D-1CX---Water Right Lease Surface - CID	Max.	91	3,150	286,650
Final EUAC, Total Amount, and Max. Annual Cost:	N/A	**152**	**6,250**	**950,150**

Economic commitment in excess of requirement [1], (6,250 – 5,900) x $152 = $53,200

[1] Assuming maximum offset demand occurs; this would be a minimum excess commitment.

6.5.2 Selection by Rank

Instead of minimizing the offset option amounts, another possibility for coupling offset options is scaling back the highest ranking options that provide more than adequate available amounts. Again using the same “Acme Variable” alternative, the respective annual average and additional maximum offset demands are 3,000 and 2,900 acre-ft. For the selection by rank approach, the option with the highest score is the preferred option. If the option does not meet the demand, then it is aggregated with the option that has the next highest score. Examples of average and maximum offset using the principle of “selection by rank” follow.

The highest scoring option for average offset is “Q1-SR---Develop Well Field – Seven Rivers” which can provide 6,700 acre-ft/year of offset water supplies. This is more than is needed for the average depletion for “Acme Variable. All of the average net depletion will be satisfied by Q1-SR with 3,700 acre-ft/year excess to that requirement. The remainder of the capacity, 3,000 acre-ft/year, will also offset the maximum variable demand with 100 acre-ft/year of surplus. Table 25 presents a hypothetical example of coupling offset options with alternatives through selection by rank.

Table 25 Hypothetical Coupling of Offset Options by Amount Available with the "Acme Variable" Alternative.

Offset Option	Demand Type	Adjusted EUAC [1] ($/acre-ft/year)	Maximum Amount Available to CID Farmers (acre-ft/year)	Maximum Total Annual Cost ($/year)
Q1-SR---Develop Well Field - Seven Rivers	Avg./Max.	433	6,700	$2,901,100
Final EUAC, Total Amount, and Max. Annual Cost:	N/A	**433**	**6,700**	**$2,901,100**

It is apparent that many different selection processes could be followed yielding different results each time. Another appropriate method, which is not presented here, would be selecting options by the adjusted EUAC. This method would also tend to minimize water acquisitions.

7. Additional Water Acquisition for Flow Augmentation

The WOOG's scope initially focused on the offset of depletions to the Carlsbad Project Supply due to reoperation of Sumner Dam for the benefit of the PBNS. A subsequent issue addressed by the WOOG was the acquisition of additional water supplies for the PBNS. Additional water acquisition is defined as new water added to the Pecos River system, obtained for the purpose of providing instream flows for the PBNS. Additional water acquisition is required when re-operation of Sumner Dam is not adequate to provide instream habitat for the PBNS.

7.1. Distinction between Additional Water Acquisition and Offset of Carlsbad Project Supply

A distinction is made between offset water for replenishing depletions to Carlsbad Project Supply and water that is additionally acquired for augmenting instream flows, since the two modes of acquisition can have different effects on CID supply. Bypassing Carlsbad Project Supply through Sumner Dam for the PBNS is a *conjunctive* use of the surface water right. Part of the water is benefiting the shiner, while part of the water makes it to Brantley for use as irrigation water. In the process, some of the supply is depleted since it wasn't released with the high efficiency of a block release. Conversely, additional water acquisition may have, depending on the season and the additional acquisition amount, an *incidental benefit* to Carlsbad Project Supply. If water is solely purchased for the benefit of augmenting flows for the PBNS, some of that water will likely become Carlsbad Project Supply, thus augmenting its supply.

7.2. Additional Water Acquisition Options

Additional water acquisition options were formulated by revisiting the list of water offset options and determining which of those options could be applied upstream of the PBNS critical habitat. In addition, WOOG members developed additional acquisition options. Some of the options presented may not be practical in the scope of this NEPA process since public meetings and public information were not addressed upstream of Santa Rosa, NM. Additional water acquisition options, along with those that may not be feasible due to their location, are identified in Table 26.

Table 26. Possible Additional Water Acquisition Options Above Sumner Dam

Option Designation	Option Name	Description
A	Water Right Purchase	Water right purchase in CID, FSID, Near FSID, Puerto de Luna, Anton Chico, Villanueva╫, or the Gallinas Tributary╫.
B	Water Right Lease	Water right lease in CID, FSID, Near FSID, Puerto de Luna, Anton Chico, Villanueva╫, or the Gallinas Tributary╫.
C	On Farm Conservation	On-farm conservation in CID, FSID, Near FSID, Puerto de Luna, Anton Chico, Villanueva╫, or the Gallinas Tributary╫. Requires agreements with water purveyor for release of saved water
D	Cropping Pattern Changes	Cropping pattern changes in CID, FSID, Near FSID, Puerto de Luna, Anton Chico, Villanueva╫, or the Gallinas Tributary╫. Requires agreements with land owners for payments in lieu of crop revenues and release of saved water

Table 26. Possible Additional Water Acquisition Options Above Sumner Dam

Option Designation	Option Name	Description
E	Riparian Vegetation Control (upstream of upper critical habitat)	Eradicate and control exotic vegetation growth, such as Salt Cedar and Russian Olive, in the riparian corridor upstream of the upper critical habitat.
F	Import Canadian River Water	Import Canadian River water by building a trans-basin diversion between Conchas and Santa Rosa. Water would be supplied by saved irrigation losses from lining the Arch-Hurley canal Requires contract with district for transport of saved water from Canadian Basin
G	Range and Watershed Management	Eradicate mesquite and juniper from adjacent range and tributary areas to river to increase tributary flows and river base flows. Also, thin upland forest areas (in the Sangre de Cristos) to increase stream flow from Pecos headwaters.
H	Evaporation Suppression	Suppress evaporation on the two major reservoirs upstream of the upper critical habitat (Sumner and Santa Rosa).
I	Fort Sumner Area—Gravel Pit Pumping	Pump water from abandoned gravel pits in the Fort Sumner area to the river.
J	Fort Sumner Well Field	Develop a well field in the Ft. Sumner Area and pump water to the river.

╫ Does not fall within defined affected environment.

8. WOOG Documentation Matrix for Additional Water Acquisition to Augment Pecos River Flows

The documentation matrix for additional water acquisition options is shown as Table A.4 in Appendix A. For the most part, similarly related forms of acquisition and offset are derived from the numerical sources used for offset options. Options located in the affected environment upstream of Santa Rosa are listed in the matrix, but were not evaluated in the detail as other Additional Water Acquisition Options.

8.1. Additional Water Acquisition Options Redundant with Carlsbad Project Supply Offset Options

Redundant water acquisition options are offset options that would work to provide water upstream of the upper critical habitat by exchange for CID's supply. Because these options require the use of CID's supply, they are redundant with the analysis performed for offset options. Possible water right transfers or changes in the purpose or place of use may facilitate the implementation of such redundant offset options, without further offset of CID water rights.

8.2. Research and Investigation for Additional Water Acquisition Options

Additional water acquisition options were largely developed from offset options analyzed earlier. Options developed independent of the offset analysis were documented similarly to the offset options.

8.2.1. Additional Water Acquisition Options – Documentation Matrix Parameter Summary

Documentation parameters for additional water acquisition options are identical to those used for offset options. Please refer to section 3.2 for a description of those documented parameters.

8.2.2. Additional Water Acquisition Report Research

Also identical to the offset investigation process, report research for additional water acquisition was completed. In some cases, previously researched values from WOOG offset reports were used. These sources were documented in the WOOG documentation matrix for additional water acquisition.

8.2.3. Subsets of Additional Water Acquisition Options

A few subsets are noted in each major category of additional water acquisition options. Similar to the offset options, some additional water acquisition options contain multiple input parameters, such as differing irrigated acreages depending on the district in question. These options were divided into subsets to facilitate the evaluation of the different input parameters. A brief description of direct water acquisition options containing sub-categories and why they were divided follows:

- **Water Right Purchase (A):** Water right purchase options contain two tiers of sub-categories. The first tier is options that have projected prices based on time regression of prices from the 1990's. The second tier are options that are additionally inflated (after the time regression); these options are indicated with an "X" following their designation. Also, water right purchase options are divided by district. Since it is anticipated that only surface water rights will be available, with the exception of the "Near FSID" subcategory, groundwater acquisition options in the listed districts were not considered as they were for the offset options.
- **Water Right Lease (B):** Water right lease options are divided by district, with the exception of the "Near FSID" subcategory, which is not part of the FSID and has groundwater rights instead of surface water rights.
- **On Farm Conservation (C):** Differing irrigation districts have different proximities to the upper critical habitat and also have different amounts available based on irrigated acreage.
- **Cropping Pattern Changes (D):** Cropping patterns have two-tiered sub-categories. Cropping pattern changes vary by irrigation district (number suffixes of 1, 2, 3, 4, and 5) and additionally vary by input parameters from three different replacement crops or the average cost of all three replacement crops (letter suffixes—A, B, C, and D).
- **Riparian Vegetation Control (E):** Two subsets studied including removing Salt Cedar and replacing Russian Olive trees with Cottonwood trees.
- **Range and Watershed Management:** This additional water acquisition option was split into two tiers of sub-categories. The first tier distinguished range and watershed management in the lower watershed, such as management of vegetation in the adjacent uplands to the Pecos River, from upper watershed management, which is the management of the forest in the headwaters of the Pecos River. The second tier of divisions depends on the sub-category for the first tier. Lower watershed management was split into the range indicated by the researcher for salvage (upper, lower, and average amounts available) and upper watershed management was split into the range of costs associated with it (upper limit costs, lower limit costs, and average costs).
- **Evaporation Suppression:** This option was also divided into two tiers of sub-categories. The first tier divided new evaporation suppression methods from old evaporation suppression methods, which varied in cost. Additional sub-categories were then created for the aggregate of the two reservoirs upstream of the critical habitat, and also for Santa Rosa and Sumner individually.

8.2.4. Quantitative Data in the Additional Water Acquisition Option Forms

Documentation of quantitative data in the additional water acquisition option forms is identical to the documentation for offsets described in Section 3.4.

9. WOOG Ranking Matrix for Additional Water Acquisition to Augment Pecos River Flows

The WOOG Ranking Matrix for Additional Water Acquisition is shown as Table B-2 in Appendix B. The ranking matrix is nearly identical to the one used for evaluating water offset with the exception of three criteria changes which are described in the next section.

9.1. Quantitative Parameters and Ranking Criteria for Additional Water Acquisition Options

Two quantitative ranking criteria changes were implemented to the ranking matrix to modify it so it could be used to evaluate direct water acquisition for the PBNS. Supply flexibility, amount available and proximity were all modified to apply to the effectiveness of providing water for the PBNS. The remainder of the criteria applies to direct water acquisition without changes. Ranking criteria for two quantitative parameters were modified. Those modifications are shown in Tables 27 and 28.

Table 27. Amount Available Ranking Criteria Table-
Modified for PBNS Additional Water Acquisition

Greater than or equal to acre-ft/year:	
5	5000
4	4000
3	3000
2	2000
1	1000
0	100

Table 28. Proximity Ranking Criteria Table-Modified for PBNS Additional Water Acquisition

Based on where on the river the water would be realized or where the outfall would be located if the offset source is not adjacent to the river. Additional criteria addresses affected compact calculations.	
Rank	Description/Other Conditions
5	Upstream of Crockett Draw and Downstream of Dunlap Gage
4	Upstream of Dunlap Gage and Downstream of Taiban Gage
3	Upstream of Taiban Gage and Downstream of Sumner Dam
2	Upstream of Sumner Dam-Not Subject to Compact
1	Upstream of Sumner Dam-Subject to Compact -or- Upstream of Santa Rosa-Not Subject to Compact
0	Upstream of Santa Rosa-Subject to Compact

9.2 Qualitative Parameters and Ranking Criteria for Additional Water Acquisition Options

One of the qualitative parameters was modified for adaptation to additional water acquisition. The supply flexibility criteria were revised to reflect additional water acquisition for the PBNS. As with the quantitative parameters, the remaining qualitative parameters were not modified and applied to additional water acquisition options just as they did to WOOG options. Table 29 shows the modified supply flexibility criteria table.

Table 29. Supply Flexibility Ranking Criteria Table-Modified for PBNS Additional Water Acquisition

Based (seasonally) on when water is available for bypass.	
5	Provides bypass water on demand or allows storage of such water (any time of year)
2.5	Provides bypass water on demand in summer and spring
0	Provides bypass water in off seasons (winter and fall) only

9.3 Ranking for Additional Water Acquisition Options

Ranking of additional water acquisition options is accomplished in an identical manner as ranking for offset options as presented in Section 4.3, with the exception of the WOOG trial run through the option ranking.

9.4 Preferred Additional Water Acquisition Options – “A” and “B” Lists

As with the Offset Options, the Additional Water Acquisition Options were divided into “A” and “B” lists to indicate the timing of the available water. For Additional Water Acquisition Options in which the time to implement the option and time to realize water from that option was determined to be less than three years, the option was included on the “A” list. All other options were included on the “B” list. Table 30 itemizes the “A” list for Additional Water Acquisition Options and Table 31 itemizes the “B” list.

Table 30. Additional Water Acquisition Options - "A" List

Designation	Option Name	Amount Available (acre-feet/year)	Combined Total Score	EUAC[1] ($/acre-ft)
A-1	Surface Water Right Purchase-CID	3,150	75.5	99
A-2	Surface Water Right Purchase-FSID	1,000	73.5	99
A-1X	Surface Water Right Purchase-CID (additional 40% inflation)[2]	3,150	73.5	139
B-1	Surface Water Right Lease-CID	3,150	71.5	91
A-2X	Surface Water Right Purchase-FSID (additional 40% inflation)[2]	1,000	71.5	139
B-2	Surface Water Right Lease-FSID	1,000	70.5	91
I	Fort Sumner Gravel Pit Pumping	300	63.5	10
J-2	Fort Sumner Well Field-Pump Crop Pattern Savings	1,384	62.0	150
J-1	Fort Sumner Well Field-Groundwater Purchase and Conservation Savings	500	61.0	164
D-1C	Change Cropping Pattern-CID (Small Grain)	15,000	60.0	128
D-1A	Change Cropping Pattern-CID (Average of All Crops)	12,750	60	144
D-1D	Change Cropping Pattern-CID (Corn)	8,500	60.0	147
D-1B	Change Cropping Pattern-CID (Cotton)	12,500	59	158
D-2	Change Cropping Patterns-FSID (Small Grain)	3,375	59	158
A-4	Water Right Purchase-Puerto de Luna	110	57.5	99
A-4X	Water Right Purchase-Puerto de Luna (additional 40% inflation)[2]	110	55.5	139
B-4	Water Right Lease-Pureto de Luna	110	54.5	91
D-4	Change Cropping Patterns-Pureto de Luna (Small Grain)	360	47.5	168

Table 31. Additional Water Acquisition Options - "B" List

Designation	Option Name	Amount Available (af/year)	Combined Total Score	EUAC[1] ($/acre-ft)
C-1	On-Farm Conservation-CID	4,000	66.5	50
F	Import Canadian River Water	20,000	65	285
C-2	On-Farm Conservation-FSID	2,225	62	116
A-3	Groundwater Purchase-FSPA	235	60.5	67
A-3X	Groundwater Purchase-FSPA (additional 40% inflation)[2]	235	60.5	94
C-4	On-Farm Conservation-Puerto de Luna	1,620	57.5	42
B-3	Groundwater Right Lease-FSPA	235	57.5	69
A-5	Water Right Purchase-Above Santa Rosa	330	57.5	99
K	Renegotiate Compact-forbearance	18,500	57	145
G-1	Range and Lower Watershed Management (adjacent river upland)	13,271	56.5	6
G-2	Range and Lower Watershed Management (adjacent river upland)	7,300	56.5	10
C-3	On-Farm Conservation-FSPA	272	55.5	10
E-1	Riparian Vegetation Control (Salt Cedar)	3,125	55.5	27
A-5X	Groundwater Purchase-Above Santa Rosa (additional 40% inflation)[2]	330	55.5	139
E-2	Riparian Vegetation Control (Replace Russian Olive trees with Cottonwood trees)	4,000	54.5	51
B-5	Water Right Lease-Above Santa Rosa	330	53.5	91
C-5	On-Farm Conservation-Above Santa Rosa	330	52.5	184
G-6	Range and Lower Watershed Management (adjacent river upland)	12,700	51.5	-378
H-1	Evaporation Suppression (old methods)-Santa Rosa and Sumner	11,000	49.5	100
D-3	Change Cropping Patterns-FSPA (Small Grains)	1,388	48.5	108
H-3	Evaporation Suppression (old methods)-Sumner	6,100	47.5	100
G-3	Range and Lower Watershed Management (adjacent river upland)	1,296	46.5	57
D-5	Change Cropping Patterns-Above Santa Rosa (Small Grains)	315	46.5	147
G-5	Range and Lower Watershed Management (forest thinning)	12,700	45.5	482
G-4	Range and Lower Watershed Management (forest thinning)	12,700	45.5	1134
H-2	Evaporation Suppression (old methods)-Santa Rosa	4,900	44.5	100
H-4	Evaporation Suppression (new methods)-Santa Rosa and Sumner	11,000	36.5	3
H-6	Evaporation Suppression (new methods)-Sumner	6,100	36.5	6
H-5	Evaporation Suppression (new methods)-Santa Rosa	4,900	34.5	7

10. Recommendations on use of Offset and Additional Water Acquisition Options

Recommendations on the use of Offset Options or Additional Water Acquisition Options are provided to NEPA decision makers to guide selection of options that fulfill the purpose of the EIS. Development of "A" and "B" lists segregated the options into offsets or additional water sources that can reasonably be instituted within a time frame of three years. The "A" lists are those options that are reasonably likely to provide the needed water supplies within a three year period, and the "B" lists are those options that may provide the needed water supplies, but not within a three-year period. It was felt that in order for the USBR to implement offsets and additional acquisitions in a timely manner at the conclusion of this EIS, options should be implementable within three years.

Rankings within the "A" list are suggested preferences but do not preclude the decision maker from selecting any of the "A" options. It is the WOOG's opinion that options with very low unit costs (even those on the "B" lists) should be considered for ongoing research and development as means of securing the needed water supplies at the least cost. These options may not provide the assurances or timeliness required in the short term, but may provide long-term solutions that do not require implementation of options with major resource commitments. Long-term programs to control vegetation, import water supplies and even conduct cloud seeding operations are all worthy of ongoing investment and research. If any of these options were to prove effective, the dollar savings could be significant. It is also apparent that the commitment of resources should be tempered with the unknown quantities of water required for the PBNS and the possibility that offset options and additional water supplies could be less in the future. Water right purchases and the corresponding drying of lands to balance depletions is a time honored method of securing water supplies, but requires a transfer of water away from irrigated agriculture. Offsets and Additional Acquisitions in amounts that likely will change in the future may be better fulfilled through leases in the short term, so that water not needed for these purposes may be returned to original uses without major economic dislocations or permanent transfers.

However, WOOG analyses clearly identify the purchase or lease of existing water rights as options for offset or additional acquisitions that remain viable with fairly predicable short-term results. Even more effective at supplying water (but less cost effective) are options to develop well fields that pump water to the river. These options should be developed concurrently with the state's implementation of the Consensus Plan, if possible, to avoid competition for limited resources and take advantage of economies of scale.

11. References

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Appendix A

WOOG Documentation and Ranking Matrices

Table A.1. WOOG Documentation Matrix for Offset of Carlsbad Water Supply

WOOG PARAMETER DOCUMENTATION MATRIX

Last Updated by: **TBS 05/06/04**

Color Legend

- ⬜ -Base Parameter from report/investigation/or derived from alternative source
- 🟥 -Parameter estimated by Stockton
- 🟩 -Original costs annualized with 5.875% planning rate to reflect time value of money by Stockton
- 🟪 -Options eliminated
- ▨ -Subjective parameter-not determined in this matrix.
- 🟨 -Need more information.
- 🟦 -Parameter estimated by Soice

Ranking Criteria (Administrative/Documentation Form)

1) Equivalent Uniform Annual Cost (EUAC) of Water: Measured in $/acre-ft (annualized on yearly basis-using planning rate of 5.875%, end of period payments, and project life).
2) Timing: Not a quantitative value in this matrix-will be saved for ranking matrix.
3) Salvage Risk: Not a quantitative value in this matrix-will be saved for ranking matrix.
4) Political, Social, Legal, and Institutional Risk: Not a quantitative value in this matrix-will be saved for ranking matrix.
5) Amount available: Acre-ft per year available.
6) Proximity to CID: Measured in river miles from Rio Grande Confluence. * indicates some or majority of salvage water is subject to PR compact (above Sumner).
7) Sustainability: Not a quantitative value in this matrix-will be saved for ranking matrix.
8) Time to implement: Number of years to resolve all legal, infrastructure, and financial issues; water becomes available in river.
9) Time to realize: Number of years between end of time to implement before additional water becomes available to CID.

Cost Administration and Time Value of Money Categories

A) Willing seller: Options that do not meet this requisite will not be considsered, water must be able to be purchased or realized to be considered as an alternative.
B) Upfront capital cost: Initial cost at start of project (year 0).
C)Operation, Maintenance, and Replacement: Operation and maintenance costs, replacement automatic by definition of EUAC.
D) Project Life: How long the project will last and function before it needs replaced.
E) Total Present Value: Present worth of annual O,M,&R in year 0 (using project life and 5.875% planning rate) plus upfront capital cost.

NOTES:

[1] Mean river mile for majority of control/replacement (e.g. Sumner to Brantley for salt cedar or Sumner to Acme for Russian Olive).
[2] Water subject to Pecos River Interstate Compact
[3] Original "amount available" values broken up using (sum of) monthly reservoir estimates (by reservoir) from RiverWare Model.
[4] Treatment costs ($3050/acre-ft[Y-1] and $1342/acre-ft[Y-2]) are included in final per acre-ft number (not included in other capital cost columns)
[5] Values were inflated an additional 40% from original linear regression values predicted in Soice's report to account for ISC water right buy up.
[6] Option uses 40% inflated water right purchase numbers

<----------------------- RANKING CRITERIA -- <COST ADMINISTRATION AND TIME VALUE OF MONEY>

ID	Description	Lead Reviewer(s) Base Unit---->	1) EUAC of Water ($/af/year)	2) Tim.	3) Sal. Risk	4) Pol. Risk	5) Amt. Avail. (af/yr)	6) Close to CID? (r. mi.)	7) Sust.	8) Time to Impl. (years)	9) Time to Real. (years)	A) Upfront Capital Cost $ in year 0	B) O,M, & R $/year n	C) Proj. Life (years)	Total Cost (PV) $ in year 0	Parameter Comments
A-1	On Farm Conservation-FSID	Brummer	96	▨	▨	▨	5400	683	▨	5	0	6,000,000	0	20	6,000,000	Annual cost based on $1000/irrigated acre (upfront capital) for salvage of 1.5 acre-ft/acre and 6000 irrigated acres
A-2	On Farm Conservation-PVACD	Brummer	216	▨	▨	▨	8000	562	▨	5	0	20,000,000	0	20	20,000,000	Annual cost based on $1000/irrigated acre (upfront capital) for salvage of 0.4 acre-ft/acre and 20000 irrigated acres
A-3	On Farm Conservation-CID	Brummer	50	▨	▨	▨	4000	469	▨	5	0	0	200,000	20	2,317,445	Annual cost based on $10/irrigated acre*year for salvage of 0.2 acre-ft/acre and 20000 irrigated acres
A-4	Canal Refurbishing-FSID	Brummer	3.01	▨	▨	▨	9000	683	▨	5	0	205,000	14,350	50	435,189	Annual O&M estimated at 7% original capital cost.
A-5	Canal Refurbishing-CID	Brummer	44	▨	▨	▨	10000	469	▨	5	0	3,360,000	235,200	50	7,132,858	Annual O&M estimated at 7% original capital cost. Assumes only relining some areas.
B	Drain Construction	Soice		TRUNCATED												Option has problems with water rights and also has one time only use for very small amount.
C-1	Hernandez Idea-10 cfs	Shomaker		TRUNCATED												Option was forwarded to Alternative Development Group for Review
C-2	Hernandez Idea-25 cfs	Shomaker		TRUNCATED												Option was forwarded to Alternative Development Group for Review
C-3	Hernandez Idea-50 cfs	Shomaker		TRUNCATED												Option was forwarded to Alternative Development Group for Review
C-4	Hernandez Idea-90 cfs	Shomaker		TRUNCATED												Option was forwarded to Alternative Development Group for Review
D-1A	Water Right Purch. Surface (FSID)	Soice	99	▨	▨	▨	1000	683	▨	2	0	1,687	N/A	Infinite	1,687,000	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-1B	Water Right Purch. Surface (PVACD)	Soice	99	▨	▨	▨	1600	562	▨	2	0	1,687	N/A	Infinite	2,699,200	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-1C	Water Right Purch. Surface (CID)	Soice	99	▨	▨	▨	3150	469	▨	2	0	1,687	N/A	Infinite	5,314,050	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-2A	Water Right Purch.-Shallow GW (PVACD)	Soice	67	▨	▨	▨	7000	562	▨	2	0	1,147	N/A	Infinite	8,029,000	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-2B	Water Right Purch.-Shallow GW (CID)	Soice	67	▨	▨	▨	400	469	▨	2	0	1,147	N/A	Infinite	458,800	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-3A	Water Right Purch.-Artesian GW (PVACD)	Soice	84	▨	▨	▨	7000	562	▨	2	0	1,434	N/A	Infinite	10,038,000	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-3B	Water Right Purch.-Reef GW (CID)	Soice	84	▨	▨	▨	400	469	▨	2	0	1,434	N/A	Infinite	573,600	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
D-1AX	Water Right Purch. Surface (FSID)[5]	Soice	139	▨	▨	▨	1000	683	▨	2	0	2,362	N/A	Infinite	2,361,800	Same as D-1A, except cost numbers have additional 40% inflation value.
D-1BX	Water Right Purch. Surface (PVACD)[5]	Soice	139	▨	▨	▨	1600	562	▨	2	0	2,362	N/A	Infinite	3,778,880	Same as D-1B, except cost numbers have additional 40% inflation value.
D-1CX	Water Right Purch. Surface (CID)[5]	Soice	139	▨	▨	▨	3150	469	▨	2	0	2,362	N/A	Infinite	7,439,670	Same as D-1C, except cost numbers have additional 40% inflation value.
D-2AX	Water Right Purch.-Shallow GW (PVACD)[5]	Soice	94	▨	▨	▨	7000	562	▨	2	0	1,606	N/A	Infinite	11,240,600	Same as D-2A, except cost numbers have additional 40% inflation value.
D-2BX	Water Right Purch.-Shallow GW (CID)[5]	Soice	94	▨	▨	▨	400	469	▨	2	0	1,606	N/A	Infinite	642,320	Same as D-2B, except cost numbers have additional 40% inflation value.
D-3AX	Water Right Purch.-Artesian GW (PVACD)[5]	Soice	118	▨	▨	▨	7000	562	▨	2	0	2,008	N/A	Infinite	14,053,200	Same as D-3A, except cost numbers have additional 40% inflation value.
D-3BX	Water Right Purch.-Reef GW (CID)[5]	Soice	118	▨	▨	▨	400	469	▨	2	0	2,008	N/A	Infinite	803,040	Same as D-3B, except cost numbers have additional 40% inflation value.
E-1A	Water Right Lease/Land Fallowing-Surface (FSID)	Rocha	91	▨	▨	▨	1000	683	▨	2	0	91,000	91,000	5	384,632	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
E-1B	Water Right Lease/Land Fallowing-Surface (PVACD)	Rocha	91	▨	▨	▨	1600	562	▨	2	0	145,600	145,600	5	615,411	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
E-1C	Water Right Lease/Land Fallowing-Surface (CID)	Rocha	91	▨	▨	▨	3150	469	▨	2	0	286,650	286,650	5	1,211,591	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
E-2A	Water Right Lease/Land Flw.-Shlw. GW (PVACD)	Rocha	69	▨	▨	▨	7000	562	▨	2	0	483,000	483,000	5	2,041,509	Numbers based on 5 year existing BOR leases, upfront capital cost assumes yearly payments.
E-2B	Water Right Lease/Land Fallowing-Shallow GW (CID)	Rocha	69	▨	▨	▨	400	469	▨	2	0	27,600	27,600	5	116,658	Numbers based on 5 year existing BOR leases, upfront capital cost assumes yearly payments.
E-3A	Water Right Lease/Land Flw.-Artesian GW (PVACD)	Rocha	106	▨	▨	▨	7000	562	▨	2	0	742,000	742,000	5	3,136,231	Numbers based on 5 year existing BOR leases, upfront capital cost assumes yearly payments.
E-3B	Water Right Lease/Land Fallowing-Reef GW (CID)	Rocha	106	▨	▨	▨	400	469	▨	2	0	42,400	42,400	5	179,213	Numbers based on 5 year existing BOR leases, upfront capital cost assumes yearly payments.
F-1	Rip. Veg. Control-Salt Cedar	Brummer	27	▨	▨	▨	12500	594 [1]	▨	2	5	3,000,000	80,000	20	3,926,978	Assumes 25% reveg. and aerial herbicide application, 5 yr. to implement (time for herbicide to kill plant).
F-2	Veg. Control-Kochia Eradication	Brummer	13	▨	▨	▨	3600	503	▨	1	8	0	48,000	1	45,336	Uses wet and normal year salvage number, Dry year=$40/af
F-3	Replace RO with CW	Brummer	51	▨	▨	▨	4000	648 [1]	▨	2	5	3,000,000	8,000	40	3,122,292	Assumes 1000 acres replaceable
G	Acequia Improvements	Sidlow	28	TRUNCATED			250	720 [2]				110,650	N/A	50	110,650	Option is being built anyway.
H	Pump Supplemental Wells	Rhoton	23	▨	▨	▨	10000	469	▨	5	0	1,837,500	76,400	20	2,722,764	
I	Import Canadian River Water	Soice	285	▨	▨	▨	20000	750	▨	9	0	59,800,000	1,794,000	40	87,223,898	Rough estimate, doesn't include cost of ROW, lift stat., O&M, etc. Assumed 3% orig. cost for O&M
J	Res. Entitlement Storage Flexibility	Stockton	80	▨	▨	▨	3500	469	▨	5	0	4,500,000	0	50	4,500,000	Lowers Santa Rosa Conservation Storage by 10,000 AF and Raises Brantley by 10,000 AF.
K-1	Desalinization-Lower Limit Cost	Brummer	652	▨	▨	▨	10000	586	▨	9	0	8,236,000	5,930,000	30	90,964,930	Feed water is brackish (10000 ppm). See option form for other assumptions.
K-2	Desalinization-Upper Limit Cost	Brummer	1639	▨	▨	▨	10000	586	▨	9	0	8,236,000	15,800,000	30	228,660,468	Feed water is 35000 ppm. See option form for other assumptions.
L-1	Change Cropping Patterns (CID)-Ave. All Crops	Brummer	144	▨	▨	▨	12750	469	▨	2	0	1,831,650	N/A	1	1,831,650	Average of 3 crop types
L-2	Change Cropping Patterns (CID)-Cotton	Brummer	175	▨	▨	▨	12500	469	▨	2	0	2,188,250	N/A	1	2,188,250	
L-3	Change Cropping Patterns (CID)-Small Grain	Brummer	128	▨	▨	▨	15000	469	▨	2	0	1,912,800	N/A	1	1,912,800	
L-4	Change Cropping Patterns (CID)-Corn	Brummer	147	▨	▨	▨	8500	469	▨	2	0	1,252,100	N/A	1	1,252,100	
M	Lower Groundwater Levels	Stockton		TRUNCATED												Option's water savings are insignificant and near impossible to realize.
N-1	Rng. and (Lower) Watershed Mng.-Upper Limit Slvg.	Smith	6	▨	▨	▨	13271	646	▨	5	7.5	855,360	0	20	855,360	For adjacent (river) removal of mesquite in uplands from Taiban to Acme. Upper limit salvage value
N-2	Rng. and (Lower) Watershed Mng.-Average Slvg.	Smith	10	▨	▨	▨	7300	646	▨	5	7.5	855,360	0	20	855,360	For adjacent (river) removal of mesquite in uplands from Taiban to Acme. Average salvage value
N-3	Rng. and (Lower) Watershed Mng.-Lower Limit Slvg.	Smith	57	▨	▨	▨	1296	646	▨	5	7.5	855,360	0	20	855,360	For adjacent (river) removal of mesquite in uplands from Taiban to Acme. Lower limit salvage value
N-4	Rng. and (Upper) Watershed Mng.-Upper Limit Cost	Springer	1134	▨	▨	▨	25400	blw.586	▨	5	10	462,000,000	0	50	462,000,000	Highest estimated cost ($2000/acre); 231000 acres thinned
N-5	Rng. and (Upper) Watershed Mng.-Average Cost	Springer	482	▨	▨	▨	25400	blw.586	▨	5	10	196,350,000	0	50	196,350,000	Most probable cost according to land managers; 231000 acres thinned
N-6	Rng. and (Upper) Watershed Mng.-Lower Limit Cost	Springer	-378	▨	▨	▨	25400	blw.586	▨	5	10	-154,000,000	0	50	-154,000,000	Commercial sales from thinning (numbers based on small Cloudcroft project); 231000 acres thinned
O	Cloud Seeding	Springer	0.98	▨	▨	▨	43000	758 [2]	▨	2	0	0	44,720	1	42,238	Assumes $.052/acre of drainage area seeded. Assumes conc. point for drain area upstream of Sumner.
P	GW recharge/conjunctive use	Shomaker		TRUNCATED												Identical to well field development since amount must be offset every year.
Q1-SR	Develop Well Field-Seven Rivers	Sims	290	▨	▨	▨	10000	479	▨	2	0	22,335,166	1,303,402	30	40,518,817	Adds cost of artesian and shallow water right purchase (10000 af each) [D-3].
Q1-BV	Develop Well Field-Buffalo Valley	Sims	264	▨	▨	▨	10000	479	▨	2	0	18,593,052	1,303,402	30	36,776,703	Adds cost of artesian and shallow water right lease (10000 af each)
R	Rio Hondo Flood Control	Sidlow		TRUNCATED												Option is being built anyway.
S	Additional Metering (mostly PVACD)	Stockton	55	▨	▨	▨	6250	586	▨	1	1	2,800,000	163,000	40	5,291,692	Source: Lower Pecos Valley Regional Water Plan, pgs 235-236. Costs are for study--does not include lobbying.
T-1	Evaporation Suppresion-Old Methods (All Major)	Shomaker	100	▨	▨	▨	17500	709 [2]	▨	2	0	1,750,000	N/A	1	1,750,000	
T-1A	Evaporation Suppresion-Old Methods (Santa Rosa)[3]	Shomaker	100	▨	▨	▨	4900	758 [2]	▨	2	0	490,000	N/A	1	490,000	Location apportionment for amount based on RiverWare monthly evap estimates.
T-1B	Evaporation Suppresion-Old Methods (Sumner)[3]	Shomaker	100	▨	▨	▨	6100	709 [2]	▨	2	0	610,000	N/A	1	610,000	Location apportionment for amount based on RiverWare monthly evap estimates.
T-1C	Evaporation Suppresion-Old Methods (Brantley)[3]	Shomaker	100	▨	▨	▨	6500	479	▨	2	0	650,000	N/A	1	650,000	Location apportionment for amount based on RiverWare monthly evap estimates.
T-2	Evaporation Suppresion-New Rsrch. (All Major)	Shomaker	3.25	▨	▨	▨	17500	709 [2]	▨	10	0	56,875	N/A	1	56,875	
T-2A	Evaporation Suppresion-New Rsrch. (Santa Rosa)[3]	Shomaker	3.25	▨	▨	▨	4900	758 [2]	▨	10	0	15,925	N/A	1	15,925	Location apportionment for amount based on RiverWare monthly evap estimates.
T-2B	Evaporation Suppresion-New Rsrch. (Sumner)[3]	Shomaker	3.25	▨	▨	▨	6100	709 [2]	▨	10	0	19,825	N/A	1	19,825	Location apportionment for amount based on RiverWare monthly evap estimates.
T-2C	Evaporation Suppresion-New Rsrch. (Brantley)[3]	Shomaker	3.25	▨	▨	▨	6500	479	▨	10	0	21,125	N/A	1	21,125	Location apportionment for amount based on RiverWare monthly evap estimates.
U	FS Area Gravel Pit Pumping	Stockton	10	▨	▨	▨	300	683	▨	2	0	11,500	1,862	20	33,075	O&M includes maintenance and labor for 1 month of operation--does not include elec. hookup or ROW costs.
V	Kaiser Channel Lining	Stockton	180	▨	▨	▨	9900	503	▨	10	0	14,672,800	733,640	30	24,907,750	
W	Water Imprt. From Salt Bas. or Cap. Reef	Springer	620	▨	▨	▨	20000	479	▨	9	0	144,152,000	2,967,000	40	189,506,908	
X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	Springer	7884	▨	▨	▨	22000	586	▨	10	0	472,100,000	142,562,350	40	2,651,372,734	For comparison with desalination option
X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	Springer	8965	▨	▨	▨	22000	586	▨	10	0	472,100,000	166,340,125	40	3,014,850,586	For comparison with desalination option
X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	Springer	7026	▨	▨	▨	22000	586	▨	10	0	472,100,000	123,690,248	40	2,362,885,221	For comparison with desalination option
X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	Springer	2222	▨	▨	▨	22000	586	▨	10	0	472,100,000	17,996,702	40	747,205,744	Industrial sale of electric compareable with wholesale; gas transmission costs are omitted.
X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	Springer	3082	▨	▨	▨	22000	586	▨	10	0	472,100,000	36,928,003	40	1,036,598,194	Industrial sale of electric compareable with wholesale; gas transmission costs are omitted.
X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	Springer	1484	▨	▨	▨	22000	586	▨	10	0	472,100,000	1,756,485	40	498,950,423	Industrial sale of electric compareable with wholesale; gas transmission costs are omitted.
X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale	Springer	-236	▨	▨	▨	22000	586	▨	10	0	472,100,000	-36,074,705	40	-79,354,295	Sales price optimistic without cost of electric distribution system; gas transmission costs are omitted.
X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	Springer	862	▨	▨	▨	22000	586	▨	10	0	472,100,000	-11,930,402	40	289,726,465	Sales price optimistic without cost of electric distribution system; gas transmission costs are omitted.
X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	Springer	-1164	▨	▨	▨	22000	586	▨	10	0	472,100,000	-56,494,025	40	-391,493,279	Sales price optimistic without cost of electric distribution system; gas transmission costs are omitted.
Y-1	Oil Field Production Well Waste Water-Example 1[4]	Sims	3188	▨	▨	▨	8815	479	▨	5	0	30,781,000	5,878,000	10	74,300,958	Uses cheapest delivery option-final number includes tax credit of $1000/acre-ft delivered to Pecos River
Y-2	Oil Field Production Well Waste Water-Example 2[4]	Sims	1687	▨	▨	▨	9030	479	▨	5	0	31,599,000	7,879,000	10	89,934,106	Uses cheapest delivery option-final number includes tax credit of $1000/acre-ft delivered to Pecos River

Table A.2. Stockton's Ranking Matrix for Offset of Carlsbad Water Supply

WOOG CARLSBAD PROJECT RANKING MATRIX

Tetra Tech, Inc.
Updated: 4/11/04

Ranking Criteria (Translated to 0-5 scale)	**Weight**
1) Cost (EUAC)	Initial weight of 1
2) Timing	Initial weight of 1
3) Salvage Risk	Initial weight of 1
4) Political, Legal, Social, and Institutional Risk	Initial weight of 1
5) Amount available	Initial weight of 1
6) Proximity to CID	Initial weight of 1
7) Sustainability	Initial weight of 1
8) Time to implement	Initial weight of 1
9) Time to physically realize (measured from end of time to implement)	Initial weight of 1
10) Positive cooncidental benefit for Pecos Bluntnose Shiner	Initial weight of 1
11) Stateline Effects	Initial weight of 1

░	Ranked by WOOG Group on 04/02/03
☐	Ranked by Stockton
▓	Option Eliminated
⬚	Revised rank 11/19/03

RANKING CRITERIA as 0-5 SCALE

ID	Description	1) Cost	2) Timing	3)Salvage Risk	4) Pol. Risk	5) Amt. Available	6) Close to CID?	7) Sust.	8) Time to Impl.	9) Time to Realize	10) State Benefit?	EUAC ($/acre-ft)	Total Score
	WEIGHT----->	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
A-1	On Farm Conservation-FSID	4	3	4	0	2	3	4	3	5	2.5	96	30.5
A-2	On Farm Conservation-PVACD	3	3	4	0	2	4	4	3	2	2.5	216	27.5
A-3	On Farm Conservation-CID	5	3	4	0	2	5	4	3	5	0	50	31.0
A-4	Canal Refurbishing-FSID	5	3	4	0	2	3	4	3	5	2.5	3	31.5
A-5	Canal Refurbishing-CID	5	3	4	0	3	5	4	3	5	0	44	32.0
B	Drain Construction		OPTION	ELIMINATED									
C-1	Hernandez Idea-10 cfs		OPTION FORWARDED TO ALTERNATIVE DEVELOPMENT GROUP										
C-2	Hernandez Idea-25 cfs		OPTION FORWARDED TO ALTERNATIVE DEVELOPMENT GROUP										
C-3	Hernandez Idea-50 cfs		OPTION FORWARDED TO ALTERNATIVE DEVELOPMENT GROUP										
C-4	Hernandez Idea-90 cfs		OPTION FORWARDED TO ALTERNATIVE DEVELOPMENT GROUP										
D-1A	Water Right Purch/Land Retirement-Surface (FSID)	4	1	5	4	1	3	5	4	5	2.5	99	34.5
D-1B	Water Right Purch/Land Retirement-Surface (PVACD)	4	1	5	4	1	4	5	4	5	2.5	99	35.5
D-1C	Water Right Purch/Land Retirement-Surface (CID)	4	1	5	4	1	5	5	4	5	0	99	34.0
D-2A	Water Right Purch/Land Ret.-Shallow GW (PVACD)	4	3	4	4	2	4	5	4	3	2.5	67	35.5
D-2B	Water Right Purch/Land Ret.-Shallow GW (CID)	4	1	4	4	0	5	5	4	3	2.5	67	32.5
D-3A	Water Right Purch/Land Ret.-Artesian GW (PVACD)	4	3	4	4	2	4	5	4	2	2.5	84	34.5
D-3B	Water Right Purch/Land Ret.-Reef GW (CID)	4	1	4	4	0	5	5	4	3	2.5	84	32.5
D-1AX	Water Right Purch/Land Retirement-Surface (FSID)-40% Infl.	3	1	5	4	1	3	5	4	5	2.5	139	33.5
D-1BX	Water Right Purch/Land Retirement-Surface (PVACD)-40% Infl.	3	1	5	4	1	4	5	4	5	2.5	139	34.5
D-1CX	Water Right Purch/Land Retirement-Surface (CID)-40% Infl.	3	1	5	4	1	5	5	4	5	0	139	33.0
D-2AX	Water Right Purch/Land Ret.-Shallow GW (PVACD)-40% Infl.	4	3	4	4	2	4	5	4	3	2.5	94	35.5
D-2BX	Water Right Purch/Land Ret.-Shallow GW (CID)-40% Infl.	4	1	4	4	0	5	5	4	3	2.5	94	32.5
D-3AX	Water Right Purch/Land Ret.-Artesian GW (PVACD)-40% Infl.	3	3	5	4	2	4	5	4	2	2.5	118	34.5
D-3BX	Water Right Purch/Land Ret.-Reef GW (CID)-40% Infl.	3	1	5	4	0	5	5	4	3	2.5	118	32.5
E-1A	Water Right Lease/Land Fallowing-Surface (FSID)	4	1	5	5	1	3	3	4	5	2.5	91	33.5
E-1B	Water Right Lease/Land Fallowing-Surface (PVACD)	4	1	5	5	1	4	3	4	5	2.5	91	34.5
E-1C	Water Right Lease/Land Fallowing-Surface (CID)	4	1	5	5	1	5	3	4	5	0	91	33.0
E-2A	Water Right Lease/Land Flw.-Shallow GW (PVACD)	4	3	4	5	2	4	3	4	3	2.5	69	34.5
E-2B	Water Right Lease/Land Flw.-Shallow GW (CID)	4	1	4	5	0	5	3	4	5	2.5	69	33.5
E-3A	Water Right Lease/Land Flw.-Artesian GW (PVACD)	3	3	4	5	2	4	3	4	2	2.5	106	32.5
E-3B	Water Right Lease/Land Fallowing-Reef GW (CID)	3	1	4	5	0	5	3	4	5	2.5	106	32.5
F-1	Rip. Veg. Control-Salt Cedar	5	3	0	4	3	3	4	4	3	2.5	27	31.5
F-2	Veg. Control-Kochia Eradication	5	3	1	4	1	4	3	5	3	2.5	13	31.5
F-3	Replace RO with CW	4	3	0	4	1	3	4	4	3	2.5	51	28.5
G	Acequia Improvements		OPTION	ELIMINATED									
H	Pump Supplemental Wells	5	3	1	0	3	5	0	3	5	0	23	25.0
I	Import Canadian River Water	3	5	5	0	5	2	4	0	5	2.5	285	31.5
J	Res. Entitlement Storage Flexibility	4	0	4	2	1	5	5	3	5	0	80	29.0
K-1	Desalinization-Lower Limit Cost	2	3	5	2	3	4	4	0	5	2.5	652	30.5
K-2	Desalinization-Upper Limit Cost	1	3	5	2	3	4	4	0	5	2.5	1,639	29.5
L-1	Change Cropping Patterns (CID)-Ave. All Crops	3	3	4	0	3	5	3	4	5	0	144	30.0
L-2	Change Cropping Patterns (CID)-Cotton	3	3	4	0	3	5	3	4	5	0	175	30.0
L-3	Change Cropping Patterns (CID)-Small Grain	3	5	4	0	4	5	3	4	5	0	128	33.0
L-4	Change Cropping Patterns (CID)-Corn	3	3	4	0	2	5	3	4	5	0	147	29.0
M	Lower Groundwater Levels		OPTION	ELIMINATED									
N-1	Rng. and (Lower) Watershed Mng.-Upper Limit Slvg.	5	3	1	4	3	3	4	3	1	2.5	6	29.5
N-2	Rng. and (Lower) Watershed Mng.-Average Slvg.	5	3	1	4	2	3	4	3	3	2.5	10	30.5
N-3	Rng. and (Lower) Watershed Mng.-Lower Limit Slvg.	4	1	1	4	1	3	4	3	3	2.5	57	26.5
N-4	Rng. and (Upper) Watershed Mng.-Upper Limit Cost	1	5	1	4	5	4	4	3	3	2.5	1,134	32.5
N-5	Rng. and (Upper) Watershed Mng.-Average Cost	3	5	1	4	5	4	4	3	3	2.5	482	34.5
N-6	Rng. and (Upper) Watershed Mng.-Lower Limit Cost	5	5	1	4	5	4	4	3	3	2.5	-378	36.5
O	Cloud Seeding	5	4	0	2	5	1	2	4	5	2.5	1	30.5
P	GW recharge/conjunctive use		OPTION REDUNDANT TO THOSE STUDIED UNDER DESIGNATION Q										
Q1-SR	Develop Well Field-Seven Rivers	3	3	5	5	3	5	4	4	5	2.5	290	39.5
Q1-BV	Develop Well Field-Buffalo Valley	3	3	5	5	3	5	4	4	5	2.5	264	39.5
R	Rio Hondo Flood Control		OPTION	ELIMINATED									
S	Additional Metering	4	2	1	1	2	4	5	4	3	2.5	55	28.5
T-1	Evap. Suppresion-Old Methods (All Major)	4	4	2	0	4	2.3	3	4	5	2.5	100	30.8
T-1A	Evap. Suppresion-Old Methods (Santa Rosa)	4	2	2	0	1	1	3	4	5	2.5	100	24.5
T-1B	Evap. Suppresion-Old Methods (Sumner)	4	2	2	0	2	1	3	4	5	2.5	100	25.5
T-1C	Evap. Suppresion-Old Methods (Brantley)	4	2	2	0	2	5	3	4	5	2.5	100	29.5
T-2	Evap. Suppresion-New Rsrch. (All Major)	5	4	0	0	4	2.3	0	0	5	2.5	3	22.8
T-2A	Evap. Suppresion-New Rsrch. (Santa Rosa)	5	0	0	0	1	1	0	0	5	2.5	3	14.5
T-2B	Evap. Suppresion-New Rsrch. (Sumner)	5	2	0	0	2	1	0	0	5	2.5	3	17.5
T-2C	Evap. Suppresion-New Rsrch. (Brantley)	5	2	0	0	2	5	0	0	5	2.5	3	21.5
U	FS Area Gravel Pit Pumping	5	0	3	4	0	3	4	4	5	2.5	10	30.5
V	Kaiser Channel Lining	3	2	5	0	2	5	4	0	5	2.5	180	28.5
W	Water imprt. From Salt Bas. or Cap. Reef	2	5	5	0	5	5	4	1	5	5	620	37.0
X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	0	5	5	0	5	4	4	0	5	2.5	7,884	30.5
X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	0	5	5	0	5	4	4	0	5	2.5	8,965	30.5
X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	0	5	5	0	5	4	4	0	5	2.5	7,026	30.5
X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	0	5	5	0	5	4	4	0	5	2.5	2,222	30.5
X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	0	5	5	0	5	4	4	0	5	2.5	3,082	30.5
X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	1	5	5	0	5	4	4	0	5	2.5	1,484	31.5
X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale)	5	5	5	0	5	4	4	0	5	2.5	-236	35.5
X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	2	5	5	0	5	4	4	0	5	2.5	862	32.5
X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	5	5	5	0	5	4	4	0	5	2.5	-1,164	35.5
Y-1	Oil Field Production Well Waste Water-Low FW TDS	0	3	5	2	2	5	4	3	5	2.5	3,188	31.5
Y-2	Oil Field Production Well Waste Water-High FW TDS	1	3	5	2	2	5	4	3	5	2.5	1,687	32.5
Z	Renegotiate Compact-Forebearance	3	5	5	0	4	2.5	5	0	5	2.5	145	32.0

Table A.3. Soice’s Ranking Matrix for Offset of Carlsbad Water Supply

WOOG CARLSBAD PROJECT RANKING MATRIX					RANKING CRITERIA as 0-5 SCALE; ranked by Phil Soice of Southwest Water Consultants										
ID	Description	Lead Reviewer(s)	1) Cost	2) Timing	3) Sal Risk	4) Pol Risk	5) Amt. Available	6)Close to CID?	7) Sustain	8) Time to Implement	9) Time to Realize	10) Benefit Stateline	EUAC per afy	Total Score	Initial Cap millions$
	WEIGHT----->		1	1	1	1	1	1	1	1	1	1		11	
A-1	On Farm Conservation-FSID	Brummer	4	3	1	1	2	3	5	3	5	2.5	96	29.5	6
A-2	On Farm Conservation-PVACD	Brummer	3	3	1	1	2	4	5	3	2	2.5	216	26.5	20
A-3	On Farm Conservation-CID	Brummer	5	3	5	1	2	5	5	3	5	0	50	34	0.0
A-4	Canal Refurbishing-FSID	Brummer	5	3	1	1	2	3	5	3	5	2.5	3	30.5	0.2
A-5	Canal Refurbishing-CID	Brummer	5	3	3	2	3	5	5	3	5	0	44	34	3
B	Drain Construction	Soice		OPTION ELIMINATED										0	
C-1	Hernandez Idea-10 cfs	Shomaker		OPTION ELIMINATED										0	
C-2	Hernandez Idea-25 cfs	Shomaker		OPTION ELIMINATED										0	
C-3	Hernandez Idea-50 cfs	Shomaker		OPTION ELIMINATED										0	
C-4	Hernandez Idea-90 cfs	Shomaker		OPTION ELIMINATED										0	
D-1A	Water Right Purch Sur FSID	Soice	4	3	5	5	1	3	5	4	5	2.5	99	37.5	2
D-1B	Water Right Purch Sur Roswell Area	Soice	4	3	5	5	1	4	5	4	5	2.5	99	38.5	3
D-1C	Water Right Purch Sur CID	Soice	4	3	5	5	1	5	5	4	5	0	99	37	5
D-2A	Water Right Purch Shallow PVACD	Soice	4	3	4	5	2	4	5	4	3	2.5	67	36.5	8
D-2B	Water Right Purch Shallow CID	Soice	4	3	4	5	0	5	5	4	3	0	67	33	0.5
D-3A	Water Right Purch Artesian PVACD	Soice	4	3	4	5	2	4	5	4	2	2.5	84	35.5	10
D-3B	Water Right Purch Reef CID	Soice	4	3	4	5	0	5	5	4	3	0	84	33	0.6
D-1AX	Water Right Purch Sur FSID	Soice	3	3	5	5	1	3	5	4	5	2.5	139	36.5	2
D-1BX	Water Right Purch Sur Roswell Area	Soice	3	3	5	5	1	4	5	4	5	2.5	139	37.5	4
D-1CX	Water Right Purch Sur CID	Soice	3	3	5	5	1	5	5	4	5	0	139	36	7
D-2AX	Water Right Purch Shallow PVACD	Soice	4	3	4	5	2	4	5	4	3	2.5	94	36.5	11
D-2BX	Water Right Purch Shallow CID	Soice	4	3	4	5	0	5	5	4	3	0	94	33	0.6
D-3AX	Water Right Purch Artesian PVACD	Soice	3	3	4	5	2	4	5	4	2	2.5	118	34.5	14
D-3BX	Water Right Purch Reef CID	Soice	4	3	4	5	0	5	5	4	3	0	118	33	0.8
E-1A	Water Right Lease Sur FSID	Rocha	4	3	5	5	1	3	4	5	5	2.5	91	37.5	0.1
E-1B	Water Right Lease Sur Roswell	Rocha	4	3	5	5	1	4	4	5	5	2.5	91	38.5	0.1
E-1C	Water Right Lease Sur CID	Rocha	4	3	5	5	1	5	4	5	5	0	91	37	0.3
E-2A	Water Right Lease Shallow PVACD	Rocha	4	3	4	5	2	4	4	5	3	2.5	69	36.5	0.5
E-2B	Water Right Lease Shallow CID	Rocha	4	3	4	5	0	5	4	5	3	0	69	33	0.03
E-3A	Water Right Lease Artesian PVACD	Rocha	3	3	4	5	2	4	4	5	3	2.5	106	35.5	0.7
E-3B	Water Right Lease Reef CID	Rocha	3	3	4	5	0	5	4	5	3	0	106	32	0.04
F-1	Rip. Veg. Control-Salt Cedar	Brummer	5	3	3	5	3	5	4	4	2	2.5	27	36.5	3
F-2	Veg. Control-Kochia Eradication	Brummer	5	3	3	4	1	5	4	5	3	2.5	13	35.5	0.05
F-3	Replace RO with CW	Brummer	4	3	3	3	1	3	4	4	2	2.5	51	29.5	3
G	Acequia Improvements	Sidlow		OPTION ELIMINATED										0	
H	Pump Supplemental Wells	Rhoton	5	3	3	0	3	5	3	2	5	0	23	29	2
I	Import Canadian River Water	Soice	3	3	3	1	5	2	4	3	5	5	285	34	60
J	Res. Entitlement Storage Flexibility	Stockton	4	0	4	2	1	5	5	3	5	0	80	29	5
K-1	Desalinization-Lower Limit Cost	Brummer	2	3	5	4	3	4	4	3	5	2.5	652	35.5	8
K-2	Desalinization-Upper Limit Cost	Brummer	1	3	5	4	3	4	4	3	5	2.5	1639	34.5	8
L-1	Change Cropping Patterns (CID)-Ave. All Crops	Brummer	3	3	4	1	3	5	4	5	5	2.5	144	35.5	2
L-2	Change Cropping Patterns (CID)-Cotton	Brummer	4	3	4	1	3	5	4	5	5	2.5	175	36.5	2
L-3	Change Cropping Patterns (CID)-Small Grain	Brummer	5	3	4	1	4	5	4	5	5	2.5	128	38.5	2
L-4	Change Cropping Patterns (CID)-Corn	Brummer	4	3	4	1	2	5	4	5	5	2.5	147	35.5	1.3
M	Lower Groundwater Levels	Stockton		OPTION ELIMINATED										0	
N-1	Rng. And Watershed Management-Upper Limit	Smith	5	3	3	4	3	4	4	3	1	2.5	6	32.5	0.9
N-2	Rng. And Watershed Management-Average	Smith	5	3	3	4	2	4	4	3	1	2.5	10	31.5	0.9
N-3	Rng. And Watershed Management-Lower Limit	Smith	4	3	3	4	1	4	4	3	1	2.5	57	29.5	0.9
N-4	Range and (Upper) Watershed Management-high cost	Springer	1	3	3	4	5	4	4	0	3	2.5	1134	29.5	462
N-5	Range and (Upper) Watershed Management-prob. cost	Springer	3	3	3	4	5	4	4	0	3	2.5	482	31.5	196
N-6	Range and (Upper) Watershed Management-no cost	Springer	5	3	3	4	5	4	4	0	3	2.5	-378	33.5	-154
O	Cloud Seeding	Springer	5	2	2	2	3	1	4	4	5	2.5	1	30.5	0.04
P	GW recharge/conjunctive use	Shomaker		OPTION ELIMINATED										0	
Q-1SR	Develop Well Field Seven Rivers	Sims	3	4	5	3	3	5	4	3	5	2.5	290	37.5	22
Q-2BV	Develop Well Field Buffalo Valley	Sims	3	4	5	3	3	4	4	3	5	2.5	264	36.5	19
R	Rio Hondo Flood Control	Sidlow		OPTION ELIMINATED										0	
S	Additional Metering	Soice	5	3	2	1	2	4	4	4	2	2.5	55	29.5	3
T-1	Evaporation Suppresion-Old Methods	Shomaker	4	3	2	0	4	5	3	3	5	2.5	100	31.5	2
T-1A	Evaporation Suppresion-Old Methods (Santa Rosa)	Shomaker	4	3	2	0	1	1	3	3	5	2.5	100	24.5	0.5
T-1B	Evaporation Suppresion-Old Methods (Sumner)	Shomaker	4	3	2	0	2	1	3	3	5	2.5	100	25.5	0.6
T-1C	Evaporation Suppresion-Old Methods (Brantley)	Shomaker	4	3	2	0	2	5	3	3	5	2.5	100	29.5	0.7
T-2	Evaporation Suppresion-New Research	Shomaker	5	3	0	0	4	5	0	0	5	2.5	3	24.5	0.06
T-2A	Evaporation Suppresion-New Methods (Santa Rosa)	Shomaker	5	3	0	0	1	1	0	0	5	2.5	3	17.5	0.02
T-2B	Evaporation Suppresion-New Methods (Sumner)	Shomaker	5	3	0	0	2	1	0	0	5	2.5	3	18.5	0.02
T-2C	Evaporation Suppresion-New Methods (Brantley)	Shomaker	5	3	0	0	2	5	0	0	5	2.5	3	22.5	0.02
U	FS Area Gravel Pit Pumping	Stockton	5	2	3	1	4	3	2	4	5	2.5	10	31.5	0.01
V	Kaiser Channel Lining	Stockton	3	3	4	2	2	5	5	3	5	2.5	180	34.5	15
W	Water imprt. From Salt Bas. or Cap. Reef	Springer	2	3	5	0	5	5	4	3	5	5	620	37	144
X-1	Dsl. Pwr. Plant-No Power Offset-2002 Cost of Gas	Springer	0	3	5	0	5	5	4	0	5	2.5	7884	29.5	472
X-2	Dsl. Pwr. Plant-No Power Offset-Past 3 -Yr. Cost of Gas	Springer	0	3	5	0	5	5	4	0	5	2.5	8965	29.5	472
X-3	Dsl. Pwr. Plant-No Power Offset-Past 10-Yr. COG	Springer	0	3	5	0	5	5	4	0	5	2.5	7026	29.5	472
X-4	Dsl. Pwr. Plant-2002 Energy Prices (Industrial Elec. Sale)	Springer	0	3	5	0	5	5	4	0	5	2.5	2222	29.5	472
X-5	Dsl. Pwr. Plant-Past 3-yr Energy Prices (Industrial ES)	Springer	0	3	5	0	5	5	4	0	5	2.5	3082	29.5	472
X-6	Dsl. Pwr. Plant-Past 10-yr Energy Prices (Industrial ES)	Springer	1	3	5	0	5	5	4	0	5	2.5	1484	30.5	472
X-7	Dsl. Pwr. Plant-2002 Energy Prices (All Sector Elec. Sale	Springer	5	3	5	0	5	5	4	0	5	2.5	-236	34.5	472
X-8	Dsl. Pwr. Plant-Past 3-yr Energy Prices (All Sector ES)	Springer	2	3	5	0	5	5	4	0	5	2.5	862	31.5	472
X-9	Dsl. Pwr. Plant-Past 10-yr Energy Prices (All Sector ES)	Springer	5	3	5	0	5	5	4	0	5	2.5	-1164	34.5	472
Y-1	Oil Field Production Well Waste Water-Low FW TDS	Sims	0	3	5	2	2	5	4	3	5	2.5	3188	31.5	31
Y-2	Oil Field Production Well Waste Water-High FW TDS	Sims	1	3	5	2	2	5	4	3	5	2.5	1687	32.5	32
Z	Renegotiate Compact-Forebearance	Springer	3	3	5	0	4	2.5	5	0	5	2.5	145	30	46

Table A.4. Additional Water Acquisition Documentation Matrix

WOOG ADDITIONAL WATER ACQUISITION PARAMETER DOCUMENTATION MATRIX

Last Updated by: **TBS 06/08/04**

Legend

🟥	-Parameter estimated by Stockton.
🟦	-Parameter estimated by Soice.
⬜	-From original WOOG reports
🟩	-Original costs annualized with 5.875% planning rate to reflect time value of money by Stockton
▨	-Subjective parameter-not determined in this matrix.
🟦	-New research by WOOG member for fish water acquisition.
🟨	-Additional information needed

Ranking Criteria (Administrative/Documentation Form)

1) Equivalent Uniform Annual Cost (EUAC) of Water: Measured in $/acre-ft (annualized on yearly basis-using planning rate of 5.875%, end of period payments, and project life).
2) Timing: Not a quantitative value in this matrix-will be saved for ranking matrix.
3) Salvage Risk: Not a quantitative value in this matrix-will be saved for ranking matrix.
4) Political, Social, Legal, and Institutional Risk: Not a quantitative value in this matrix-will be saved for ranking matrix.
5) Amount available: Acre-ft per year available.
6) Proximity to Upper Critical Habitat: Measured in river miles from Rio Grande Confluence. * indicates some or majority of salvage water is subject to PR compact (above Sumner).
7) Sustainability: Not a quantitative value in this matrix-will be saved for ranking matrix.
8) Time to implement: Number of years to resolve all legal, infrastructure, and financial issues; water becomes available in river.
9) Time to realize: Number of years between end of time to implement before additional water becomes available to CID.

Cost Administration and Time Value of Money Categories

A) Willing seller: Options that do not meet this requisite will not be consisdered, water must be able to be purchased or realized to be considered as an alternative.
B) Upfront capital cost: Initial cost at start of project (year 0).
C)Operation, Maintenance, and Replacement: Operation and maintenance costs, replacement automatic by definition of EUAC.
D) Project Life: How long the project will last and function before it needs replaced.
E) Total Present Value: Present worth of annual O,M,&R in year 0 (using project life and 5.875% planning rate) plus upfront capital cost.

NOTES:

[1] Mean river mile for majority of control/replacement (e.g. Santa Rosa to Crockett Draw for salt cedar and Russian Olive).
[2] Water subject to Pecos River Interstate Compact
[3] Original "amount available" values broken up using (sum of) monthly reservoir estimates (by reservoir) from RiverWare Model.
[4] Values were inflated an additional 40% from original linear regression values predicted in Soice's report to account for ISC water right buy up.

			<----------------------	RANKING CRITERIA	---							<COST ADMINISTRATION AND TIME VALUE OF MONEY>				
ID	Description	Lead Reviewer(s Base Unit--	1) EUAC of Water ($/af/year)	2) Sup. Flex.	3) Sal. Risk	4) Pol. Risk	5) Amt. Avail. (af/yr)	6) Close to UCH? (r. mi.)	7) Sust.	8) Time to Impl. (years)	9) Time to Real. (years)	A) Upfront Capital Cost $ in year 0	B) O,M, & R $/year n	C) Proj. Life (years)	Total Cost (PV) $ in year 0	Parameter Comments
A-1	Surface Water Right Purchase-CID	Soice	99	▨	▨	▨	3150	709	▨	2	0	1,687	N/A	Infinite	5,314,050	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-2	Surface Water Right Purchase-FSID	Soice	99	▨	▨	▨	1000	683	▨	2	0	1,687	N/A	Infinite	1,687,000	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-3	Groundwater Right Purchase-FSPA	Soice	67	▨	▨	▨	235	675	▨	2	0	1,147	N/A	Infinite	269,545	Uses shallow aquifer water right prices.
A-4	Water Right Purchase-Puerto de Luna	Soice	99	▨	▨	▨	110	720	▨	2	0	1,687	N/A	Infinite	185,570	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-5	Water Right Purchase-Above Santa Rosa	Soice	99	▨	▨	▨	330	>758	▨	2	0	1,687	N/A	Infinite	556,710	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-1X	Surface Water Right Purchase-CID (add. 40% inflat.) [4]	Soice	139	▨	▨	▨	3150	709	▨	2	0	2,362	N/A	Infinite	7,439,670	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-2X	Surface Water Right Purchase-FSID (add. 40% inflat.) [4]	Soice	139	▨	▨	▨	1000	683	▨	2	0	2,362	N/A	Infinite	2,361,800	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-3X	Groundwater Right Purchase-FSPA (add. 40% inflat.) [4]	Soice	94	▨	▨	▨	235	675	▨	2	0	1,606	N/A	Infinite	377,363	Uses shallow aquifer water right prices.
A-4X	Water Right Purchase-Puerto de Luna (add. 40% inflat.) [4]	Soice	139	▨	▨	▨	110	720	▨	2	0	2,362	N/A	Infinite	259,798	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
A-5X	Water Right Purchase-Above Santa Rosa (add. 40% inflat.) [4]	Soice	139	▨	▨	▨	330	>758	▨	2	0	2,362	N/A	Infinite	779,394	Upfront capital cost per single af in year 0, EUAC is infinite an. series. Cost numbers inflated w/time series regression
B-1	Surface Water Right Lease-CID	Rocha	91	▨	▨	▨	3150	709	▨	2	0	0	286,650	5	1,211,591	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
B-2	Surface Water Right Lease-FSID	Rocha	91	▨	▨	▨	1000	683	▨	2	0	0	91,000	5	384,632	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
B-3	Groundwater Right Lease-FSPA	Rocha	69	▨	▨	▨	235	675	▨	2	0	0	16,215	5	68,536	Numbers based on 5 year existing BOR leases, upfront capital cost assumes yearly payments.
B-4	Water Right Lease-Puerto de Luna	Rocha	91	▨	▨	▨	110	720	▨	2	0	0	10,010	5	42,310	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
B-5	Water Right Lease-Above Santa Rosa	Rocha	91	▨	▨	▨	330	>758	▨	2	0	0	30,030	5	126,929	Numbers based on 5 year existing BOR leases for river pumpers, upfront capital cost assumes yearly payments.
C-1	On Farm Conservation-CID	Brummer	50	▨	▨	▨	4000	709	▨	5	0	0	200,000	20	2,317,445	Annual cost based on $10/irrigated acre*year for salvage of 0.2 acre-ft/acre and 20000 irrigated acres
C-2	On Farm Conservation-FSID	Brummer	116	▨	▨	▨	2225	683	▨	5	0	3,000,000	0	20	3,000,000	
C-3	On Farm Conservation-FSPA	Brummer	25	▨	▨	▨	272	675	▨	5	0	80,000	0	20	80,000	Assumes groundwater accrual to river for 25/acre-ft.
C-4	On Farm Conservation-Puerto de Luna	Brummer	42	▨	▨	▨	1620	720	▨	5	0	705,000	7,050	20	786,690	
C-5	On Farm Conservation-Above Santa Rosa	Brummer	184	▨	▨	▨	1100	>758	▨	5	0	2,100,000	21,000	20	2,343,332	
D-1A	Change Cropping Patterns-CID (Ave. All Crops)	Brummer	144	▨	▨	▨	12750	709	▨	2	0	1,831,650	N/A	1	1,831,650	Average of 3 crop types
D-1B	Change Cropping Patterns-CID (Cotton)	Brummer	175	▨	▨	▨	12500	709	▨	2	0	2,188,250	N/A	1	2,188,250	
D-1C	Change Cropping Patterns-CID (Small Grain)	Brummer	128	▨	▨	▨	15000	709	▨	2	0	1,912,800	N/A	1	1,912,800	
D-1D	Change Cropping Patterns-CID (Corn)	Brummer	147	▨	▨	▨	8500	709	▨	2	0	1,252,100	N/A	1	1,252,100	
D-2	Change Cropping Patterns-FSID (Small Grain)	Brummer	158	▨	▨	▨	3375	683	▨	2	0	532,500	N/A	1	532,500	
D-3	Change Cropping Patterns-FSPA (Small Grain)	Brummer	108	▨	▨	▨	1388	675	▨	2	0	150,000	N/A	1	150,000	
D-4	Change Cropping Patterns-Puerto de Luna (Small Grain)	Brummer	168	▨	▨	▨	360	720	▨	2	0	60,346	N/A	1	60,346	
D-5	Change Cropping Patterns-Above Santa Rosa (Small Grain)	Brummer	147	▨	▨	▨	315	>758	▨	2	0	46,305	N/A	1	46,305	
E-1	Riparian Veg. Control (Salt Cedar)	Brummer	27	▨	▨	▨	3125	695 [1]	▨	2	5	750,000	20,000	20	981,745	Uses approximate location centroid from Santa Rosa Reservoir to Atkins Ranch
E-2	Riparian Veg. Control (Replace RO with CW)	Brummer	51	▨	▨	▨	4000	695 [1]	▨	2	5	3,000,000	8,000	40	3,122,292	Assumes 1000 acres replaceable
F	Import Canadian River Water	Rocha	285	▨	▨	▨	20000	750	▨	9	0	59,800,000	1,794,000	40	87,223,898	Rough estimate, doesn't include cost of ROW, lift stat., O&M, etc. Assumed 3% orig. cost for O&M
G-1	Range and Lower Watershed Management (adj. river upland)	Smith	6	▨	▨	▨	13271	646 [1]	▨	5	7.5	855,360	0	20	855,360	Entire treatment area applies to Additional Water Acquisition Limits.
G-2	Range and Lower Watershed Management (adj. river upland)	Smith	10	▨	▨	▨	7300	646 [1]	▨	5	7.5	855,360	0	20	855,360	Entire treatment area applies to Additional Water Acquisition Limits.
G-3	Range and Lower Watershed Management (adj. river upland)	Smith	57	▨	▨	▨	1296	646 [1]	▨	5	7.5	855,360	0	20	855,360	Entire treatment area applies to Additional Water Acquisition Limits.
G-4	Range and Upper Watershed Management (forest thinning)	Springer	1134	▨	▨	▨	12700	>758	▨	5	10	231,000,000	0	50	231,000,000	Areas were reduced by %50 from WOOG #'s since thinning would only take place in Sangre de Cristos
G-5	Range and Upper Watershed Management (forest thinning)	Springer	482	▨	▨	▨	12700	>758	▨	5	10	98,175,000	0	50	98,175,000	Areas were reduced by %50 from WOOG #'s since thinning would only take place in Sangre de Cristos
G-6	Range and Upper Watershed Management (forest thinning)	Springer	-378	▨	▨	▨	12700	>758	▨	5	10	-77,000,000	0	50	-77,000,000	Areas were reduced by %50 from WOOG #'s since thinning would only take place in Sangre de Cristos
H-1	Evaporation Suppression (old meth.)-Santa Rosa and Sumner	Shomaker	100	▨	▨	▨	11000	733 [1]	▨	2	0	1,100,000	N/A	1	1,100,000	Proximity average of RM for both reservoirs.
H-2	Evaporation Suppression (old meth.)-Santa Rosa	Shomaker	100	▨	▨	▨	4900 [3]	758	▨	2	0	700,000	N/A	1	700,000	Location apportionment for amount based on RiverWare monthly evap estimates.
H-3	Evaporation Suppression (old meth.)-Sumner	Shomaker	100	▨	▨	▨	6100 [3]	709	▨	2	0	700,000	N/A	1	700,000	Location apportionment for amount based on RiverWare monthly evap estimates.
H-4	Evaporation Suppression (new meth.)-Santa Rosa and Sumner	Shomaker	3.25	▨	▨	▨	11000	733 [1]	▨	10	0	35,750	N/A	1	35,750	Proximity average of RM for both reservoirs.
H-5	Evaporation Suppression (new meth.)-Santa Rosa	Shomaker	7.29	▨	▨	▨	4900 [3]	758	▨	10	0	35,700	N/A	1	35,700	Location apportionment for amount based on RiverWare monthly evap estimates.
H-6	Evaporation Suppression (new meth.)-Sumner	Shomaker	5.85	▨	▨	▨	6100 [3]	709	▨	10	0	35,700	N/A	1	35,700	Location apportionment for amount based on RiverWare monthly evap estimates.
I	Fort Sumner Gravel Pit Pumping	Stockton	10	▨	▨	▨	300	683	▨	2	0	11,500	1,862	20	33,075	O&M includes maintenance and labor for 1 month of operation--does not include elec. hookup or ROW costs.
J-1	Fort Sumner Well Field-GW Purchase and Cons. Savings	Stockton	164	▨	▨	▨	500	680	▨	2	0	898,200	17,750	30	1,145,829	10 cfs capacity, can pump for 25 days at full capacity
J-2	Fort Sumner Well Field-Pump Crop Pattern Savings	Stockton	150	▨	▨	▨	1384	680	▨	2	0	455,000	174,872	30	2,894,625	10 cfs capacity, can pump for 69 days at full capacity
K	Renegotiate Compact--Forebearance	Springer	145	▨	▨	▨	18500	Blw. Avl.	▨	10	0	45,548,064		10000	45,548,064	See option form for all assumptions

Table A.5. Stockton’s Additional Water Acquisition Ranking Matrix

WOOG ADDITIONAL WATER ACQUISITION RANKING MATRIX

Tetra Tech, Inc.

Last Updated by: **TBS 6/8/04**

Ranking Criteria (Translated to 0-5 scale)	**Weight**
1) Cost (EUAC)---same as CID ranking	Initial weight of 1
2) Timing---revised from CID ranking	Initial weight of 1
3) Salvage Risk---same as CID ranking	Initial weight of 1
4) Political, Legal, Social, and Institutional Risk---same as CID ranking	Initial weight of 1
5) Amount available---revised from CID ranking	Initial weight of 1
6) Proximity to Upper Critical Habitat---revised from CID ranking	Initial weight of 1
7) Sustainability---same as CID ranking	Initial weight of 1
8) Time to implement---same as CID ranking	Initial weight of 1
9) Time to physically realize (measured from end of time to implement)---same as CID ranking	Initial weight of 1
10) Stateline Effects---same as CID ranking	Initial weight of 1

RANKING CRITERIA as 0-5 SCALE

ID	Description	1) Cost	2) Supply Flexibility	3)Salvage Risk	4) Pol. Risk	5) Amt. Available	6) Close to UCH?	7) Sust.	8) Time to Impl.	9) Time to Realize	10) State Benefit?	EUAC ($/acre-ft)	Total Score
	WEIGHT----->	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
A-1	Surface Water Right Purchase-CID	4	5	5	4	3	2	5	4	5	0	99	37.0
A-2	Surface Water Right Purchase-FSID	4	2.5	5	4	1	3	5	4	5	2.5	99	36.0
A-3	Groundwater Right Purchase-FSPA	4	0	4	4	0	4	5	4	3	2.5	67	30.5
A-4	Water Right Purchase-Puerto de Luna	4	2.5	5	2	0	2	5	4	5	2.5	99	32.0
A-5	Water Right Purchase-Above Santa Rosa	4	2.5	5	2	0	1	5	4	5	2.5	99	31.0
A-1X	Surface Water Right Purchase-CID (add. 40% inflat.) [4]	3	5	5	4	3	2	5	4	5	0	139	36.0
A-2X	Surface Water Right Purchase-FSID (add. 40% inflat.) [4]	3	2.5	5	4	1	3	5	4	5	2.5	139	35.0
A-3X	Groundwater Right Purchase-FSPA (add. 40% inflat.) [4]	4	0	4	4	0	4	5	4	3	2.5	94	30.5
A-4X	Water Right Purchase-Puerto de Luna (add. 40% inflat.) [4]	3	2.5	5	2	0	2	5	4	5	2.5	139	31.0
A-5X	Water Right Purchase-Above Santa Rosa (add. 40% inflat.) [4]	3	2.5	5	2	0	1	5	4	5	2.5	139	30.0
B-1	Surface Water Right Lease-CID	4	5	5	4	3	2	3	4	5	0	91	35.0
B-2	Surface Water Right Lease-FSID	4	2.5	5	4	1	3	3	4	5	2.5	91	34.0
B-3	Groundwater Right Lease-FSPA	4	0	4	4	0	4	3	4	3	2.5	69	28.5
B-4	Water Right Lease-Puerto de Luna	4	2.5	5	2	0	2	3	4	5	2.5	91	30.0
B-5	Water Right Lease-Above Santa Rosa	4	2.5	5	2	0	1	3	4	5	2.5	91	29.0
C-1	On Farm Conservation-CID	5	5	4	0	4	2	4	3	5	0	50	32.0
C-2	On Farm Conservation-FSID	3	2.5	4	0	2	3	4	3	5	2.5	116	29.0
C-3	On Farm Conservation-FSPA	5	0	4	0	0	4	4	3	3	2.5	25	25.5
C-4	On Farm Conservation-Puerto de Luna	5	2.5	4	0	1	2	4	3	5	2.5	42	29.0
C-5	On Farm Conservation-Above Santa Rosa	3	2.5	4	0	1	1	4	3	5	2.5	184	26.0
D-1A	Change Cropping Patterns-CID (Ave. All Crops)	3	5	4	0	5	2	3	4	5	0	144	31.0
D-1B	Change Cropping Patterns-CID (Cotton)	3	5	4	0	5	2	3	4	5	0	175	31.0
D-1C	Change Cropping Patterns-CID (Small Grain)	3	5	4	0	5	2	3	4	5	0	128	31.0
D-1D	Change Cropping Patterns-CID (Corn)	3	5	4	0	5	2	3	4	5	0	147	31.0
D-2	Change Cropping Patterns-FSID (Small Grain)	3	2.5	4	0	3	3	3	4	5	2.5	158	30.0
D-3	Change Cropping Patterns-FSPA (Small Grain)	3	0	4	0	1	4	3	4	3	2.5	108	24.5
D-4	Change Cropping Patterns-Puerto de Luna (Small Grain)	3	2.5	4	0	0	2	3	4	5	2.5	168	26.0
D-5	Change Cropping Patterns-Above Santa Rosa (Small Grain)	3	2.5	4	0	0	1	3	4	5	2.5	147	25.0
E-1	Riparian Veg. Control (Salt Cedar)	5	0	0	4	3	3	4	4	3	2.5	27	28.5
E-2	Riparian Veg. Control (Replace RO with CW)	4	0	0	4	4	3	4	4	3	2.5	51	28.5
F	Import Canadian River Water	3	5	5	0	5	2	4	0	5	2.5	285	31.5
G-1	Range and Lower Watershed Management (adj. river upland)	5	0	1	4	5	5	4	3	1	2.5	6	30.5
G-2	Range and Lower Watershed Management (adj. river upland)	5	0	1	4	5	5	4	3	1	2.5	10	30.5
G-3	Range and Lower Watershed Management (adj. river upland)	4	0	1	4	1	5	4	3	1	2.5	57	25.5
G-4	Range and Upper Watershed Management (forest thinning)	2	0	1	4	5	0	4	3	3	2.5	1,134	24.5
G-5	Range and Upper Watershed Management (forest thinning)	2	0	1	4	5	0	4	3	3	2.5	482	24.5
G-6	Range and Upper Watershed Management (forest thinning)	5	0	1	4	5	0	4	3	3	2.5	-378	27.5
H-1	Evaporation Suppression (old meth.)-Santa Rosa and Sumner	4	0	2	0	5	1	3	4	5	2.5	100	26.5
H-2	Evaporation Suppression (old meth.)-Santa Rosa	3	0	2	0	4	0	3	4	5	2.5	100	23.5
H-3	Evaporation Suppression (old meth.)-Sumner	3	0	2	0	5	1	3	4	5	2.5	100	25.5
H-4	Evaporation Suppression (new meth.)-Santa Rosa and Sumne	5	0	0	0	5	1	0	0	5	2.5	3	18.5
H-5	Evaporation Suppression (new meth.)-Santa Rosa	5	0	0	0	4	0	0	0	5	2.5	7	16.5
H-6	Evaporation Suppression (new meth.)-Sumner	5	0	0	0	5	1	0	0	5	2.5	6	18.5
I	Fort Sumner Gravel Pit Pumping	5	2.5	3	4	0	3	4	4	5	2.5	10	33.0
J-1	Fort Sumner Well Field-GW Purchase and Cons. Savings	3	5	4	0	0	3	4	4	5	2.5	164	30.5
J-2	Fort Sumner Well Field-Pump Crop Pattern Savings	3	5	4	0	1	3	3	4	5	2.5	150	30.5
K	Renegotiate Compact--Forebearance	3	2.5	3	0	5	2	5	0	5	2.5	145	28.0

Table A.6. Soice's Additional Water Acquisition Ranking Matrix

WOOG ADDITIONAL WATER ACQUISITION RANKING MATRIX **RANKING CRITERIA as 0-5 SCALE; ranked by Phil Soice of Southwest Water Consultants**

Updated:	6/8/2004	Lead	1) Cost	2) Supply	3) Sal Risk	4) Pol Risk	5) Amt.	6)Close to	7) Sustain	8) Time to	9) Time to	10) Benefit	EUAC	Total	Initial Cap
ID	Description	Reviewer(s)		Flexibility			Available	CID?		Implement	Realize	Stateline	per afy	Score	millions$
	WEIGHT----->		1	1	1	1	1	1	1	1	1	1			
A-1	Surface Water Right Purchase-CID	Soice	4	5	5	2	3	3	5	4	5	2.5	99	38.5	5.3
A-2	Surface Water Right Purchase-FSID	Soice	4	5	5	3	1	3	5	4	5	2.5	99	37.5	1.7
A-3	Groundwater Right Purchase-FSPA	Soice	4	2.5	4	3	0	3	5	4	2	2.5	67	30	0.3
A-4	Water Right Purchase-Puerto de Luna	Soice	4	2.5	5	0	0	1	5	3	5	0	99	25.5	0.2
A-5	Water Right Purchase-Above Santa Rosa	Soice	4	2.5	5	0	0	1	5	4	5	0	99	26.5	0.6
A-1X	Surface Water Right Purchase-CID (add. 40% inflat.)[4]	Soice	3	5	5	2	3	3	5	4	5	2.5	139	37.5	7.4
A-2X	Surface Water Right Purchase-FSID (add. 40% inflat.)[4]	Soice	3	5	5	3	1	3	5	4	5	2.5	139	36.5	2.4
A-3X	Groundwater Right Purchase-FSPA (add. 40% inflat.)[4]	Soice	4	2.5	4	3	0	3	5	4	2	2.5	94	30	0.4
A-4X	Water Right Purchase-Puerto de Luna (add. 40% inflat.)[4]	Soice	3	2.5	5	0	0	1	5	3	5	0	139	24.5	0.3
A-5X	Water Right Purchase-Above Santa Rosa (add. 40% inflat.)[4]	Soice	3	2.5	5	0	0	1	5	4	5	0	139	25.5	0.8
B-1	Surface Water Right Lease-CID	Rocha	4	5	5	2	3	3	4	4	5	2.5	91	37.5	1.2
B-2	Surface Water Right Lease-FSID	Rocha	4	5	5	3	1	3	4	4	5	2.5	91	36.5	0.4
B-3	Groundwater Right Lease-FSPA	Rocha	4	2.5	4	3	0	3	4	4	2	2.5	69	29	0.1
B-4	Water Right Lease-Puerto de Luna	Rocha	4	2.5	5	0	0	1	4	3	5	0	91	24.5	0.04
B-5	Water Right Lease-Above Santa Rosa	Rocha	4	2.5	5	0	0	1	4	3	5	0	91	24.5	0.1
C-1	On Farm Conservation-CID	Brummer	5	2.5	5	1	4	3	5	4	5	0	50	34.5	0.00
C-2	On Farm Conservation-FSID	Brummer	3	2.5	5	1	2	3	5	4	5	2.5	116	33	3.0
C-3	On Farm Conservation-FSPA	Brummer	5	2.5	3	3	0	3	5	4	2	2.5	25	30	0.1
C-4	On Farm Conservation-Puerto de Luna	Brummer	5	2.5	5	0	1	1	5	4	5	0	42	28.5	0.7
C-5	On Farm Conservation-Above Santa Rosa	Brummer	3	2.5	5	0	1	1	5	4	5	0	184	26.5	2.1
D-1A	Change Cropping Patterns-CID (Ave. All Crops)	Brummer	3	2.5	4	0	5	1	3	3	5	2.5	144	29	1.8
D-1B	Change Cropping Patterns-CID (Cotton)	Brummer	3	2.5	4	0	5	1	3	3	5	2.5	175	29	2.2
D-1C	Change Cropping Patterns-CID (Small Grain)	Brummer	3	2.5	4	0	5	1	3	3	5	2.5	128	29	1.9
D-1D	Change Cropping Patterns-CID (Corn)	Brummer	3	2.5	4	0	5	1	3	3	5	2.5	147	29	1.3
D-2	Change Cropping Patterns-FSID (Small Grain)	Brummer	3	2.5	4	0	5	1	3	3	5	2.5	158	29	0.5
D-3	Change Cropping Patterns-FSPA (Small Grain)	Brummer	3	2.5	4	0	1	3	3	3	2	2.5	108	24	0.2
D-4	Change Cropping Patterns-Puerto de Luna (Small Grain)	Brummer	3	2.5	4	0	0	1	3	3	5	0	168	21.5	0.1
D-5	Change Cropping Patterns-Above Santa Rosa (Small Grain)	Brummer	3	2.5	4	0	0	1	3	3	5	0	147	21.5	0.05
E-1	Riparian Veg. Control (Salt Cedar)	Brummer	5	0	3	5	3	1	4	4	2	0	27	27	0.8
E-2	Riparian Veg. Control (Replace RO with CW)	Brummer	4	0	3	4	4	1	4	4	2	0	51	26	3.0
F	Import Canadian River Water	Rocha	3	2.5	3	1	5	2	4	3	5	5	285	33.5	59.8
G-1	Range and Lower Watershed Management (adj. river upland)	Smith	5	0	3	4	5	1	4	3	1	0	6	26	0.9
G-2	Range and Lower Watershed Management (adj. river upland)	Smith	5	0	3	4	5	1	4	3	1	0	10	26	0.9
G-3	Range and Lower Watershed Management (adj. river upland)	Smith	4	0	3	4	1	1	4	3	1	0	57	21	0.9
G-4	Range and Upper Watershed Management (forest thinning)	Springer	2	0	1	3	5	0	4	3	3	0	1134	21	231.0
G-5	Range and Upper Watershed Management (forest thinning)	Springer	2	0	1	3	5	0	4	3	3	0	482	21	98.2
G-6	Range and Upper Watershed Management (forest thinning)	Springer	5	0	1	3	5	0	4	3	3	0	-378	24	-77.0
H-1	Evaporation Suppression (old meth.)-Santa Rosa and Sumner	Shomaker	4	0	2	0	5	1	3	3	5	0	100	23	1.1
H-2	Evaporation Suppression (old meth.)-Santa Rosa	Shomaker	3	0	2	0	4	1	3	3	5	0	100	21	0.7
H-3	Evaporation Suppression (old meth.)-Sumner	Shomaker	3	0	2	0	5	1	3	3	5	0	100	22	0.7
H-4	Evaporation Suppression (new meth.)-Santa Rosa and Sumner	Shomaker	5	0	0	0	5	1	0	2	5	0	3	18	0.04
H-5	Evaporation Suppression (new meth.)-Santa Rosa	Shomaker	5	0	0	0	5	1	0	2	5	0	7	18	0.04
H-6	Evaporation Suppression (new meth.)-Sumner	Shomaker	5	0	0	0	5	1	0	2	5	0	6	18	0.04
I	Fort Sumner Gravel Pit Pumping	Stockton	5	5	3	1	0	3	2	4	5	2.5	10	30.5	0.01
J-1	Fort Sumner Well Field-GW Purchase and Cons. Savings	Stockton	3	5	4	1	0	3	4	3	5	2.5	164	30.5	0.9
J-2	Fort Sumner Well Field-Pump Crop Pattern Savings	Stockton	3	5	4	1	1	3	4	3	5	2.5	150	31.5	0.5
K	Renegotiate Compact--Forebearance	Springer	3	2.5	4	0	5	2	5	0	5	2.5	145	29.0	46

Appendix 3

Hydrologic and Water Resources

Hydrologic and Water Resources Technical Appendices to the Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

INTRODUCTION

This technical appendix to the Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement contains 8 individual contributions. These documents contain technical details regarding individual components of the Pecos River Decision Support System (PRDSS) and associated modeling and processing of data used for alternatives impact analysis.

As described in Chapter 4 of the EIS, the PRDSS is comprised of several linked modeling tools that are used to quantify Pecos Basin hydrologic responses to management actions. While Chapter 4 presents the overall PRDSS impact analysis results with respect to the water resource / hydrologic resource indicators, technical details related to the analysis (including descriptions of modeling tools, approaches, and assumptions) are provided technical documents listed below. Included in the list with each document title is a brief description of how that particular document relates to the analyses in this EIS.

- Results Memorandum for Alternative Modeling Using Bypass Water: This document describes surface water modeling of alternatives, including bypasses and block release restrictions, without Carlsbad Project Water Acquisition (CPWA) or additional water acquisition (AWA). It provides flow duration results and net depletions results along with background information and interpretations of the modeled output.
- Pecos River Bypass and Additional Water Needed (AWN) Modeling and Post-Processing: This document details RiverWare modeling and post-processing calculations for bypass operations alone, and computation of additional water needed (beyond the bypasses) to meet flow targets for the PBNS 100% of the time. Summary results are presented.
- Pecos River RiverWare Model Offset Modeling Documentation Report: This report describes the surface water modeling of CPWA options with the Taiban and Acme Constant alternatives. The report presents modeled results and interpretations for effective CPWA reaching CID, and also presents derivations for Brantley transit efficiencies, along with estimated Brantley transit efficiencies.
- Pecos River RiverWare Model Additional Water Acquisition Modeling Documentation Report: This report describes the surface water modeling of AWA options. Improvements (and degeneration) of intermittency and flow duration from AWA options are presented as results along with some interpretation.
- New Mexico-Texas Stateline Modeling and Post-Processing Report: This memorandum addresses the assumptions and methods used to compute impacts of operational alternatives and selected Water Offset options modeling on flows at the New Mexico-Texas Stateline. It also provides summary results.
- Roswell Artesian Basin Ground Water Model Technical Report: This report summarizes the application of the RABGW model to the EIS alternatives analysis. The document focuses in particular on RABGW analyses of the Carlsbad Project Water Acquisition options of groundwater rights retirement and installation of an augmentation well field to supplement the chronically short Carlsbad Project water supplies
- Analysis of Intermittency: This memorandum describes the calculation of intermittency in the upper critical habitat reach (focused specifically on the near Acme gage). In particular the conditional probability and confidence interval

methods and results are developed and presented. Length of intermittency is also investigated, and the results emphasize comparison by hydrologic season.

- Geomorphology Technical Memorandum: This memorandum documents a field reconnaissance visit from Sumner Reservoir to Brantley Reservoir along the Pecos River. It illustrates the different geomorphic conditions found along the Pecos River in this reach. It also provides channel geometry predictions for the modeled flow duration of alternatives.

Each separate document is intended to disclose to the interested members of the public details related to distinct aspects and/or water resource indicators that were not included in the main body of the EIS. Besides this technical appendix, additional supporting documentation related to the hydrological and water resource investigations undertaken in support of the EIS can be found in the EIS Administrative Record.

In particular, essentially all of the hydrologic analysis and evaluations presented here and in the body of the EIS were provided through the collaborative efforts of the Pecos River Hydrology Working Group (HWG), which has maintained an Administrative Record (AR) of all of their activities. The HWG is a multiagency / Pecos Basin stakeholder group that has been meeting on an approximately monthly basis since 2000. Jointly led by representatives of the US Bureau of Reclamation and the New Mexico Interstate Stream Commission, the HWG included representatives from Carlsbad Irrigation District, Fort Sumner Irrigation District, the US Army Corps of Engineers, Debaca County, and Sandia National Laboratories, and on occasion other stakeholders. All of the modeling tools and methodologies described in Chapter 4 and the following technical documents were developed through the HWG. Important investigations, analyses, and issues scoping undertaken by the HWG are documented in detailed notes taken at each meeting, and in memos, reports, and PowerPoint presentations prepared by HWG members. Some of these reports provide yet more detailed coverage of the modeling tools than that found in some of the following technical appendices. All of these items can be found in the HWG files as part of the EIS AR.

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New Mexico-Texas Stateline Modeling and Post-Processing Report

Roswell Artesian Basin Ground Water Model Technical Report

Analysis of Intermittency

Geomorphology Technical Memorandum

Results Memorandum for Alternative Modeling Using Bypass Water

Written by: Alaina Briggs, P.E.

And

Tomas Stockton, P.E.

With contributions from the Carlsbad Project
Hydrology / Water Operations Work Group

January 2006

Preface

The following memorandum was first drafted in the fall of 2004 by Alaina Briggs with the contributions of other NEPA Hydrology / Water Operations (HWG) members. This preface was attached to the current version of this memorandum to explain the changes made to the memorandum for inclusion in the HWG's Technical Appendix in support of the Carlsbad Water Operations EIS. The alternative reoperations modeling (with the absence of water acquisitions) is a piece of a larger picture of NEPA hydrologic analyses and modeling that included such aspects as: alternative reoperations, Carlsbad Project water acquisition (CPWA), State-line flow, additional water acquisition (AWA), geomorphology, and sub-sets of the aforementioned aspects of analysis and modeling including Roswell basin modeling (which applies to CPWA), and finally Carlsbad basin modeling (which applies to State-line flow modeling).

Included in the original memorandum were intermittency, flow exceedance, and net depletion analyses. The intermittency and flow exceedance information was for the most part left untouched in this revision; however, the net depletion section was extensively rewritten to account for new perspectives on interpreting the modeled output. Now included in this document is a detailed breakdown of net depletion sources to CID from reoperations using 60-year modeled averages. These concepts were originally presented in a draft of the "Pecos River RiverWare Model CPWA Modeling Documentation Report" (Stockton Engineering and Tetra Tech, 2005a), but were removed and inserted in this document since they directly applied to the results presented in this document. Also included are estimated maximum annual transmission losses in the reach from Sumner Reservoir to Brantley Reservoir due to bypass operations only. In addition, a section is now included showing the effects of comparisons using net depletions that can indicate erroneous net depletions. Net depletions to State-line flows were also reworked to remove the effects that temporally unequal modeled spills can have on indicating erroneous maximum and minimum net depletions to State-line flows. All of these improvements and the revised supporting methods for interpreting output were included in the revision of the memorandum. The methods in this memorandum are current with the results presented in the Public Draft EIS for Carlsbad Project Reoperations.

1.0 Introduction

This memorandum summarizes hydrologic impacts (based on model results) of NEPA alternatives to reoperate Sumner Dam for the Pecos bluntnose shiner (PBNS) and discloses modeling limitations and assumptions associated with the quantification of those impacts. The analysis and results discussed in this memorandum were completed as part of the Carlsbad Project Water Operations and Water Supply Conservation EIS.

The results used to evaluate the hydrologic impacts were determined by the Hydrology/Water Operations Work Group (HWG) using a surface water model (Tetra Tech, 2000b, 2003b, 2003d), two groundwater models (Hydrosphere, 2003c; Barroll, et al., 2004), and an output post-processor (Hydrosphere, 2001a). The aggregate of these models is referred to as the Pecos River Decision Support System or PRDSS. Impacts examined by the HWG include:

1) Anticipated changes to flow frequency at select river locations corresponding to USGS gage locations;
2) Amounts of total water needed to meet demands for each flow target alternative for instream flows to benefit the PBNS, referred to as “total water needed”;
3) Amounts of water available from Carlsbad Irrigation District / Carlsbad Supply (CID supply) to meet demand for instream flows to benefit the PBNS, referred to as “water bypassed”;
4) The net of the two aforementioned amounts, referred to as “additional water needed”, for times for when CID supply is not great enough to meet the demand;
5) The reduction in total irrigation supply to the CID due to bypassing flows and modifying block releases through Sumner Dam for the PBNS, referred to as “net depletions to CID”;
6) The net impact to water deliveries at the state line, referred to as “net depletions to State-line flows”.

2.0 Alternatives and the Pre-1991 Baseline – Parameter Summary and Assumptions

The alternatives and baseline examined by the hydrology work group are shown in Table 1. The No Action Alternative represents operations on the Pecos River according to the current (2003-2006) Biological Opinion (BO) of the U.S. Fish and Wildlife Service (2003). The pre-1991 baseline represents operations on the Pecos River before 1991 when the system was operated solely for efficiency.

In addition to the No Action Alternative and pre-1991baseline, five other alternatives were examined. These alternatives vary mostly by target flow stipulations. Two of the alternatives specify target flows at the Taiban gage (Taiban Constant and Taiban Variable); two alternatives specify flows at the Acme gage (Acme Constant and Acme Variable). The Critical Habitat Alternative specifies: flows at the Taiban gage (in the non-irrigation season), flows at the Acme gage during normal and wet hydrologic periods during the irrigation season, and pro-rated flows by river mile from the Dunlap gage to the Acme gage to keep the river wet from Taiban to the mouth of Crockett Draw, which is located at the lower end of the upper critical habitat. The No Action Alternative also specifies targets at the Acme gage with the exception of dry irrigation condition targets, which only keep the critical habitat wet (just as in the critical habitat alternative). The pre-1991 baseline does not specify flow targets. Flow targets for all the alternatives are shown in Table 1.

The global assumption in the execution of the model is that all available CID supply used to achieve targeted river flows downstream of Sumner Dam is bypassed through the reservoir when available. Flow was not taken from CID storage to meet flow targets. This assumption stems from current operations and Reclamation's available latitude to bypass incoming flows through the reservoirs, but lack of authority to store the water in any of the reservoirs. Reclamation and CID jointly hold the right to divert and store river water for irrigation purposes. Bypass flows are those that Reclamation is simply not exercising its right to divert and store, with the understanding on CID's part that Reclamation will offset associated depletions with that bypass. For the modeling of NEPA alternatives, available bypass flow was evaluated on a daily basis.

Flow targets were modeled by inputting flow values into the model corresponding to the irrigation season and the hydrologic condition (wet, dry, or average). The irrigation season spans from March 1 through October 31 and throughout the NEPA process was sometimes interchanged with the word "summer". The non-irrigation season runs from November 1 to the end of February and was also sometimes interchanged with the word "winter".

The model computes hydrologic condition based on the method described in the current BO, which builds on the memorandum from Hydrosphere, detailing an approach for computing hydrologic condition using reservoir storage in the Lower Pecos Valley (Service, 2003; Hydrosphere, 2003d). It should be noted that previous memorandums, etc. referred to wet, dry, and average as hydrologic seasons, however, for clarification, the term hydrologic conditions is now employed.

In addition to flow targets, stipulations for block releases are modeled in all of the alternatives, including the No Action Alternative. The pre-1991 baseline does not have any stipulations on block releases. All of the alternatives include specifications of a 15-day maximum for block release duration and a frequency stipulation originally stated as, "space out as long as possible". This was later interpreted by the Biology Work Group as a minimum of 14 days in between releases. Additionally, all of the alternatives with the exception of the No Action Alternative also include the specification to "avoid release" for a 6-week period around August 1st. For modeling purposes, this stipulation was interpreted as a strict "no release" period from three weeks before to three weeks after August 1st.

The individual alternatives were modeled as follows:

- The Taiban Constant Alternative model has a constant flow target of 35 cfs at the Taiban gage for all hydrologic conditions and for both the irrigation season and the non-irrigation season.
- The Taiban Variable Alternative model consists of a constant non-irrigation season flow target of 35 cfs at the Taiban gage and variable irrigation season targets at the Taiban gage between 40 and 55 cfs. Due to the range of targets for this alternative, it was split into three sub alternative models including: a high range "summer" (HRS) target of 55 cfs, a mid-range "summer" (MRS) target of 45 cfs, and a low range "summer" (LRS) target of 40 cfs. The designation of "summer" for irrigation season targets is somewhat of a misnomer, but was carried through the analysis for consistency with the original alternative development process.
- The Acme Constant Alternative model has a constant flow target of 35 cfs at the Acme gage for all hydrologic conditions and for both the irrigation season and the non-irrigation season..
- The Acme Variable Alternative model consists of a constant non-irrigation season flow target at the Acme gage of 35 cfs and irrigation season flow targets of 12, 24, and 48 cfs for the respective dry, average, and wet hydrologic conditions.

- The Critical Habitat Alternative model contains a hybrid of flow targets because flow targets are specified at two gages. Non-irrigation season flow targets are specified as 35 cfs at the Taiban gage for all hydrologic conditions. Irrigation season targets for the average and wet seasons are 5 and 10 cfs, respectively at the Acme gage. For the dry hydrologic condition, during the irrigation season target, the alternative specifies keeping the critical habitat wet. This was modeled as a flow target of 0 cfs at the Acme Gage, corresponding to flow at Crocket Draw (the lower end of the upper critical habitat). The relationship between the two locations is dictated by season (winter, spring, summer and fall) as well as the distance from Dunlap to Crocket Draw and Crocket Draw to the Acme gage.
- The No Action Alternative has flow targets of 35 cfs at Acme in the non-irrigation season for all hydrologic conditions and flow targets of 20 cfs and 35 cfs for respective average and wet hydrologic conditions during the irrigation season. For the dry hydrologic condition, during the irrigation season target, the alternative specifies keeping the critical habitat wet. This was modeled as a flow target of 0 cfs at the Acme Gage, corresponding to flow at Crocket Draw (the lower end of the critical habitat).

It should be noted that the Critical Habitat and No Action alternatives have “designed intermittency” at the Acme gage for dry hydrologic conditions during the irrigation season. Since the upper critical habitat is *upstream* of the Acme gage, flow targets designed to only “keep the critical habitat wet,” result in intermittency at Acme.

Two criteria specified along with flow targets for some alternatives were not included in the models. The omissions are the Lynch Well pumping at Acme to prevent intermittency and the “minimum” stipulation tied to the non-irrigation targets at Taiban for the Critical Habitat Alternative. Modeling of the Lynch Well pumping at Acme was not included since this was considered to be an Additional Water Acquisition option, the effects of which aren’t covered in this memorandum. The 35 cfs “minimum” stipulation was not included for two reasons. The first reason is the model’s ability to meet targets on a ± 1 cfs basis is still subject to a total residual distribution on the order of 100 cfs. In order to truly meet the minimum statement as far as all modeling uncertainty is concerned, the target would have to be set unreasonably higher than 35 cfs. Secondly, since CID supply is not always available to be bypassed, the rigid “minimum” flow target would not be met anyway.

A fish conservation pool (FCP), to be used to augment bypass flows, was identified in the alternative development process. In addition to the modeling efforts for the alternative, quantities that would be needed for the FCP along with the potential impact to the flow exceedence curves by adding all of the additional water needed to the modeled Pecos River system are evaluated and presented in this report. Refer to the white paper by Hydrosphere et al. titled “Fish Conservation Pool Considerations for Carlsbad Project Water, Operations and Water Supply Conservation EIS” December, 2004.

Table 1. Baseline and Alternatives with Specified Flow Targets

Baseline or Alternative	Dry		Average		Wet	
	Non-irrigation Season Target (cfs)	Irrigation Season Target (cfs)	Non-irrigation Season Target (cfs)	Irrigation Season Target (cfs)	Non-irrigation Season Target (cfs)	Irrigation Season Target (cfs)
Taiban Constant	35 at Taiban	35 at Taiban[1]	35 at Taiban	35 at Taiban[1]	35 at Taiban	35 at Taiban[1]
Taiban Variable	35 at Taiban	40-55 at Taiban	35 at Taiban	40-55 at Taiban	35 at Taiban	40-55 at Taiban
Acme Constant	35 at Acme	35 at Acme	35 at Acme	35 at Acme	35 at Acme	35 at Acme
Acme Variable	35 at Acme	12 at Acme	35 at Acme	24 at Acme	35 at Acme	48 at Acme
Critical Habitat	35 at Taiban[2]	0 at Acme[3]	35 at Taiban[2]	5 at Acme	35 at Taiban[2]	10 at Acme
No Action	35 at Acme	0 at Acme[4]	35 at Acme	20 at Acme	35 at Acme	35 at Acme
Pre-1991 Baseline	N/A	N/A	N/A	N/A	N/A	N/A

[1] Use pumps to avoid intermittency at Acme.
[2] Specified as "minimum".
[3] Critical Habitat Kept Wet; Avoid Intermittency at Acme.
[4] Upper Critical Habitat Kept Wet; Avoid Intermittency at Acme.

The remainder of this memorandum documents the results and interpretations for the modeled alternatives, as compared to the pre-1991 baseline where appropriate.

3.0 Results

Flow exceedance curves at Taiban and Acme, comparisons of those modeled flow durations, net depletions to CID supply, net depletions to flows at the state line, and water accounting for bypasses and additional water needs for each of the alternatives are presented in sections 3.1 through 3.5.

3.1 Flow Exceedance Curves

Flow exceedance curves for each of the alternatives are shown in this section. The curves represent the amount of time (shown on the x-axis) that the discharge (shown on the y-axis) is met or exceeded. Note that the flow values for the entire model analysis (60 years of values, 365 days per year, and 366 days in leap years) were used in the calculations performed for creating the curves.

For example, in Figure 1, 70% of the time, the flow at the Taiban gage is approximately 37 cfs or more based on model results of the pre-1991 baseline, and 50 cfs or more based on the model results for the No Action Alternative.

Comparing the alternatives to the pre-1991 baseline allows the reader to determine if the alternative acts to increase or decrease the percent of time the flows are met or exceeded. In most cases, the alternatives increase the flows in the lower ranges of the discharge, typically in the vicinity of the flow target, and correspondingly decrease the flows in the upper ranges of the discharges, in the block release (1,000-1,200 cfs) range. The discharge of the y-axis is plotted on a log scale to allow the reader to view the entire range of flows while still allowing for some detail to be observed in the lower ranges.

The results of the analysis for the hypothetical case that all of the additional water needs (AWN) can be met are also included on the graphs as “with all AWN added”. It is important to note that in modeling river flow with AWN, the water added to the system is assumed to be non-project water. The importance of this assumption is that if the water was analyzed as CID water, the flow frequency curve would be affected in a different manner. If the water is taken from CID supply, the amount available for block releases decreases additionally to the decrease already caused by bypassing. Since AWN was modeled as water input from “outside” the system, the change in flow durations is only evident in the low flow range. In other words the water wasn’t taken from one portion of the curve and distributed into another, as is the case with the bypass modeling.

For ease of comparison, all of the alternative model results at the Taiban gage are presented in Figures 1 through 8 with all of the results at the Acme gage presented in Figures 9 through 16. Modeled intermittency statistics at the Acme Gage are presented in Tables 2 through 4. Table 2 presents bypass intermittency statistics with intermittency at Acme defined as zero cubic-feet per second. Table 3 also presents bypass intermittency statistics at Acme, but with intermittency defined as flows less than or equal to 1.6 cubic-feet per second. Table 4 presents intermittency statistics using non-project water to supply a fish conservation pool, with intermittency defined as zero cubic feet per second at Acme. Figure 17 is a graphical depiction of Tables 2 and 3.

Figure 1. Flow Frequency at the Taiban Node –No Action Alternative

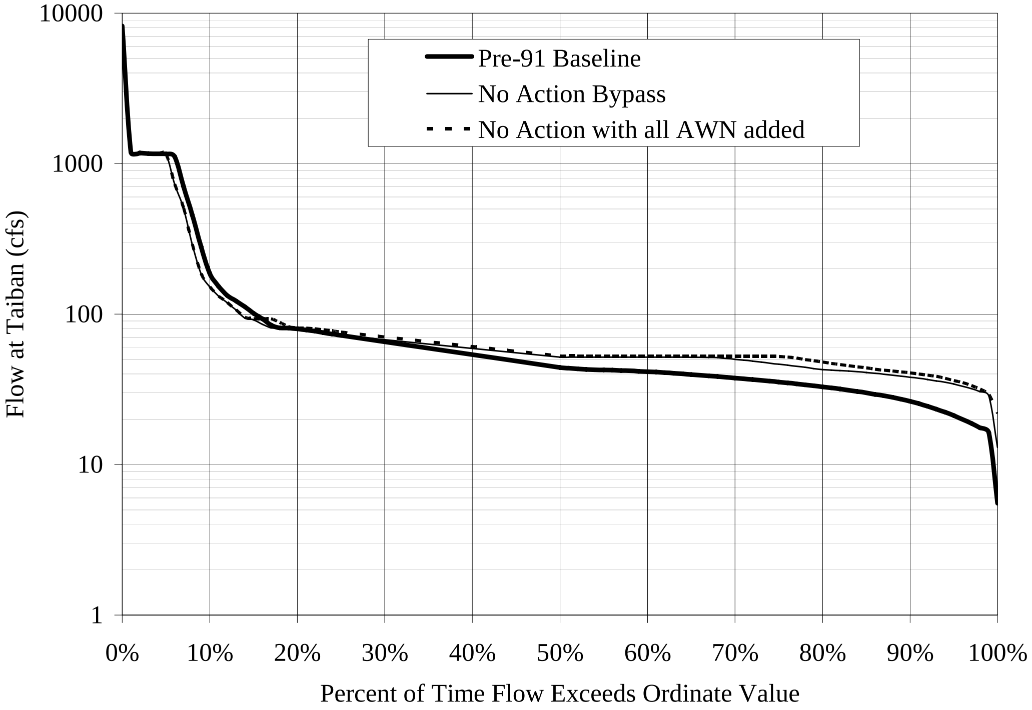


Figure 2. Flow Frequency at the Taiban Node – Taiban Constant Alternative

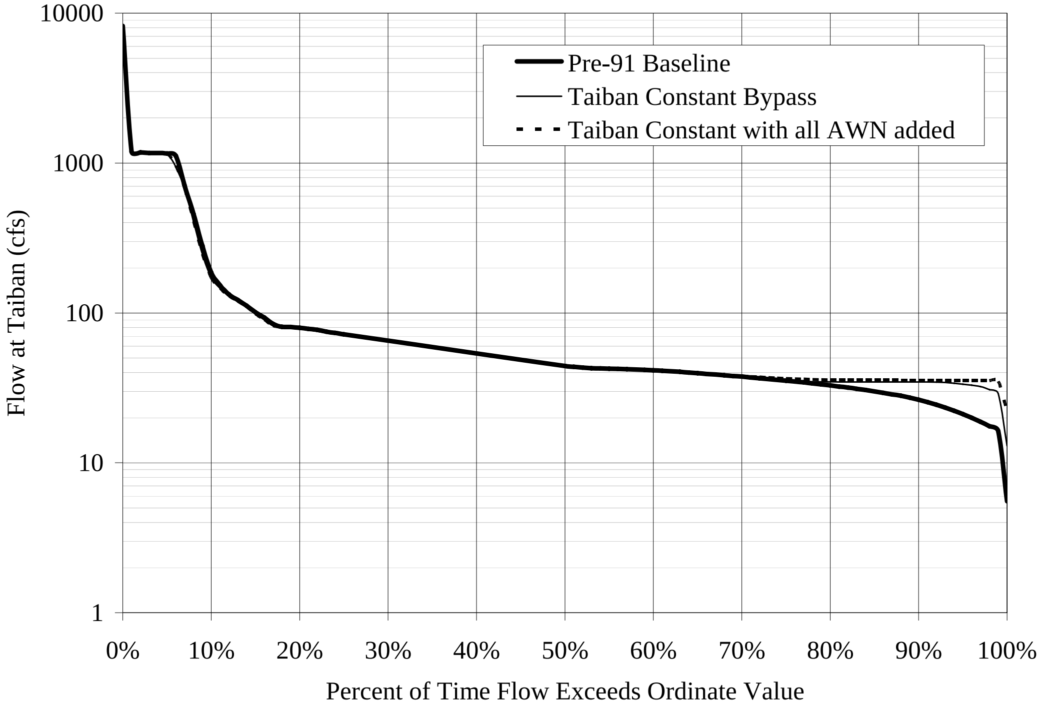


Figure 3. Flow Frequency at the Taiban Node – Taiban Variable HRS (55 cfs) Alternative

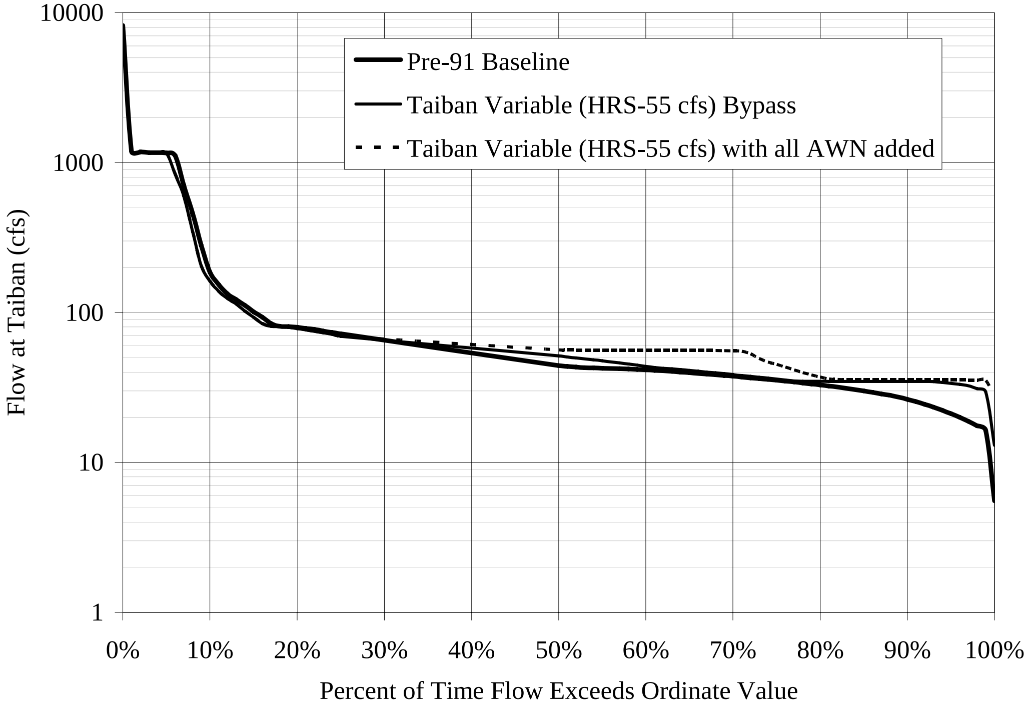


Figure 4. Flow Frequency at the Taiban Node – Taiban Variable MRS (45cfs) Alternative

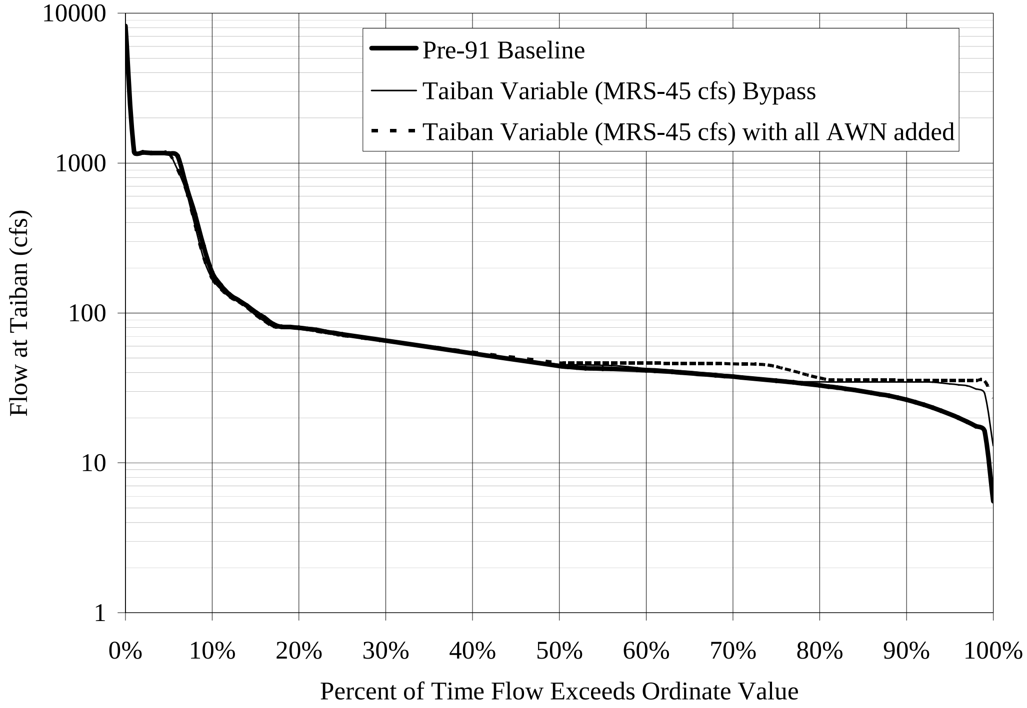


Figure 5. Flow Frequency at the Taiban Node – Taiban Variable LRS (40cfs) Alternative

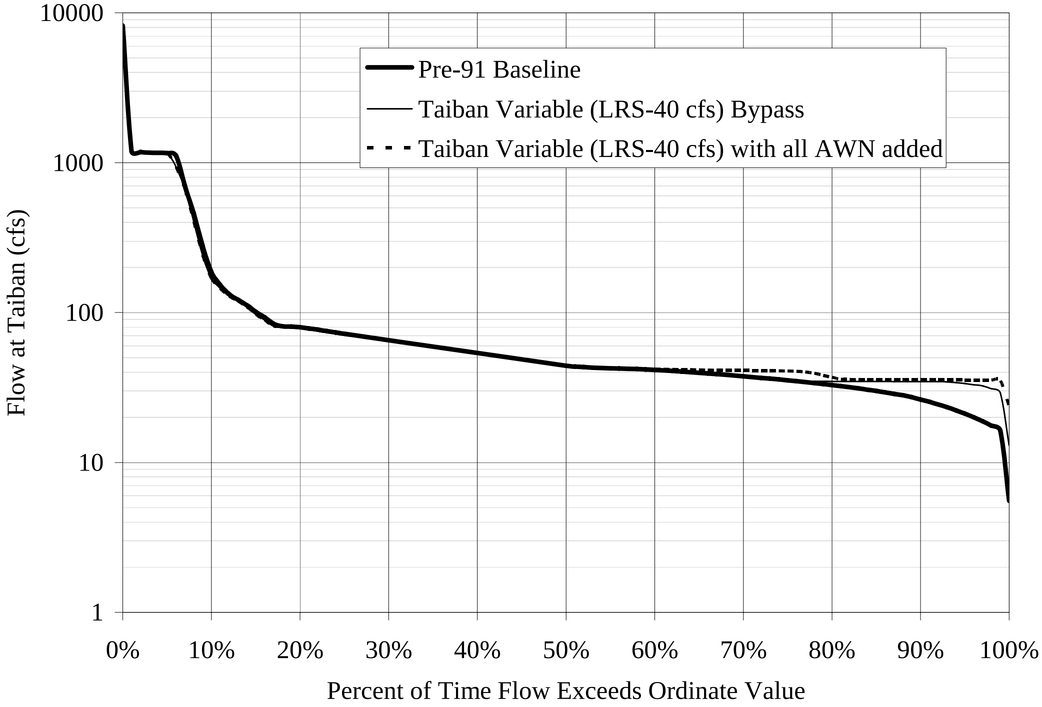


Figure 6. Flow Frequency at the Taiban Node – Acme Constant Alternative

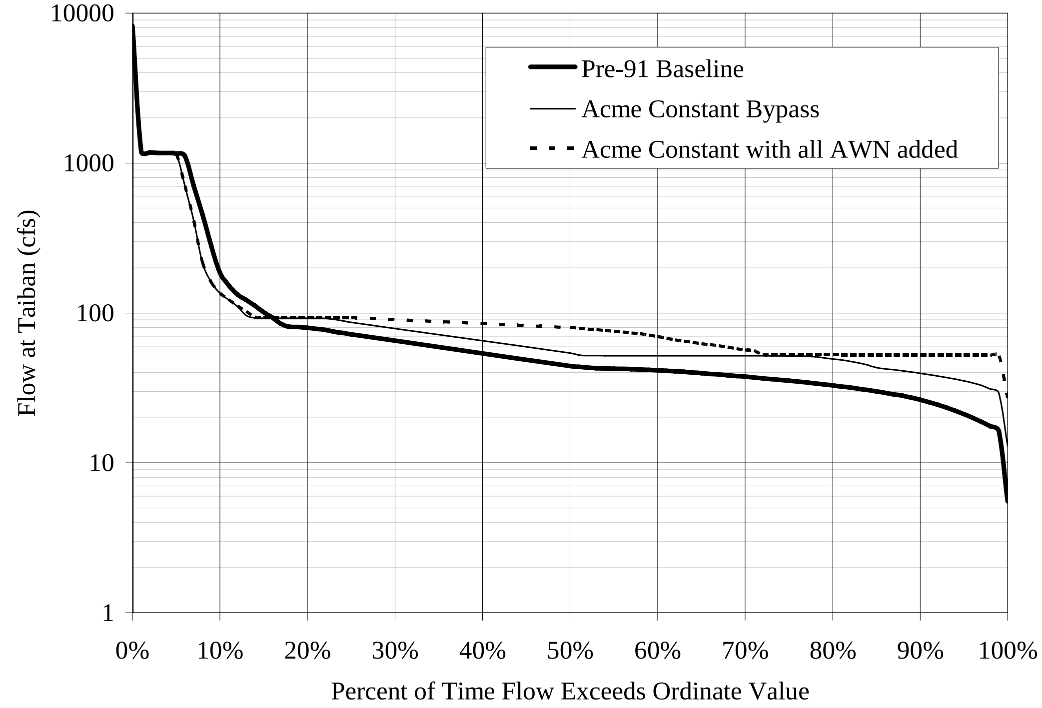


Figure 7. Flow Frequency at the Taiban Node – Acme Variable Alternative

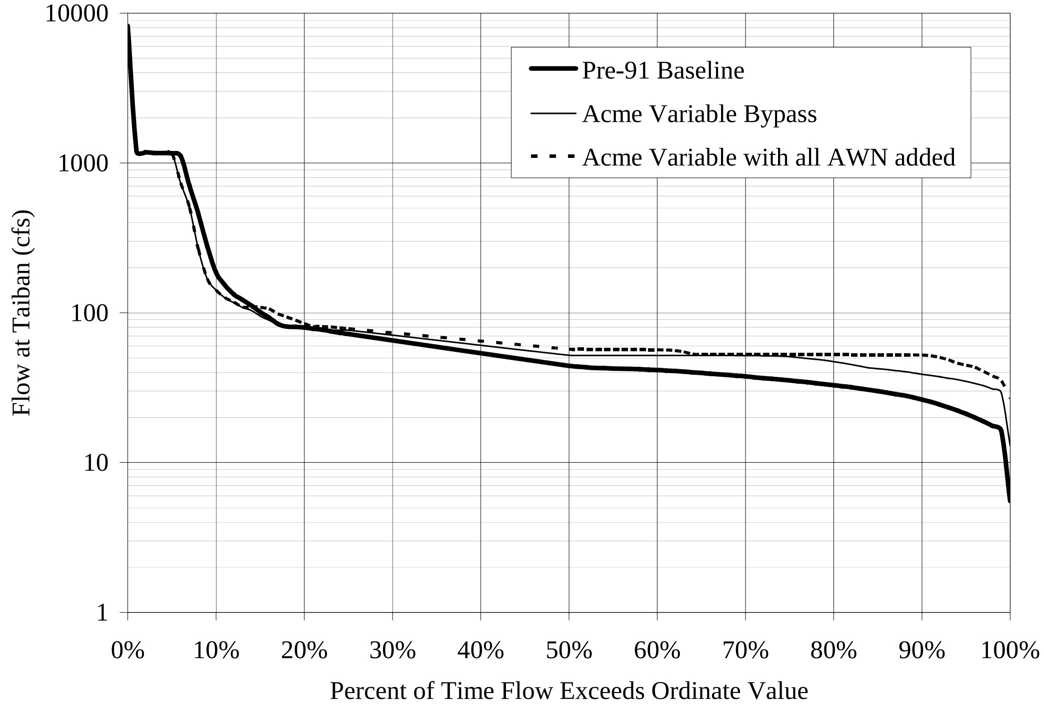


Figure 8. Flow Frequency at the Taiban Node – Critical Habitat Alternative

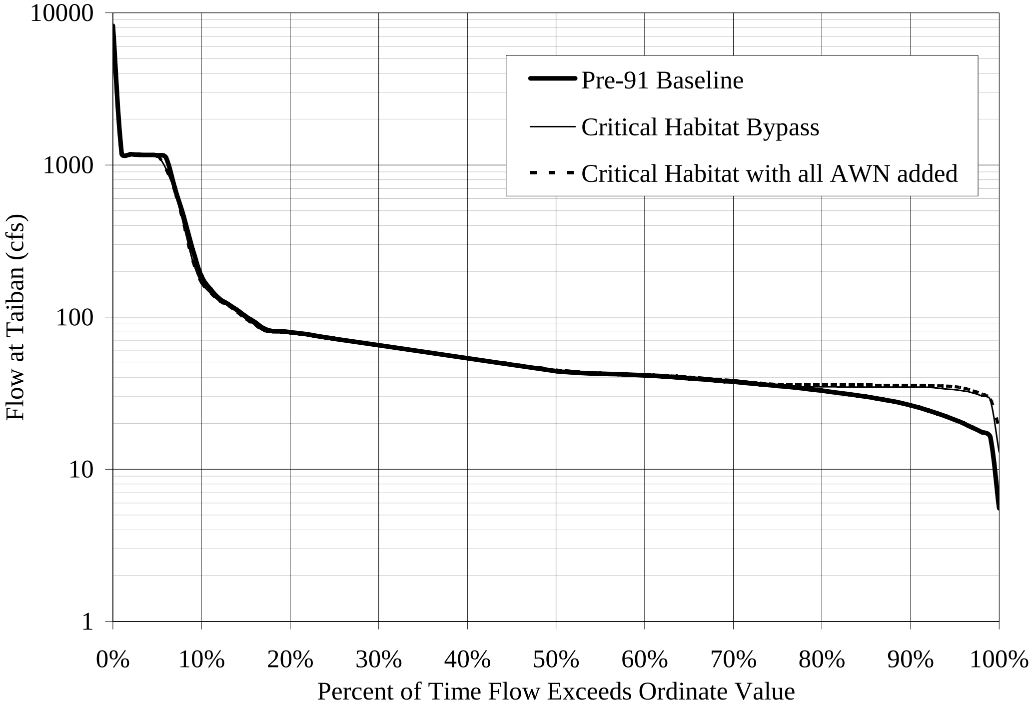


Figure 9. Flow Frequency at the Acme Node –No Action Alternative

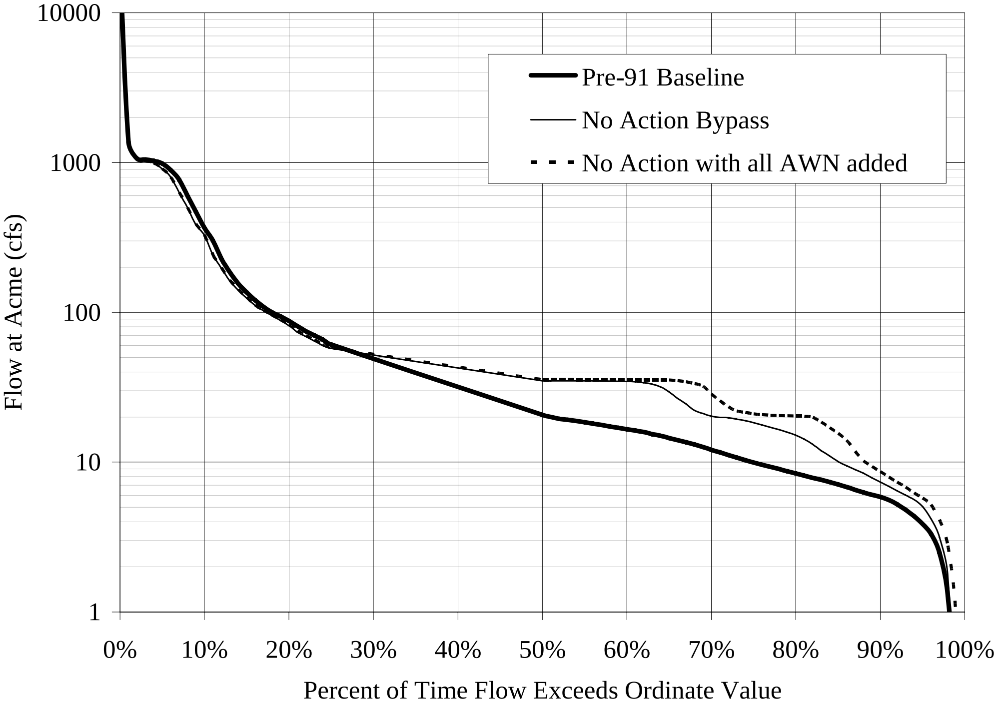


Figure 10. Flow Frequency at the Acme Node – Taiban Constant Alternative

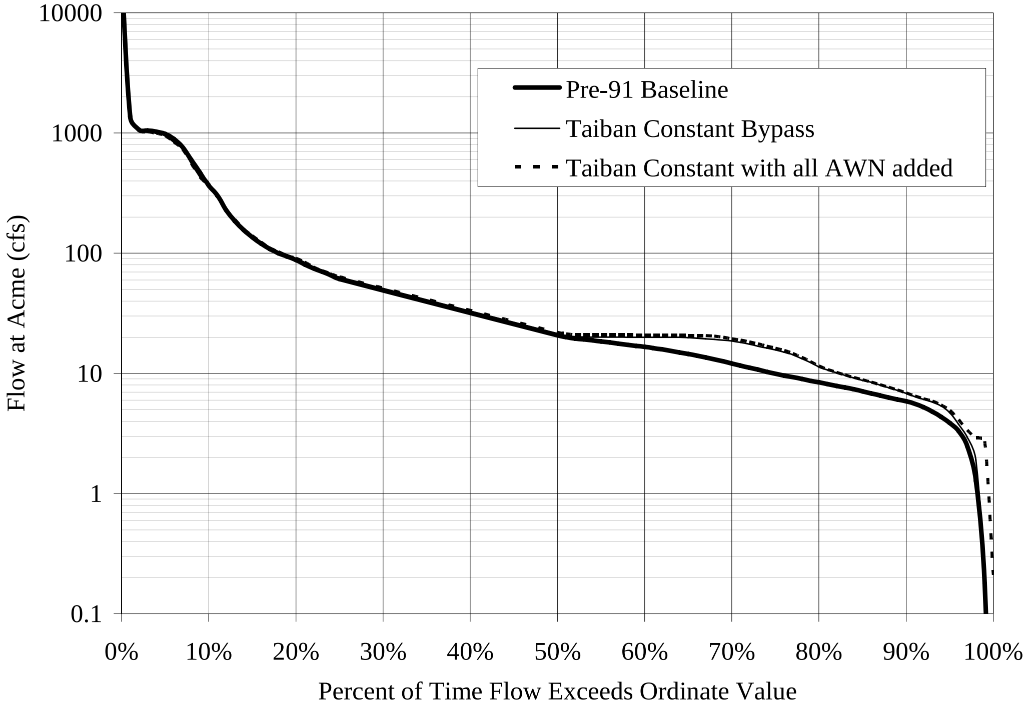


Figure 11. Flow Frequency at the Acme Node – Taiban Variable HRS (55cfs) Alternative

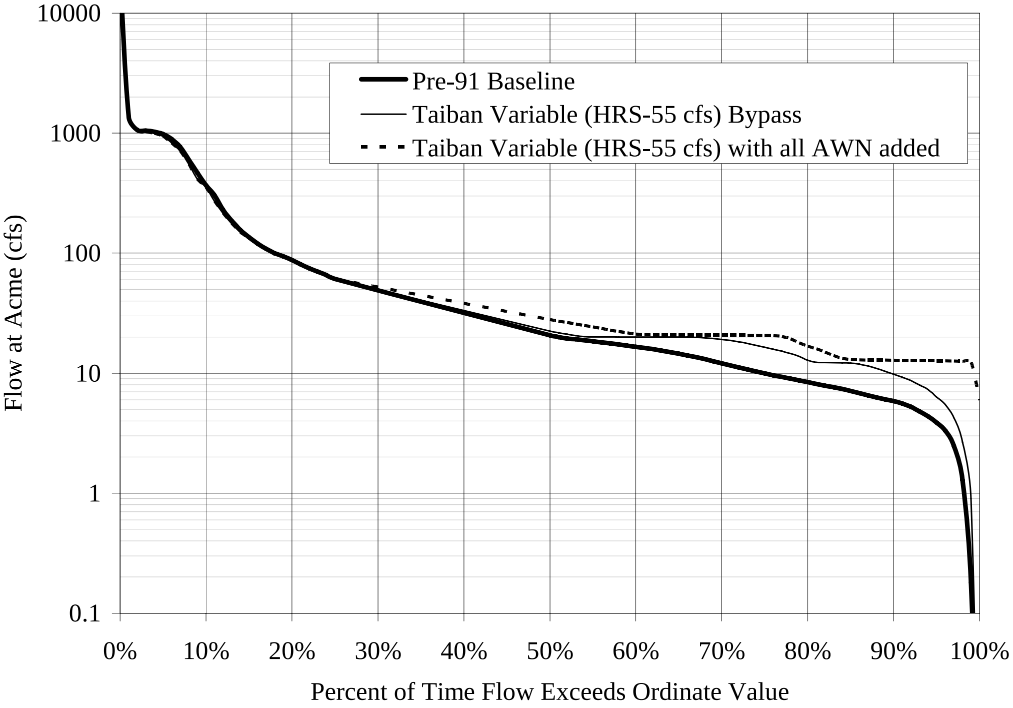


Figure 12. Flow Frequency at the Acme Node – Taiban Variable MRS (45cfs) Alternative

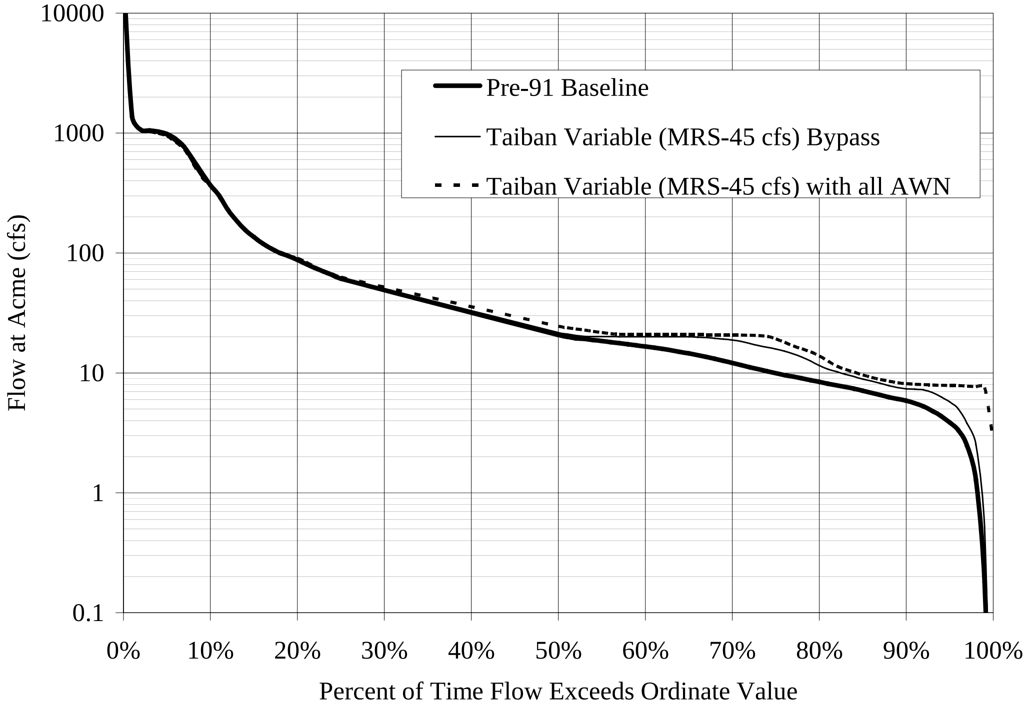


Figure 13. Flow Frequency at the Acme Node – Taiban Variable LRS Alternative

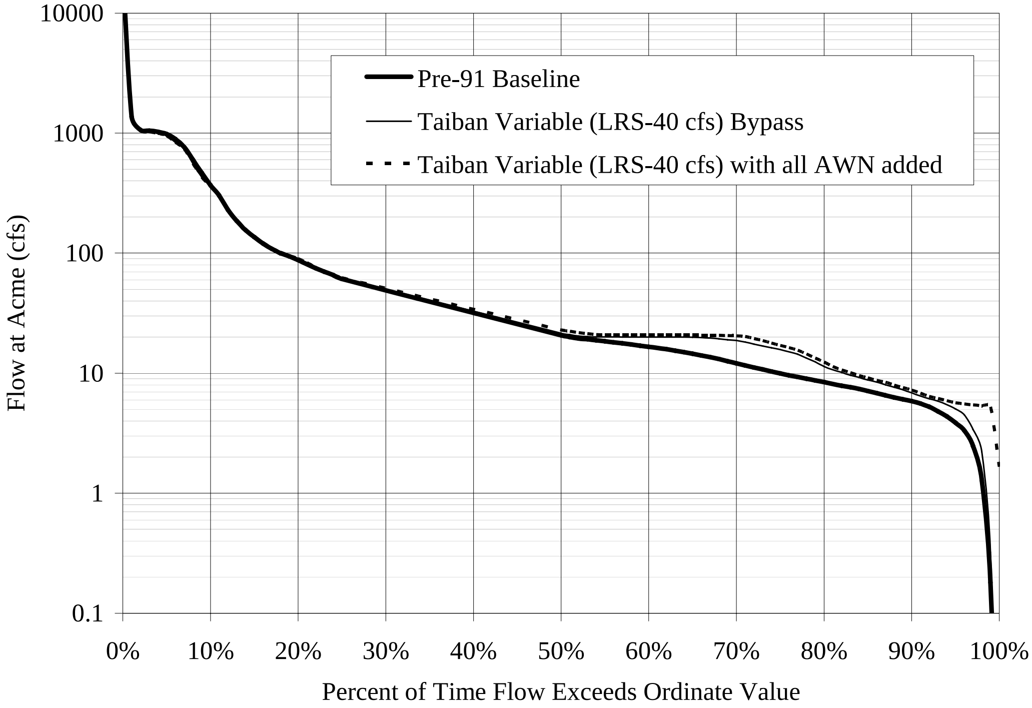


Figure 14. Flow Frequency at the Acme Node – Acme Constant Alternative

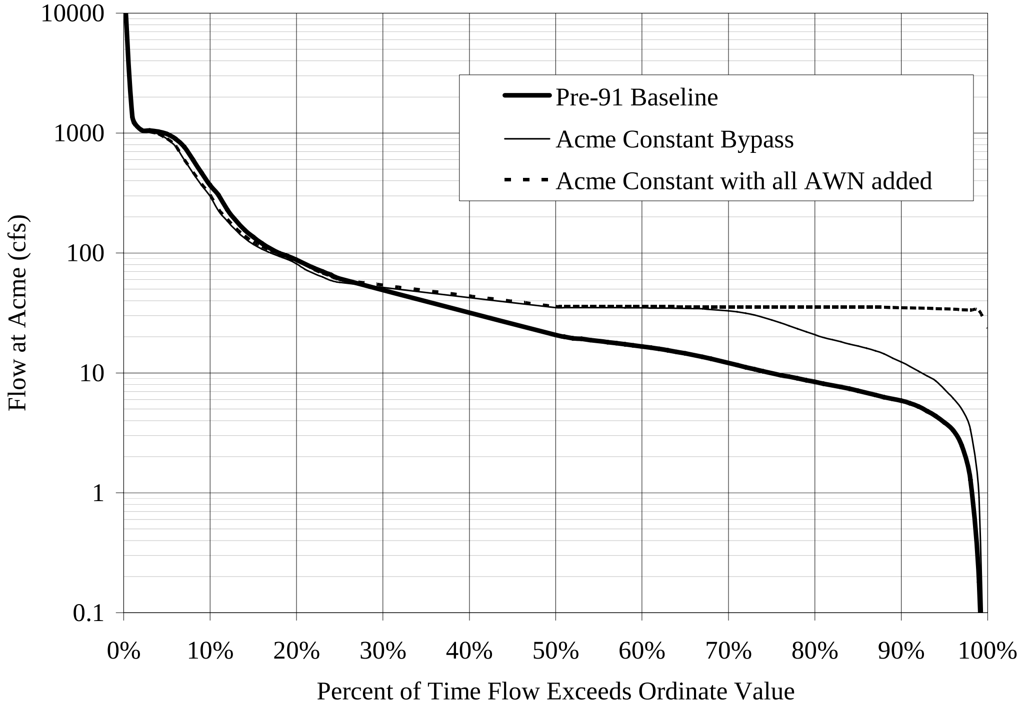


Figure 15. Flow Frequency at the Acme Node – Acme Variable Alternative

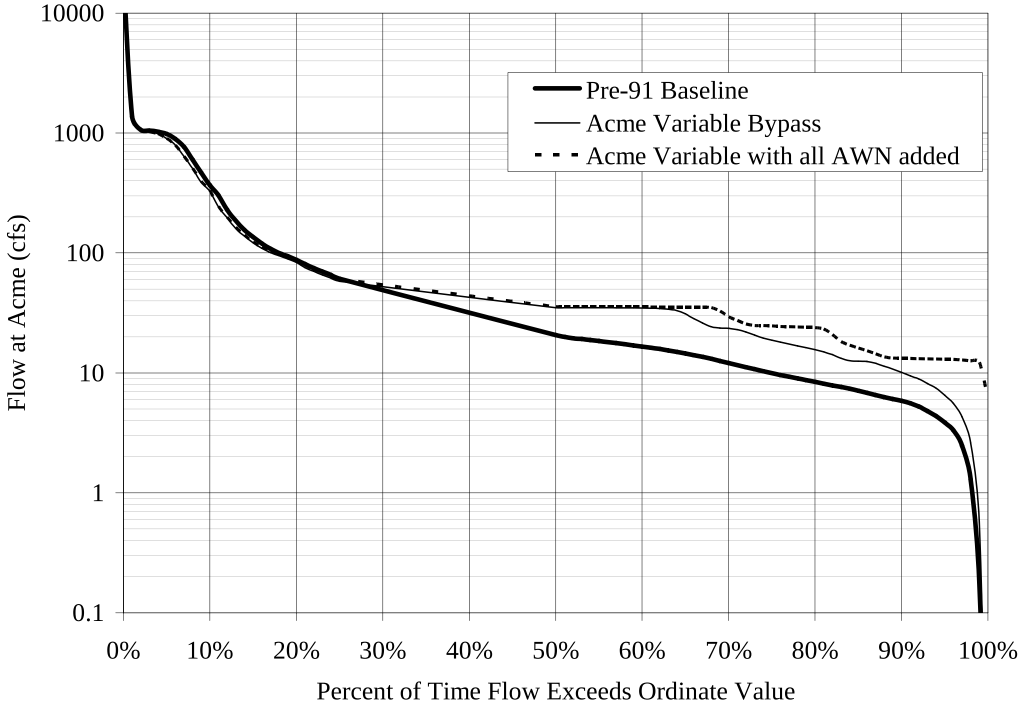


Figure 16. Flow Frequency at the Acme Node – Critical Habitat Alternative

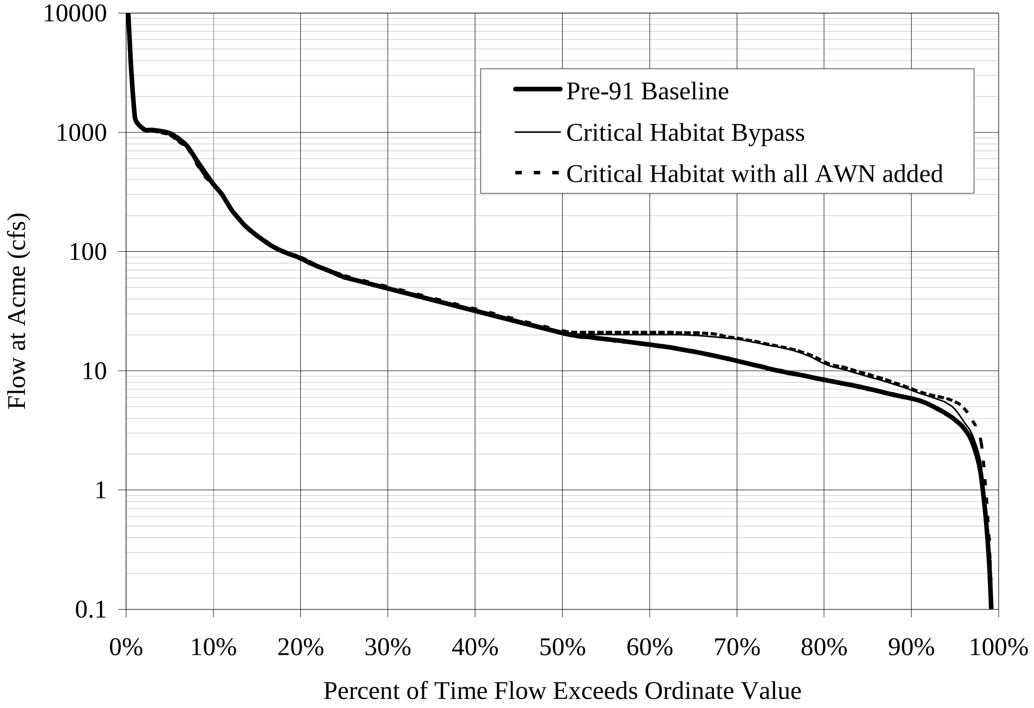


Table 2. Bypass and Block Release Reoperations—Intermittency Statistics for the Alternatives and the Pre-1991 Baseline

Acme Intermittency Statistics
(Intermittency defined as less than or equal to **0.0** cfs)

	No Action w/ 6-Week	**No Action wo/ 6-Week**	**Pre-1991 Baseline**	**Taiban Constant**	**Taiban Variable (HRS-55 cfs)**	**Taiban Variable (LRS-40 cfs)**	**Taiban Variable (MRS-45 cfs)**	**Acme Constant**	**Acme Variable**	**Critical Habitat**
Percent of Time Intermittent	0.9	0.9	1.2	0.9	0.6	0.8	0.8	0.7	0.7	1.1
Total No. of Intermittent Days	193	205	263	196	137	187	176	147	150	234
Total No. of Days in Run	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915
Periods of Intermittency: Single or Consecutively Intermittent Days										
1 day	3	1	4	6	1	2	1	3	4	2
2 to 5 days	9	10	8	5	4	6	5	2	3	10
6 to 10 days	8	5	9	6	6	5	7	5	5	8
11 to 20 days	4	2	3	2	3	2	2	2	3	3
21 to 30 days	2	3	5	4	1	4	3	3	2	4
> 30 days	0	1	0	0	0	0	0	0	0	0

Table 3. Bypass and Block Release Reoperations—Intermittency Statistics for the Alternatives and the Pre-1991 Baseline

Acme Intermittency Statistics
(Intermittency defined as less than or equal to **1.6** cfs)

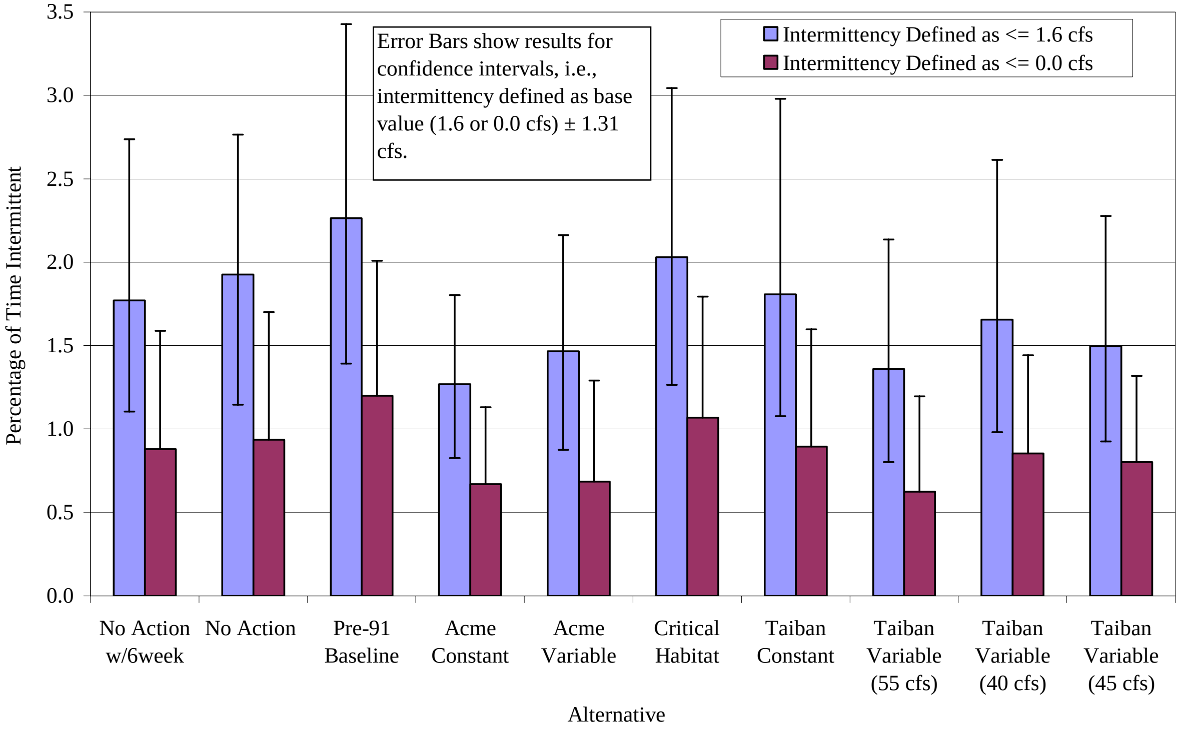
	No Action w/ 6-Week	**No Action wo/ 6-Week**	**Pre-1991 Baseline**	**Taiban Constant**	**Taiban Variable (HRS-55 cfs)**	**Taiban Variable (LRS-40 cfs)**	**Taiban Variable (MRS-45 cfs)**	**Acme Constant**	**Acme Variable**	**Critical Habitat**
Percent of Time Intermittent	1.8	1.9	2.3	1.8	1.4	1.7	1.5	1.3	1.5	2.0
Total No. of Intermittent Days	388	422	496	396	298	363	328	278	321	445
Total No. of Days in Run	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915
Periods of Intermittency: Single or Consecutively Intermittent Days										
1 day	9	8	9	9	7	9	8	5	8	10
2 to 5 days	16	16	15	15	8	14	11	11	10	17
6 to 10 days	11	14	14	8	9	10	9	7	9	13
11 to 20 days	6	4	9	8	6	5	5	3	3	7
21 to 30 days	4	4	5	3	2	3	3	4	5	4
> 30 days	1	2	2	2	1	2	2	1	1	2

Table 4. Bypass with All Additional Water Needs Added to Sumner Outflow—Intermittency Statistics for the Alternatives and the Pre-1991 Baseline

Acme Intermittency Statistics
(Intermittency defined as less than or equal to **0.0** cfs)

	No Action w/ 6-Week	No Action wo/ 6-Week	Pre-1991 Baseline	Taiban Constant	Taiban Variable (HRS-55 cfs)	Taiban Variable (LRS-40 cfs)	Taiban Variable (MRS-45 cfs)	Acme Constant	Acme Variable	Critical Habitat
Percent of Time Intermittent	0.7	0.7	1.2	0	0	0	0	0	0	0.8
Total No. of Intermittent Days	158	263	0	0	0	0	0	0	0	187
Total No. of Days in Run	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915	21,915
Periods of Intermittency: Single or Consecutively Intermittent Days										
1 day	1	1	4	0	0	0	0	0	0	2
2 to 5 days	10	10	8	0	0	0	0	0	0	9
6 to 10 days	7	4	9	0	0	0	0	0	0	7
11 to 20 days	3	3	3	0	0	0	0	0	0	2
21 to 30 days	1	2	5	0	0	0	0	0	0	3
> 30 days	0	0	0	0	0	0	0	0	0	0

Figure 17. Acme Percentage of Time Intermittent
(99% Confidence Intervals Results Are Included as Error Bars)



3.2 Alternative Comparisons – Flow Frequency and Intermittency

Table 5 presents flows exceeding 1, 25, 50, 75, and 100 percent of the total flow record for the given alternative or baseline at the Puerto de Luna, Taiban, Dunlap, Acme, Artesia, and Kaiser model nodes. For example, the flow at the Puerto de Luna Node is greater than or equal to 96 cfs 25% of the time under the Taiban Constant Alternative.

Nodes at Hagerman and Lake Arthur are not presented since the final flow frequency curves were not modified to account for the spatial distribution of accumulating base inflows in this reach. Base inflows are lumped together at the Artesia node in the model, and for this reason the Artesia and Kaiser nodes were included.

Table 5
Flow Frequency at Selected Model Nodes

Percent of Time Flow is Greater Than:	**No Action w/ 6-Week**	**No Action wo/ 6-Week**	**Taiban Const.**	**Taiban Var. (HRS-55 cfs)**	**Taiban Var. (LRS-40 cfs)**	**Taiban Var. (MRS-45 cfs)**	**Acme Const.**	**Acme Var.**	**Crit. Hab.**	**Pre-91**
	Flow at the Puerto de Luna Node (cfs)									
1%	1416	1397	1400	1414	1400	1413	1405	1400	1400	1431
25%	96	96	96	95	96	95	95	95	95	96
50%	77	77	77	77	77	77	77	77	77	77
75%	65	65	65	65	65	65	65	65	65	64
100%	6	6	6	6	6	6	13	6	6	6
	Flow at the Taiban Node (cfs)									
1%	1183	1184	1182	1187	1183	1184	1183	1185	1182	1188
25%	73	72	72	69	71	71	86	76	71	72
50%	52	52	44	51	44	45	54	52	44	44
75%	46	46	36	36	36	36	52	51	35	35
100%	13	13	13	13	13	13	13	13	13	6
	Flow at the Dunlap Node (cfs)									
1%	1142	1145	1143	1144	1144	1143	1142	1142	1144	1149
25%	64	64	65	63	65	64	70	66	65	65
50%	47	47	33	37	33	33	47	47	33	33
75%	33	33	30	30	30	30	46	37	30	26
100%	8	8	8	8	8	8	8	8	8	1
	Flow at the Acme Node (cfs)									
1%	1294	1362	1316	1312	1317	1315	1287	1307	1316	1370
25%	59	57	63	60	62	62	57	58	63	61
50%	35	35	21	22	22	22	35	35	21	21
75%	18	18	16	16	16	16	28	19	16	10
100%	0	0	0	0	0	0	0	0	0	0
	Flow at the Artesia Node (cfs)									
1%	1524	1553	1546	1549	1546	1540	1479	1528	1546	1585
25%	131	128	132	130	132	132	128	130	132	129
50%	84	83	76	76	76	76	84	84	76	73
75%	53	51	51	52	51	51	57	53	51	46
100%	6	6	6	6	6	6	6	6	6	6
	Flow at the Kaiser Node (cfs)									
1%	1562	1592	1606	1584	1610	1601	1546	1554	1610	1625
25%	127	123	129	126	128	128	123	125	128	125
50%	79	78	71	71	71	71	79	79	71	68
75%	48	46	47	47	47	47	51	48	46	42
100%	2	2	2	2	2	2	2	2	2	2

Observations concerning bypass flow frequency include:

- No alternative or baseline prevents intermittency entirely at Acme when only bypass operations are considered.
- Percent of intermittency is generally related to bypass flow targets: higher flow targets have lower intermittency, but the change percent is not that significant among all the alternatives.
- Only No Action and Critical Habitat show intermittency with unlimited water supply to meet all of the AWN; however, these two alternatives were designed to be intermittent in dry times.
- The Acme Constant Alternative shows a considerably higher flow (~10cfs), for the 75th percentile at the Acme node, than all of the other alternatives or the pre-1991 baseline.
- Even though the Acme Constant Alternative targets 35 cfs at Acme, due to the shortage of incoming supply, this alternative is only able to maintain this flow in the Pecos River 50% of the time.
- The Taiban Variable and Taiban Constant Alternatives show very little flow frequency difference at the Taiban and Acme nodes for the 75th and 100th percentile once again indicating the limitation of supply, and especially during dry times.
- Flows for equal percentiles at the Artesia gage and Kaiser gage are very similar for all of the alternatives and the baseline indicating that flow targets have little bearing on flow frequency in the Pecos River downstream of base inflows occurring in the Acme to Artesia reach.

3.3 Net Depletions to the Carlsbad Project Supply

Net depletions to Carlsbad Project supply and to State-line flows were computed by subtracting the change over time of the output parameter in question (storage and diversions for CID, flows at Red Bluff for the state line) for an alternative from the same parameter, over the same length of time, for the pre-1991 baseline. This section defines many components of net depletions with equations and explains their relative importance in this EIS and also explains the limitations of the interpretations of output data with these types of comparisons. In addition, annual average net depletion results for the alternatives are presented at the end of the section along with maximum and minimum annual transmission depletions between Sumner Reservoir and Brantley Reservoir due to bypassing.

Calculations for Net Depletions

The annual values computed with the equations presented in this section were sometimes presented discretely, but were typically averaged to show a trend. This average can be rather informative about the long term effects of operations on water supply over the 60-year modeling period. Through the development of modeling interpretations, several problems were discovered with the use of these equations for estimating annual net depletions to CID. At first attempts were made to correct the annual values (See Eq. 3.3.), but eventually the annual terms were found to contain annual variables that could skew the annual net depletion values on the order of 1,000's of acre-feet (See Erroneous Net Depletions further in this section.). For this reason only 60-year averages are presented when using the equations in this section. Definitions for net depletion terms and equations used in this memorandum are summarized in bulleted format below.

- Total net depletions to CID: the total net depletion to CID is computed using the change in Effective Brantley Storage (Tetra Tech, 2000b) and diversions at the CID main canal. Annual total net depletions to CID are computed using Equation 3.1. Note that negative values computed with this equation would indicate an *accretion* to CID.

$$\begin{matrix}\textit{Annual}\\ \textit{Net Depletion}\\ \textit{to CID}\end{matrix} = \begin{matrix}\textit{No Action Annual}\\ \textit{Change in Eff.}\\ \textit{Brantley Storage}\end{matrix} - \begin{matrix}\textit{Action Annual}\\ \textit{Change in Eff.}\\ \textit{Brantley Storage}\end{matrix} \\ + \begin{matrix}\textit{No Action CID}\\ \textit{Annual Diversion}\\ \textit{Volume}\end{matrix} - \begin{matrix}\textit{Action CID}\\ \textit{Annual Diversion}\\ \textit{Volume}\end{matrix} \qquad \text{(Eq. 3.1)}$$

- Net depletions at the CID main: net depletions to CID considering only diversions from Avalon Dam made by CID. Equation 3.1 can be used with the Effective Brantley Storage terms removed.

- Net depletions to Effective Brantley Storage: net depletions to CID storage normalized as if all of the water were present in Brantley or Avalon Reservoirs. Eq 3.1 can be used with the diversion volume terms removed.

- Annual net depletions to Avalon spills: the decrease of spills from Avalon dam. Eq. 3.2 can be used to compute net depletions to Avalon spills.

$$\begin{matrix}\textit{Net Depletion}\\ \textit{to Avalon Spills}\end{matrix} = \begin{matrix}\textit{No Action}\\ \textit{Avalon Spills}\end{matrix} - \begin{matrix}\textit{Action}\\ \textit{Avalon Spills}\end{matrix} \qquad \text{(Eq. 3.2)}$$

- Corrected reoperation net depletions to CID: the total net depletion to CID with year-to-year spill variabilities removed from the net depletions, but with the long-term spill trend contribution to the net depletions added back (Tetra Tech, 2003e). Corrected reoperation net depletions are computed using Equation 3.3.

$$\begin{matrix}\textit{Corrected Net}\\ \textit{Depletions to Carlsbad}\\ \textit{Supply due to}\\ \textit{Reoperation}\end{matrix} = \begin{matrix}\textit{Total Net}\\ \textit{Depletions}\\ \textit{to Carlsbad}\\ \textit{Supply}\end{matrix} + \begin{matrix}\textit{Net Depletions}\\ \textit{to Avalon}\\ \textit{Spills}\end{matrix} - \begin{matrix}\textit{60 - year Average}\\ \textit{Net Depletion}\\ \textit{to Avalon}\\ \textit{Spills}\end{matrix} \qquad \text{(Eq. 3.3)}$$

- Reoperation net depletions to CID: the total net depletion to CID with all the effects of the spills removed. Equation 3.4 computes the reoperation net depletions to CID.

$$\begin{matrix}\textit{Net Depletions}\\ \textit{to Carlsbad Supply}\\ \textit{due to Reoperations}\end{matrix} = \begin{matrix}\textit{Total Net}\\ \textit{Depletions}\\ \textit{to Carlsbad Supply}\end{matrix} + \begin{matrix}\textit{Net Depletions}\\ \textit{to Avalon Spills}\end{matrix} \qquad \text{(Eq. 3.4)}$$

Up to this point, net depletion results are presented by using the change in storage and the change in diversions measured at the CID main to predict total changes in CID operations. Consider Equation 3.5, which is the mass balance equation for reservoirs. The left side of the equation represents the sum total of operations as defined by the right side of the equation. Equation 3.5 can be expanded and combined with net depletion terminology to develop Equation 3.6.

- The storage mass balance equation is shown below as Equation 3.5.

$$\Delta \mathit{Storage} = \mathit{Inflow} - \mathit{Outflow} \qquad \text{(Eq. 3.5)}$$

- The relationship between net depletions to storage, inflow, and outflow is shown below as Equation 3.6.

$$\mathit{Net\ Depletion\ to\ } \Delta \mathit{Storage} = \mathit{Net\ Depletion\ to\ Inflow} - \mathit{Net\ Depletion\ to\ Outflow} \qquad \text{(Eq. 3.6)}$$

- Recognizing that outflow takes many forms and expanding terms generates Equation 3.7, which can be used for any reservoir.

$$\begin{aligned} \substack{\mathit{Net\ Depletion} \\ \mathit{to\ } \Delta \mathit{Storage}} &= \substack{\mathit{Net\ Depletion} \\ \mathit{to\ Inflow}} - \substack{\mathit{Net\ Depletion} \\ \mathit{to\ Outflow}} - \substack{\mathit{Net\ Depletion} \\ \mathit{to\ Evaporation}} - \substack{\mathit{Net\ Depletion} \\ \mathit{to\ Diversion}} \\ &\quad - \substack{\mathit{Net\ Depletion} \\ \mathit{to\ } \Delta \mathit{\ in\ Res.Bank\ Stor}} - \substack{\mathit{Net\ Depletion\ to} \\ \mathit{Reservoir\ Seepage}} \end{aligned} \qquad \text{(Eq. 3.7)}$$

- Next, additional transmission depletions for a specific reach can be calculated by combining coefficients for Effective Brantley Storage with inflow and outflow terms for adjacent reservoirs from the right hand side of Eq. 3.7. It would follow that the additional transmission loss would be equal to the shortage of incoming water at the downstream reservoir (net depletions to inflows) plus the additional amount released from the upstream reservoir (net accretion to outflow = -net depletion to outflow). Using the preceding logic and coefficients for Effective Brantley Storage, Equations 3.8, 3.9, and 3.10 calculate additional transmission losses (normalized to Brantley storages) for the Santa Rosa Reservoir to Sumner Reservoir, Sumner Reservoir to Brantley Reservoir, and Brantley Reservoir to Avalon Reservoir, river reaches, respectively.

$$\begin{aligned} \substack{\mathit{Additional\ Transmission\ Loss} \\ \mathit{From\ Santa\ Rosa\ to\ Sumner}} &= 0.75 * \substack{\mathit{Net\ Depletions\ to\ Inflows} \\ \mathit{At\ Sumner\ Reservoir}} \\ &\quad - 0.65 * \substack{\mathit{Net\ Depletions\ to\ Outflows} \\ \mathit{At\ Santa\ Rosa\ Reservoir}} \end{aligned} \qquad \text{(Eq. 3.8)}$$

$$\begin{aligned} \substack{\mathit{Additional\ Transmission\ Loss} \\ \mathit{From\ Sumner\ to\ Brantley}} &= \substack{\mathit{Net\ Depletions\ to\ Inflows} \\ \mathit{At\ Brantley\ Reservoir}} \\ &\quad - 0.75 * \substack{\mathit{Net\ Depletions\ to\ Outflows} \\ \mathit{At\ Sumner\ Reservoir}} \end{aligned} \qquad \text{(Eq. 3.9)}$$

$$\begin{aligned} \substack{\mathit{Additional\ Transmission\ Loss} \\ \mathit{From\ Brantley\ to\ Avalon}} &= \substack{\mathit{Net\ Depletions\ to\ Inflows} \\ \mathit{At\ Avalon\ Reservoir}} \\ &\quad - \substack{\mathit{Net\ Depletions\ to\ Outflows} \\ \mathit{At\ Brantley\ Reservoir}} \end{aligned} \qquad \text{(Eq. 3.10)}$$

Total additional transmission losses (normalized to Brantley storages) are equal to the sum of the three preceding equations.

- Similarly, total saved evaporation can be computed by combining the net depletions to evaporation at every reservoir with the Effective Brantley Storage coefficients. This is presented as Equation 3.11.

$$\begin{array}{l}\textit{Saved Reservoir}\\ \textit{Evaporation}\end{array} = 0.65 * \begin{array}{r}\textit{Net Depletions}\\ \textit{to Santa Rosa Evap}\end{array} + 0.75 * \begin{array}{r}\textit{Net Depletions}\\ \textit{to Sumner Evap}\end{array} + \begin{array}{c}\textit{Net Depletions to}\\ \textit{Brantley Evap}\end{array} + \begin{array}{c}\textit{Net Depletions}\\ \textit{to Avalon Evap}\end{array} \qquad \text{(Eq. 3.11)}$$

Equations 3.10 and 3.11 can be combined with the unused terms of Equation 3.7 (net depletions to seepage at Avalon and net depletions to bank storage at Brantley) to calculate the same result for corrected reoperation net depletions as Equation 3.3.

60-year Average Results Using Net Depletion Mass Balance

60-year average net depletion results are presented here. Tables 6-9 show net depletion mass balances for the respective reservoirs: Santa Rosa, Sumner, Brantley, and Avalon. The net depletions in these tables are not normalized to Effective Brantley Storage and all of the columns (net depletion components) in each table sum to zero. Table 10 shows additional transmission (reach) losses due to the alternatives (sum of Equations 3.8 through 3.10). Table 11 shows saved evaporation normalized to Effective Brantley Storage (Eq. 3.11). Table 12 presents 60-year average corrected reoperation net depletions (includes long-term spill trend) to CID for all the alternatives and Table 13 presents 60-year average reoperation net depletions to CID (excludes spills completely).

Table 6. Net Depletion Mass Balance for Santa Rosa Reservoir

Alternative	**60-year average (acre-feet per year)**			
	Net Depletion to Inflow	Net Depletion to Outflow	Net Depletion to Evaporation	Net Depletion to Change in Storage
Acme Constant	0	-522	618	-96
Acme Variable	0	-299	395	-96
Critical Habitat	0	4	93	-96
Taiban Constant	0	16	80	-96
Taiban Variable LRS	0	-10	106	-96
Taiban Variable MRS	0	-64	160	-96
Taiban Variable HRS	0	-137	233	-96
No Action	0	229	-133	-96

Table 6 shows that Carlsbad Project reoperations modeling indicates evaporation will be saved at Santa Rosa reservoir and outflows will be increased by a similar amount. Note that inflow net depletions are all zero; this is because all of the alternatives and the pre-1991 baseline have equal inflows.

Table 7. Net Depletion Mass Balance for Sumner Reservoir

Alternative	60-year average (acre-feet per year)			
	Net Depletion to Inflow	Net Depletion to Outflow	Net Depletion to Evaporation	Net Depletion to Change in Storage
Acme Constant	-68	-1494	1742	-317
Acme Variable	-26	-1204	1495	-317
Critical Habitat	211	276	253	-317
Taiban Constant	262	208	372	-317
Taiban Variable LRS	232	150	400	-317
Taiban Variable MRS	147	-166	629	-317
Taiban Variable HRS	62	-266	646	-317
No Action	347	-7	531	-177

Table 7 indicates Sumner reservoir operations were somewhat different between alternatives. The largest bypass alternatives saved a significant amount per year on evaporation, and released a similar amount as outflow. The higher ranges of Taiban Variable showed a similar trend with an order of magnitude less in terms of increased outflow from the reservoir. The lower range target alternatives and the lower end of the Taiban Variable Alternative all showed decreases in Sumner outflow. All of the modeled alternatives indicated saved evaporation at Sumner Reservoir; however, Acme Constant and Acme Variable showed the most.

Table 8. Net Depletion Mass Balance for Brantley Reservoir

Alternative	60-year average (acre-feet per year)				
	Net Depletion to Inflow	Net Depletion to Outflow	Net Depletion to Evaporation	Net Depletion to Change in Storage	Net Depletion to Change in Bank Storage
Acme Constant	3082	3075	-295	241	61
Acme Variable	2230	2349	-410	233	58
Critical Habitat	1188	795	147	199	47
Taiban Constant	1016	681	120	174	40
Taiban Variable LRS	1180	957	6	176	40
Taiban Variable MRS	1611	1347	24	195	46
Taiban Variable HRS	2260	2037	-28	203	48
No Action	2156	1642	380	110	23

Table 8 demonstrates that Brantley reservoir showed significantly reduced inflows and outflows under all the alternatives; ranging from 700 acre-feet per year to 3,100 acre-feet per year. Reservoir evaporation increased slightly for the higher bypass alternatives such as Acme Constant and Acme Variable. Most other alternatives showed slight increases to slight decreases with the No Action being the most significant in terms of evaporation savings.

Table 9. Net Depletion Mass Balance for Avalon Reservoir

Alternative	60-year average (acre-feet per year)					
	Net Depletion to Inflow	Net Depletion to Outflow	Net Depletion to Evaporation	Net Depletion to Change in Storage	Net Depletion to Seepage	Net Depletion to Diversion
Acme Constant	2963	-916	-12	0	-80	3971
Acme Variable	2292	-723	-10	0	-68	3094
Critical Habitat	732	-577	-4	0	-18	1331
Taiban Constant	621	-661	-4	0	-18	1304
Taiban Variable LRS	892	-400	-4	0	-18	1312
Taiban Variable MRS	1271	-323	-5	0	-29	1629
Taiban Variable HRS	1950	209	-6	0	-42	1789
No Action	1617	13	-5	0	-36	1645

Table 9 shows decreased inflows to Avalon Reservoir due to the alternatives, which subsequently reduced diversions to CID farms. Also contributing to reduced diversions are increased losses of project water supply to a greater frequency of conservation spills from Avalon (net depletions to outflows).

Table 10. Additional Reach Transmission Losses due to Alternative Reoperations

Alternative	60-year Average Additional Transmission Losses as Effective Brantley Storage (acre-feet per year)			
	Reach from Santa Rosa Reservoir to Sumner Reservoir	Reach from Sumner Reservoir to Brantley Reservoir	Reach from Brantley Reservoir to Avalon Reservoir	Total for All Reaches
Acme Constant	288	4202	-112	4378
Acme Variable	175	3133	-57	3251
Critical Habitat	156	981	-63	1074
Taiban Constant	186	860	-60	986
Taiban Variable LRS	181	1067	-66	1183
Taiban Variable MRS	152	1735	-75	1811
Taiban Variable HRS	136	2460	-87	2509
No Action wo/6-wk	111	2161	-25	2248

Table 10 demonstrates that all of the modeled alternatives indicate larger reach losses from Santa Rosa Reservoir to Sumner Reservoir and from Sumner Reservoir to Brantley Reservoir with the most significant of those occurring in the latter reach. Modeled transmission losses between Brantley Reservoir and Avalon Reservoir were slightly lower. From Santa Rosa to Sumner, increased losses are due to short spikes to move water down to Sumner for bypassing. Since Santa Rosa doesn't have a low-flow outlet works, water must be moved in short duration (1 to 3 days)-large blocks (typically 600 cfs). From Sumner to Brantley, increased losses are due to bypasses and shortened block releases with the former being the more significant cause for these increased losses. Decreased losses from Brantley to Avalon are mostly due to less water movement between these two reservoirs (since it was depleted upstream).

Table 11. Saved Reservoir Evaporation due to Alternative Reoperations

Alternative	60-year Average Saved Reservoir Evaporation (acre-feet per year)				
	Santa Rosa Reservoir	Sumner Reservoir	Brantley Reservoir	Avalon Reservoir	Total for All Reservoirs
Acme Constant	402	1132	-295	-12	1401
Acme Variable	257	972	-410	-10	958
Critical Habitat	60	164	147	-4	393
Taiban Constant	52	241	120	-4	447
Taiban Variable LRS	69	260	6	-4	371
Taiban Variable MRS	104	409	24	-5	595
Taiban Variable HRS	151	420	-28	-6	601
No Action	-86	345	380	-5	687

Table 11 shows that most saved evaporation occurs at Santa Rosa and Sumner reservoirs. This is from decreased detention time of water since bypassing occurs in Sumner Reservoir and also since Santa Rosa Reservoir frequently sends two day spikes out of the reservoir to accommodate bypasses through Sumner. Increased evaporation in Brantley is only noted for the higher target alternatives. This is due to the increased detention time of the bypass water that actually reaches Brantley.

The corrected reoperation net depletion includes all of the sources that water is lost or gained from in the Carlsbad Project due to reoperation. Table 12 shows that high-target alternatives such as Acme Constant and Acme Variable deplete more total water from the Project than the lower-target alternatives. Note that the second column in Table 12, which represents the dominant Project net depletion components, plus the third column in the table, which are insignificant components of the Project net depletions, equals the fourth column in the table.

In Table 13, the reoperation net depletions indicate all the effects of reoperations with the effects of Project net depletions due to differences in spills removed. The sum of the Project net depletion components shown in the second and third columns equals the total reoperation net depletion shown in the fourth column.

Table 12. Corrected Reoperation Net Depletions to CID

Alternative	**60-year average (acre-feet per year as Effective Brantley Storage)**		
	Additional Transmission Losses, plus Water Lost to Spills, minus Saved Evaporation	Net Depletions from Seepage and Brantley Bank Storage	Corrected Reoperation Net Depletion
Acme Constant	3892	19	3911
Acme Variable	3017	10	3027
Critical Habitat	1258	-28	1230
Taiban Constant	1200	-22	1178
Taiban Variable LRS	1212	-23	1189
Taiban Variable MRS	1540	-17	1523
Taiban Variable HRS	1698	-6	1692
No Action wo/6-wk	1547	13	1560

Table 13. Reoperation Net Depletions to CID

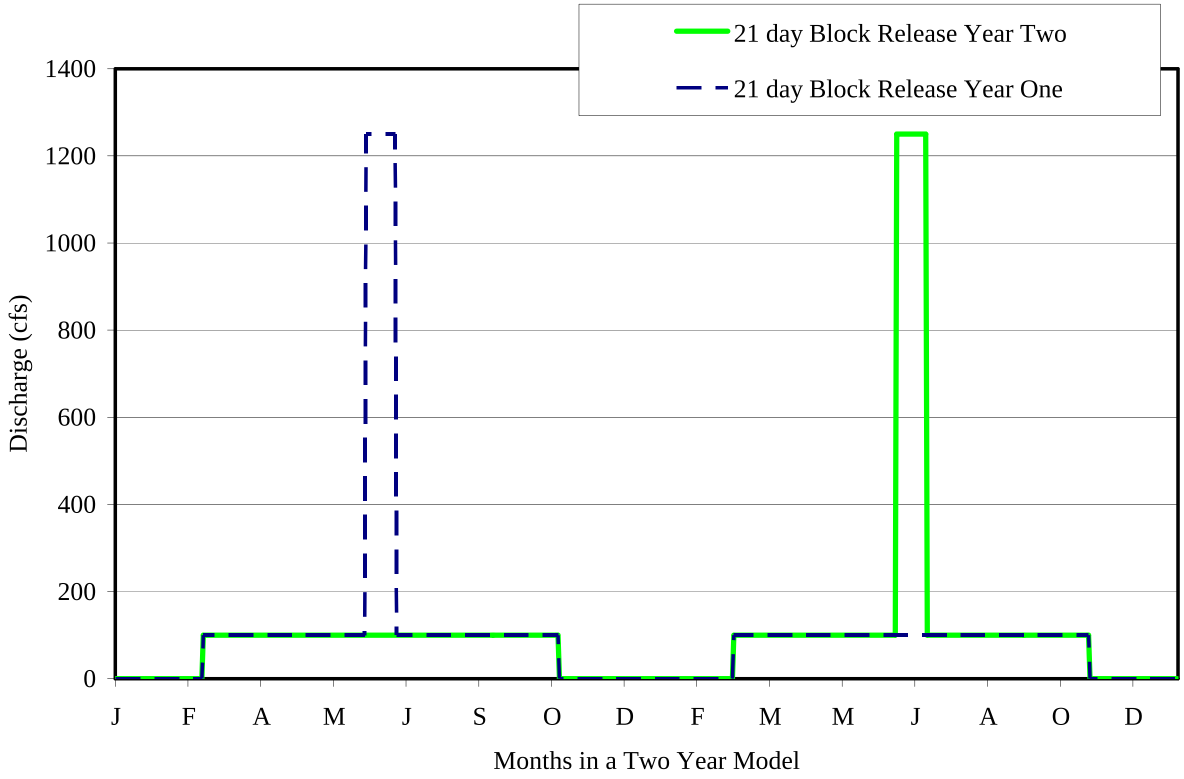
Alternative	**60-year average (acre-feet per year as Effective Brantley Storage)**		
	Additional Transmission Losses minus Saved Evaporation	Net Depletions from Seepage and Brantley Bank Storage	Reoperation Net Depletion
Acme Constant	2976	19	2995
Acme Variable	2293	10	2304
Critical Habitat	681	-28	653
Taiban Constant	539	-22	517
Taiban Variable LRS	812	-23	789
Taiban Variable MRS	1217	-17	1200
Taiban Variable HRS	1908	-6	1901
No Action wo/6-wk	1560	13	1573

Erroneous Net Depletions

Net depletion numbers must be used with caution. Over a 60-year model period, it is the average result that is more meaningful than discrete values from year-to-year. This is because year-to-year variables in operations can cause net depletions in that year that are canceled out in some other year by the same variable. This variable difference is caused by the different timing of operations between two model simulations. Consider spills from Avalon dam. One model may spill in the modeled year 1941 while the other spills an equal amount in 1942. In one year the interpretation using annual net depletions will show a large net depletion to spills, but by the next year this net depletion will be canceled out since the other model also spilled. This is also a problem with spills from Sumner dam and the subsequent reduced efficiency that a *flood bypass* causes. Ultimately, this causes problems when trying to identify annual depletions due to bypassing for the shiner as opposed to bypassing for flood control. These types of erroneous net depletions (erroneous because they have nothing to do with the reoperations) are caused by variations in operational aspects of the models; other problems also arise from the normalization of reservoir storage in the equations.

Evaluating net depletions on an annual basis also leads to problems using Effective Brantley Storage. Consider the two modeled block releases over a two-year period depicted in Figure 18. One model releases a block release in the first year and the other doesn't. The second year, the model that didn't make a block release does, and the other doesn't. It is apparent that operations in one model are a "mirror" of the other. Note that this particular modeled block release (21 days at 1,150 cfs) is 80% efficient. That is 80% of the modeled release volume reached Brantley Reservoir as modeled inflow. At the end of the first year, storage counted in Brantley for the model that made a block release would be 80% of the release volume (0.80*47,900 acre-feet) or 38,300 acre-feet, the model that didn't make one still only receives 75% credit for the same volume still stored in Sumner as Effective Brantley Storage (0.75*47,900 acre-feet), which is 35,900 acre-feet. After the first year, an erroneous net depletion of 2,400 acre-feet will be calculated using Effective Brantley Storage. After the second year, when both releases have made it to Brantley, both are counted with 80% efficiency and the erroneous net depletion indicated the first year is gone.

Figure 18. 21-Day "Mirror" Block Releases Over a Two Year Period

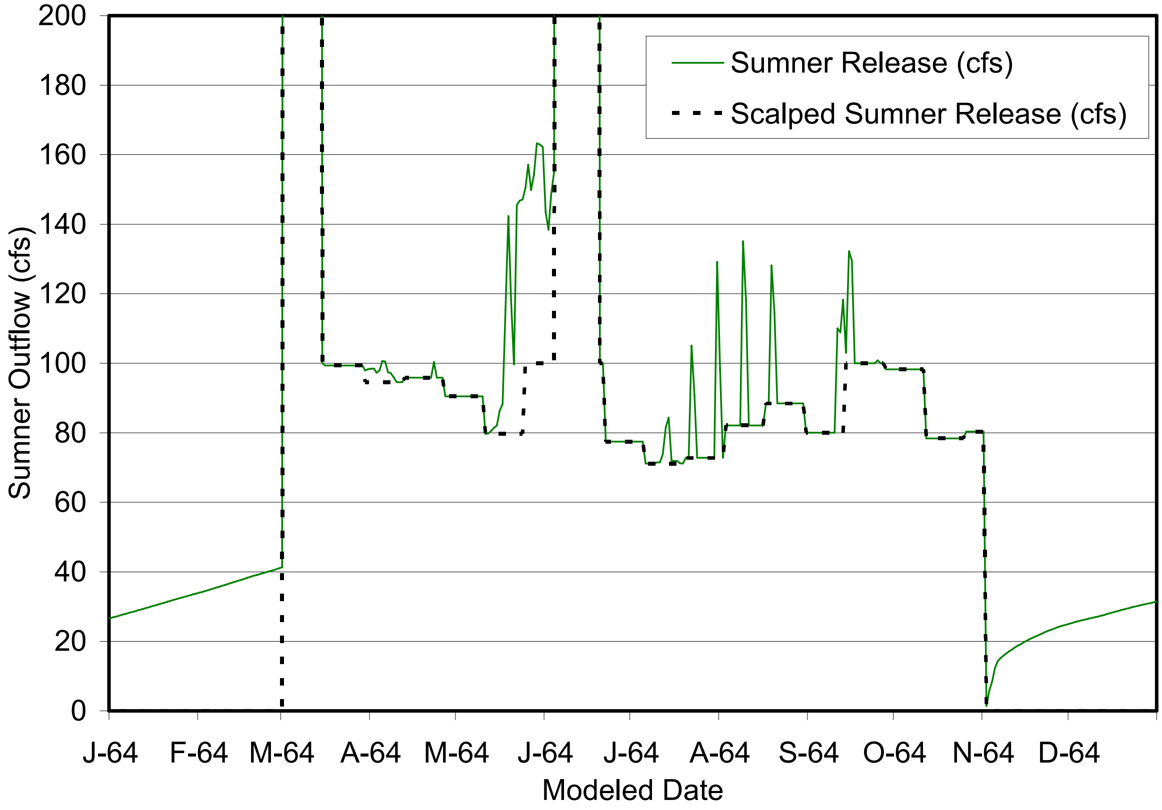


Calculation of Additional Transmission Losses in the Reach from Sumner to Brantley due to Bypass Operations Only

Due to the problems calculating the annual year-to-year variability of net depletions to the Project due to reoperations, a different approach was taken to isolate the annual transmission losses due to bypasses for the shiner. This was deemed the only acceptable way to estimate the variability without including other aspects of operations that could influence the results. Since bypasses for the shiner are the dominating loss in net depletions to the Project, annual maximums due to bypassing are a conservative estimate of maximum net depletions since they won't include the subsequent saved evaporation or increased losses in conservation spills that a bypass would create (Tetra Tech, 2003e).

In order to estimate transmission losses due to bypasses for the shiner, modeled inflows to Brantley without the shiner bypasses were determined. Bypasses were removed from Sumner outflows (See Figure 19) and this release was modeled to Brantley reservoir to determine the corresponding inflow volume. This inflow was then compared with the original Brantley inflow to determine annual efficiencies for the annual bypass volumes. These efficiencies were then subtracted from an average modeled efficiency for an appended block release volume (82%--which assumes an average bypass volume appended to a block release at a typical block discharge) to determine the additional transmission depletion due to the bypass (as opposed to moving the water by block release).

Figure 19. Example of Sumner Outflow Including Bypass for Shiner and Sumner Outflow with Bypass Removed (Scalped)



Results for Additional Transmission Losses in the Reach from Sumner to Brantley due to Bypass Operations Only

Maximum additional transmission depletions in the reach between Sumner Reservoir and Brantley Reservoir, due to bypassing only, are shown in Table 14. It is apparent that the maximum additional transmission depletions follow the same flow target-net depletion trend: larger flow targets cause larger maximum additional transmission depletions among alternatives. Minimum additional transmission depletions in the same reach due to only bypassing are shown in Table 15. These values also exhibit the same trend with bypass flow targets among alternatives.

Table 14. Average and Maximum Additional Transmission Depletions for the reach between Sumner Reservoir and Brantley Reservoir-Shown with Modeled Maximum Depletion years, Bypass Volumes, and Efficiencies

Alternative	**Average 60-Year Transmission Depletion (AF)** [1]	**Maximum Occurs in Modeled Year**	**Bypass Volume Leaving Sumner (AF)**	**Bypass Volume Arriving at Brantley (AF)** [2]	**Bypass Efficiency**	**Estimated Maximum Additional Transmission Depletion (AF)** [3]
Acme Constant	4202	1979	19086	8845	46%	**6900**
Acme Variable	3133	1943	13631	5314	39%	**5900**
Critical Habitat	981	1961	3001	1103	37%	**1400**
Taiban Constant	860	1971	3995	1548	39%	**1700**
Taiban Variable-LRS	1067	1971	4303	1623	38%	**1900**
Taiban Variable-MRS	1735	1975	5012	1523	30%	**2600**
Taiban Variable-HRS	2460	1943	6208	1411	23%	**3700**
No Action	2161	1943	11399	3954	35%	**5400**

[1] Using 60-year NEPA simulation, average outflow net depletion at Sumner multiplied by 75% efficiency, and average inflow net depletion at Brantley **(Sumner to Brantley reach only)**.

[2] Using identical (pattern) Sumner outflow hydrograph with all bypass removed to determine Brantley Inflow scalping hydrograph.

[3] Assumes 82% efficiency for appended block release volumes -- estimated transmission depletion **for reach between Sumner and Brantley Reservoirs for bypass operations only**

Table 15. Average and Minimum Additional Transmission Depletions for the reach between Sumner Reservoir and Brantley Reservoir-Shown with Modeled Maximum Depletion years, Bypass Volumes, and Efficiencies

Alternative	Average 60-Year Transmission Depletion (AF) [1]	Minimum Occurs in Modeled Year	Bypass Volume Leaving Sumner	Bypass Volume Arriving at Brantley (AF)[2]	Bypass Efficiency	Estimated Minimum Additional Transmission Depletion (AF) [3]
Acme Constant	4202	1958	4305	1809	42%	**1700**
Acme Variable	3133	1946	7027	3789	54%	**2000**
Critical Habitat	981	1959	243	4	2%	**200**
Taiban Constant	860	1986	15	2	15%	**10**
Taiban Variable-LRS	1067	1986	36	3	7%	**30**
Taiban Variable-MRS	1735	1958	706	252	36%	**320**
Taiban Variable-HRS	2460	1958	1826	603	33%	**900**
No Action wo/6wk	2161	1991	3928	2961	75%	**270**

[1] Using 60-year NEPA simulation, average outflow net depletion at Sumner multiplied by 75% efficiency, and average inflow net depletion at Brantley **(Sumner to Brantley reach only)**.

[2] Using identical (pattern) Sumner outflow hydrograph with all bypass removed to determine Brantley Inflow scalping hydrograph.

[3] Assumes 82% efficiency for appended block release volumes -- estimated transmission depletion **for reach between Sumner and Brantley Reservoirs for bypass operations only**

3.4 Net Depletions to State-line Flows

Net depletions to State-line flows are calculated using the same action to baseline comparison as net depletions to the Carlsbad Project. Modeled alternative flows at the State line, over a specified time period, are subtracted from modeled pre-1991 baseline flows, over the same time period, at the State line. Since State-line flow is only one net depletion parameter, it greatly simplifies the computations; however, State-line flows are still affected by modeled differences in conservation spills from the Carlsbad Project.

Calculation of Net Depletions to State-line Flows

To remove the annual effect of conservation spills from modeled State-line flows, a similar approach to Equation 3.3 was used. The annual differences in spills were removed from the annual State-line net depletions and the annual long-term average of those spills was added back into all of the annual State-line net depletions. Equation 3.12 is the formula for removing these spill differences.

$$\begin{array}{c}\textit{Annual Corrected}\\ \textit{Net Depletion to}\\ \textit{State - line Flows}\end{array} = \begin{array}{c}\textit{Annual Net}\\ \textit{Depletion to}\\ \textit{State - line Flows}\end{array} - \begin{array}{c}\textit{Annual Net}\\ \textit{Depletion to}\\ \textit{Avalon Spills}\end{array} + \begin{array}{c}\textit{60 - Year Average}\\ \textit{Net Depletion to}\\ \textit{Avalon Spills}\end{array} \qquad \text{Eq. 3.12}$$

Modeled Results for Net Depletions to State-line Flows

Figures 20-27 illustrate the year-to-year variability of net depletions to State-line flows. 60-year averages are also printed on each figure. Once again the same general net depletion trend is noted among alternatives with higher versus lower targets. Higher flow target alternatives, such as Acme Constant and Acme Variable, show larger net depletions to State-line flows and lower flow target alternatives, such as Taiban Constant and Critical Habitat, show smaller net depletions to State-line flows.

Figure 20. Net Depletions to State-line Flows for the No Action Alternative

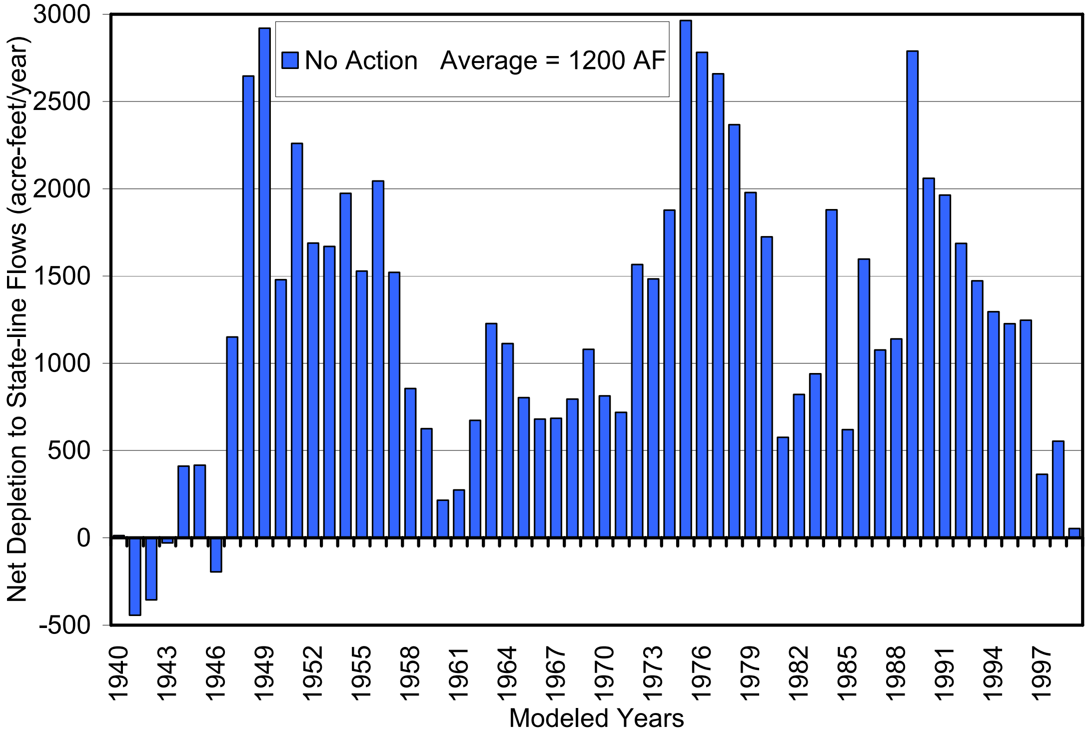


Figure 21. Net Depletions to State-line Flows for the Taiban Constant Alternative

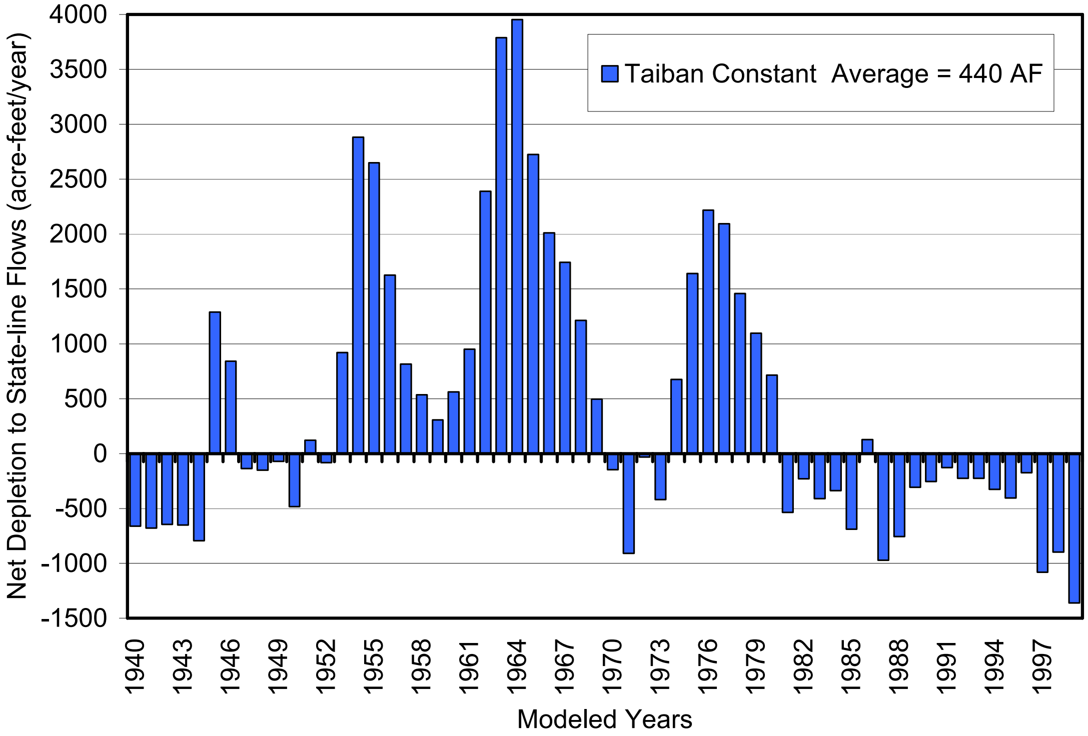


Figure 22. Net Depletions to State-line Flows for the Taiban Variable Alternative (High Range, 55 cfs, Irrigation Season Target)

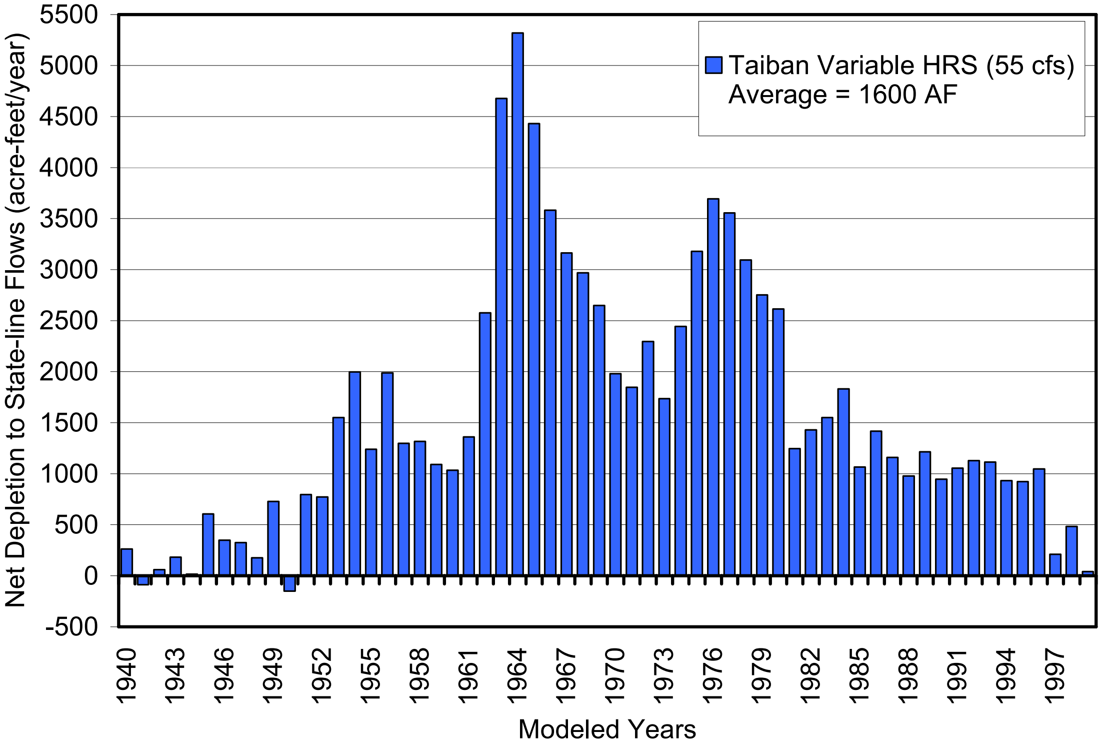


Figure 23. Net Depletions to State-line Flows for the Taiban Variable Alternative (Mid-Range, 45 cfs, Irrigation Season Target)

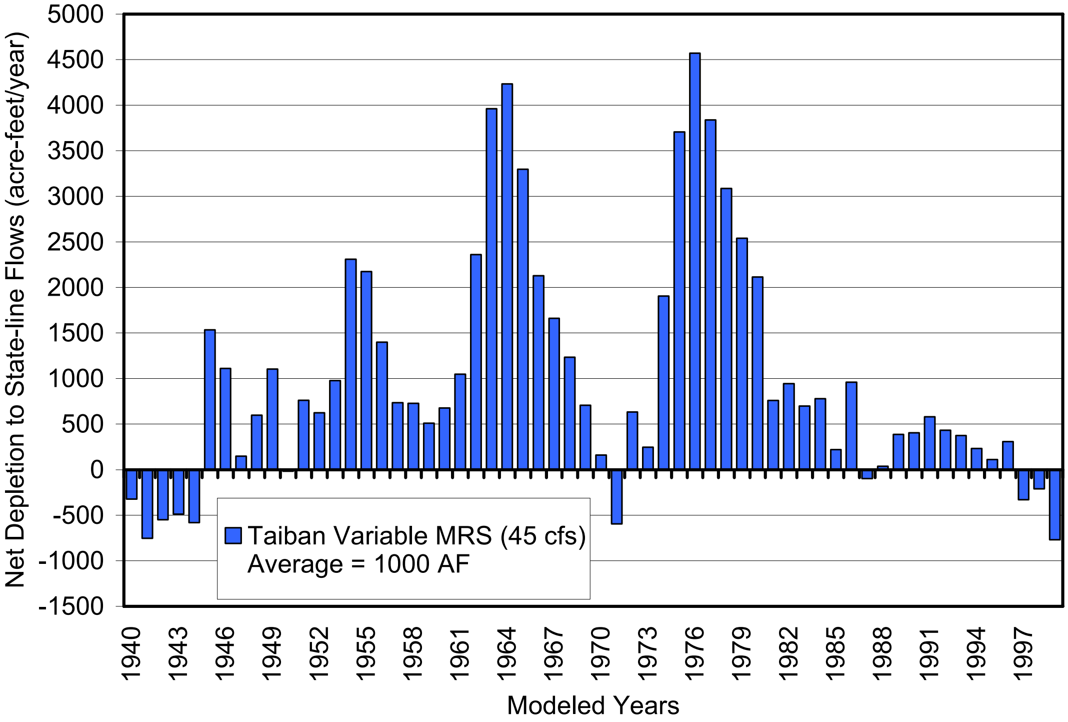


Figure 24. Net Depletions to State-line Flows for the Taiban Variable Alternative (Low Range, 40 cfs, Irrigation Season Target)

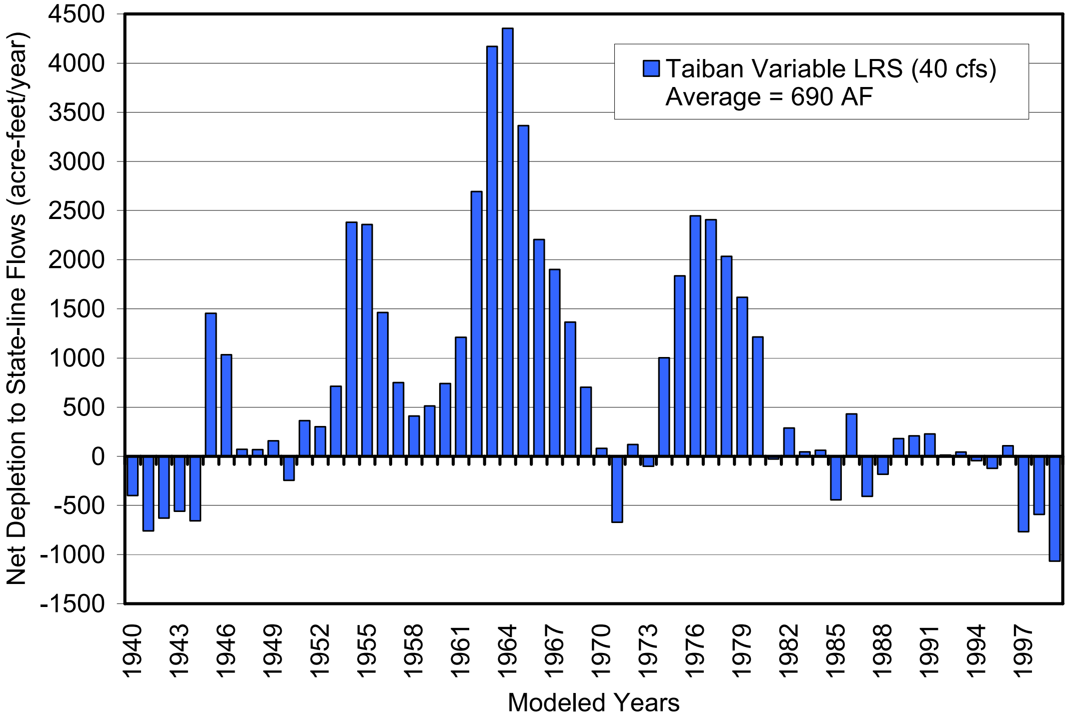


Figure 25. Net Depletions to State-line Flows for the Acme Constant Alternative

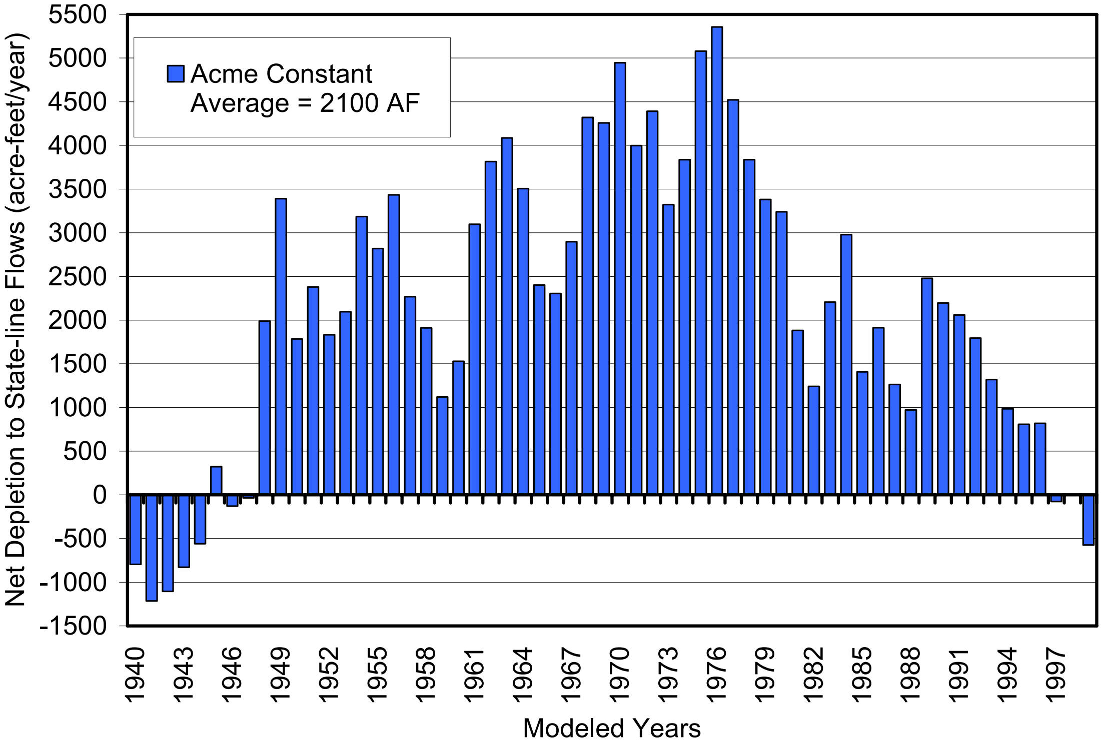


Figure 26. Net Depletions to State-line Flows for the Acme Variable Alternative

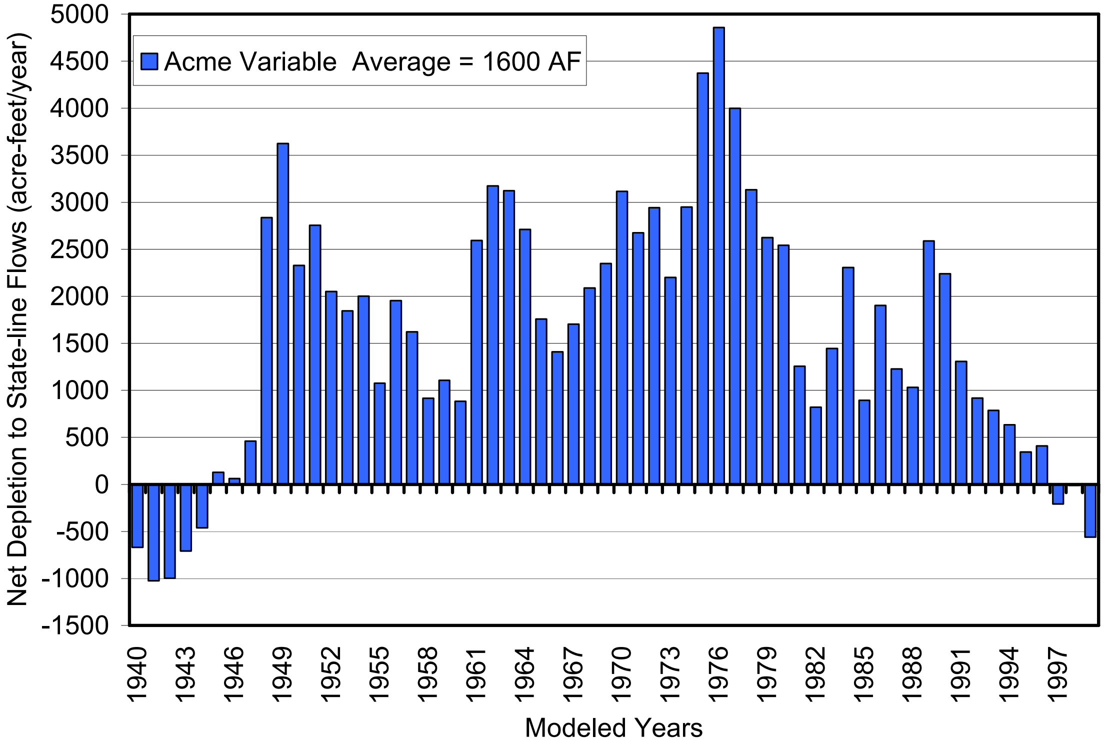
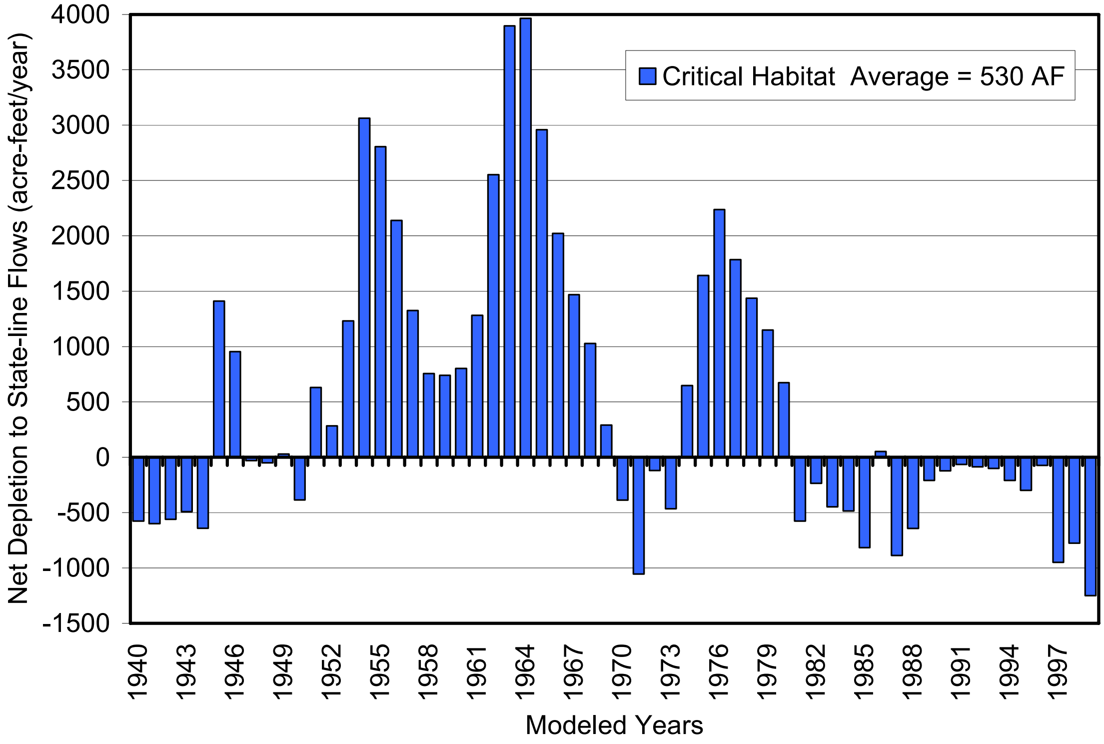


Figure 27. Net Depletions to State-line Flows for the Critical Habitat Alternative



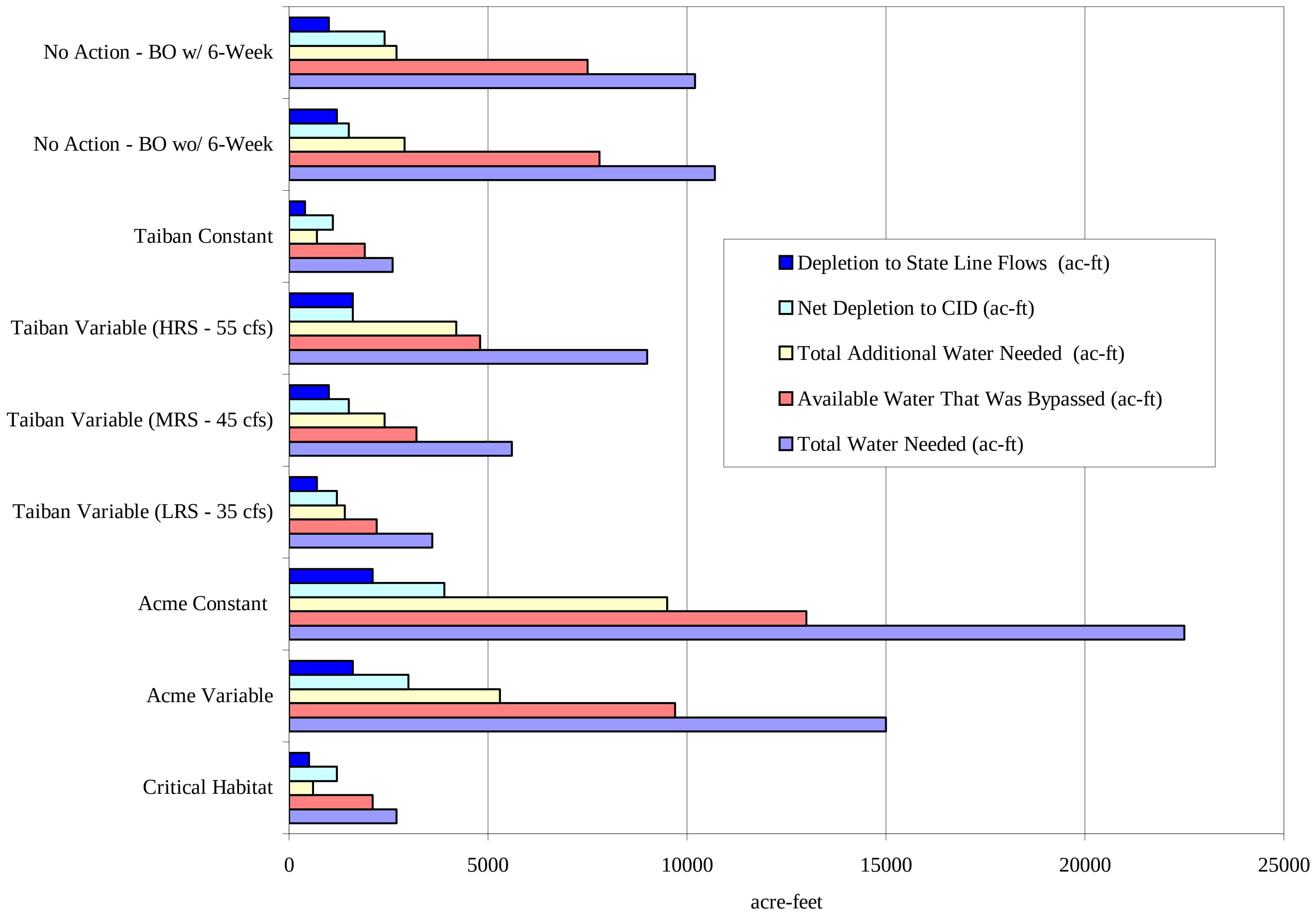
3.5 Summary of Alternative Water Accounting and Net Depletions

Table 16 is a summary of the water accounting results for all of the alternatives. The table summarizes the total water needed for each alternative to meet the target flows as much as possible, the available water that was bypassed, and the additional amount of water that would be needed to meet the demand (the difference between the first two columns). The table also summarizes the corrected reoperation net depletion to CID and the net depletion to State-line flows. The values in the last two columns are the 60-year average values for each alternative. Figure 28 is a graphical representation of the numbers contained in Table 16.

Table 16. Alternative Summary Water Accounting Table

Alternative	Total Water Needed (ac-ft)	Available Water that was Bypassed (ac-ft)	Additional Water Needed (AWN) to Meet Demand Completely (ac-ft)	Corrected Reoperation Net Depletion to CID (ac-ft)	Net Depletion to State Line Flows (ac-ft)
No Action	10,700	7,800	2,900	1,500	1,200
Taiban Constant	2,600	1,900	720	1,100	440
Taiban Variable (HRS - 55 cfs)	9,000	4,800	4,200	1,700	1,600
Taiban Variable (MRS - 45 cfs)	5,600	3,200	2,400	1,500	1,000
Taiban Variable (LRS - 40 cfs)	3,600	2,200	1,400	1,200	690
Acme Constant	22,500	13,000	9,500	3,900	2,100
Acme Variable	15,000	9,700	5,300	3,000	1,600
Critical Habitat	2,700	2,100	620	1,200	530

Figure 28. Modeled 60-Year Annual Averages of PBNS Alternative Total Water Needs, Bypasses, Additional Water Needs.



The first column in Table 16, “total water needed”, represents the amount of water that is required to be released from Sumner Dam to meet the specified flow criteria for each alternative. The “available water that was bypassed” (column 2) represents the amount of water that was bypassed. In some cases there is more inflow than is needed to meet the targets and this surplus remains in Sumner Reservoir for CID. The bypass flows do not include any additional water such as water taken from CID storage, water supplied through options determined by the water offset options group (WOOG), or additional water acquisition (AWA) options, or water from a fish conservation pool (FCP). Column 3, “additional water needed” or AWN represents the difference between column 1 and column 2. It should be noted that AWN is what is required to meet all the targets, all of the time. If a fish conservation pool is used for this purpose, this is the amount of water that would be needed for the pool, without considering evaporation. It is not necessarily the volume of the pool that would be needed if the pool is stipulated to be a refillable pool.

Alternative Comparisons – Water Accounting and Net Depletions

Water that travels from Sumner Reservoir to Brantley Reservoir incurs losses such as evaporation and transpiration. When water is moved from one reservoir to another in large amounts, i.e. higher discharges for consecutive days, the losses incurred are less than if the water is transferred at lower discharges over longer periods of time. The season also affects the rate of loss as more water is lost during the hotter, dryer periods such as summer than is lost during cooler times of the year. All of the alternatives alter the flow duration pattern, decreasing the amount and frequency of block releases and increasing the volume of water that is transported at lower flows. This alteration of the hydrograph causes an increase in transmission losses between the two reservoirs. The fourth column of Table 16 represents the net depletion to CID supply mostly due to these losses.

Although the 60-year average masks the year-to-year variability of the accounting numbers, the averages are good for comparing the water use of the different alternatives with each other. With regard to water use, the following qualitative statements can be made concerning the alternatives:

- The Acme Alternatives require the most total water and additional water. Total water is what would be needed to meet the criteria set forth in the alternative and additional water is water that would be need to meet targets 100% of the time in addition to CID bypass water. Due to the large amount of water bypassed for these alternatives, the impacts to CID and flows at the state line are significant.
- The Taiban Variable Alternative uses a minor to moderate amount of water as far as total water needs and bypasses are concerned.
- Results for alternatives with low additional water needs indicate these alternatives have more reasonable flow targets with respect to incoming supply. Conversely, note that the Taiban Variable-High Range Summer target (55 cfs) sub-alternative actually requires more additional water than both permutations of the No Action Alternative. For the high range summer sub-alternative, it is evident that targets may be set unreasonably high at times when there is not much CID supply available to bypass through Sumner Reservoir.
- The Critical Habitat and Taiban Constant Alternatives use the least amount of total water and require a negligible amount of additional water when compared to the Acme Alternatives.
- Net Depletions to flows at the New Mexico—Texas State line correlate directly with the total water needs of the alternatives including the No Action Alternative.

4.0 Summary and Conclusions

Preliminary alternative modeling for the current NEPA process to reoperate Sumner Dam showed varied results among the alternatives. Total water needs for alternatives ranged from fairly minor (2,600 acre-ft/year for Taiban Constant) to extremely major amounts (22,500 acre-ft/year for Acme Constant).

Improvements in flow duration due to reoperations are evident; but since incoming supply is limited, no single alternative using bypasses alone prevents intermittency at the Acme node. The flow exceedance improvements are mostly due to availability of incoming supply to hit targets during the winter. In the summer, these supplies are sporadic and will cause intermittency at times unless sufficient additional water acquisition (AWA) is acquired to meet the target demands (AWN) of the alternatives. The Critical Habitat and No Action Alternatives will always have some intermittency since they were designed that way.

Modeling results indicate that net depletions to both Carlsbad Project supply and the State-line are caused by bypassing, and larger flow target alternatives cause larger net depletions to 60-year averages and 60-year maximums. 60-year average values are useful for determining trends for components of net depletions such as average additional transmission losses, average saved evaporation, or average decreases in conservation spills, but annual values should be used with caution (in the case of State-line flows) or not at all (for Carlsbad Project supply).

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Technical Appendix to the:

Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

Pecos River Bypass and Additional Water Needed (AWN) Modeling and Post-Processing

January 2006

By Hydrosphere Resource Consultants, Inc.

HYDROSPHERE
Resource Consultants

TABLE OF CONTENTS

1.0 Introduction

To evaluate the impacts of NEPA alternatives to reoperate Sumner Dam for the Pecos Bluntnose Shiner (PBNS), the Hydrology/Water Operations Work Group (HWG) modeled alternatives using the Pecos River Decision Support System (PRDSS) (Barroll et al, 2004; Hydrosphere Resource Consultants, 2003 and 2005; and Tetra Tech, Inc, 2003a and 2003b). The PRDSS consists of a RiverWare surface water model, two MODFLOW groundwater models, and an MS Access-based output post-processor/data reformatter. Model outputs were saved in an MS Access results database and results for requested resource indicators were distributed to EIS work groups. This document details RiverWare modeling and post-processing calculations for bypass operations alone, and computation of additional water needed (beyond the bypasses) to meet flow targets for the PBNS 100% of the time.

2.0 Summary of Alternatives Modeling and Initial Post-Processing

The following describes alternatives bypass modeling and the RiverWare "fish rules" used to simulate bypass operations, as well as the post-processing of model results to determine the additional water needed (AWN) in excess of bypasses to meet fish flow targets. Model runs including both bypasses and AWN water are also described.

2.1 Bypass-Only Modeling

Individual RiverWare surface water models (run on a daily timestep) and rulesets were created for each alternative. Alternatives, designed to conserve the PBNS, vary mostly by flow targets[1] in the PBNS Upper Critical Habitat and at the Taiban and Acme gages (a matrix summarizing alternatives is presented in attachment A).

In RiverWare, a series of rules, collectively referred to as the “fish rules”, were designed to model water bypassed through Sumner reservoir (Sumner) to meet NEPA alternative flow targets for the PBNS. Flow targets may vary according to the irrigation season[2] and the hydrologic condition (wet, dry, and average). The fish rules determine local inflows above Sumner which are “available[3]”, i.e., in excess of the Fort Sumner Irrigation District’s (FSID) entitlement, to be bypassed to meet flow targets. In these model simulations, water was not taken from Carlsbad Irrigation District (CID) storage to meet flow targets. The Bureau of Reclamation (Reclamation) and CID jointly hold the right to divert and store river water for the benefit of the Carlsbad Project. Bypasses to meet flow targets occur when Reclamation does not exercise its right to divert and store for the Carlsbad Project, with the understanding on CID’s part that Reclamation will offset depletions to CID’s supply associated with that bypass.

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[1] The Taiban Constant and Taiban Variable alternatives specify flows at the Taiban gage. The Acme Constant and Acme Variable alternatives specify flows at the Acme gage. The Critical Habitat alternative specifies flows at the both the Taiban and Acme gages as well as flows to keep the river wet from Taiban to the mouth of Crockett Draw (located at the lower end of the upper Critical Habitat.) The No Action alternative specifies flows at Acme and to the mouth of Crocket Draw.

[2] The irrigation season extends from March 1 through October 31 and this time period is often referred to as “summer.” The non-irrigation season extends from November 1 to the end of February and is often referred to as “winter.”

[3] Available local inflows which are storable, i.e., in excess of FSID’s diversion request, become part of Carlsbad Irrigation District (CID) supply.

2.2 Fish Rule Overview

One basic premise behind the fish rules is that the Pecos River experiences characteristic losses that vary by season over the course of the year. These average daily losses have been determined from historical gage data and are dependent on the magnitude of the flows. Figure 1 illustrates how loss coefficients vary both seasonally and according to the flow. The larger a coefficient, the greater the loss. Losses are lowest in the winter months, ramp up in the spring, are highest in the summer, and ramp down in the fall. In addition, loss coefficients decrease as flows in the river increase, i.e. for higher flows a smaller percentage of the total flow is lost. To meet a flow target at a particular gage below Sumner dam, sufficient water must be passed through Sumner dam to overcome the expected losses.

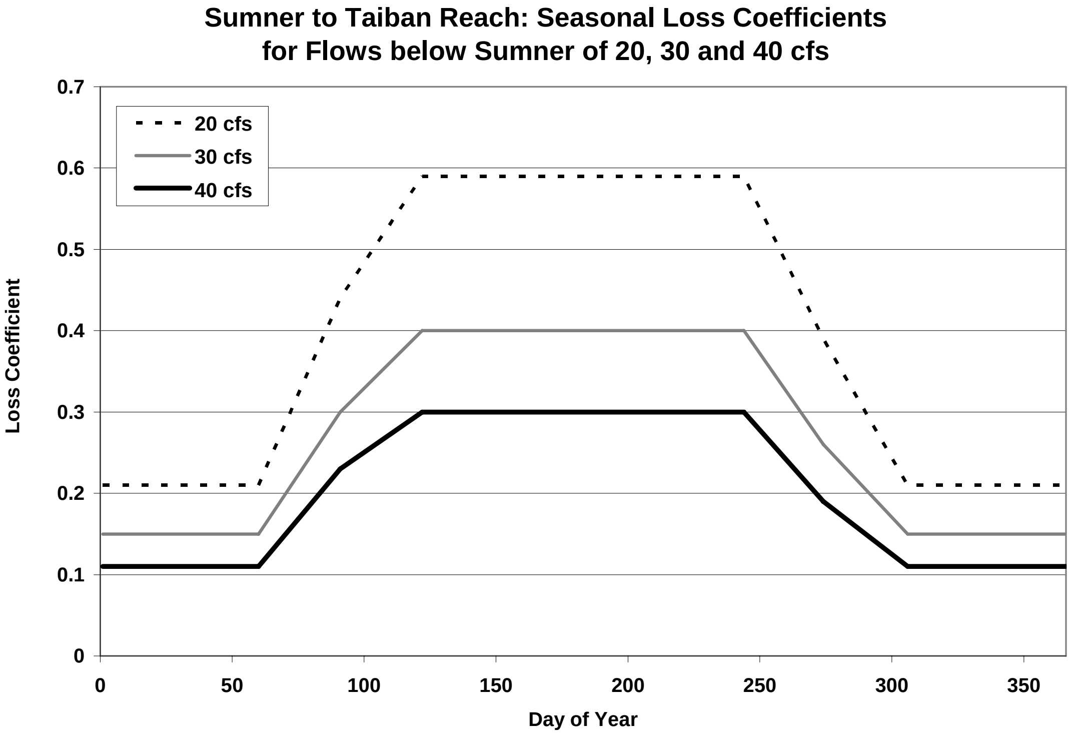
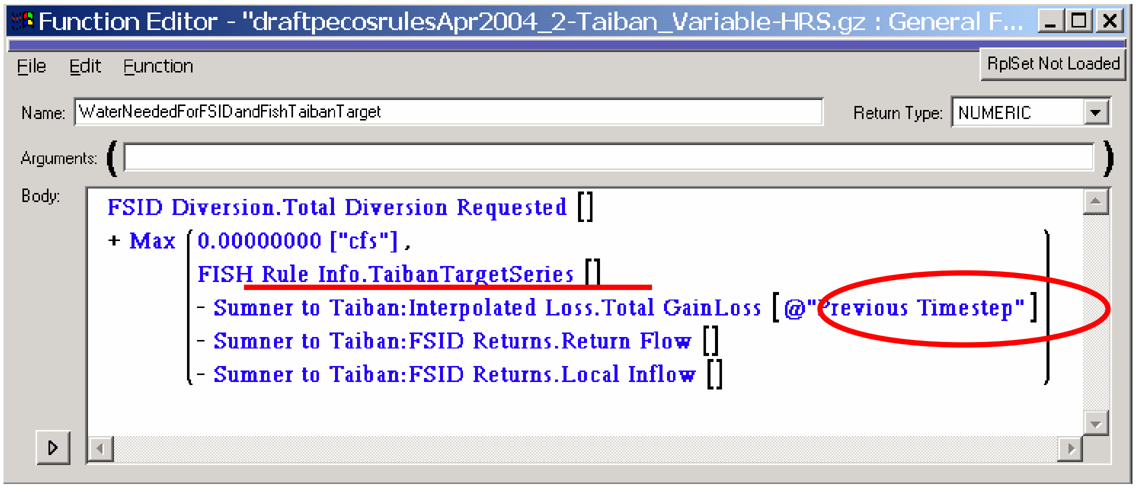


Figure 1: Seasonal Loss coefficients applied to flows of 20, 30 and 40 cubic feet per second (cfs) below Sumner Dam.

In the RiverWare model, one of the fish rules first converts all target flows (regardless of target location) to a flow needed at Taiban. If an alternative specifies a flow target at a location other than Taiban, the flow target is converted to a Taiban flow via the loss function between the subject gage and the Taiban gage. Flows needed at Taiban are then converted to flows at the Pecos River below Sumner Dam using the loss function illustrated in Figure 1 and by subtracting off flows already in the river at Taiban (i.e. FSID return flows and non-applied water). Again, following the basic premise described above, enough water must be released from Sumner to cover river losses in the Sumner to Taiban reach. RiverWare does not easily solve for river losses until the inflows to the reach are known, so the previous day's loss for the Sumner to Taiban reach was used as an approximation. To determine the total water needed in the river below Sumner to meet both FSID and PBNS demands, FSID's diversion requests are added to the water needed for the fish. There are three different RiverWare functions used to determine the total water needed below Sumner depending on the flow target location (Figs 2 – 4). Note that the name of the function specifies the flow target location.



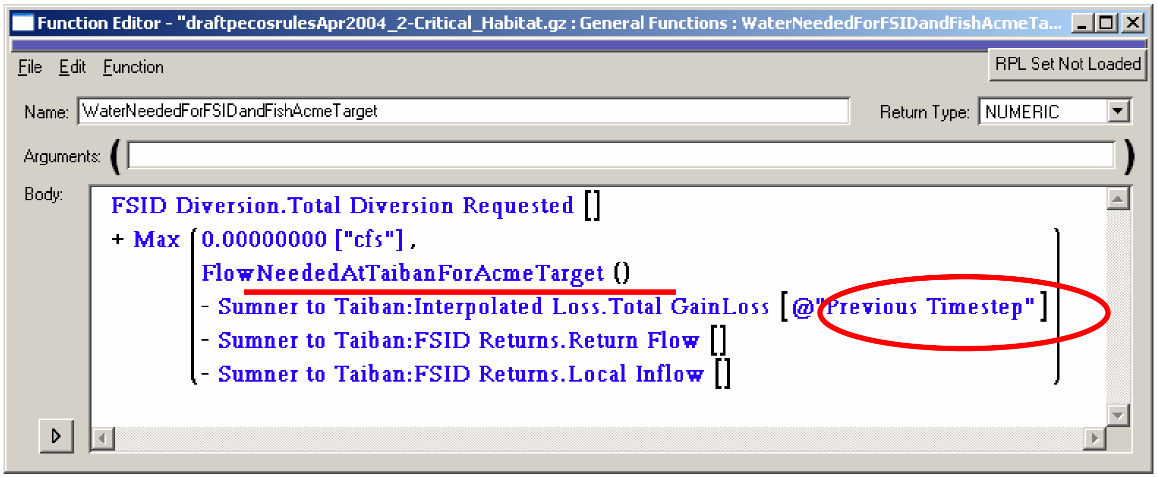
Function Editor - "draftpecosrulesApr2004_2-Taiban_Variable-HRS.gz : General F...

Name: WaterNeededForFSIDandFishTaibanTarget

Return Type: NUMERIC

```
FSID Diversion.Total Diversion Requested []
+ Max (0.00000000 ["cfs"] ,
       FISH Rule Info.TaibanTargetSeries []
       - Sumner to Taiban:Interpolated Loss.Total GainLoss [@"Previous Timestep"]
       - Sumner to Taiban:FSID Returns.Return Flow []
       - Sumner to Taiban:FSID Returns.Local Inflow [])
```

Figure 2: RiverWare ruleset function which sets the Sumner outflow needed to meet FSID's diversion request and the fish flow target for Alternatives with Taiban flow targets.



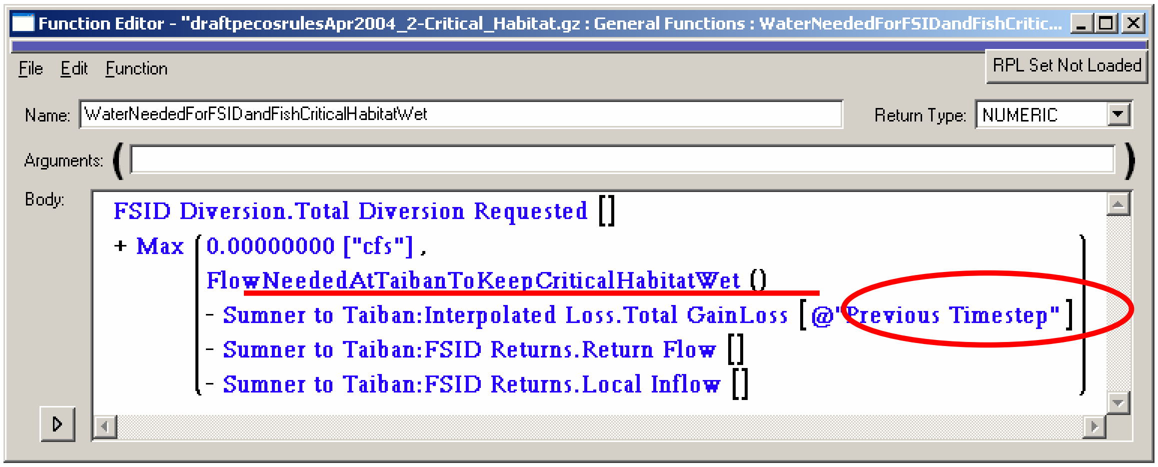
Function Editor - "draftpecosrulesApr2004_2-Critical_Habitat.gz : General Functions : WaterNeededForFSIDandFishAcmeTa...

Name: WaterNeededForFSIDandFishAcmeTarget

Return Type: NUMERIC

```
FSID Diversion.Total Diversion Requested []
+ Max (0.00000000 ["cfs"] ,
       FlowNeededAtTaibanForAcmeTarget ()
       - Sumner to Taiban:Interpolated Loss.Total GainLoss [@"Previous Timestep"]
       - Sumner to Taiban:FSID Returns.Return Flow []
       - Sumner to Taiban:FSID Returns.Local Inflow [])
```

Figure 3: RiverWare ruleset function which sets the Sumner outflow needed to meet FSID's diversion request and the fish flow target for alternatives with Acme flow targets.

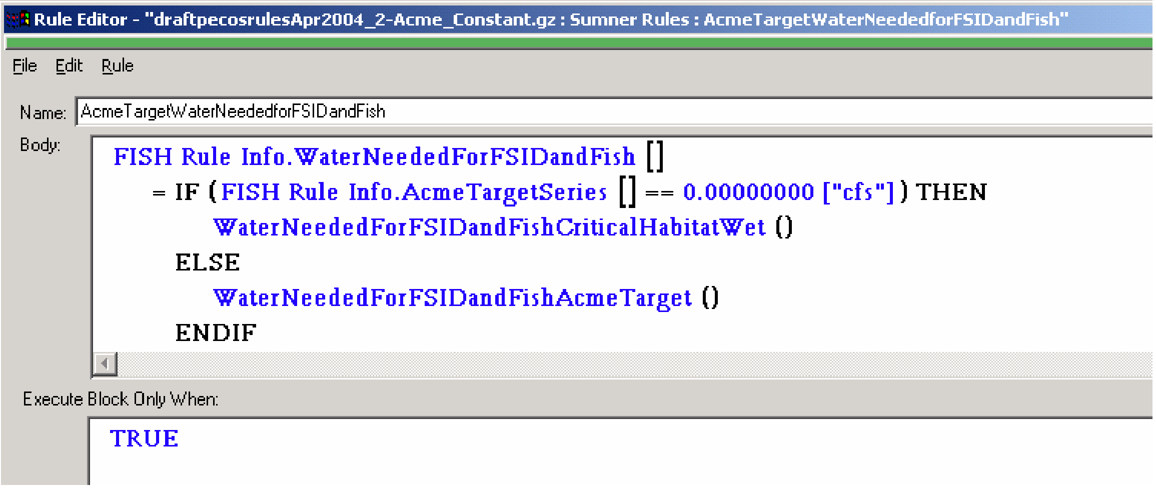


Name: WaterNeededForFSIDandFishCriticalHabitatWet

```
FSID Diversion.Total Diversion Requested []
+ Max (0.00000000 ["cfs"],
       FlowNeededAtTaibanToKeepCriticalHabitatWet ()
       - Sumner to Taiban:Interpolated Loss.Total GainLoss [@"Previous Timestep"]
       - Sumner to Taiban:FSID Returns.Return Flow []
       - Sumner to Taiban:FSID Returns.Local Inflow [])
```

Figure 4: RiverWare ruleset function which sets the Sumner outflow needed to meet FSID's diversion request and the fish flow target for alternatives with Critical Habitat flow targets.

The Critical Habitat and No Action alternatives have Taiban and/or Acme targets as well as dry summer targets designed to keep the upper critical habitat wet. For these alternatives, one of the fish rules, "Acme TargetWaterNeededForFSIDandFish" rule (fig. 5), determines whether to call the "WaterNeededForFSIDandFishAcmeTarget" (fig. 3) or "WaterNeededForFSIDandFishCriticalHabitatWet" (Fig. 4) function when calculating the water needed below Sumner for FSID and the fish. During dry summer periods, the Acme target series is set to 0.0 cfs. The rule then evaluates the Acme target, and if it is set to 0.0, calls the "WaterNeededForFSIDandFishCriticalHabitatWet" function. Otherwise, the "WaterNeededForFSIDandFishAcmeTarget" function is called.



Name: AcmeTargetWaterNeededforFSIDandFish

```
FISH Rule Info.WaterNeededForFSIDandFish []
    = IF (FISH Rule Info.AcmeTargetSeries [] == 0.00000000 ["cfs"]) THEN
          WaterNeededForFSIDandFishCriticalHabitatWet ()
      ELSE
          WaterNeededForFSIDandFishAcmeTarget ()
      ENDIF
```

Execute Block Only When:

```
TRUE
```

Figure 5: Fish Rule which sets the water needed below Sumner for FSID and the fish for alternatives with Critical Habitat and/or Acme targets.

Once the total water needed for FSID and the fish has been determined, additional RiverWare rules compare this value to Sumner inflows, bypassing what is available. FSID's diversion requests are fully met before water is bypassed for the fish.

2.3 Additional Water Needed Post-Processing and Modeling

The definition of each alternative implies having sufficient water to meet the targets 100% of the time. In modeling the NEPA alternatives, bypassing incoming available water was often insufficient to meet the flow targets for many of the alternatives at all times. To characterize those periods when available storable inflows were insufficient to meet flow targets via bypasses, additional amounts of water for each alternative that would be required to meet the targets 100% of the time were quantified by post-processing bypass-only model results. This additional water is referred to as AWN[4] (additional water needed). The acquisition and management of this water would likely include (but is not limited to) storage in a fish conservation pool (FCP) in either Sumner or Santa Rosa reservoir.

AWN to meet fish target flows in excess of bypasses was calculated by post-processing results from alternative model simulations. On a daily basis, bypasses were evaluated to determine if they were sufficient to meet fish target flows. If additional water was needed, this was considered AWN.

2.4 Fish Conservation Pool Model Runs

To evaluate the effects of a fish conservation pool on Pecos River flows to Acme, a simplified “mini” RiverWare model for the reach below Sumner down to Acme was created. The NEPA RiverWare ruleset was also condensed to contain only the FSID portion of the RiverWare rules. For each alternative, a set of Sumner outflows, including bypasses and FCP water was developed for input into the “mini” model. Except for Sumner outflows being input rather than being set by rules, the "mini" model is consistent with the complete model for the reaches modeled.

Several runs of the mini-model were initially done to evaluate the impacts of a finite FCP in Sumner Reservoir which was refilled on January 1 of each year. For each alternative, revised Sumner outflows were generated by taking daily Sumner outflows from the alternative simulations with bypass operations and adding water from the FCP pool in order to meet the flow target. In any given year, once the FCP ran out, Sumner outflows were set equal to the bypass operations values. Taiban, Dunlap and Acme flows were output from this simplified model and flow exceedance curves and intermittency statistics generated.

3.0 RiverWare Fish Rule Limitations

While examining results from bypass model runs, the fish rules were found to have several limitations. The total water needed for the fish was not adjusted in the rules for times when Sumner was spilling or there was a block release. Additional model data which had not been saved and exported was needed to evaluate the impact of flow targets on certain resource indicators. Also, the use of the previous day's loss in the Sumner to Taiban reach led to over- and under-estimations of the actual modeled loss.

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[4] The HWG first referred to AWN water as FCP water, though not all additional water needed (in additional to bypasses) would likely be maintained in a pool in Sumner Reservoir and/or Santa Rosa Reservoir. Additional Water Acquisition (AWA) terminology found throughout EIS documentation should not be confused with AWN. AWN is the total demand to meet flow targets 100% of the time after all available inflows above FSID’s diversion right have been bypassed. AWA is limited to the additional water that would be acquired with available resources to further augment flows but not necessarily always meet flow targets.

Additional model runs were made to determine the impact these limitations had on bypass operations results.

3.1 Total Water Needed Calculations

When the fish rules were developed, the need for certain data for reporting was not anticipated. For example, the rules did not keep track of the total water needed for the fish at Taiban before FSID returns flows and river losses were considered.

Several problems were encountered when working with the output water needed for FSID and the fish (below Sumner) value. This value was set prior to other rules which consider if there is a spill or block release to take priority over the fish rules, but which will put water in the river. In these cases, because the water needed for FSID and the fish was not adjusted, when comparing bypasses to water needed for the fish, the calculated AWN was significantly larger than the "actual"[5] water needed for FSID and the fish.

In addition, using the previous day's loss in the Sumner to Taiban reach when calculating the water needed for FSID and the fish inflated results for days when there had been a spill or block release on the previous day which resulted in a large loss value. This also led to water needed for FSID and fish values greater than was actually necessary. To address these issues, model results were disregarded and the water needed for FSID and fish recalculated in post-processing files.

3.2 Intermittency Concerns

To evaluate the impact of FCP water on Pecos River flows, "mini" RiverWare models (as described in section 2.4) were run including an FCP of 2,500 acre-feet (af) which refilled January 1 of each year. Though the AWN calculated in post-processing files for the several alternatives (Critical Habitat, Taiban Constant and Taiban Variable LRS) was less than 2,500 af, infrequent intermittency at Acme (less than 1% of the time) occurred when a 2,500 af FCP was modeled. The Biology Work Group requested that the HWG investigate the reason for these intermittency occurrences when all requested AWN water was modeled.

3.3 Revised Fish Rules QA Simulations

To evaluate the sensitivity of model results to methods for computing channel losses in the fish rules, a quality assurance (QA) model run was performed employing a different approach to specify expected losses. The RiverWare fish rules where modified so that the previous day's loss for the Sumner to Taiban reach was replaced with the breakthrough flow for this reach. The RiverWare model was rerun with the modified fish rules for two alternatives, Acme Constant and Taiban Constant, expected to cover a range of impacts.

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[5] Water needed adjusted for water in the stream resulting from block releases and spills.

After final modifications were made to post-processing files[6], the effects of the modified fish rules on Acme flows, Taiban flows, and CID supplies were examined to determine how significantly model results were impacted. Figure 6 shows exceedance curves for flows at Taiban for the Taiban Constant alternative for the “Original” (original fish rules, using previous day’s loss) and “Revised” (modified fish rules, using breakthrough flows) RiverWare model runs. Figure 7 shows flow exceedance curves at Acme for the Acme Constant alternative. In both figures, the flow exceedance curves are virtually unchanged.

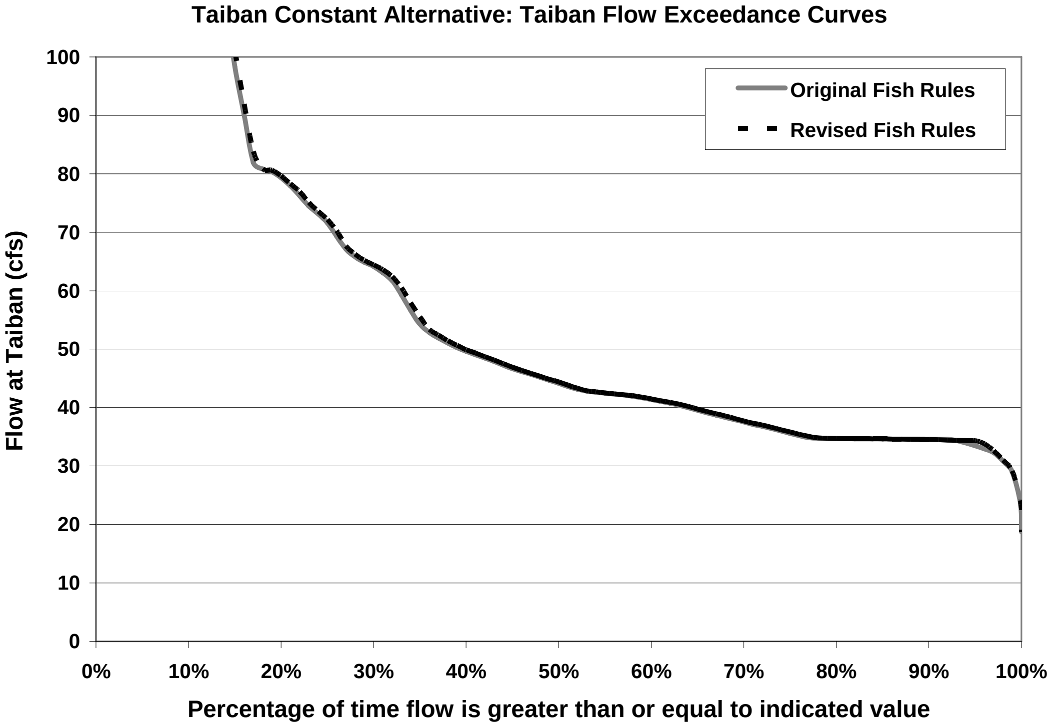

Figure 6: "Original" and "Revised" fish rule Taiban flow exceedance curves for the Taiban Constant alternative

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[6] Initially it was thought that using the previous day’s loss had a significant impact on the total water needed below Sumner for FSID and the fish. A comparison between exceedance curves for annual AWN volumes from RiverWare for the “Original” and “Revised” fish rule Acme Constant and Taiban Constant model runs appeared to show that the annual volume of AWN to meet fish targets increased substantially with the revised fish rules. Upon further evaluation, these differences were found to be due to inconsistent calculations being used to determine the actual water needed for the fish and AWN in post-processing files. Final changes made to post-processing calculations are documented in section 4.2 below.

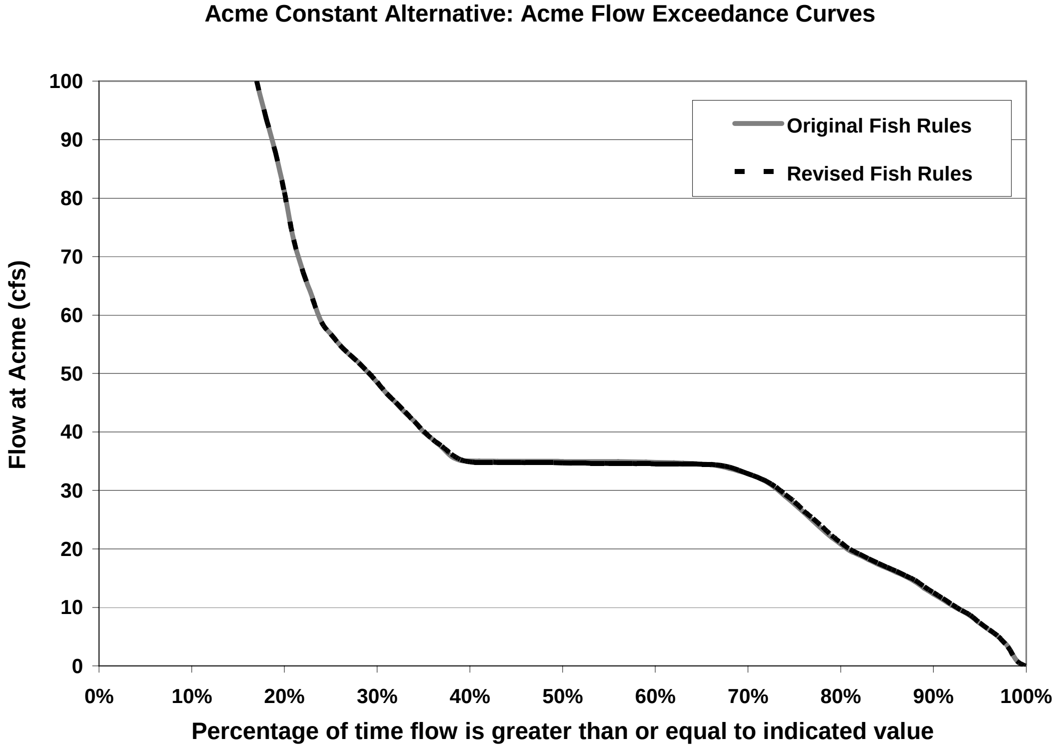

Figure 7: "Original" and "Revised" fish rules Acme flow exceedance curves for the Acme Constant alternative

Using the breakthrough flow slightly decreased intermittency (Table 1) which occurred less than 1% of the time in all model runs. The availability of water for bypasses was the limiting factor in both the “Original” and “Revised” fish rule runs.

Table 1: Intermittency Statistics at Acme for Taiban Constant and Acme Constant “Original” and “Revised” fish rule model runs.

Intermittency at Acme (intermittency defined as 0.0 cfs)				
	Taiban Constant Original Rule	Taiban Constant Revised Rule	Acme Constant Original Rule	Acme Constant Revised Rule
Percent of time intermittent	0.89	0.83	0.67	0.65
Number of days[1] intermittent	196	182	147	143

[1] *Total number of days in model runs was 21,915.*

Figures 8 and 9 show net depletions to CID for the Taiban Constant and Acme Constant Alternatives. CID net depletions are the decrease in supplies and deliveries for an alternative in comparison to the Pre-91 Baseline model run which does not include bypasses for the fish. While the differences between the original and revised fish rule runs were significant in a few years, the overall results show that changes to CID net depletions were small. The average annual CID net depletions (the results presented in the EIS) changed by only 19 acre-feet for the Taiban Constant alternative and 178 acre-feet for the Acme Constant alternative.

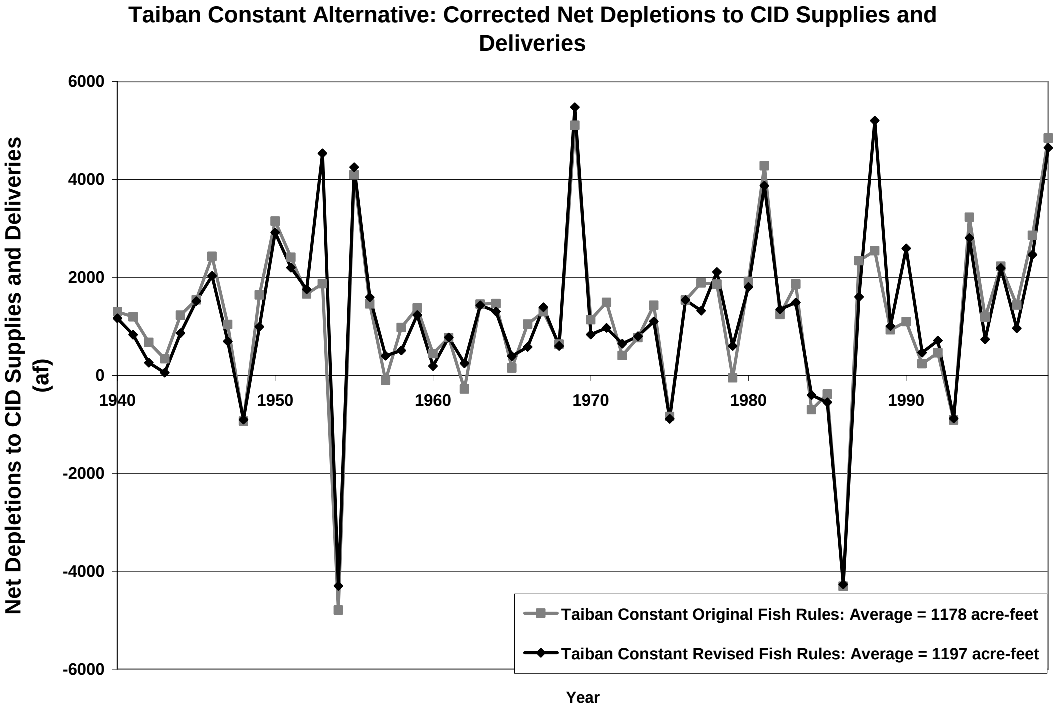

Figure 8: Annual net depletions to CID supplies and deliveries for the original Taiban Constant NEPA model run and the run with revised fish rules

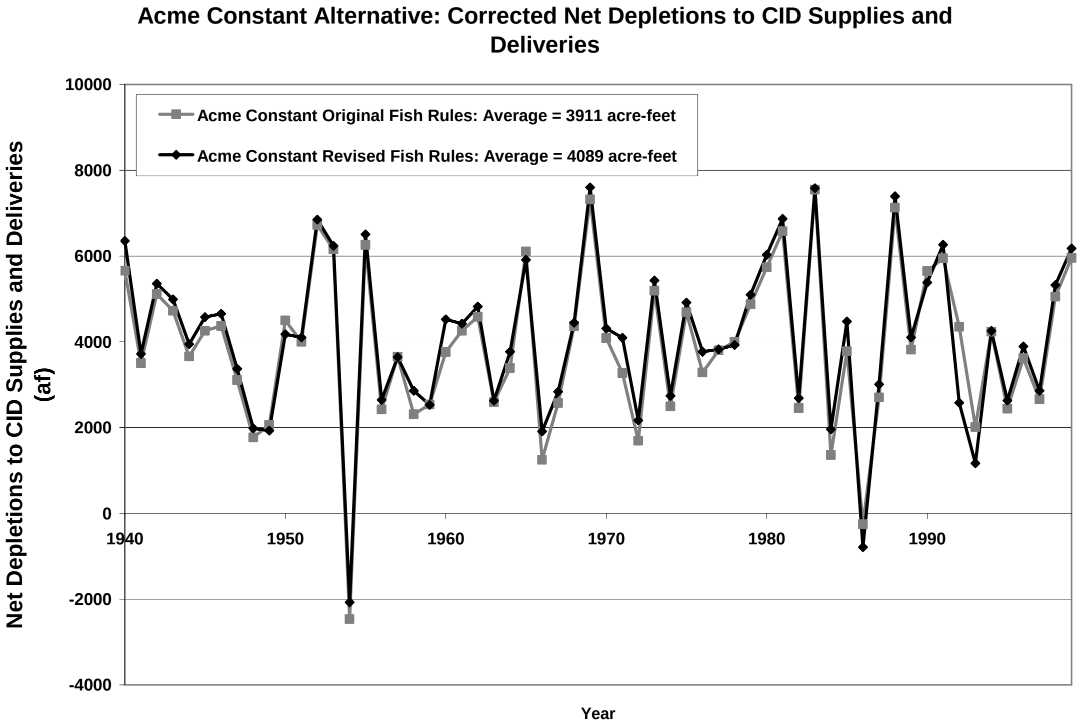

Figure 9: Annual net depletions to CID supplies and deliveries for the original Acme Constant NEPA model run and the run with revised fish rules

These results suggest that the use of the previous day's river losses in the fish rules had little impact on bypasses as the water available to be bypassed was the limiting factor.

Exceedance curves (Figure 10) show that the annual AWN for both the "Original" and "Revised" fish rule runs vary only slightly. These curves also show that initial calculations which determined that a 2,500 af FCP would be sufficient to meet target flows for the Taiban Constant alternative were erroneous, as approximately 5% of the time an FCP greater than this volume would be required.

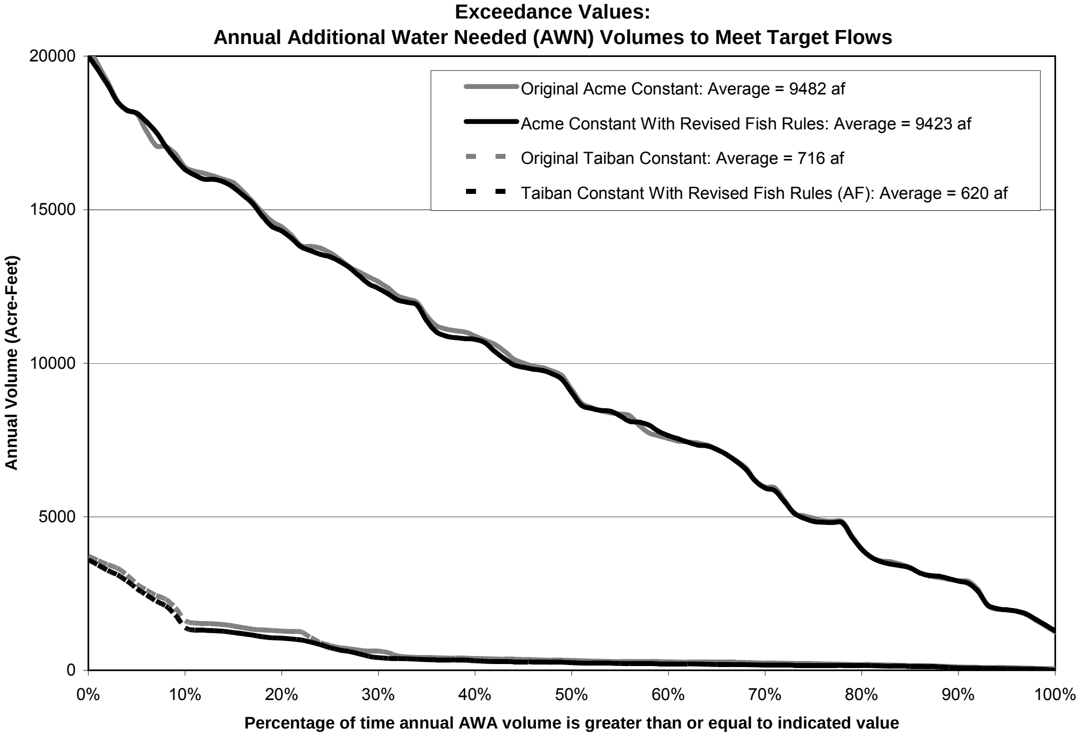

Figure 10: "Original" and "New Rule" annual additional water needed (in excess of bypasses) exceedance curves for Acme Constant and Taiban Constant alternatives

4.0 Revised Water Needed for Fish and AWN Calculations

After examining the results of the revised fish rule runs, the HWG discussed rerunning the entire PRDSS and revising bypass operations results for all of the alternatives. We decided to recalculate the correct water needed for the fish and the AWN for each alternative in post-processing files while leaving the original bypass operations results intact. This decision was made due to:

- the minimal impact on the bypass results;
- the effort which would be required to rerun the models and process results;
- the impact this would have on other work groups' schedules; and
- the overall EIS process schedule.

4.1 Rerunning Original RiverWare Models for Additional Output

To correctly calculate the actual water needed for the fish and the AWN additional data were needed (which had not been output) from the original fish rule runs. In the models, new slots were created and additional rules written to save needed data, which had originally been in the form of functions[7]. Each model was run using the original ruleset (without the revised fish rules) to insure consistency among results. The following lists the additional data which were exported from these runs and saved to the results database:

---

[7] In a RiverWare ruleset, functions are mathematical expressions which return temporary, unsaved information to a rule or another function for use in calculations.

- Taiban Target Series: daily Taiban target flow for alternatives with Taiban targets.
- Taiban Flow Needed for Acme Targets: daily Acme target series converted to Taiban flows for alternatives with Acme targets.
- Flow Needed at Taiban to Keep Critical Habitat Wet: daily Critical Habitat target series converted to Taiban flows for alternatives with critical habitat targets.
- Acme Target Series: daily Acme target flows for alternatives with Acme targets.
- Acme Outflow: Acme flow to check against original results to insure RiverWare models solved the same.

4.2 Post-Processing Revised Water Needed For the Fish and AWN

Separate post-processing Excel files were created for each alternative. To correctly determine the water needed for the fish (below Sumner) and AWN, several modifications were made to post-processing calculations:

- the breakthrough flow plus 1 cfs (added as buffer in the case that the flow in the river due to FSID return flows led to slightly greater losses) was used in place of the previous day's loss in the Sumner to Taiban reach;

- the water needed for the fish was adjusted so that no water was needed if there was a block release;

- if Sumner outflow was greater than 350 cfs for either of the previous two days, i.e., if Sumner was spilling, it was assumed that the reaches were still filled with water from these releases so the water needed for the fish was set to 0.0 cfs; and

- If Sumner was spilling, a check was made to see if the spills were sufficient to meet the flow target. If not, the additional water needed to be released was determined.

The following details the specific logic used in the post-processing files to determine the water needed (below Sumner) for the fish:

(1) To determine the water needed at Taiban for the fish for alternatives with critical habitat targets, the RiverWare rule (Fig. 4) which determines the Taiban target was mimicked. When the daily Acme Target Series value equaled zero, the critical habitat target was in place so the daily Taiban flow needed for the fish was set equal to the "Flow Needed at Taiban to Keep Critical Habitat Wet". Otherwise the Taiban flow needed for the fish was set equal to the "Taiban Flow Needed for Acme Targets" value.

For alternatives with Taiban targets, the water needed at Taiban for fish was set equal to the Taiban target series taken directly from the RiverWare model. For alternatives with Acme targets, the water needed at Taiban for fish was the converted Acme target taken directly from the RiverWare model.

(2) The next step was to determine the water needed (below Sumner) for the fish (Eqn. 1). If water returning to the river from FSID (return flows plus non-applied water) was greater or equal to the water needed at Taiban for fish

then no water was needed below Sumner specifically for the fish. Water returning from FSID will meet the flow target. Also, if there was a block release or large spill for any of the previous two days, i.e., Sumner outflow was greater than 350 cfs, no water needed to be released from Sumner specifically for the fish. It was assumed that enough water remained in the reach to meet the flow target. Otherwise, the water needed for the fish was calculated as the maximum of: a) 0.0 cfs (to avoid negatives) and b) water needed at Taiban for the fish plus the breakthrough flow plus 1 cfs minus water returning to the river from FSID (returns flows plus non-applied water).

Equation 1:

```
Water Needed below Sumner for Fish =
IF FSID Return Flow + FSID Non-Applied Water > Flow Needed at Taiban for Fish
THEN 0.0
ELSE
    IF Sumner Outflow at t, t-1 or t -2 > 350 cfs
    THEN 0.0
    ELSE
        MAXIMUM 0.0 OR Flow Needed at Taiban for Fish
        + Breakthrough Flow (+ 1 cfs) – FSID Return Flow
        – FSID Non-Applied Water
```

The resulting value was further adjusted (Eqn. 2) if Sumner was spilling to determine if Sumner outflow was sufficient to meet the fish target. If Sumner was spilling, a check was made to see if the outflow minus FSID's diversion request was greater or equal to the water needed for the fish. If it was, then no water needed to be released specifically for the fish. If it was not, then the adjusted water needed for the fish equaled the water needed below Sumner for the fish (from Eqn. 1) minus Sumner outflow in excess of FSID's diversion request. The result of these calculations was the corrected, or final, water needed for the fish.

Equation 2:

```
(Final) Water Needed below Sumner for Fish =

 IF Sumner Storage ≥ Conservation Spill Storage Trigger
THEN
    IF Sumner Outflow from Bypass Model – FSID Diversion
    Request < Water Needed below Sumner for Fish
    THEN Water Needed below Sumner for Fish  - Maximum
    (0.0, Sumner Outflow from Bypass Model – FSID
    Diversion Request)
    ELSE
    0.0
ELSE Water Needed below Sumner for Fish (from Eqn. 1)
```

(3) To determine the daily AWN (Eqn. 3), the water bypassed for the fish (from the original bypass run) was subtracted from the final water needed for fish. What remained was the unmet need, or the AWN.

Equation 3:

AWN = Final Water Needed below Sumner for Fish – Water Bypassed for Fish from Bypass Model

(4) A revised set of Sumner outflows including bypasses and AWN water was then calculated (Eqn. 4):

Equation 4:

Sumner Outflow to Meet Fish Targets 100% of the Time = Sumner Outflow from Bypass Model + AWN

4.3 Model Simulations with AWN Added

To evaluate the effects of bypasses and AWN water on Pecos River flows, the “mini” RiverWare models from Sumner to Acme, with a simplified ruleset containing only the FSID portion of the RiverWare rules, was used. A new set of Sumner outflows was developed by adding the daily AWN (from section 4.2) to the original (bypass only) Sumner outflows. These values were imported into the mini RiverWare model and the models run for each alternative. The following data were exported: Sumner outflows (QA/QC to insure correct input values were used in run), Sumner to Taiban gain/loss, Taiban flow, Dunlap flow and Acme flow.

Revised water needed for the fish, AWN values, and "mini" model results were imported into the database, AWN and flow exceedance curves and intermittency statistics generated, and results delivered to EIS work groups.

5.0 Modeling and Post-Processing Results

This section summarizes results for a few key hydrologic resource indicators. More detailed descriptions of resource indicators and the analysis results are described in the EIS.

5.1 Bypass Operations Only

The magnitude and variability of flows in the Pecos River strongly impact the health of the PBNS population. Perhaps the most important measure with regard to the PBNS is the flow at the Acme gage. The Acme gage is located 26 miles downstream from the Upper Critical Habitat reach for the PBNS, and it is also along the reach just upstream of Acme that the river is most susceptible to intermittency.

Flow exceedance curves were used to measure flow changes at Acme for impact analysis. Flow exceedance curves show the probability that the average daily flow will exceed any given value. Figure 11 shows flow frequency curves at Acme for each alternative, when using Sumner bypass water only. In the lower flow ranges (less than

50 cfs), alternatives with higher flow targets (e.g., the Acme Constant alternative) tend to exhibit higher flows at the Acme gage.

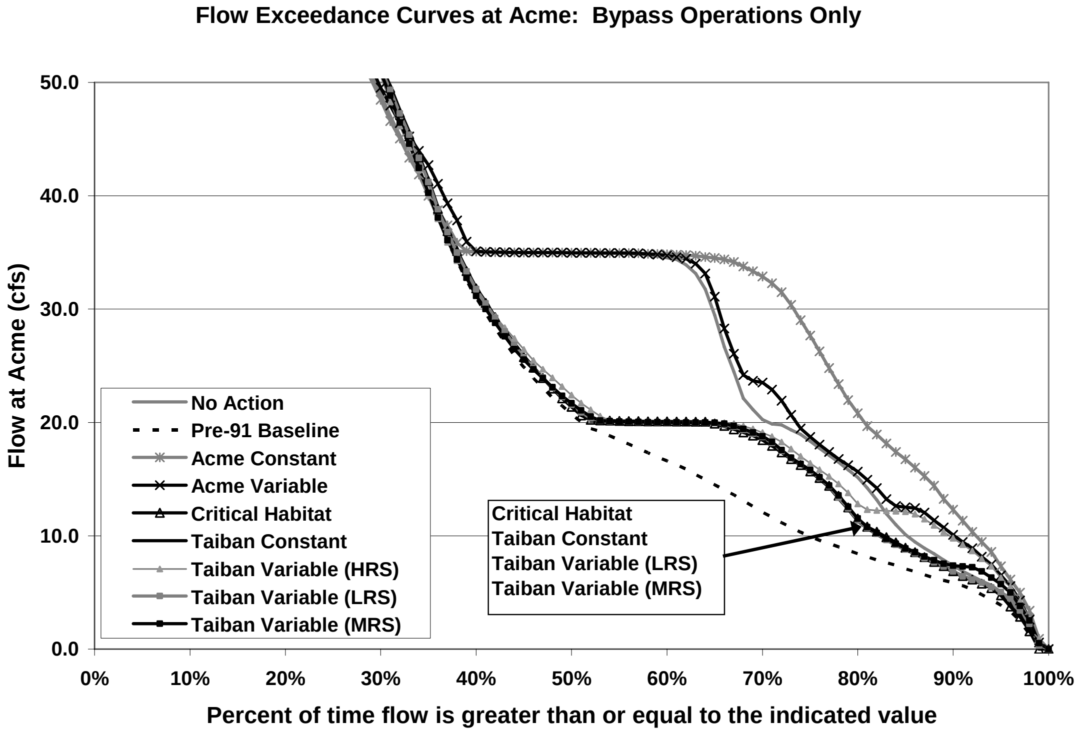

Figure 11: Flow exceedance curves at Acme for alternatives with bypass operations only

When bypass operations are used to meet the flow targets, intermittency (Table 2) occurred under all alternatives, ranging from a low of 0.67% of the time for the Acme Constant alternative to 1.07% of the time for the Critical Habitat alternative. Intermittency occurred 1.20% of the time for the Pre-91 Baseline.

Table 2: Acme intermittency statistic for bypass operation only (no AWN available)

Intermittency defined as Acme flow = **0.0 cfs**									
	No Action	**Pre-91 Baseline**	**Acme Constant**	**Acme Variable**	**Critical Habitat**	**Taiban Constant**	**Taiban Variable (55 cfs)**	**Taiban Variable (40 cfs)**	**Taiban Variable (45 cfs)**
Percent of Time Intermittent	0.94	1.20	0.67	0.68	1.07	0.89	0.63	0.85	0.80
Total # Intermittent Days	205	263	147	150	234	196	137	187	176
Total # Days in Run	21915	21915	21915	21915	21915	21915	21915	21915	21915
Number of Consecutively Intermittent Days									
1 day	1	4	3	4	2	6	1	2	1
2 to 5 days	10	8	2	3	10	5	4	6	5
6 to 10 days	5	9	5	5	8	6	6	5	7
11 to 20 days	2	3	2	3	3	2	3	2	2
21 to 30 days	3	5	3	2	4	4	1	4	3
> 30 days	1	0	0	0	0	0	0	0	0

5.2 *Bypass Operations with AWN*

Table 3 shows average values for the water needed for the fish, water that was bypassed for the fish, and AWN to meet flow targets. It is important to note that in any given year, these values can vary greatly. For example, the average annual AWN ±1 standard deviation is presented. Standard deviations are large, and for several alternatives are equal to or greater than the average values. A strong correlation between the flow target magnitude and the amount of additional water needed to meet that target is evident.

Table 3: Average annual water needed for the fish: total, bypassed and AWN

Alternative	Average Annual Volumes[1] (acre-ft)			
	Total Water Needed	Available Water that was Bypassed	Additional Water Needed[2] (AWN)	AWN ±1 Standard Deviation
Taiban Constant	2600	1900	700	700 ±900
Taiban Variable (LRS cfs)	3600	2200	1400	1400 ±1500
Taiban Variable (MRS cfs)	5600	3200	2400	2400 ±1800
Taiban Variable (HRS cfs)	9000	4800	4200	4200 ±2700
Acme Constant	22500	13000	9500	9500 ±5200
Acme Variable	15000	9700	5300	5300 ±3300
Critical Habitat	2700	2100	600	600 ±700
No Action	10700	7800	2900	2900 ±2900

[1] All values are rounded to the nearest 100 acre-feet.

[2] AWN is the additional water needed, in addition to bypasses, to meet flow targets 100% of the time.

Figure 12 shows exceedance curves for the annual additional water needed for each alternative. The volumes vary greatly, with the highest required AWN for each alternative occurring only a small percentage of the time. The Acme Constant alternative stands out as requiring by far the largest AWN, followed by the Acme Variable alternative. The extremely variable nature of annual AWN requirements should be addressed as options for additional water acquisition are considered.

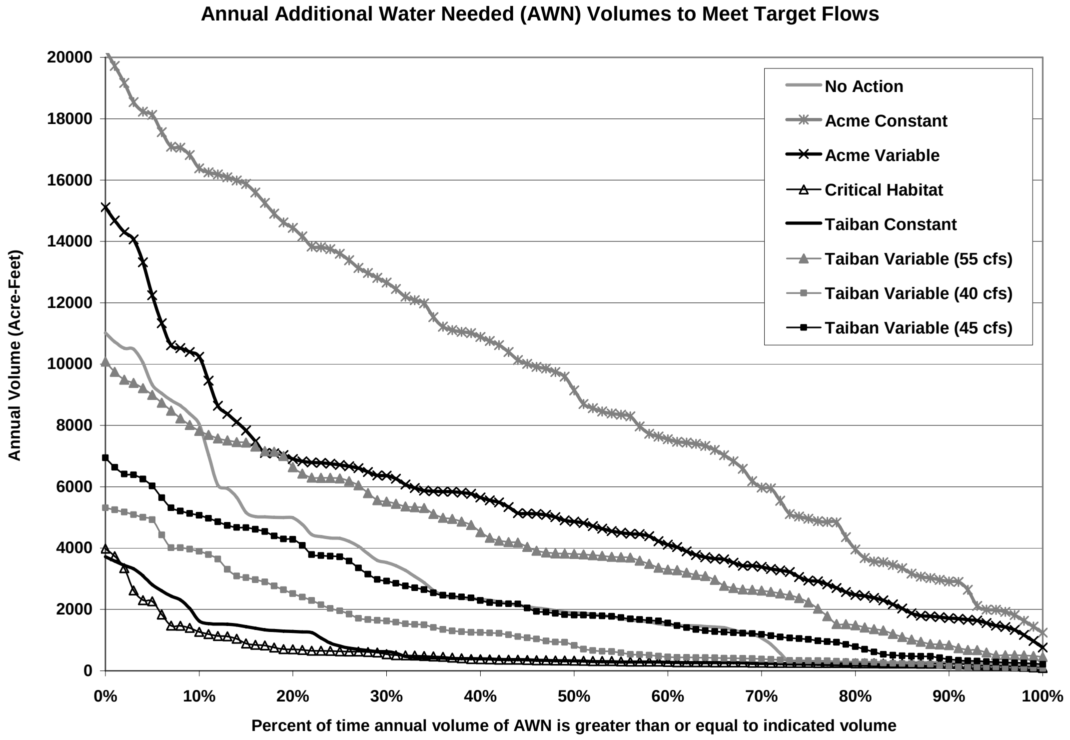

Figure 12: Annual additional water needed below Sumner Reservoir for the fish exceedance curves

Figure 13 shows how bypasses combined with AWN water effect Acme flows. For example, target flows for the 35 cfs Acme Constant alternative are met nearly all of the time. The small percent of the time when target flows are not met is due to the model being unable to exactly predict downstream flows when determining the water needed below Sumner to meet targets.

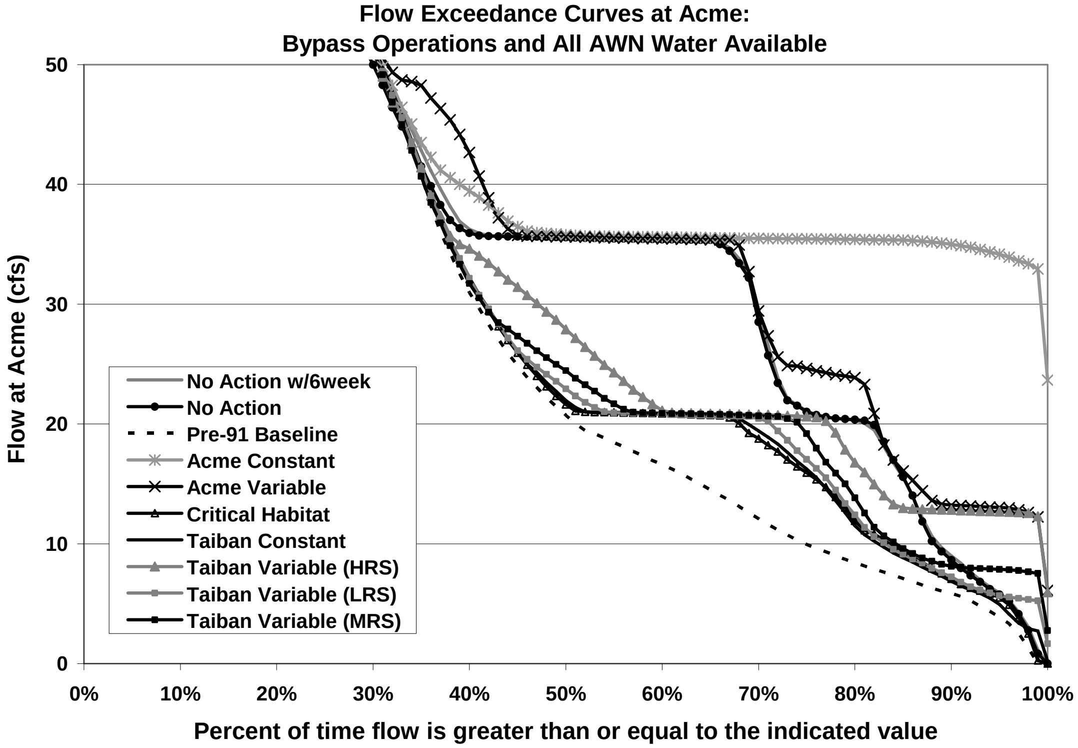

Figure 13: Flow exceedance curves at Acme for alternatives with bypass operations and all AWN available

Intermittency statistics are presented in Table 4. When AWN water is added to bypass water, intermittency at Acme only occurred for the No Action and Critical Habitat alternatives when the flow target was for the Critical Habitat, a more upstream reach. For all other alternatives, no intermittency occurred with AWN water.

Table 4 : Acme intermittency statistic for bypass operation with all AWN available

Intermittency defined as Acme flow = **0.0 cfs**									
	No Action	**Pre-91 Baseline**	**Acme Constant**	**Acme Variable**	**Critical Habitat**	**Taiban Constant**	**Taiban Variable (HRS)**	**Taiban Variable (LRS)**	**Taiban Variable (MRS)**
Percent of Time Intermittent	0.72	1.20	0.00	0.00	0.85	0.00	0.00	0.00	0.00
Total # Intermittent Days	158	263	0	0	187	0	0	0	0
Total # Days in Run	21915	21915	21915	21915	21915	21915	21915	21915	21915
Number of Consecutively Intermittent Days									
1 day	1	4	0	0	2	0	0	0	0
2 to 5 days	10	8	0	0	9	0	0	0	0
6 to 10 days	4	9	0	0	7	0	0	0	0
11 to 20 days	3	3	0	0	2	0	0	0	0
21 to 30 days	2	5	0	0	3	0	0	0	0
> 30 days	0	0	0	0	0	0	0	0	0

6.0 Note on Water Needed for the Fish as Reported

As discussed in Section 3, the HWG decided not to rerun the bypass only simulations with the revised fish rules because the impacts on bypasses were minimal. As a result, the original modeled bypasses for the fish are reported in results files while the water needed below for fish was recalculated in post-processing files. The revised results led to infrequent times in the original simulations when water was bypassed for the fish though it was not needed. There were also infrequent times when additional water was available, and should have been bypassed, but was not. The overall result is that the sum of annual water bypassed for the fish (from the original bypass runs) plus the annual AWN (as calculated in post-processing files) is greater than the annual water needed for fish which was calculated in post-processing files. Table 5 presents the differences between the calculated water needed for the fish and sum of bypasses and calculated AWN water. The greatest annual discrepancy was 443 acre-feet for the Taiban Variable (45 cfs) alternative, which also had the greatest average annual difference of 117 acre-feet.

Table 5: : Annual differences between a) annual water needed below Sumner for fish and b) annual bypasses plus annual AWN

<table>
<tr><th colspan="9">Annual Water Needed below Sumner for Fish - [Annual Water Bypassed for Fish + Annual AWN Water] (acre-feet)</th></tr>
<tr><th>50 year</th><th>No Action</th><th>Acme Constant</th><th>Acme Variable</th><th>Critical Habitat</th><th>Taiban Constant</th><th>Taiban Variable (55 cfs)</th><th>Taiban Variable (40 cfs)</th><th>Taiban Variable (45cfs)</th></tr>
<tr><td>Maximum</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Average</td><td>-14</td><td>-18</td><td>-26</td><td>-61</td><td>-32</td><td>-27</td><td>-89</td><td>-117</td></tr>
<tr><td>Minimum</td><td>-104</td><td>-53</td><td>-226</td><td>-344</td><td>-214</td><td>-250</td><td>-362</td><td>-443</td></tr>
<tr><td colspan="9"></td></tr>
<tr><th colspan="9">Annual Water Needed Below Sumner For Fish (acre-feet)</th></tr>
<tr><td>Average</td><td>10645</td><td>22512</td><td>15023</td><td>2638</td><td>2569</td><td>9019</td><td>3538</td><td>5456</td></tr>
</table>

In response to these discrepancies and to insure results mass-balanced, the water needed for fish was reported (Table 3) as the sum of bypasses and AWN (rather than as the water needed for fish as calculated in the post-processing files). Because these values are higher than the post-processed water needed for the fish, results slightly overestimate the total annual volume of water needed to meet fish targets.

7.0 Summary of Caveats and Considerations for Future Model Runs

For future NEPA PRDSS simulations, the following should be considered as potential edits to the fish rules:

1. Rewrite the fish rules to mimic the revisions described in this document.
2. Create new slots and rules to save additional values used in fish rule calculations.
3. Apply losses to local inflows above Sumner when determining water available for bypasses. Currently no loss is applied to these values.
4. Use the actual loss[8] from Sumner to Taiban instead of the breakthrough flow + 1 cfs.
5. Include side inflows in reaches above the flow target locations when calculating the water needed for the fish.
6. Use a two week average of local inflows available when calculating “available water” for the fish as is currently done by operators in the actual Pecos River system. If this is done, it should be noted that if FSID is not getting their full diversion right, they can divert water bypassed for fish up to their full right. This would require completely rewriting the fish rules.

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[8] Since bypass modeling was completed, Tetra Tech, Inc. has further refined Sumner to Taiban loss calculations by developing a loss relationship from Sumner to Taiban for use in the RiverWare rules.

7. Consider additional refinements in modeling to simplify and/or eliminate much of post-processing calculations.

8.0 Summary and Conclusions

This document describes NEPA alternative bypass operations modeling, fish rule concerns, and additional modeling and post-processing to back out additional results necessary to evaluate alternative impacts on resource indicators. Summary results are presented for bypass operations with and without AWN water. Though the fish rules were found to have certain limitations, bypass operations results were impacted only slightly with revised rules because the availability of water to be bypassed was the limiting factor. Total water needed for fish and AWN values were impacted by the fish rules edits. Rather than rerun all alternatives models, needed values were backed out in post-processing files. Simplified model runs were made to evaluate the impact of runs with bypass and AWN on Pecos River flows to Acme.

9.0 References

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Tetra Tech, Inc., 2003a. “Pecos River RiverWare Model Report—Volume II in a Series of Model Documents—Internal Workgroup Draft.”

Tetra Tech, Inc., 2003b. Pecos River RiverWare Model Report, Volume II, Appendix F: Detailed Rule Descriptions and Documentation. Internal Work Group Draft.

ATTACHMENT A: Summary Alternative Matrix

Carlsbad Project Water Operations and Water Supply Conservation EIS Alternatives

	{------------------Range of Flows -----------------------}						{------------------------------------Block Releases---------------------------------}					
	{-----Dry-----}		{-----Average-----}		{---Wet---}							
Alternative Designation	**Winter Target**	**Summer Target**	**Winter Target**	**Summer Target**	**Winter Target**	**Summer Target**	**Duration**	**Frequency**	**Magnitude**	**Ramp Down**	**Delivery**	**Time of Year**
Taiban Constant	35 cfs @ Taiban	35 cfs @ Taiban. Use pumps to prevent intermittency @ Acme	35 cfs @ Taiban	35 cfs @ Taiban. Use pumps to prevent intermittency @ Acme	35 cfs @ Taiban	35 cfs @ Taiban. Use pumps to prevent intermittency @ Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Taiban Variable	35 cfs @ Taiban	45cfs, -5, +10 @Taiban.	35 cfs @ Taiban	45cfs, -5, +10 @Taiban.	35 cfs @ Taiban	45cfs, -5, +10 @Taiban.	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Acme Constant	35 cfs Acme	35 cfs Acme	35 cfs Acme	35 cfs Acme	35 cfs Acme	35 cfs Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Acme Variable	35 cfs Acme	12 cfs Acme	35 cfs Acme	24 cfs Acme	35 cfs Acme	48 cfs Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Critical Habitat	35 cfs Taiban Minimum	Critical Habitat Kept Wet; Avoid Intermittency @ Acme	35 cfs Taiban Minimum	5 cfs Acme	35 cfs Taiban Minimum	10 cfs Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
No Action (Current Operations, 2003-2006 Biological Opinion)	35 cfs Acme	Upper Critical Habitat Kept Wet; Avoid Intermittency @ Acme	35 cfs Acme	20 cfs Acme	35 cfs Acme	35 cfs Acme	15 day max at peak. 65 days per year.	Space out to 14 + days apart	1200 cfs	None	Maximum Efficiency	No winter. On CID demand

Notes:

Reflects screening by the Alternatives Workgroup on 9/18/03 with 9/24/03 input from the Biology Workgroup and changes from 12/04/03 meeting.

Screening focused on flows and releases. Specific habitat restoration and conservation measures were not evaluated.

Unless specified differently in an alternative, all alternatives would have the following actions incorporated: (Some may require additional project-specific NEPA analysis)

- ✓ Offset all depletions through actions and priorities developed by the WOOG Group.
- ✓ Establishment and management of a conservation pool in Fort Sumner and Santa Rosa Reservoirs.
- ✓ Creation of a management plan addressing monitoring of the flow targets and establishing procedures, mitigative actions and sources of water available in case flow targets are threatened.
- ✓ Execution of an agreement document among the agencies governing the conservation pool and adaptive management plan

The following conservation actions would be considered by the appropriate agencies: (Some may require additional project-specific NEPA analysis)

- ✓ Continue to develop wells and pumping infrastructure to respond for the need to supplement flows in the short-term.
- ✓ Continue to remove non-native riparian vegetation.
- ✓ Restore natural channels to provide better riparian habitat.

*Net Depletions are calculated by comparing to historic, pre-fish operations

Pecos River RiverWare Model
CPWA Modeling Documentation Report

Report on Modeling Assumptions and
Output Analysis for Determination of
Effective CPWA Amounts

January 2006 Final Report

Stockton Engineering

TETRA TECH, INC.

1.0 Introduction

This report documents the use of the Pecos River RiverWare Model (Tetra Tech, 2003b, 2003d, 2000b) to study the effects of Carlsbad Project Water Acquisition (CPWA) options on selected resource indicators identified for the ongoing Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement (Carlsbad Project EIS). This report contains model results concerning the effectiveness of the CPWA options recommended by the Water Offset Options Group (WOOG) as the most viable options that could be implemented within 3 years of completion of this EIS (designated as the “A” list of CPWA Options).

1.1 Carlsbad Project Water Acquisition Options—Definition

CPWA options are explicitly designated for the purpose of eliminating net depletions to the Carlsbad Irrigation District (CID) caused by the reoperation of Sumner Dam for the Pecos bluntnose shiner (PBNS). Changes to CID supply from bypass operations primarily come from three sources: loss in transmission efficiency caused by bypass operations through Sumner Dam, increased or saved reservoir evaporation from the average differences in reservoir storage configurations, and increased conservation spills from Avalon Reservoir. From a WOOG perspective, the purpose of these options is solely to “keep CID whole”, as is stated in the purpose and need for the Carlsbad Project EIS. The goal of the CPWA modeling was to quantify the effectiveness of each option in eliminating net depletions to CID supply since the original amounts identified by the WOOG only indicated the amount available at the source. Modeling of the CPWA options accounts for CID water operations and is a good indication of the amount of water available to CID considering the source of the option, its transmission efficiency, evaporative losses and savings, and timing.

1.2 CPWA—Modeled Options

CPWA options were compiled, examined and ranked qualitatively and quantitatively by the WOOG for their suitability to eliminate net depletions to CID (Reclamation, 2005b). The results of the ranking were two ordered lists, an “A” and a “B” list. Each list contains the options ranked from most viable to least viable. The “A” list contains options that are estimated to be implemented in a 3-year time horizon. The “B” list contains all of the remaining options identified by the WOOG. For efficiency and given the scope of this EIS, it was decided that only the “A” list options would be examined in detail using the alternative models and the “B” list options would be given a more qualitative hydrologic evaluation. The A-list modeled options along with their modeled amounts of water to be acquired are shown in Table 1. For options D and E, purchase and lease numbers, as provided by the WOOG and shown in the table (with the exceptions of D-1B, D-1BX, and D-1E, which have one extra permutation), were aggregated to form larger amounts from the same agricultural source. For these cases, it was assumed half of the water would be obtained through purchase, and the other half of the water would be obtained by renewing leases over the 60-year modeling period. The amounts shown for the CID cropping pattern and retirement options represent the maximum savings possible based on a full annual allotment for CID, which does not occur every year.

Table 1. A-List CPWA Options and Their Average Annual Modeled Amounts

CPWA Option Designation(s)	CPWA Option	Modeled CPWA Amounts (acre-ft/year) [1]
D-1A, D-1AX, and E-1A	Surface Water Right Purchase in FSID	1,500 3,100 [2]
D-1B, D-1BX, and E-1B	Surface Water Right Purchase in PVACD (River Pumpers)	1,600 2,250 4,215 [2]
D-1C, D-1CX, and E-1C	Surface Water Right Purchase in CID	5,550 11,100 [2 & 2]
L	Change Cropping Patterns in CID – ranging from very low to medium crop irrigation requirements (relative to alfalfa crop requirement)	6,000 to 10,500 [3]
Q1-SR	Seven Rivers Well Field	10,000 [4]
Q1-BV	Buffalo Valley Well Field	10,000 [4]
U	Fort Sumner Gravel Pit Pumping	300

[1] From WOOG analyses; see Southwest Water Consultants and Tetra Tech, Inc. (2004).
[2] Larger number represents amount available through both purchase and lease; diversion amounts shown.
[3] Assumes maximum CID allotment for the entire irrigation season; theoretical maximums shown.
[4] Retired or leased consumptive use amount—well field maximum annual pumping capacity subject to groundwater right administration.

2.0 Explanation of CPWA Options with Modeling Assumptions

The following sub-sections explain modeling assumptions associated with the investigation of each A-list CPWA option shown in Table 1. Modeled amounts for retirement and leasing scenarios were converted to diversion amounts where appropriate from the original consumptive use values (amounts available) indicated by the WOOG. The remaining options utilized direct WOOG estimates for amounts available; but depending on the option, this amount may not be realized due to limiting constraints explained in each sub-section.

2.1 FSID Lease and Purchase

The FSID retirement scenarios, CPWA Options D-1A, D-1AX, and E-1A, consisted of retiring and leasing a portion of FSID's irrigated acreage and holding that water back in Sumner Reservoir for CID to deliver to Brantley Reservoir in a block release. Since FSID's average diversion and irrigated acreage does not correspond to usual farm deliveries of 3.0 acre-feet/acre for water right administration, retirement was based upon an average CPWA forbearance amount and the corresponding acreage was retired on a percentage basis. Annual FSID forbearance amounts for CPWA included 1,500 acre-ft/year and 3,100 acre-ft/year. Retired acreages corresponding to those amounts, which were reduced for the algorithm determining return flow, were 190 and 380 acres, respectively. Pump back flows were not reduced in the FSID return flow method.

2.2 River Pumper Lease and Purchase

CPWA Options D-1B, D-1BX, and E-1B, represent surface water retirement of diverters in the vicinity of or within the Pecos Valley Artesian Conservancy District (PVACD), which are more commonly referred to as “river pumpers”. River pumpers take their diversions from the Pecos River by pumping directly from the river. Three diversion amounts were investigated for the river pumper lease and purchase modeling scenarios including retirement or lease of 1,600, 2,250, and 4,215 AF/year.

These CPWA options were implemented by curbing river pumper diversions within the Pecos River RiverWare model. The daily diversions were reduced by subtracting the Pre-91 daily diversion amount times the ratio of the retirement scenario (using the annual amount of Pre-91 diverters—4,215 AF/year—to obtain the ratio) from the Pre-91 daily diversion. The 4,215 AF reduction represents retirement of most of the remaining active diverters that have not been bought out completely.

Return flows were modeled as 40% of the diversion amounts. Given the proximity of the river pumpers place of use to the Pecos River and a modeling period of 60-years, no lag is applied to the return flows and they are immediately added back to the river at the same time-step the diversion was subtracted.

2.3 CID Lease and Purchase

Purchase and lease CPWA options within CID, CPWA options D-1C, D-1CX, and E-1C, consisted of three different model methods for estimating effective CPWA amounts:

- The first consisted of only curbing the “actual irrigated acreage” in the model. This scenario represented the minimum possible amount available for eliminating net depletions to CID.
- The second method consisted of also reducing the “total irrigable acreage” by a constant amount in addition to the “actual irrigated acreage”. In other words, if the “actual irrigated acreage” was reduced by 3,000 acres then the “total irrigable acreage” was also reduced by 3,000 acres.
- The third scenario consisted of reducing the “actual irrigated acreage” (by the estimated retirement amount) and reducing the “total irrigable acreage” by the ratio of the “total irrigable acreage” / ”actual irrigated acreage” (25,055 acres/20,000 acres) times the estimated retirement amount. In other words, if the “actual irrigated acreage” was reduced by 3,000 acres then the “total irrigable acreage” was reduced by 25,055/20,000 * 3,000 = 3760 acres.

“Actual irrigated acreage” is used to determine the diversion in the RiverWare model while “total irrigable acreage” is used to set the diversion amount per acre for CID irrigators in the RiverWare model. The effect on the algorithm from reducing the “actual irrigated acreage” is more water becomes available in storage and is included in setting the amount diverted per acre. Reducing the “total irrigable acreage” has the same effect by also increasing the amount of water that each farmer is able to divert per acre. Both reductions simulate the redistribution of retired or leased water rights onto the remaining farms.

2.4 Cropping Pattern Changes

Cropping pattern changes within the CID were also modeled by limiting farm headgate delivery volumes from 0.7 ft to 2.0 ft per irrigated acre dependent on crop type. Originally, volumes were meant to correspond to replacement crop types from small grain to sorghum or corn compared to alfalfa. During the WOOG process the water from the required diversion amounts for these crop types were developed by comparing the farm delivery requirement (including annual rainfall and soil leaching requirements) to the typical farm delivery requirement in the Carlsbad area for alfalfa, which amounts to 4.5 acre-ft per acre (Brummer, 2003). However, since the average normalized diversion per acre at the farm headgate for the pre-91 baseline simulation was only 2.8 acre-ft/acre, the savings identified by the WOOG, shown in Table 1, were overestimated. In addition, the comparison of the water savings identified by the WOOG to a maximum farm delivery of 3.7 acre-ft/acre to compute maximum cropping pattern deliveries at the farm headgate led to an underestimation of crop irrigation requirements for the aforementioned crop types. For these reasons, the crop names were dissociated from the modeled farm delivery amounts and the headgate delivery volumes were used to represent the conversion to lower-water-use crops.

For all of the cropping pattern CPWA scenarios, replacement acreage of 5,000 acres was used. Those 5,000 acres of replacement crops were modeled by limiting the maximum farm delivery per acre on the 5,000 acres. Those maximum amounts (at the farm headgate) are shown in the second column of Table 2. The third column in Table 2 shows the amount limited at the diversion of the CID main headgate from Avalon Dam. These amounts include a transmission efficiency of 74.6% to the farm headgates. Modeled cropping pattern changes within the CID also did not include changes to the "irrigable acres" in the algorithm in an attempt to simulate redistribution of saved water to the remaining farmers.

Table 2. Maximum Deliveries at the Farm Headgate and Maximum Diversions at Avalon Dam for Cropping Pattern CPWA Simulations

Range of Relative Water Use of Replacement Crop Type	Maximum Delivery at Farm Headgate (acre-ft/acre)	Maximum Diversion at Avalon Dam (acre-ft/acre)
Very Low	0.7	0.9
Low	1.2	1.6
Medium	2.0	2.7
(pre-91 for comparison)	3.7 [1]	5.0 [1]

[1] Full allotments for CID do not occur every year. In the pre-91 simulation, a full allotment only occurred in the modeled year 1942; diversions at Avalon Dam exceeded 4.9 acre-ft/acre (nearly full allotments) in modeled years: 1942, 1943, 1958, 1987, 1992, and 1998. The average 60-year diversion at Avalon Dam for the Pre-91 simulation was 3.7 acre-ft/acre (2.8 acre-ft/acre at the farm headgate).

2.5 Well Field Pumping – Lagged Month Pumping at Seven Rivers or Buffalo Valley

Pumping from a well field was modeled to simulate the effects of retiring pumping rights in the PVACD and using those rights to pump water to augment CID supply. Two different scenarios were investigated including a well field located near Buffalo Valley and a well field located near

Seven Rivers. The scenarios were simulated using “lagged month” pumping, which summed all of the daily bypass volumes from the previous month and estimated the depletions for that month as 50% of the bypass volume. Included with the 50% depletion estimates were transit losses, which were modeled as 5% of the pumped CPWA flow for Seven Rivers and 15% of the pumped CPWA flow for Buffalo Valley. Well field diversions for the current month target the estimated depletions for the previous month plus any carry over estimated depletion amount from the month before the previous month. This was implemented since the well field capacity did not always meet or exceed the estimated monthly depletion. The well fields were modeled assuming 10,000 AF of consumptive use retirement in PVACD. The well fields were assumed to have an annual pumping capacity of 12,100 AF/year or 33.14 AF/day. The Pecos River RiverWare model was used to compute the initial pumping amounts, and the Roswell Artesian Basin Groundwater Model—RABGW (DBS&A, 1995; Keyes, 2000; SSPA, 2003; Hydrosphere, 2003c) was used (in collaboration with Hydrosphere and the NMISC) to model the base inflow change from Acme to Artesia resulting from the retired acreage in PVACD and the pumping used to eliminate net depletions to CID. These base inflows were then input into the RiverWare model once again, and the final model simulation was made to incorporate all the effects of the CPWA option. Using this methodology, pumping amounts changed less than 6% by the second iteration (after base inflow accretion due to retirement), which was deemed satisfactory for convergence.

2.6 Gravel Pit Pumping

Near Ft. Sumner, NM is a large gravel pit that accumulates groundwater. It is estimated that this gravel pit has nearly 300 AF/year of inflow. Pumping from the gravel pit was modeled with the RiverWare model by assuming a constant inflow of 300 AF/year to the pit and adding up to 300 AF/year to the river at the Taiban node whenever flows in the river were at or above 350 cfs. By supplementing larger flows with gravel pit pumping, it was anticipated that the gravel pit pumping would be more effective as a CPWA option. Pumping was switched on with a 350 cfs Sumner outflow trigger, but typically pumping was initiated during flood flows and block releases if adequate supply was available in the pit. Rates of pumping from the pit were simulated at 10 AF/day and 20 AF/day.

2.7 Modeled Alternatives and Assumption of Superposition

Due to the large number of permutations of model simulations required when matching each A-list WOOG option with the six alternatives and the pre-91 baseline, only the pre-91 baseline (no depletion), Acme Constant (most depletive alternative), and Taiban Constant (least depletive alternative) alternatives were simulated with A-list CPWA options. This cut the amount of modeling by more than half. By grouping the permutations this way, it was assumed that results from the two alternatives could be superimposed upon the remaining alternatives. Conclusions concerning this assumption are summarized in Section 3.4.

3.0 CPWA Options Modeling Results

This section presents a summary of CPWA modeling results along with analysis tools used to isolate effective CPWA amounts. Section 3.1 presents a summary of analysis tools. Sub-section 3.1.1 provides references for basic definitions for net depletion components, sub-section 3.1.2 shows definitions for CPWA components, sub-section 3.1.3 identifies sources for ineffective portions of CPWA, and section 3.1.4 provides estimates for CPWA Brantley transit efficiencies. Section 3.2 presents summary annual average results using the analysis tools defined in Section 3.1. Section 3.3 provides detailed results. Sub-section 3.3.1 provides

Brantley transit efficiency results, sub-section 3.3.2 shows detailed daily examples of effective CPWA and net depletions for select years and non-Project derived CPWA options, and sub-section 3.3.3 presents cumulative effective CPWA figures for non-Project derived CPWA options. Sub-section 3.3.4 presents daily effective CPWA derived from Project supply, and sub-section 3.3.5 shows cumulative 60-year Project derived CPWA results. Sub-section 3.3.6 reconciles ineffective Project CPWA results, and sub-section 3.3.7 presents correlations between theoretical CPWA amounts and ineffective CPWA due to spills from the system. Finally section 3.4 summarizes conclusions regarding superposition of CPWA results onto alternatives that weren't modeled with CPWA options.

3.1 Summary of Analysis Tools

Analysis tools to isolate effective CPWA from model output are defined and explained in the following sub-sections. These analysis tools include use of the "net depletion" calculation, which is simply a comparison of a model output parameter or multiple model output parameters between two model runs. Net depletions to CID are useful in determining effectiveness of CPWA for non-Project related CPWA options, such as forbearance in the FSID. For Project related CPWA options, such as retirement in CID, effective allotments and normalized daily diversions, which are based on diversion amounts and remaining irrigated acreage, are used to calculate effective CPWA to CID to eliminate net depletions to CID.

3.1.1 Definition of Net Depletion Terms

In general the net depletions to CID and the subsequent calculation of non-Project effective CPWA at the diversion are presented in this memorandum three different ways including:

- corrected reoperation net depletions to CID,
- reoperation net depletions to CID,
- and net depletions at the CID main.

For further information and derivations of net depletions to CID, please refer to the memorandum titled "Carlsbad Project Supply Net Depletion Calculations with Avalon Spill Variability Removed" (Tetra Tech, 2003e), and also refer to the memorandum titled "Results Memorandum for Alternative Modeling Using Bypass Water" (Briggs et al., 2005). Additional transmission depletions and saved reservoir evaporation are only presented in the Project derived mass balance section (3.3.6) and to develop the Brantley transit efficiencies shown in section 3.3.1; however, mass balance using transmission depletions and saved evaporation was calculated for every CPWA option. Due to the large amount of information that would need to be presented, these mass balance values are not presented here, but are documented as part of the administrative record of this EIS.

3.1.2 Definition of CPWA Terms

CPWA options follow the same terminology as net depletions for non-Project CPWA options since the effectiveness of the CPWA option must be derived from the net depletion results. Four computation methods for effectiveness of CPWA options are presented in this report. These include the non-Project CPWA options, which are computed using the corrected reoperation net depletion to CID, the reoperation net depletion to CID, and the net depletion at the CID main. The fourth method applies to Project derived CPWA options. It determines the additional amount diverted to the remaining farmers, which is the effective CPWA for these options. It should be clarified that the Project CPWA options were measured as diversions from

Avalon Dam at the CID main and not diversions to the farm field itself. Also presented in this report with the (average) effective CPWA is the theoretical CPWA. This is the annual average amount of water added to the system. This number is always larger than any of the four other aforementioned effective CPWA amounts. For various reasons, including portions of CPWA lost to conveyance losses to Avalon from the point where the CPWA was introduced, evaporation of CPWA water held in storage, or spills from Avalon dam, CPWA options have a reduced efficiency from the theoretical values. CPWA definitions and equations are presented below.

- Theoretical CPWA: this is either the amount of water added to the system, the amount of retired diversion, or the amount of water saved from replacement crops. Calculation methods vary depending on the CPWA option.

- Effective CPWA using corrected reoperation net depletions: this effective CPWA is computed by comparing original net depletions to CID to the net depletions computed with the CPWA option implemented. Equation 3.1 is for computing non-Project related effective CPWA with the corrected reoperation net depletion.

$$\begin{matrix} \mathit{CPWA\ to\ Carlsbad} \\ \mathit{Supply\ Using} \\ \mathit{Corrected\ Reoperation} \\ \mathit{Net\ Depletions} \end{matrix} = \begin{matrix} \mathit{Alternative\ Corrected} \\ \mathit{Reoperation\ Net\ Depletion} \\ \mathit{to\ Carlsbad\ Supply} \end{matrix} - \begin{matrix} \mathit{Alternative\ with} \\ \mathit{CPWA\ Corrected} \\ \mathit{Reoperation\ Net\ Depletion} \\ \mathit{to\ Carlsbad\ Supply} \end{matrix} \quad \text{(Eq. 3.1)}$$

- Effective CPWA using reoperation net depletions: this effective CPWA calculation is identical to the above definition, but corrected reoperation net depletions are replaced with reoperation net depletions. Equation 3.12 is valid with this substitution of terms; only the reoperation net depletions are used instead.

- CPWA using net depletions at the CID main: also identical to the corrected reoperation definition, but net depletions at the CID main are used instead of corrected reoperation net depletions. Equation 3.12 is still valid with this substitution of terms; only the net depletion at the CID main should be used in place of the corrected reoperation net depletion.

With the exception of theoretical CPWA definition, the preceding bullets apply to computing effective CPWA for non-Project derived water. Project derived CPWA are computed by measuring the increase in available diversion amounts to the remaining farmers. The following bullets and equations describe methods used for computing daily effective CPWA for CID land retirement or leasing.

- Equations 3.2 and 3.3 calculate the respective normalized daily diversion (NDD) for the baseline and for the baseline with a retirement CPWA option.

$$NDD_{BL} = \frac{\mathit{Pre\text{-}91\ Daily\ CID\ Diversion}}{\mathit{Original\ Irrigated\ Acreage}} \quad \text{(Eq. 3.2)}$$

$$NDD_{BL+CPWA} = \frac{\mathit{Pre\ \text{-}\ 91\ with\ \ CPW\ \ Daily\ \ CID\ \ Diversion}}{\mathit{Remaining\ \ Irrigated\ \ Acreage}} \quad \text{(Eq. 3.3)}$$

- Equations 3.4 and 3.5 compute the respective normalized daily diversions for an alternative and an alternative with a retirement CPWA option.

$$NDD_{ALT} = \frac{Alternative\ Daily\ CID\ Diversion}{Original\ Irrigated\ Acreage} \quad \text{(Eq. 3.4)}$$

$$NDD_{ALT+CPWA} = \frac{Alternative\ with\ CPWA\ Daily\ CID\ Diversion}{Remaining\ Irrigated\ Acreage} \quad \text{(Eq. 3.5)}$$

- Effective CPWA amounts are then computed by using equation 3.6 for the baseline combined with retirement CPWA or by using equation 3.7 for alternatives combined with retirement CPWA.

$$Daily\ Effective\ CPWA = (NDD_{BL+CPWA} - NDD_{BL}) * Remaining\ Irrigated\ Acreage \quad \text{(Eq. 3.6)}$$

$$Daily\ Effective\ CPWA = (NDD_{ALT+CPWA} - NDD_{ALT}) * Remaining\ Irrigated\ Acreage \quad \text{(Eq. 3.7)}$$

Cropping pattern CPWA options follow a similar format, although an additional term of cropping pattern diversions must be introduced into the equations. The following bullets and equations detail computations for determining daily effective CPWA for cropping pattern CPWA options.

- To determine normalized daily diversions for the baseline or alternative with cropping patterns as CPWA options, Equations 3.8 and 3.9 are employed. Notice that the amount diverted to the cropping pattern fields is subtracted out of the total diversion to obtain the amount of diversion to be delivered to the remaining farmers.

$$NDD_{BL+CPWA} = \frac{Pre\text{-}91\ with\ CPWA\ Total\ CID\ Diversions\ \text{-}\ Crop\ Pattern\ CID\ Diversions}{Total\ Irrigated\ Acreage\ \text{-}\ Crop\ Pattern\ Acreage} \quad \text{(Eq. 3.8)}$$

$$NDD_{ALT+CPWA} = \frac{Alternative\ with\ CPWA\ Total\ CID\ Diversions\ \text{-}\ Crop\ Pattern\ CID\ Diversions}{Total\ Irrigated\ Acreage\ \text{-}\ Crop\ Pattern\ Acreage} \quad \text{(Eq. 3.9)}$$

- Effective CPWA amounts still use equations 3.3 and 3.5 for comparison and determination of the additional amount delivered to the remaining farmers that did not participate in the cropping pattern program. Effective CPWA amounts for cropping patterns are calculated with equations 3.10 and 3.11.

$$Daily\ Effective\ CPWA = (NDD_{BL+CPWA} - NDD_{BL}) * (Total\ Irrigated\ Acreage\ \text{-}\ Crop\ Pattern\ Acreage) \quad \text{(Eq. 3.10)}$$

$$Daily\ Effective\ CPWA = (NDD_{ALT+CPWA} - NDD_{ALT}) * (Total\ Irrigated\ Acreage\ \text{-}\ Crop\ Pattern\ Acreage) \quad \text{(Eq. 3.11)}$$

So far the entire discussion of this section is mostly concerned with effective CPWA or the portion that is used by the farmers in CID. The following sub-sections provide calculation methods for determining ineffective CPWA amounts (amounts lost in transit or to reservoir evaporation from increased detention times) and only considering efficiency to Brantley Reservoir from the CPWA option source.

3.1.3 Ineffective CPWA

Ineffective CPWA amounts include water added to or reallocated within the system that: was lost to conservation (Avalon) spills, evaporated in a reservoir, or was lost in transmission.

The portion lost to conservation spills is calculated by comparing the original net depletion to Avalon spills for a given alternative to the spill net depletion for an alternative with a CPWA option implemented. The equation for computing CPWA lost to spills (3.12) is as follows:

$$\begin{array}{l}\textit{CPWA Lost to}\\ \textit{Spills}\end{array} = \begin{array}{l}\textit{Alternative with CPWA}\\ \textit{Option Net Depletion to}\\ \textit{Carlsbad Supply due to}\\ \textit{Avalon Spills}\end{array} - \begin{array}{l}\textit{Alternative Net Depletion to}\\ \textit{Carlsbad Supply due to}\\ \textit{Avalon Spills}\end{array} \qquad \text{(Eq. 3.12)}$$

The other portion of the CPWA amount that is ineffective is due to transmission loss and evaporative loss of stored CPWA water. Equations 3.13 and 3.14 compute the respective CPWA lost in transmission and lost to evaporation.

$$\begin{array}{l}\textit{CPWA Lost in}\\ \textit{Transmission}\end{array} = \begin{array}{l}\textit{Alternative with CPWA}\\ \textit{Total Additional}\\ \textit{Transmission Losses}\end{array} - \begin{array}{l}\textit{Alternative}\\ \textit{Total Additional}\\ \textit{Transmission Losses}\end{array} \qquad \text{(Eq. 3.13)}$$

$$\begin{array}{l}\textit{CPWA Lost to}\\ \textit{Evaporation}\end{array} = \begin{array}{l}\textit{Alternative with CPWA}\\ \textit{Total Saved}\\ \textit{Reservoir Evap}\end{array} - \begin{array}{l}\textit{Alternative}\\ \textit{Total Saved}\\ \textit{Reservoir Evap}\end{array} \qquad \text{(Eq. 3.14)}$$

3.1.4 Brantley Transit Efficiency CPWA Calculations

It was decided in the EIS process that the estimated effects from CPWA options would be based upon delivering the CPWA water to Brantley reservoir, and once it is in Brantley Reservoir, it would be credited as effective CPWA. To determine the amount of effective CPWA that reached Brantley (considering only transit efficiency from the CPWA source), the (60-year average) differences in Brantley inflows and Sumner outflows were determined from the alternative-CPWA permutations compared to the original alternative (without CPWA). These calculations are depicted in equations 3.15 (for Sumner Outflow) and 3.16 (for Brantley Inflow).

$$\begin{array}{l}\textit{60-Year Average}\\ \textit{Additional Sumner}\\ \textit{Outflow}\end{array} = \begin{array}{l}\textit{Alternative with}\\ \textit{CPWA 60-Year}\\ \textit{Average Sumner}\\ \textit{Outflow}\end{array} - \begin{array}{l}\textit{Alternative}\\ \textit{60-Year Average}\\ \textit{Sumner}\\ \textit{Outflow}\end{array} \qquad \text{(Eq. 3.15)}$$

$$\begin{array}{l}\textit{60-Year Average}\\ \textit{Additional Brantley}\\ \textit{Inflow}\end{array} = \begin{array}{l}\textit{Alternative with}\\ \textit{CPWA 60-Year}\\ \textit{Average Brantley}\\ \textit{Inflow}\end{array} - \begin{array}{l}\textit{Alternative}\\ \textit{60-Year Average}\\ \textit{Brantley}\\ \textit{Inflow}\end{array} \qquad \text{(Eq. 3.16)}$$

Next, the average normalized (using Effective Brantley Storage) additional Sumner outflow is subtracted from the average additional Brantley inflow. This excludes any additional (or reduced) Sumner outflows from being included in the efficiency calculation. This becomes the amount of water realized as inflow at Brantley attributable to the water added at the CPWA source (Eq. 3.17).

$$\begin{matrix}\textit{Inflow} \\ \textit{at Brantley due} \\ \textit{to CPWA Only}\end{matrix} = \begin{matrix}\textit{60 - Year Average} \\ \textit{Additional Brantley} \\ \textit{Inflow}\end{matrix} - 0.75 * \begin{matrix}\textit{60 - Year Average} \\ \textit{Additional Sumner} \\ \textit{Outflow}\end{matrix} \quad \text{(Eq. 3.17)}$$

Finally, the Brantley Transit efficiency, which is compared to either the acquired diversion amount (for FSID and River Pumper retirement) or the amount of water added or accruing to the river (for well fields and FSID gravel pit pumping), is calculated in equation 3.18.

$$\textit{Brantley Transit Efficiency} = \frac{\textit{Average CPWA at Brantley due to CPWA Only}}{\textit{Retired Diversion Amount or Amount Added to River}} \quad \text{(Eq. 3.18)}$$

In the case of retired surface water diversions, the numerator in this equation already includes the lost percentage due to only realizing the consumptive use portion of the retirement amount in the river. Pumped amounts are based on water pumped to the river and/or increased base inflows due to groundwater retirement for the well field.

3.2 Summary CPWA Results

Table 3 shows 60-year annual averages for net depletions to CID supply. Net depletions to CID supply are presented with three derivations—including and excluding spills from Avalon Dam in the long-term average and as they occur at the CID main canal (storage terms not included). Individual depletion components for corrected reoperation net depletions and reoperation net depletions, such as net depletions to Avalon spills and Effective Brantley Storage, are also presented. Table 4 shows 60-year annual averages for effective CPWA to CID supply for the most and least depletive alternatives and the Pre-91 baseline. Effective CPWA amounts computed from the two derivations are presented along with the ineffective portion of the CPWA that is lost to spills. The non-Project derived effective CPWA amounts in Table 4 are computed from the net depletion values shown in Table 3. Results in the tables are presented to the nearest ± 1 AF for ease in calculation of related parameters, but should be considered accurate only to the nearest ± 100 AF, if not ± 500 AF. Output results are presented to denote trends and for relative comparisons between alternatives; caution is advised for confidence in their absolute values.

Note that all of the permutations of CPWA options combined with alternatives are not presented in this report. Some of these model simulations were academic and were first attempts at modeling and provided guidance for subsequent improvements to later model simulations. Model simulations and results from those simulations that were not included in the output set of this report and the reasons for their omission are bulleted below.

- FSID retirement using the NMOSE's standard CIR and diversion right values: These scenarios assumed 3.0 acre-ft/acre diversion right and consisted of curbing acreages based upon that value and the diversion amount being retired (1,500 or 3,100 AF). Since FSID's diversion right divided by their irrigated acreage amounts to a per acre diversion right that is nearly 8.0 acre-ft/acre, retirement based on the 3.0 acre-ft/acre was abandoned and reduced acreages were calculated by a percentage of the reduced FSID diversion (see Section 2).

- CID retirement, retirement of “total irrigable acreage” by a constant equal to the reduction in “actual irrigated” acreage: These scenarios represented middle ground between not curbing the “total irrigable acreage” and reducing it by a ratio amount of “total irrigable acreage” to “actual irrigated acreage” (25,055 Ac / 20,000 Ac). Since reducing the entitlement by ratio and not reducing it at all produced high and low effective CPWA extremes, the middle ground values represented by reducing the “total irrigable acreage” by a constant amount were omitted from this report.

- Exact CPWA amount pumping: these scenarios used the annual net depletion values determined from the original alternative simulations to determine CPWA pumping schedules. These scenarios were deemed to be highly unrealistic since the methodology required that the net depletions to CID must be predicted before they occur. Since this method of calculating pumping schedules could never be implemented in reality, these scenarios were abandoned for the lagged CPWA pumping scenarios (see Section 2).

- Pumping scenarios with flawed second iteration base inflow sets: Earlier second iteration lagged base inflow sets did not reflect retirement of 10,000 AF/year of consumptive use in PVACD while lagged pumping was less than 10,000 AF/year. These sets did not predict the long-term base inflow gain that would be evident with such a large retirement of groundwater rights. These sets were replaced by those with the “REVRABGW” label on them. These revised sets reflect expected base inflow results for more annual consumptive use retirement than actual annual CPWA pumping.

Table 3. Net Depletions to CID Supply and Components of Net Depletions to CID Supply for Effective CPWA

Alternative and CPWA Option	Average Annual Corrected Reoperation Net Depletions to CID (AF/yr)	Average Annual Reoperation Net Depletions to CID (AF/yr)	Average Annual Net Depletions at CID Main (AF/yr)	Average Annual Net Depletions to Effective Brantley Storage (AF/yr)	Average Annual Net Depletions to Avalon Spills (AF/yr)	Average Annual Net Depletions to CID due to Avalon Spills (AF/yr)
Acme Constant (without CPWA--used for CPWA determination):	3,911	2,995	3,970	-59	-916	916
Taiban Constant (without CPWA--used for CPWA determination):	1,178	517	1,304	-126	-661	661
Pre-91(without CPWA--used for CPWA determination):	0	0	0	0	0	0
Acme Constant w/1600 AF RP Retirement:	3,097	2,408	3,176	-79	-688	688
Taiban Constant w/1600 AF RP Retirement:	623	-188	769	-145	-812	812
Pre-91 w/1600 AF RP Retirement:	-171	-524	-14	-157	-354	354
Acme Constant w/2250 AF RP Retirement:	3,224	2,223	3,308	-84	-1,000	1,000
Taiban Constant w/2250 AF RP Retirement:	595	-568	725	-130	-1,163	1,163
Pre-91 w/2250 AF RP Retirement:	129	-1,033	285	-156	-1,162	1,162
Acme Constant w/4215 AF RP Retirement:	2,374	1,488	2,482	-108	-887	887
Taiban Constant w/4215 AF RP Retirement:	-469	-1,013	-324	-144	-544	544
Pre-91 w/4215 AF RP Retirement:	-1,463	-1,417	-1,300	-163	46	-46
Acme Constant w/1500 AF FSID Retirement:	3,826	2,825	3,894	-68	-1,002	1,002
Taiban Constant w/1500 AF FSID Retirement:	610	429	740	-130	-181	181
Pre-91 w/1500 AF FSID Retirement:	-84	-127	64	-148	-42	42
Acme Constant w/3100 AF FSID Retirement:	3,513	2,658	3,582	-69	-855	855
Taiban Constant w/3100 AF FSID Retirement:	136	42	191	-54	-95	95
Pre-91 w/3100 AF FSID Retirement:	-150	-580	4	-154	-430	430

Table 3 (cont). Net Depletions to CID Supply and Components of Net Depletions to CID Supply for Effective CPWA

Alternative and CPWA Option	Average Annual Corrected Reoperation Net Depletions to CID (AF/yr)	Average Annual Reoperation Net Depletions to CID (AF/yr)	Average Annual Net Depletions at CID Main (AF/yr)	Average Annual Net Depletions to Effective Brantley Storage (AF/yr)	Average Annual Net Depletions to Avalon Spills (AF/yr)	Average Annual Net Depletions to CID due to Avalon Spills (AF/yr)
Acme Constant with Very Low Water Use CID Crop Pattern:	11,650	6,762	12,040	-389	-4,888	4,888
Taiban Constant with Very Low Water Use CID Crop Pattern:	9,539	4,420	9,982	-443	-5,119	5,119
Pre-91 with Very Low Water CID Crop Pattern:	9,965	3,495	10,340	-375	-6,470	6,470
Acme Constant with Low Water Use CID Crop Pattern:	9,747	6,053	10,063	-316	-3,694	3,694
Taiban Constant with Low Water Use CID Crop Pattern:	7,505	3,468	7,916	-410	-4,038	4,038
Pre-91 w/Low Water Use CID Crop Pattern:	7,359	2,680	7,790	-431	-4,679	4,679
Acme Constant w/Medium Water Use CID Crop Pattern:	6,989	4,486	7,226	-237	-2,503	2,503
Taiban Constant w/Medium Water Use CID Crop Pattern:	4,791	2,048	5,095	-304	-2,743	2,743
Pre-91 w/Medium Water Use CID Crop Pattern:	4,435	1,558	4,746	-311	-2,876	2,876
Acme Constant w/1500 CID acres retired (actual only):	6,183	4,801	6,367	-184	-1,382	1,382
Taiban Constant w/1500 CID acres retired (actual only):	4,601	2,101	4,833	-233	-2,500	2,500
Pre-91 w/1500 CID acres retired (actual only):	4,083	1,727	4,321	-238	-2,357	2,357
Acme Constant w/3000 CID acres retired (actual only):	9,871	6,257	10,186	-316	-3,613	3,613
Taiban Constant w/3000 CID acres retired (actual only):	8,046	3,569	8,426	-380	-4,477	4,477
Pre-91 w/3000 CID acres retired (actual only):	7,616	2,778	8,007	-391	-4,838	4,838

Table 3 (cont). Net Depletions to CID Supply and Components of Net Depletions to CID Supply for Effective CPWA

Alternative and CPWA Option	Average Annual Corrected Reoperation Net Depletions to CID (AF/yr)	Average Annual Reoperation Net Depletions to CID (AF/yr)	Average Annual Net Depletions at CID Main (AF/yr)	Average Annual Net Depletions to Effective Brantley Storage (AF/yr)	Average Annual Net Depletions to Avalon Spills (AF/yr)	Average Annual Net Depletions to CID due to Avalon Spills (AF/yr)
AC w/1500 CID acres retired (actual, and entitlement by ratio):	5,325	3,608	5,465	-140	-1,717	1,717
TC w/1500 CID acres retired (actual, and entitlement by ratio):	2,612	1,075	2,825	-213	-1,537	1,537
Pre-91 w/1500 CID acres retired (actual, and entitlement by ratio):	1,671	830	1,911	-240	-841	841
AC w/3000 CID acres retired (actual, and entitlement by ratio):	6,472	4,437	6,752	-280	-2,035	2,035
TC w/3000 CID acres retired (actual, and entitlement by ratio):	4,533	2,011	4,868	-334	-2,522	2,522
Pre-91 w/3000 CID acres retired (actual, and entitlement by ratio):	3,794	1,415	4,148	-354	-2,379	2,379
AC-Seven Rivers 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	-1,600	-4,028	-1,351	-249	-2,428	2,428
Pre-91 with Above Pumping Series – REV RABGW:	-4,390	-7,225	-4,018	-372	-2,835	2,835
TC-Seven Rivers 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	-1,218	-2,582	-959	-259	-1,364	1,364
Pre-91 with Above Pumping Series – REV RABGW:	-21	-1,850	-1,226	-271	-1,830	1,830
AC-Buffalo Valley 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	-886	-2,714	-681	-205	-1,828	1,828
Pre-91 with Above Pumping Series – REV RABGW:	-3,882	-5,926	-3,548	-334	-2,044	2,044
TC-Buffalo Valley 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	-1,292	-2,381	-1,038	-255	-1,088	1,088
Pre-91 with Above Pumping Series – REV RABGW:	-1,609	-2,963	-1,344	-265	-1,354	1,354
AC w/ Gravel Pit Pumping at 10AF/day:	3,588	2,900	3,651	-63	-688	688
TC w/ Gravel Pit Pumping at 10AF/day:	972	440	1,101	-129	-532	532
Pre-91 w/ Gravel Pit Pumping Series at 10 AF/day:	36	17	177	-141	-19	19
AC w/ Gravel Pit Pumping at 20AF/day:	3,503	2,925	3,565	-62	-579	579
TC w/ Gravel Pit Pumping at 20AF/day:	906	380	1,042	-135	-526	526
Pre-91 w/ Gravel Pit Pumping Series at 20 AF/day:	153	-85	294	-141	-238	238

Table 4. Effective CPWA to CID

Alternative and CPWA Option	Theoretical CPWA Amount Added to System (AF/yr)	Average Annual Effective CPWA using Corrected Reoperation Net Depletion to CID (AF/yr)	Average Annual Effective CPWA using Reoperation Net Depletion to CID (AF/yr)	Average Annual Effective CPWA using Net Depletion at CID Main (AF/yr)	Average Annual Effective CPWA using Normalized Daily Diversions to CID (AF/yr)	Portion of CPWA Lost to Conservation Spills (AF)
Acme Constant (without CPWA--used for CPWA determination):	0	N/A	N/A	N/A	N/A	N/A
Taiban Constant (without CPWA--used for CPWA determination):	0	N/A	N/A	N/A	N/A	N/A
Pre-91(without CPWA--used for CPWA determination):	0	N/A	N/A	N/A	N/A	N/A
Acme Constant w/1600 AF RP Retirement:	1,600	814	587	795	N/A	-227
Taiban Constant w/1600 AF RP Retirement:	1,600	555	706	535	N/A	151
Pre-91 w/1600 AF RP Retirement:	1,600	171	524	14	N/A	354
Acme Constant w/2250 AF RP Retirement:	2,250	687	772	663	N/A	85
Taiban Constant w/2250 AF RP Retirement:	2,250	584	1,085	579	N/A	502
Pre-91 w/2250 AF RP Retirement:	2,250	-129	1,033	-285	N/A	1,162
Acme Constant w/4215 AF RP Retirement:	4,215	1,537	1,508	1,489	N/A	-29
Taiban Constant w/4215 AF RP Retirement:	4,215	1,647	1,530	1,628	N/A	-117
Pre-91 w/4215 AF RP Retirement:	4,215	1,463	1,417	1,300	N/A	-46
Acme Constant w/1500 AF FSID Retirement:	1,541	85	171	76	N/A	86
Taiban Constant w/1500 AF FSID Retirement:	1,541	568	88	564	N/A	-480
Pre-91 w/1500 AF FSID Retirement:	1,541	84	127	-64	N/A	42
Acme Constant w/3100 AF FSID Retirement:	3,085	398	338	388	N/A	-60
Taiban Constant w/3100 AF FSID Retirement:	3,085	1,042	476	1,114	N/A	-566
Pre-91 w/3100 AF FSID Retirement:	3,085	150	580	-4	N/A	430

Table 4 (cont). Effective CPWA to CID

Alternative and CPWA Option	Theoretical CPWA Amount Added to System (AF/yr)	Average Annual Effective CPWA using Corrected Reoperation Net Depletion to CID (AF/yr)	Average Annual Effective CPWA using Reoperation Net Depletion to CID (AF/yr)	Average Annual Effective CPWA using Net Depletion at CID Main (AF/yr)	Average Annual Effective CPWA using Normalized Daily Diversions to CID (AF/yr)	Portion of CPWA Lost to Conservation Spills (AF)
Acme Constant w/Very Low Water Use CID Crop Pattern:	10,500	N/A	N/A	N/A	4,783	3,972
Taiban Constant w/Very Low Water Use CID Crop Pattern:	10,500	N/A	N/A	N/A	4,842	4,458
Pre-91 w/Very Low Water CID Crop Pattern:	10,500	N/A	N/A	N/A	3,505	6,470
Acme Constant w/ Low Water Use CID Crop Pattern:	8,800	N/A	N/A	N/A	3,440	2,779
Taiban Constant w/Low Water Use CID Crop Pattern:	8,800	N/A	N/A	N/A	3,577	3,377
Pre-91 w/Low Water Use CID Crop Pattern:	8,800	N/A	N/A	N/A	2,724	4,679
Acme Constant w/Medium Water Use CID Crop Pattern:	6,000	N/A	N/A	N/A	1,627	1,588
Taiban Constant w/Medium Water Use CID Crop Pattern:	6,000	N/A	N/A	N/A	1,637	2,082
Pre-91 w/Medium Water Use CID Crop Pattern:	6,000	N/A	N/A	N/A	972	2,876
Acme Constant w/1500 CID acres retired (actual only):	5,579	N/A	N/A	N/A	2,884	466
Taiban Constant w/1500 CID acres retired (actual only):	5,579	N/A	N/A	N/A	1,952	1,839
Pre-91 w/1500 CID acres retired (actual only):	5,579	N/A	N/A	N/A	1,258	2,357
	0					
Acme Constant w/3000 CID acres retired (actual only):	11,158	N/A	N/A	N/A	4,346	2,697
Taiban Constant w/3000 CID acres retired (actual only):	11,158	N/A	N/A	N/A	3,840	3,816
Pre-91 w/3000 CID acres retired (actual only):	11,158	N/A	N/A	N/A	3,151	4,838

Table 4 (cont). Effective CPWA to CID

Alternative and CPWA Option	Theoretical CPWA Amount Added to System (AF/yr)	Average Annual Effective CPWA using Corrected Reoperation Net Depletion to CID (AF/yr)	Average Annual Effective CPWA using Reoperation Net Depletion to CID (AF/yr)	Average Annual Effective CPWA using Net Depletion at CID Main (AF/yr)	Average Annual Effective CPWA using Normalized Daily Diversions to CID (AF/yr)	Portion of CPWA Lost to Conservation Spills (AF)
AC w/1500 CID acres retired (actual, and entitlement by ratio):	5,579	N/A	N/A	N/A	3,787	801
TC w/1500 CID acres retired (actual, and entitlement by ratio):	5,579	N/A	N/A	N/A	3,960	876
Pre-91 w/1500 CID acres retired (actual, and entitlement by ratio):	5,579	N/A	N/A	N/A	3,668	841
AC w/3000 CID acres retired (actual, and entitlement by ratio):	11,158	N/A	N/A	N/A	7,781	1,119
TC w/3000 CID acres retired (actual, and entitlement by ratio):	11,158	N/A	N/A	N/A	7,398	1,861
Pre-91 w/3000 CID acres retired (actual, and entitlement by ratio):	11,158	N/A	N/A	N/A	7,010	2,379
AC-Seven Rivers 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	10,000	5,511	7,023	5,322	N/A	1,512
Pre-91 with Above Pumping Series - REV RABGW:	10,000	4,390	7,225	4,018	N/A	2,835
TC-Seven Rivers 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	10,000	2,396	3,099	2,263	N/A	703
Pre-91 with Above Pumping Series - REV RABGW:	10,000	21	1,850	1,226	N/A	1,830
AC-Buffalo Valley 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	10,000	4,797	5,709	4,651	N/A	912
Pre-91 with Above Pumping Series - REV RABGW:	10,000	3,882	5,926	3,548	N/A	2,044
TC-Buffalo Valley 10,000 AF Well Field - Lagged Pumping-I2-REV RABGW:	10,000	2,471	2,898	2,342	N/A	428
Pre-91 with Above Pumping Series - REV RABGW:	10,000	1,609	2,963	1,344	N/A	1,354
AC w/ Gravel Pit Pumping at 10AF/day:	222	323	96	319	N/A	-228
TC w/ Gravel Pit Pumping at 10AF/day:	249	206	77	203	N/A	-129
Pre-91 w/ Gravel Pit Pumping Series at 10 AF/day:	248	-36	-17	-177	N/A	19
AC w/ Gravel Pit Pumping at 20AF/day:	288	408	70	405	N/A	-337
TC w/ Gravel Pit Pumping at 20AF/day:	296	272	137	262	N/A	-135
Pre-91 w/ Gravel Pit Pumping Series at 20 AF/day:	291	-153	85	-294	N/A	238

3.3 Detailed CPWA Results

The following sub-sections present effective CPWA amounts on a daily and cumulative daily basis. Detailed CPWA results are provided to show the relation that timing of CPWA has on the effective CPWA amount. In addition to example daily effective CPWA figures and cumulative daily effective CPWA figures, the last sub-section reconciles ineffective and effective CPWA amounts for Project derived CPWA options.

3.3.1 Brantley Transit Efficiencies for Non-Project CPWA Options

Brantley transit efficiencies for non-Project CPWA options are presented in Table 5. These efficiencies only consider the transit loss from the CPWA source to Brantley Reservoir. Efficiencies for retired diversions consider the retired diversion amount. Efficiencies for pumping include both the pumped amounts and any base inflow gain due to retirement. It should be noted that efficiencies for well field options don’t consider the retired groundwater consumptive use that made the base inflow change possible. These numbers were presented in the EIS and for the respective top to bottom listings in the well field section of Table 5 would be: 92%, 76%, 42%, and 40%. They represent transit efficiency to Brantley including effects such as evapotranspiration from the Roswell basin aquifer and the effects of reduced irrigation return flows caused by the retired groundwater diversion. These efficiencies can be calculated by dividing the values in the fourth column for the well field by 10,000 acre-feet.

Table 5. Transit Efficiencies to Brantley from the CPWA Source for Non-Project CPWA Options (all values except efficiency are 60-year averages in acre-feet per year)

Option / Permutation	**Additional Sumner Outflow [1]**	**Additional Brantley Inflow**	**Inflow at Brantley due to CPWA Only**	**Retired Diversion or Total Inflows to River**	**Brantley Transit Efficiency**
Acme Constant with 1500 AF from FSID	-69	182	251	1500	17%
Acme Constant with 3000 AF from FSID	-113	354	467	3000	16%
Taiban Constant with 1500 AF from FSID	-250	203	453	1500	30%
Taiban Constant with 3000 AF from FSID	-424	465	889	3000	30%
Average FSID CPWA - Brantley Transit Efficiency					23%
Acme Constant with 1600 AF from River Pumpers	-228	600	828	1600	52%
Acme Constant with 2250AF from River Pumpers	-218	899	1116	2250	50%
Acme Constant with 4215 AF from River Pumpers	-318	1922	2240	4215	53%
Taiban Constant with 1600 AF from River Pumpers	-79	872	951	1600	59%
Taiban Constant with 2250 AF from River Pumpers	-102	1264	1366	2250	61%
Taiban Constant with 4215 AF from River Pumpers	-373	1893	2266	4215	54%
Average River Pumper CPWA - Brantley Transit Efficiency					55%
Acme Constant with Seven Rivers Wellfield	-1334	7818	9153	9961	92%
Acme Constant with Buffalo Valley Wellfield	-1291	6262	7553	8846	85%
Taiban Constant with Seven Rivers Wellfield	-701	3502	4203	4618	91%
Taiban Constant with Buffalo Valley Wellfield	-645	3343	3988	4462	89%
Average Wellfield - Brantley Transit Efficiency					82%
Acme Constant with Gravel Pit Pumping at 10AF/day[2]	-56	102	158	222	71%
Acme Constant with Gravel Pit Pumping at 20AF/day[2]	-92	106	198	288	69%
Taiban Constant with Gravel Pit Pumping at 10AF/day[2]	-19	159	178	249	72%
Taiban Constant with Gravel Pit Pumping at 20AF/day[2]	-32	214	246	296	83%
Average Gravel Pit Pumping – Brantley Transit Efficiency					75%

[1] Additional Sumner Outflow in this column is normalized by 75%.

[2] Maximum annual pumping rate of 300 acre-feet per year.

3.3.2 Non-Project Derived—Daily Effective CPWA

Daily effective CPWA amounts and depletions for non-Project derived CPWA options are computed identically to those annual values presented in Tables 3 & 4 and equations 3.1 through 3.12, with the exception that annual values are replaced with daily values. Examining daily depletion and effective CPWA amounts helps to describe CPWA effectiveness, especially considering timing. CPWA options are most effective if they are delivered as the depletion is occurring (if it is within the irrigation season) or if it is delivered before it will be missed by the diverter (if the depletion occurs in the non-irrigation season). Figures 1-4 show daily net depletion and effective CPWA example years for the four non-CID retirement options coupled with the Acme Constant alternative. Net depletions and effective CPWA amounts at the CID main are presented to remove the large day-to-day swings evident as water moves into and out of the channel when using the daily corrected reoperation net depletion. In the case of Figures 1-4, all of the CPWA options show some effectiveness; however, some years in the modeling show the CPWA option is not making any difference in the net depletion at the CID main, and in some years the poor timing of an option with bad storage configurations can actually increase the net depletion. Figure 5 is an example of the latter problem occurring in a select year.

Explanation and observations concerning the following figures are bulleted below:

- Figure 1 shows net depletions at the CID main for Acme Constant based on 1951 hydrologic conditions, with and without 2,250 AF/year of river pumper diversions retired. The blue line denotes the net depletion caused by reoperation aspects of the alternative alone. The orange line represents the net depletion after the CPWA is applied. It is evident from the figure that the depletion was eliminated completely from March 1, 1951 to September 1, 1951 (the orange line indicates zero depletion with CPWA). From September 1, 1951, to the end of the irrigation season, the CPWA did not reduce the net depletion completely, but did reduce the net depletion by approximately 5-10 acre-ft/day.

- Figure 2 illustrates net depletions at the CID main for Acme Constant based on 1949 hydrologic conditions, with and without 3,100 AF/year of forbearance from FSID. Note that CPWA is effective for almost the entire irrigation season with the exceptions of where the blue line (alternative depletion only) dips below the orange line (alternative depletion with CPWA) in the spring and in the summer.

- Net depletions at the CID main, for Acme Constant for 1989 hydrologic conditions, are shown in Figure 3, with and without CPWA pumping and 10,000 AF/year of groundwater right retirement in PVACD. The square saw tooth green line represents lagged CPWA pumping. Note that from March to September the orange line (alternative with CPWA) actually delivers more water to CID than the Pre-91 model did (negative net depletion at the CID main). For the remainder of the year past September, the pumping and increased base inflows eliminate the depletions completely, but with no additional delivery (net depletion with CPWA is zero).

- Figure 4 shows a year (1991 hydrologic conditions) where not much depletion was evident at the CID main for Taiban Constant. Looking at the difference between the orange line (alternative with CPWA) and the blue line (alternative alone) shows an effective CPWA amount near 15 AF/day due to FSID gravel pit pumping. Comparing total areas under the green line to the area in between the orange and blue lines, it is apparent from the figure that the CPWA volume pumped was not nearly as large as the effective CPWA volume (creating efficiency at the CID main greater than 100%). This extra pumping helped to push the allotment higher (note the date is 7/15), and caused realization of CPWA much larger than what was actually added to the system.

- Converse to the previous bullet, Figure 5 illustrates that in some cases CPWA water can be added to the system causing the net depletions to become higher. For the modeled year of 1952 with Acme Constant, the orange line shows an additional net depletion larger than the original net depletion. This signifies that the CPWA water worsened the net depletions. This example occurs in some years with nearly every type of CPWA option although FSID supplies are directly tied back to bypass volumes since return flows diminish with FSID forbearance. This indicates that the root cause of the increased net depletion is a product of timing and storage configurations causing the allotment with the CPWA water applied to be set lower than it was without the addition of CPWA water. This occurs fairly rarely in the CPWA model output, but is still worth noting.

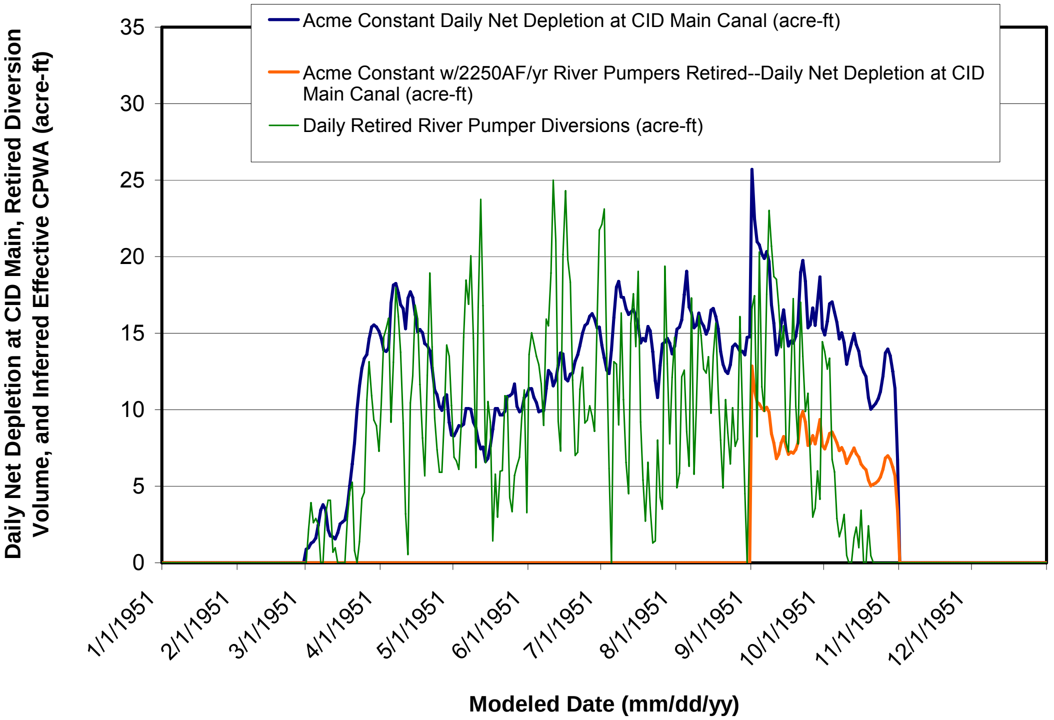

Figure 1. Acme Constant with 2,250 AF/year of River Pumper Retirement—Daily Net Depletions, Retired River Pumper Diversions, and Inferred Effective CPWA (See bulleted text in Section 3.3.2 for Figure explanation).

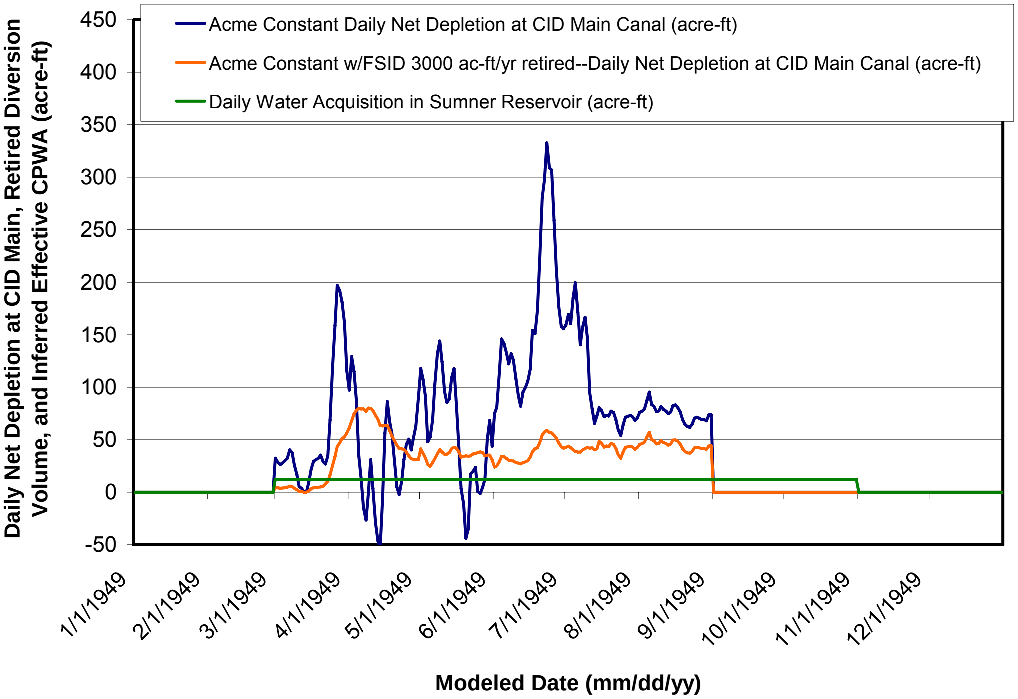

Figure 2. Acme Constant with 3,100 AF/year of FSID Retirement—Daily Net Depletions, Retired FSID Diversions, and Inferred Effective CPWA (See text in Section 3.3.2 for explanation).

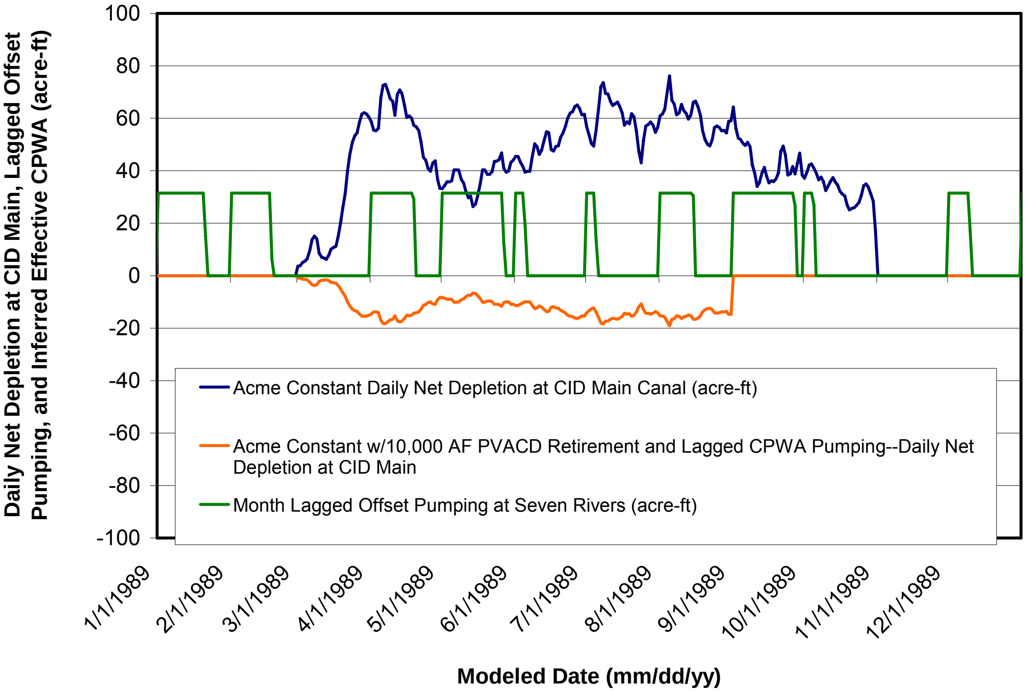

Figure 3. Acme Constant with 10,000 AF/year of PVACD Retirement and Month Lagged Well field Pumping—Daily Net Depletions, CPWA Pumping, and Inferred Effective CPWA (See text in Section 3.3.2 for explanation).

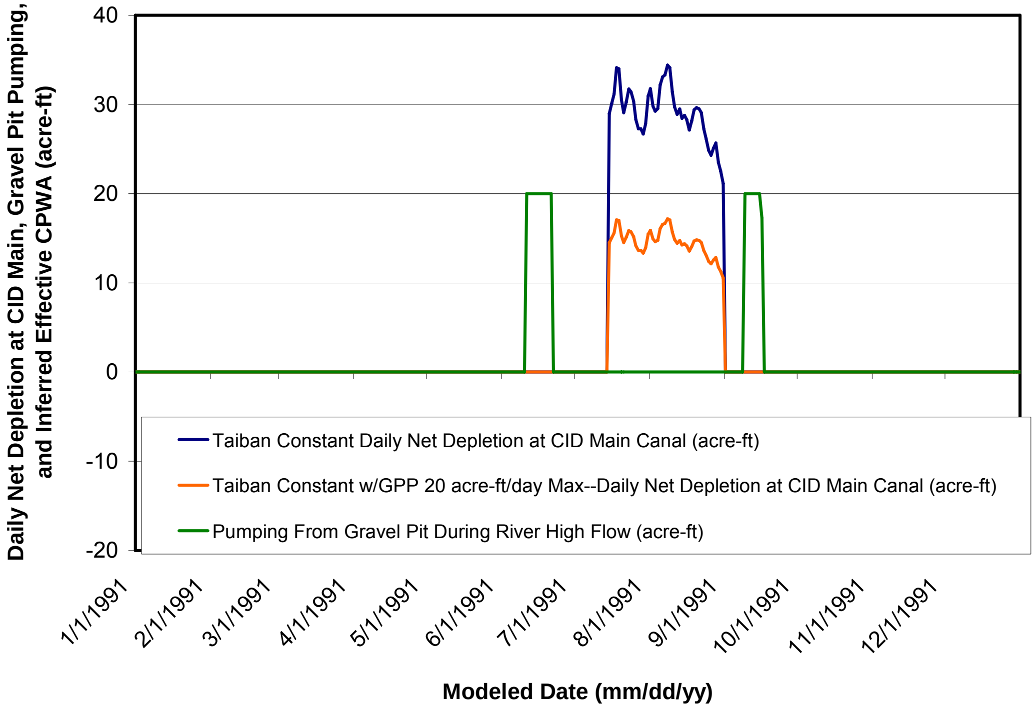

Figure 4. Taiban Constant with 20 AF/day Max. Gravel Pit Pumping—Daily Net Depletions, Gravel Pit Pumping, and Inferred Effective CPWA (See text in Section 3.3.2 for explanation).

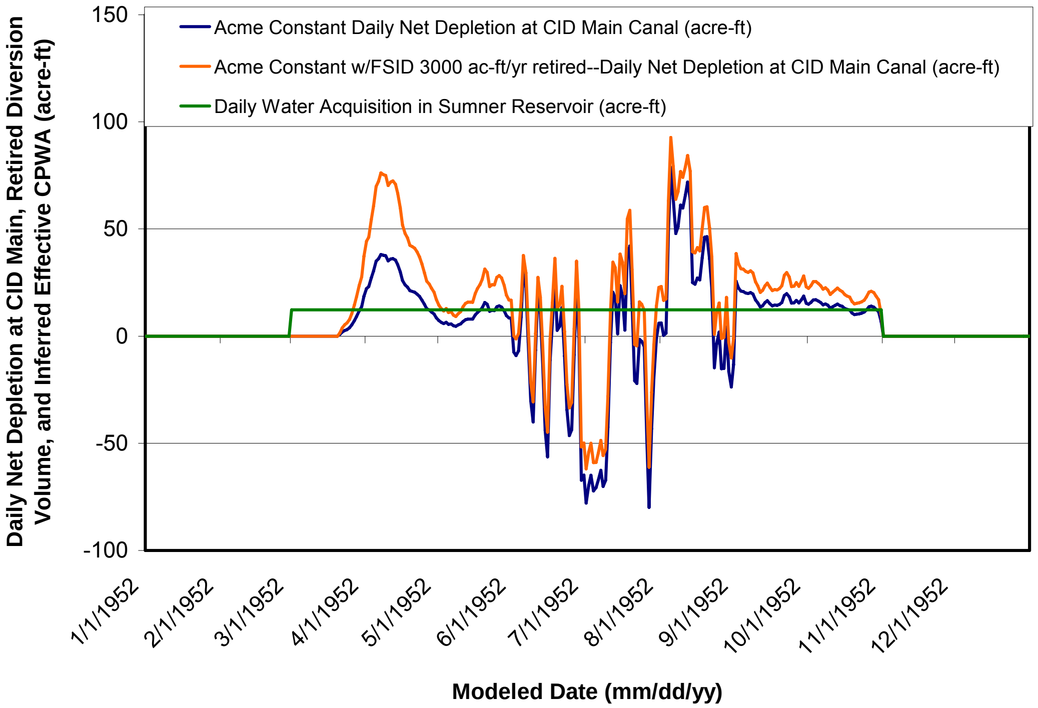

Figure 5. Acme Constant with 3,100 AF/Yr of FSID Retirement—Daily Net Depletions, Retired FSID Diversions, and Inferred (Ineffective) CPWA (See text in Section 3.3.2 for explanation).

3.3.3 Non-Project Derived—Cumulative 60-year Effective CPWA

Example cumulative 60-year corrected reoperation net depletions with and without non-Project CPWA options are presented in this section. The cumulative corrected reoperation net depletion shows large day-to-day swings, which are a result of how the depletions are computed. As stated in the previous section, these large swings are caused by water moving into and out of the channel, mostly flood flows and block releases, in both the action and baseline model simulations. Since the volume of water in the river channel is unaccounted for in the net depletion computations, this water shows up as a net depletion for a period until the volume makes it to the next reservoir in the action or baseline model. Figures 4-6 illustrate the variations in the effectiveness of the CPWA option due to changing hydrologic conditions, but they also capture the long term trend over time for a particular CPWA option.

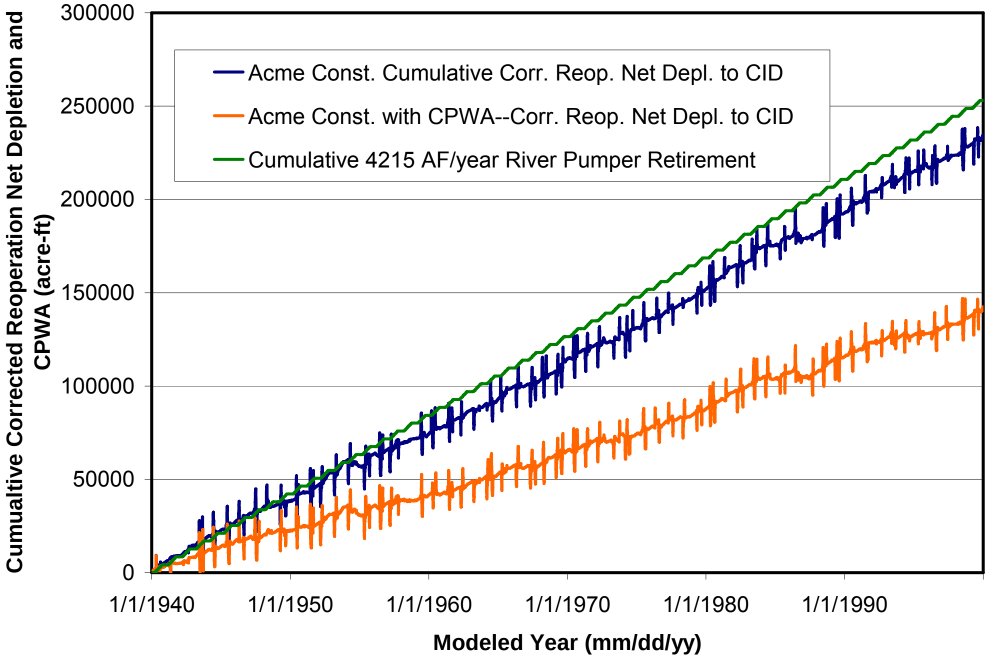

Figure 6. Acme Constant with 4215 AF/year of River Pumper Retirement—Cumulative Daily Net Depletions and Cumulative Retired River Pumpers

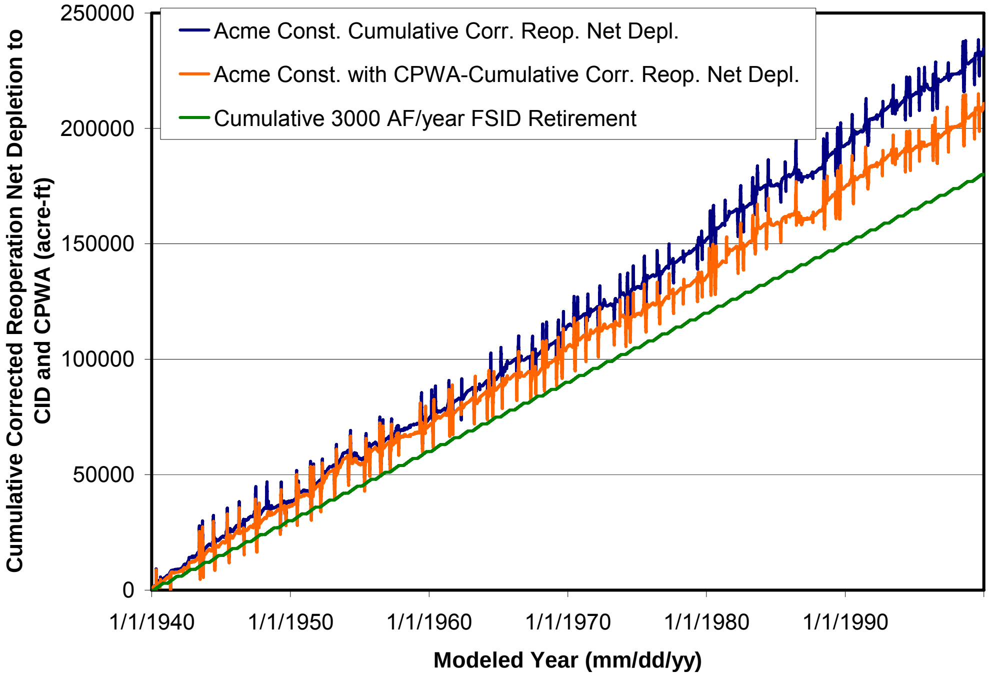

Figure 7. Acme Constant with 3,100 AF/year of FSID Retirement—Cumulative Daily Net Depletions and Cumulative FSID Retirement Volume

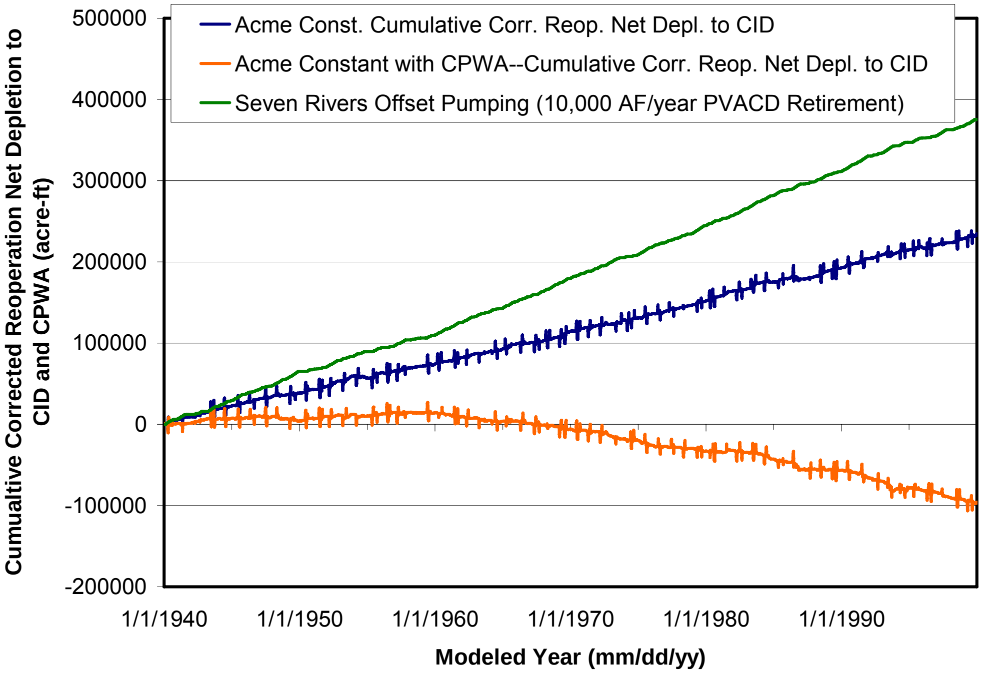

Figure 8. Acme Constant with 10,000 AF/year of PVACD Retirement and Seven Rivers Lagged Month Well Field Pumping—Cumulative Daily Net Depletions and Cumulative Pumping

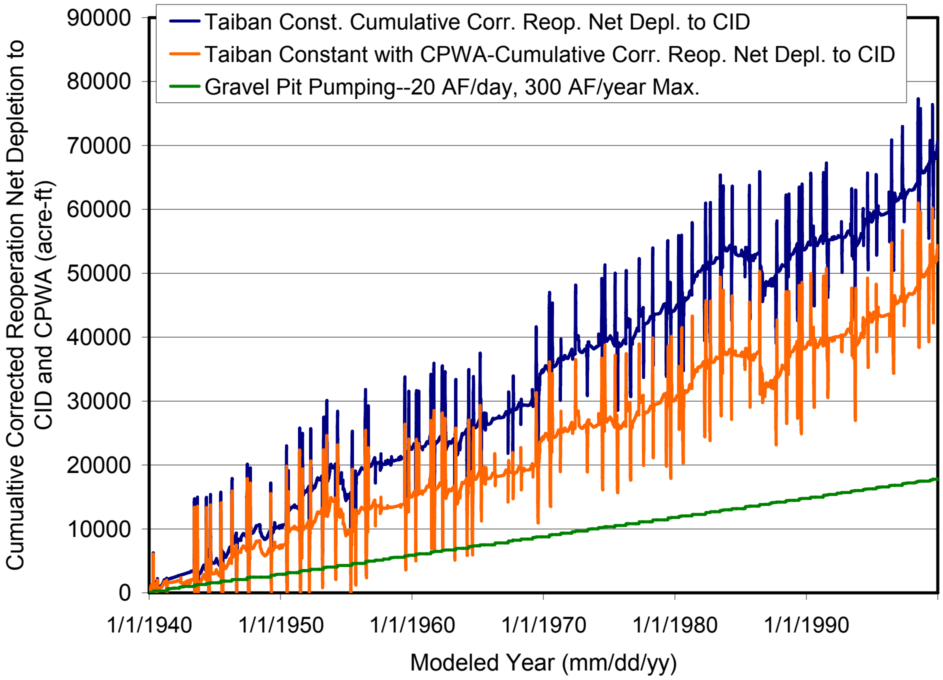

Figure 9. Taiban Constant with 300 AF/year Maximum, 20 AF/day with a 350 cfs River Flow Delivery Trigger—Cumulative Daily Net Depletions and Cumulative Pumping

3.3.4 Daily Effective CPWA Utilizing Project Supply

CPWA options that utilize Carlsbad Supply must be handled separately. Although retirement in CID represents a reduction of demand, it also creates larger net depletions to CID by the definition of net depletions. Straight retirement of CID acreage without subsequent planning policy to deliver retired CPWA water produces model results showing both increased additional depletions in the form of Avalon spills and evaporation. These losses would likely be available to balance out net depletions to the remaining farmers caused by reoperations for the PBNS, but only if it is delivered in greater quantity to augment their existing supply. In years where these remaining farmers were apportioned a full allotment, they cannot be eliminated since their (farm delivery) allotment is capped at 3.7 acre-ft/acre.

Calculation of daily effective CPWA amounts to the remaining farmers is accomplished by using equations 3.2 through 3.11. Figure 10 illustrates daily realized effective CPWA for the remaining farmers in the modeled year 1956 with the Acme Constant alternative and a 3,000 “actual irrigated acreage” reduction. Figure 11 illustrates daily realized effective CPWA for the remaining farmers also in the modeled year of 1956 with the Acme Constant alternative, a 3,000 “actual irrigated acre” reduction (acreage used to determine diversions), and a reduction in “total irrigable acreage” (acreage used to determine allotment per acre) by ratio, which amounted to 3,800 acres. As explained in the assumptions section, the reduction in “total irrigable acreage” simulates additional policy for spreading the water over a smaller portion of farm land, more effectively redistributing the water that becomes available from the retired CID farms. Comparing figures 10 and 11, it is evident that the saved diversion pattern is the same, but the daily effective CPWA magnitudes, for the scenario that also uses the irrigable acreage reduction by ratio in the model, are greater. Figure 12 again presents the same year for comparison, but this permutation is the Acme Constant alternative with 5,000 irrigated acres in the cropping pattern program with diversions limited to a low water use crop (~1.2 acre-ft/acre at the farm headgate). Comparing with the preceding figures, once again it is evident that the same pattern of diversion savings is realized except the daily effective CPWA magnitudes are lower than those shown for the retirement scenarios.

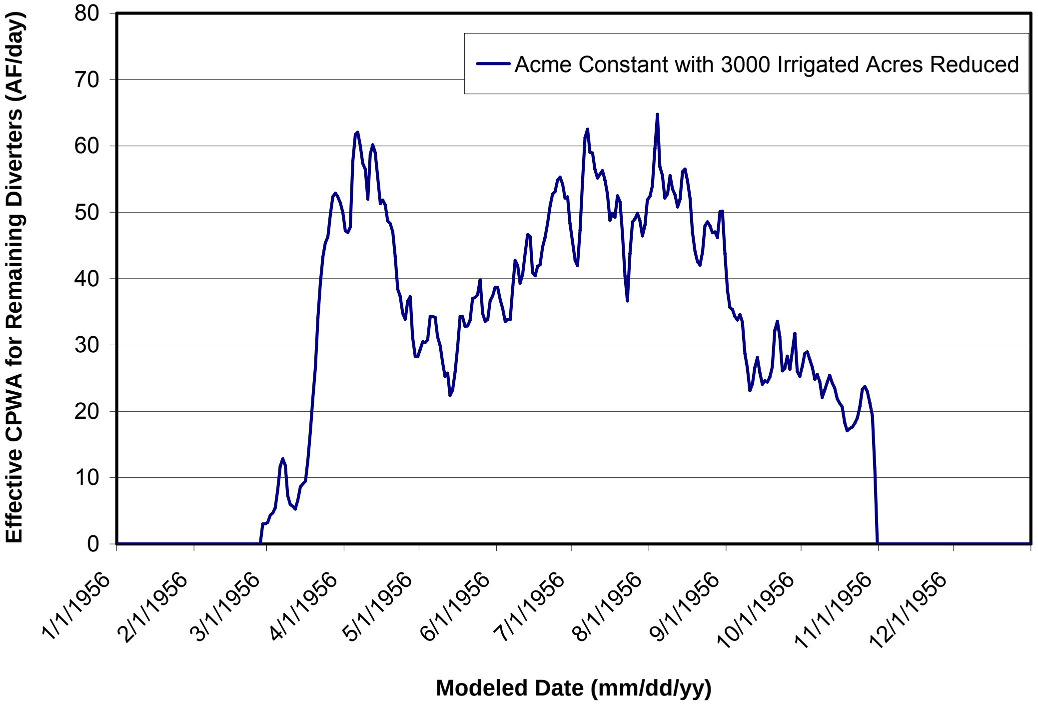

Figure 10. Effective CPWA for the Remaining Farmers (17,000 acres) within the CID for the Acme Constant Alternative with 3,000 Actual Irrigated Acres Retired.

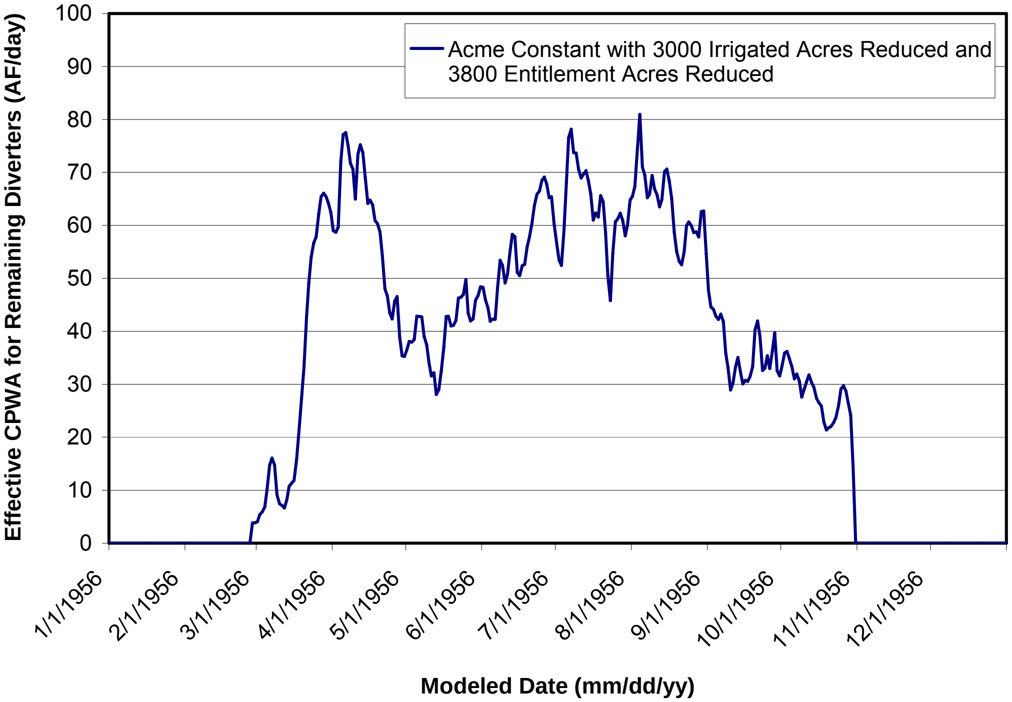

Figure 11. **Effective CPWA for the Remaining Farmers (17,000 acres) within the CID for the Acme Constant Alternative with 3,000 Actual Irrigated Acres Retired and 3,800 Irrigable Acres Reduced.**

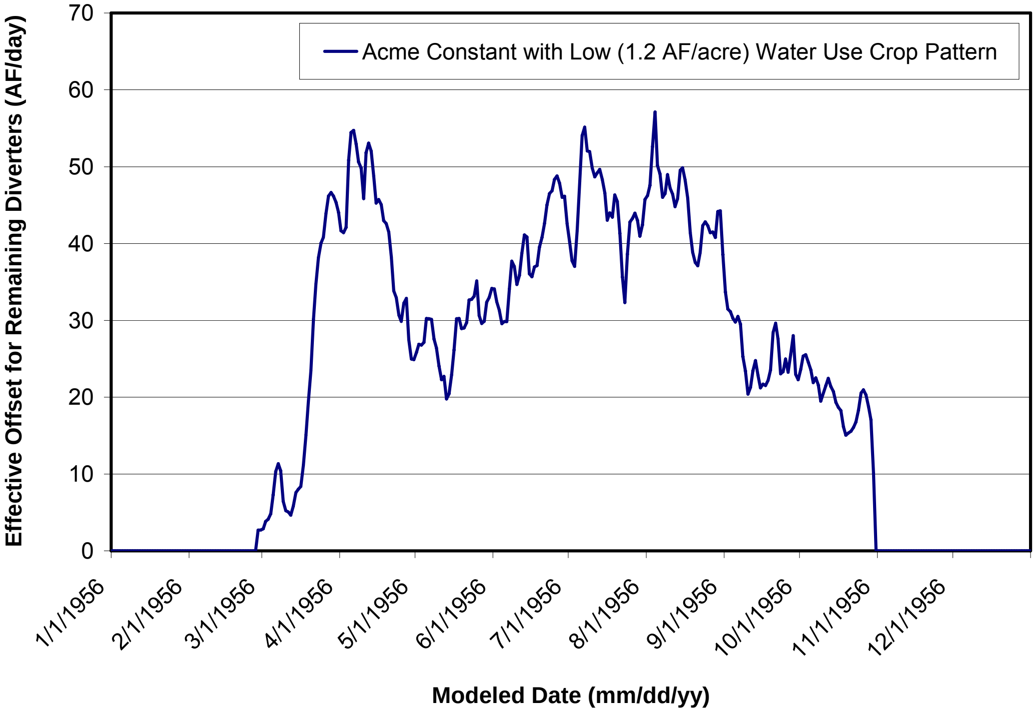

Figure 12. **Effective CPWA for Farmers not Participating in the Cropping Pattern Program (15,000 acres) within the CID for the Acme Constant Alternative with 5,000 Irrigated Acres Limited to Farm Deliveries of 1.2 acre-ft/acre.**

3.3.5 Cumulative 60-year Effective CPWA Amounts Utilizing Carlsbad Supply

Example cumulative 60-year daily effective CPWA amounts for Project derived CPWA options are presented in this section. Figure 13 presents the same three alternative/CPWA permutations presented in the previous section compared with a 60-year cumulative graph. The same trend of effective CPWA can be noted in this figure, which shows that the retirement with policy changes (simulated by “total irrigable acreage” reduction by ratio) delivers the most effective CPWA amounts. The straight irrigated acreage reduction (with no policy changes and no reduction in the “total irrigable acreage” used to compute allotments per acre) is second most in quantity of effective CPWA. The cropping pattern option delivers the smallest amount of effective CPWA. It is interesting to note from the figure that some of the flat slopes on the individual lines correspond to times when CID farmers had a nearly full allotment. In these times, unless the maximum allotment is increased, the CPWA option is totally ineffective and some of the water that becomes available is lost to evaporation in reservoirs or spills since it cannot be used at that time. This is most evident in the early 40’s and the late 80’s and early 90’s when the incoming water supply was fairly large. Policy changes do help to make some of that water available to other farmers as the increased slopes for the entitlement reduction alternative/option combination shows, but flat spots still exist demonstrating that a maximum diversion per acre ceiling is still reached in some years.

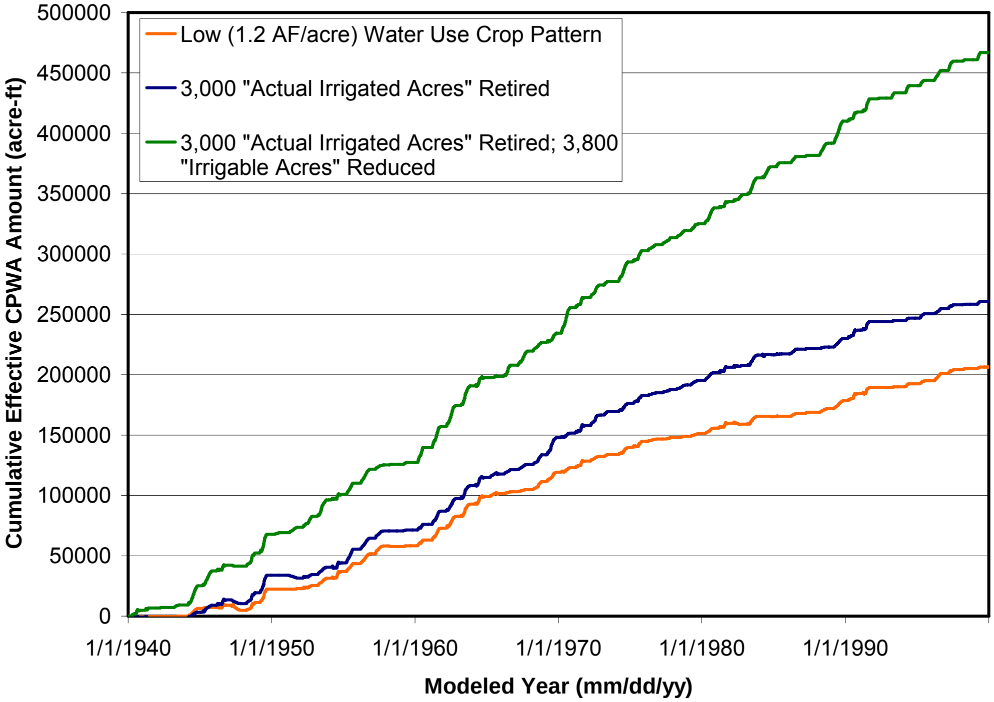

Figure 13. Cumulative Effective CPWA for 3,000 acre (Actual and by Ratio) Retirement CPWA Options Shown with 5,000 acre Cropping Pattern Change to Farm Deliveries Limited to 1.2 acre-ft/acre.

3.3.6 Ineffective and Effective CPWA Mass Balance

To determine how the reapportioned water within CID's supply is consumed as ineffective CPWA, the equations in Briggs et al (2005) were employed. Table 6 shows additional transmission depletions and saved evaporation compared to the Pre-91 condition for the original proposed alternatives (without CPWA). Table 7 presents the same net depletion components (compared with Pre-91) for the CID CPWA options listed previously in this memorandum. Table 8 presents average annual ineffective CPWA amount normalized using Effective Brantley Storage with equations 3.12 through 3.14 and normalized effective CPWA using equations 3.2 through 3.11. Comparing the sum of the ineffective and effective portions with the original theoretical CPWA amount (Table 4) shows that the CID retirement CPWA options reconcile quite well with theoretical CPWA amounts, but some discrepancy is still noted. Reasons for the slight discrepancy include allotment differences between the pre-91 model and the given alternative/retirement permutation along with normalizing the upstream depleted water with Effective Brantley Storage. The cropping pattern options don't reconcile as well between the theoretical value and the sum of the effective and ineffective CPWA components. Examining differences in total diversions indicates that much less water is being diverted for the cropping pattern options than for the CID retirement options. Since no policy changes were implemented, like estimating the savings and adding that amount back into the algorithm that determines the allotment, a larger volume of water is detained in the reservoirs than with any of the retirement options. This increases the reservoir evaporative losses for these options, and subsequently increases the mass balance discrepancy since upstream ineffective CPWA (as evaporation) is normalized with Effective Brantley Storage. With proper policy for these cropping pattern options, a significant portion of evaporated and spilled water would be available to redistribute to remaining farmers; however, a portion of the spilled water due to modified operations would not be recovered.

Table 6. Additional Transmission Loss and Saved Evaporation Measured as Effective Brantley Storage with Net Depletions due to Spills at Avalon Dam—Original Alternatives (without CPWA).

Alternative	Average Additional Transmission Loss Measured as Effective Brantley Storage (acre-ft/year)	Average Saved Evaporation Measured as Effective Brantley Storage (acre-ft/year)	Average Additional Net Depletion due to Spills from Avalon Dam (acre-ft/year)
Acme Constant	4378	1401	916
Acme Variable	3251	958	723
Critical Habitat	1074	393	577
Taiban Constant	986	447	661
Taiban Variable LRS	1183	371	400
Taiban Variable MRS	1811	595	323
Taiban Variable HRS	2509	601	-209
No Action w/6-wk	2238	725	883
No Action wo/6-wk	2248	687	-13

Table 7. Additional Transmission Loss and Saved Evaporation Measured as Effective Brantley Storage with Net Depletions due to Spills at Avalon Dam—CID CPWA Options with Taiban and Acme Constant Alternatives.

Alternative with CPWA Option	Average Additional Transmission Loss Measured as Effective Brantley Storage (acre-ft/year)	Average Saved Evaporation Measured as Effective Brantley Storage (acre-ft/year)	Average Additional Net Depletion due to Spills from Avalon Dam (acre-ft/year)
AC w/1500 Ac. CID Actual Ret.	4601	-103	1382
AC w/3000 Ac. CID Actual Ret.	4656	-1397	3613
TC w/1500 Ac. CID Actual Ret.	1208	-807	2500
TC w/3000 Ac. CID Actual Ret.	1206	-2175	4477
AC w/1500 Ac. CID Ratio Ret.	4546	1006	1717
AC w/3000 Ac. CID Ratio Ret.	4577	267	2035
TC w/1500 Ac. CID Ratio Ret.	1057	16	1537
TC w/3000 Ac. CID Ratio Ret.	1332	-572	2522
AC w/ L-1 (Average)	4663	-1387	3360
AC w/L-2 (Cotton)	4728	-1123	3695
AC w/L-3 (Small Grain)	4810	-1694	4888
AC w/L-4 (Corn)	4503	153	2503
TC w/L-1 (Average)	1307	-2128	3996
TC w/L-2 (Cotton)	1294	-1995	4038
TC w/L-3 (Small Grain)	1360	-2830	5119
TC w/L-4 (Corn)	1233	-716	2743

Table 8. Average Annual Effective and Ineffective CPWA Amounts for CID Retirement and Cropping Pattern Options.

Alternative w/ CPWA Option	Average Additional Transmission Loss as Compared to Original Alternative (normalized to BES - acre-ft/year)	Average Additional Evaporation as Compared to Original Alternative (normalized to BES - acre-ft/year)	Average Additional Spill as Compared to Original Alternative (acre-ft/year)	Total Ineffective CPWA Amount Including Spilled Water (normalized to BES - acre-ft/year)	Effective CPWA Amount (already applied through increased allotments--acre-ft/year)	Sum of Ineffective and Effective CPWA Amounts (acre-ft/year)
AC w/1500 acres actual*	224	1504	466	2194	2884	5079
AC w/3000 acres actual*	279	2798	2697	5774	4346	10121
TC w/1500 acres actual*	222	1254	1839	3315	1952	5267
TC w/3000 acres actual*	219	2622	3816	6658	3840	10498
AC w/1500 acres ratio**	169	395	801	1365	3787	5152
AC w/3000 acres ratio**	200	1135	1119	2453	7781	10234
TC w/1500 acres ratio**	71	431	876	1378	3960	5338
TC w/3000 acres ratio**	345	1019	1861	3225	7398	10624
AC w/ L-1	286	2788	2444	5518	3813	9331
AC w/L-2	350	2524	2779	5653	3440	9094
AC w/L-3	433	3095	3972	7501	4783	12284
AC w/L-4	125	1249	1588	2962	1627	4589
TC w/L-1	321	1834	3335	5490	3762	9252
TC w/L-2	308	1570	3377	5255	3577	8832
TC w/L-3	373	2141	4458	6972	4842	11814
TC w/L-4	246	295	2082	2624	1637	4261

* Even though changed policy was not implemented, a portion of the reduced diversion goes to redistribute retired water to remaining farmers since the allotment computation is based on available water in storage; however, the portion that evaporates in between the allotment allocation dates and when the reduced diversion accumulates is lost.

** Ratio retirement was implemented to demonstrate policy to enhance redistribution of retired water to the remaining farmers; redistribution for remaining farmers could also be implemented by estimating future saved diversion amounts and applying them to the allotment computation.

3.3.7 Relation between Ineffective CPWA from Spills and Added Theoretical CPWA Volumes

Some CPWA options, such as Project derived options, exhibit an increasing conservation spill trend with water added to or reallocated within the Pecos River System. Figure 14 correlates CPWA lost to spills with theoretical CPWA amounts added to or reallocated within the Pecos River System. All of the CPWA results presented in this report are included in the figure. It is apparent from the figure that as added/reallocated water volumes increase, an increased portion of that CPWA option is lost to conservation spills. Figure 14 also demonstrates the linear dependence exhibited by all the CPWA options considering either the alternative or baseline the CPWA option was combined with, policy differences between the administration of CPWA volumes, or differing pumping series for the same amount of retirement within PVACD.

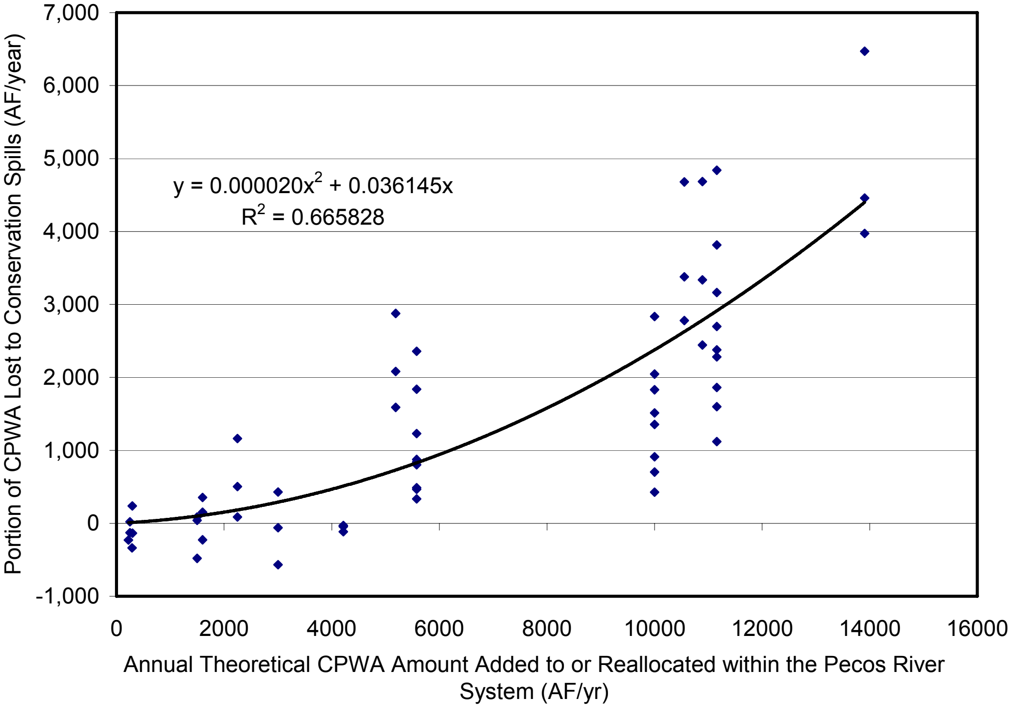

Figure 14. Theoretical CPWA Plotted Against the Portion of CPWA Lost to Spills

3.4 Superposition/Interpolation as a Function of Depletions

Although originally considered for interpolation of determining effectiveness of CPWA options combined with alternatives other than Taiban and Acme constant (the least and most depletive alternatives, respectively), output data indicates that the principle of superposition is not valid for CPWA options. Figure 15 shows an example of the poor linear correlation between net depletions to CID for an alternative and CPWA efficiency. Note in the figure that the efficiency also varies with added theoretical CPWA amount. No single set of CPWA options showed a satisfactory correlation with depletions to CID supply. Two main reasons account for the invalidation of the superposition principle. One reason is the random cyclical nature of conservation spills despite their strong correlation with increased alternative flow targets (Tetra Tech, 2003e) and their strong correlation with increased CPWA added or reallocated within the Pecos River System (Section 3.3.6). In addition, indirect effects of retirement can cause non-linear responses for CPWA effectiveness, such as forbearance in FSID. For this reason, only ranges and averages of effective CPWA amounts should be used for planning purposes.

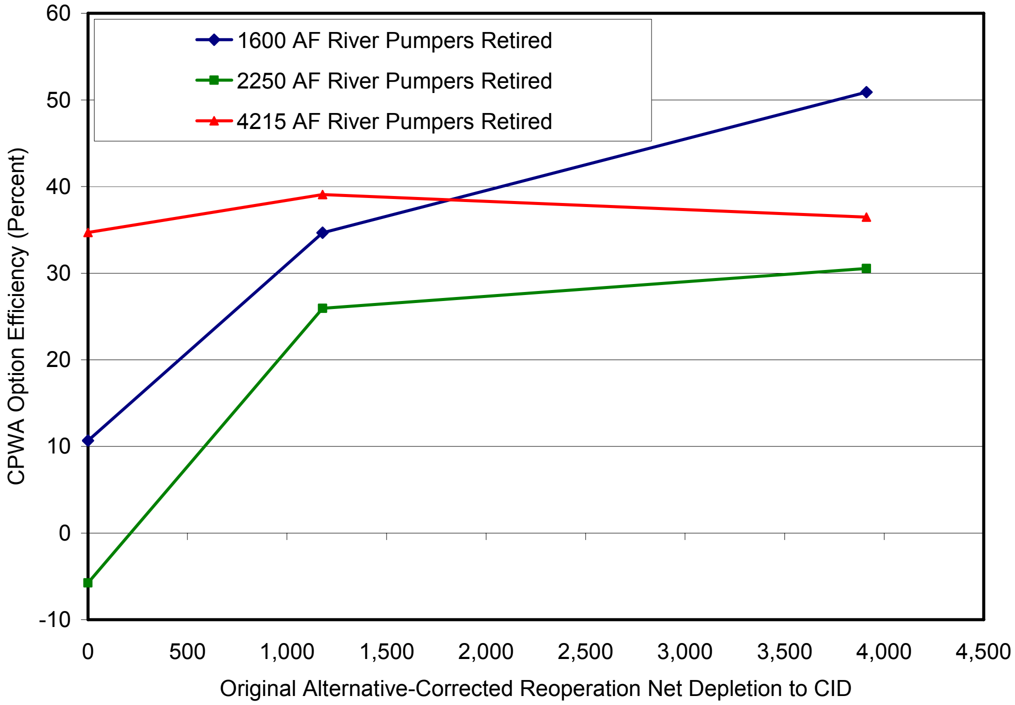

Figure 15. Alternative Net Depletions to CID plotted with CPWA Efficiency

4.0 Summary

CPWA modeling with the Pecos River RiverWare Model was used to determine effective CPWA amounts for A-list CPWA options defined for the Carlsbad Project Reoperations NEPA process.

The CPWA options that were modeled included surface water retirement in three major irrigation districts, groundwater retirement and subsequent pumping of those retired rights as CPWA, diversion reductions based on changing cropping patterns to lower use crops, and gravel pit pumping from an abandoned gravel pit in the Ft. Sumner area. CPWA scenarios were simulated with two different alternatives from the NEPA process, including Acme Constant and Taiban Constant. CPWA scenarios were also simulated against the Pre-91 NEPA baseline.

CPWA options were also reduced to determine the effective CPWA amount, or the amount of water that actually reached the Carlsbad Irrigation District for crop use effectively replacing the water depleted in transit for in stream habitat use by the Pecos bluntnose shiner. Effective CPWA amounts from non-project derived water sources were reduced by examining net depletions to CID supply. Effective CPWA amounts from project derived water sources were isolated by examining diversions normalized to the remaining acreage within the CID. Also, transit efficiencies of non-Project CPWA options from the CPWA source to Brantley reservoir were estimated.

5.0 References

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Pecos River RiverWare Model
Additional Water Acquisition Modeling Documentation Report

Report on Modeling Assumptions and Output Analysis for Determination of Effectiveness of Additional Water Acquisitions

January 2006 Final Report

TETRA TECH, INC.

Table of Contents

1.0 Introduction

Additional water acquisition (AWA) options are explicitly designated for augmenting in-channel flows with the goal of meeting specified target flows for alternatives at times when Carlsbad Project supply coming into Santa Rosa and Sumner Reservoirs is less than demand.

The US Bureau of Reclamation (Reclamation) does not have authority to store water, other than the recently permitted 500 AF “fish conservation pool”, or take project water that has been stored for CID. In the event that bypass flows are insufficient to meet target flows, Reclamation cannot supplement the flows with stored water. Because of this, additional sources would be needed to meet the demands. The AWA water would be specifically acquired to augment flows for the shiner above the level of flow that can be achieved with bypasses. AWA is limited to the additional water that would be acquired with available resources to further augment flows but may not necessarily always meet the target.

Four AWA scenarios were investigated with the Pecos River RiverWare model (Tetra Tech, 2003b, 2003d, 2000b) which included water sources from both the A & B lists designated by WOOG (Reclamation, 2005b). These four scenarios were simulated with the Taiban and Acme Constant Alternatives and included water acquisition from the following locations:

- from Fort Sumner Irrigation District (FSID) located below Sumner Dam but whose supply originates above the dam,
- from diverters above Sumner Dam along the reach from Santa Rosa Dam to Puerto de Luna (PDL) (various upstream acequias),
- below Sumner Dam from a well field (referred to as the “Ft. Sumner Well Field” option), and
- through pumping from a gravel pit in the Ft. Sumner area.

Table 1 summarizes the AWA options that were modeled using RiverWare and the amount(s) of water that was modeled for each option.

Table 1. Modeled AWA Options and the Annual Amount Acquired

AWA Option	Modeled Amount (acre-feet per year)
Acquisition from FSID (purchase and lease)	1500, 3000, 9040
Aggregate of Sources from the PDL Reach	900, 2500, 4300
Ft. Sumner Well Field	1800
Ft. Sumner Gravel Pit Pumping	300 max (10 or 20 acre-feet per day)

2.0 Model assumptions and simulation of additional water acquisitions

Analysis of AWA water involved model simulations using the four water sources listed above to directly augment in-stream flows for the Pecos Bluntnose Shiner (PBNS). Likely available amounts, as estimated by the WOOG, were modeled to determine what flow frequency benefits might be realized for those volumes. In addition, AWA water was modeled to determine if net depletions or incidental benefits to CID occur as a result of using water directly for the PBNS. As with the Carlsbad Project Water Acquisition (CPWA—See EIS Technical Appendix 3.C) options, only the Pre-91 Baseline, the Taiban Constant and the Acme Constant alternatives were examined in combination with AWA options as these alternatives represent extremes in net depletions.

2.1 FSID Retirement and Forbearance (FSID-AWA)

FSID diverts water from the Pecos River from a low-head diversion dam located on the Pecos downstream of the Sumner Dam. Water is diverted during the irrigation season, typically from March 1 though October 31. With this AWA option, a portion of the water originally allocated to FSID would not be diverted but would remain in the main stream of the Pecos River. The amounts available for purchase and lease were combined to form the 1500 ac-ft and 3,000 ac-ft options. In addition, a volume of 9,040 acre-feet per year was also modeled as this represents the 2004 irrigation season average forbearance of 18.6 cfs.

For this AWA option, water is used for augmentation only when FSID diverts water, i.e. during the irrigation season. When the volumes of water listed above are dispersed over the 245 day irrigation season the result is a continuous flow of 3.08 cfs, 6.17 cfs and 18.06 cfs, respectively.

Only water that is bypassed through Sumner Reservoir (i.e. not stored in Sumner Reservoir for CID) is available to FSID for diversion. FSID has a maximum allotment of 100 cfs during the irrigation season, or a total of 48,595 ac-ft per season. Therefore the three options of 1,500 ac-ft, 3,000 ac-ft and 9,040 ac-ft represent 3.1%, 6.2% and 18.1% of FSID's maximum annual allotment.

FSID is entitled to 100 cfs, if that much is available as inflow to Sumner Dam. With this AWA option, the RiverWare model was set up such that 100 cfs minus the AWA forbearance would be diverted to FSID and the AWA forbearance would remain in the channel. In some cases, there is insufficient inflow to allow 100 cfs to be diverted to FSID. In those cases, the AWA forbearance would be reduced by the same ratio as the reduction in the FSID allotment. For example, if 80 cfs were available for diversion to FSID, that is 80 percent of the total entitlement, only 80 percent of the AWA water remained in the channel (2.47, 4.94, and 14.88 cfs respectively for this example).

2.2 Aggregate of Upstream Acequia Options above Sumner Dam (PDL-AWA)

The aggregate of upstream acequia water options above Sumner Dam amounted to 900 acre-feet per year, 3,000 acre-feet per year, and 4,300 acre-feet per year, or a continuous flow of 1.85 cfs, 5.14 cfs, and 8.85 cfs over the 245-day irrigation season. This water was modeled as entering the system at the upstream end of the Puerto de Luna (PDL) reach. This simulated diversions that would be acquired in that reach, such as forbearance from the PDL acequia, and diversions upstream of Santa Rosa (with the modeled assumption that the water would be bypassed through Santa Rosa Dam).

The PDL-AWA water was bypassed through Sumner Dam by increasing the Sumner outflow when water was bypassed for FSID (during the irrigation season). If bypass available from incoming Carlsbad Project Supply was already sufficient to meet the target, the bypass from Project supply was curbed by an amount equal to the AWA forbearance. During times of flood releases or block releases, efforts were not made to augment the outflow with the additional water acquired in the PDL reach.

The AWA forbearance above Sumner Dam was reduced by a prorated share of the loss for the total amount of flow in the Santa Rosa to PDL reach to account for gains or losses to that fraction of the water as it traveled through the PDL reach.

2.3 Ft. Sumner Well Field (FSWF-AWA)

The Ft. Sumner Well Field option is assumed to converge with the Pecos River downstream from the FSID diversion and upstream of the confluence with Taiban Creek. The pipeline would supply an annual volume of 1,800 acre-feet with a maximum discharge of 12 cfs to supplement the river flows for the PBNS. This water is assumed to be an annual amount that does not carry over from year to year.

Water from the well field was modeled as entering the system when it was needed to help augment flows in the channel below the FSID diversion. When the downstream demand needed to meet the target exceeds the incoming bypass supply, flow from the FSWF pipeline is released to the stream. Groundwater interactions with the Pecos River and depletions to the local groundwater aquifer were not modeled for this option.

This is a simplified version of how the pipeline would be operated and actual operations may be able to better utilize the additional water to avoid intermittency as well as maintain targets.

2.4 Gravel Pit Pumping (GP-AWA)

Pumping from the gravel pit in the Ft. Sumner area was also modeled as an AWA option. Pumped water was added to the model when bypass supply was insufficient to meet target demands. Pumping was subject to an assumed maximum of 300 acre-ft/year—the estimated gravel pit annual inflow. Two pumping rates out of the pit were modeled: one at 10 ac-ft per day or 5.04 cfs and a second at a higher rate of 20 ac-ft per day or 10.08 cfs. Losses were not applied to these rates, but it is likely a small percentage of this water would be lost in transit through FSID's drain system before reaching the Pecos River.

Water from the gravel pit was pumped into the system when needed to help augment bypass flows to meet alternative targets at Acme or Taiban. The need for the water was determined in the same manner as was done for the Ft. Sumner Well Field AWA option. Groundwater interactions with the Pecos River and depletions to the local groundwater aquifer were not modeled for this option.

3.0 Impacts of AWA scenarios

The impacts of AWA were analyzed for the four separate sources of AWA modeled using RiverWare. The focus of the analyses was on the effect of AWA on the occurrence of intermittency near Acme or improvements to flow durations, but the impact was also reviewed for the amount of time that target flows are met. While the purpose of AWA is not to offset net depletions to the Carlsbad Project supply, the effects of AWA options on net depletions to the Carlsbad Project supply were also analyzed.

Due to the small volumes considered with the AWA analysis, the additional water had little effect on flow frequency and intermittency. Forbearance from FSID for the Acme Constant alternative showed an average annual increase in days the target flow was met, ranging from 6 to 46 days per year depending on the volume of forbearance. However, FSID forbearance was the only AWA option that worsened intermittency, with 1.4 to 2.4 % more intermittency for the Acme Constant alternative with bypass operations alone.

The aggregate of water from PDL showed little to no change in intermittency and a 2 to 11 day per year increase in the number of days the target flow was met for the Acme Constant alternative. The Ft. Sumner Well Field also showed little to no change in intermittency and only a 2 day increase in the average annual number of days the target flow was met. The gravel pit pumping showed virtually no benefit for intermittency or annual increase in days that the target flow was met as compared to the Acme Constant alternative. Most of the AWA options showed a worsening of flow frequency and intermittency when coupled with the Taiban Constant alternative.

3.1 AWA from FSID

Intermittency

The benefit of AWA from FSID in regards to additional river flows is limited to the consumptive portion of FSID's water right. Much of the acquired water (69% on average) would eventually be in the river anyway as return flows. This effect combined with the expected conveyance losses to seepage and evapotranspiration would yield a negligible benefit for AWA from FSID. The occurrence of intermittency near Acme would not be reduced as a result of AWA from FSID. In fact, the model results indicate that zero flow would occur more often. With the reduction in return flows from FSID corresponding to AWA, the demand for bypasses would increase. For the Taiban Constant Alternative, these effects would also impact the amount of time that target flows are met. Expected impacts of AWA from FSID on intermittency and target flows are summarized in Tables 2 and 3 for the Taiban Constant and Acme Constant Alternatives, respectively, for the Acme gage.

Table 2. Impact of AWA from FSID with the Taiban Constant Alternative

AWA with Taiban Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
FSID (1500 acre-feet/year)	3.3	5.8	-8.4
FSID (3000 acre-feet/year)	3.3	7.3	-10.7
FSID (9040 acre-feet/year)	3.3	5.6	-8.8

Table 3. Impact of AWA from FSID with the Acme Constant Alternative

AWA with Acme Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
FSID (1500 acre-feet/year)	2.5	3.4	6.0
FSID (3000 acre-feet/year)	2.5	3.6	21.7
FSID (9040 acre-feet/year)	2.5	4.9	46.3

Flow Exceedance

Flow exceedance for the FSID AWA options combined with Taiban Constant is depicted in Figure 1. FSID AWA options with Acme Constant are shown in Figure 2. As with the tables, it is apparent from the plots that AWA from FSID is mostly detrimental to flow frequency at Acme since return flows from FSID are reduced and less total water is being released below the dam.

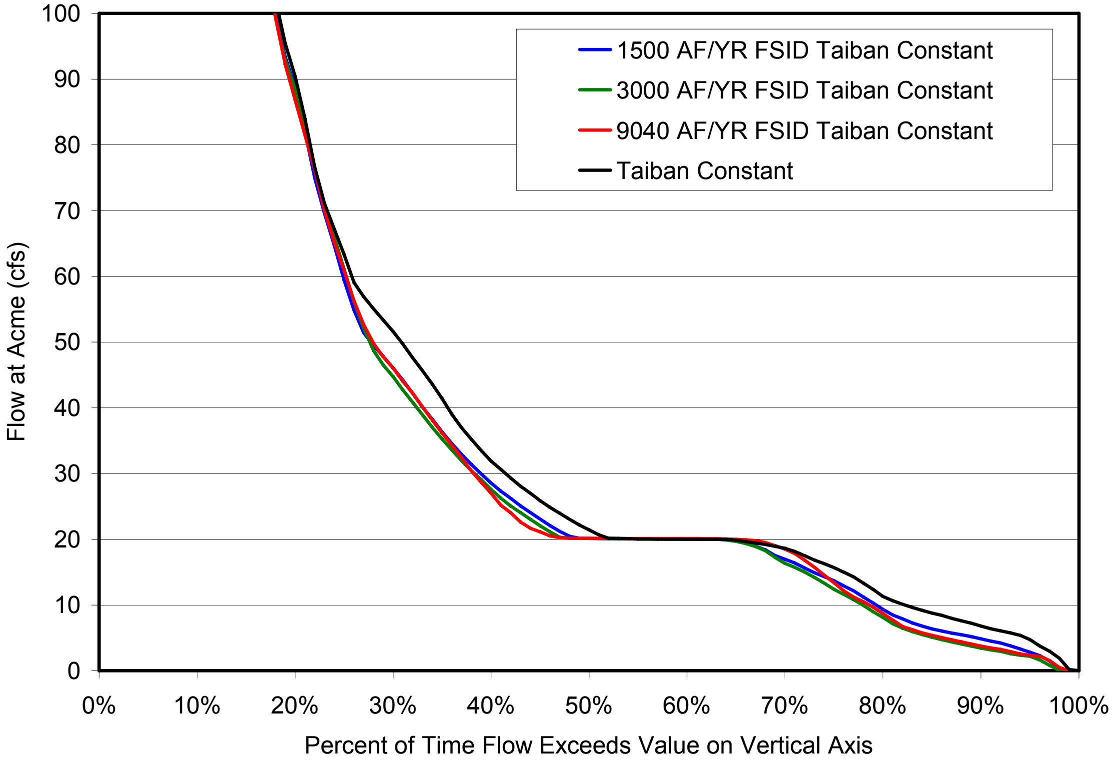

Figure 1. Flow Exceedance at Acme for the Taiban Constant Alternative with AWA from FSID.

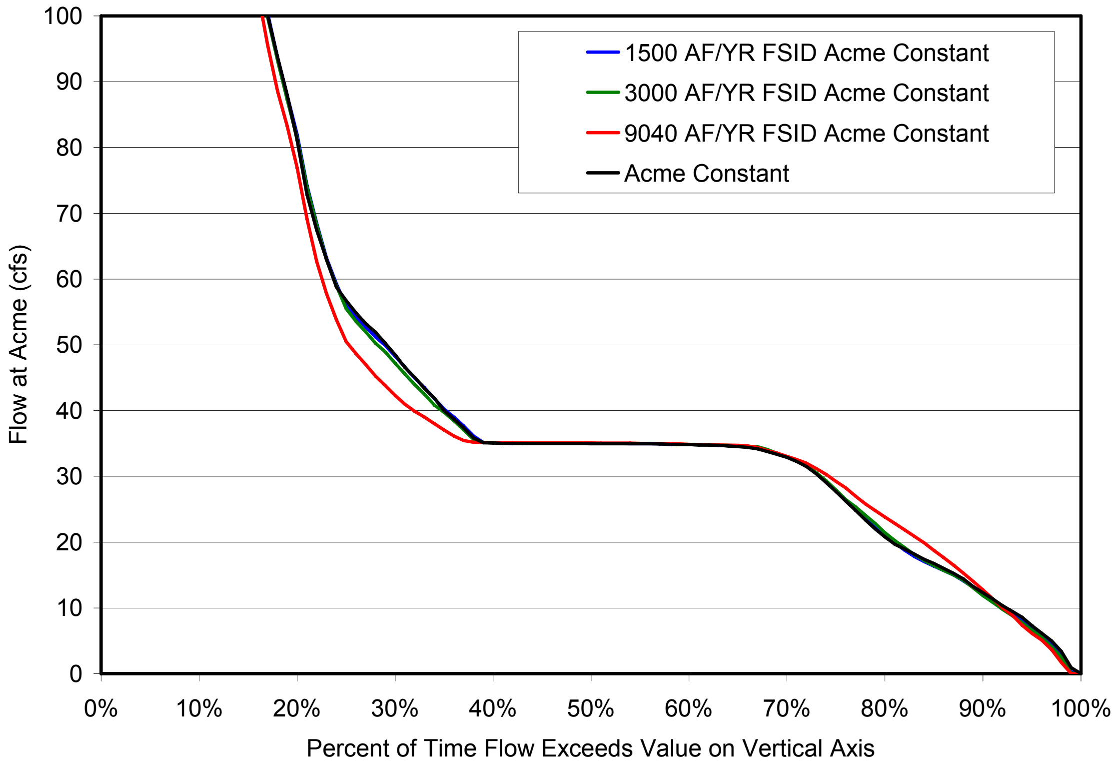

Figure 2. Flow Exceedance at Acme for the Acme Constant Alternative with AWA from FSID.

Net Depletions

NOTE: For a detailed description of net depletions including definitions and equations, refer to the "Results Memorandum for Alternative Modeling Using Bypass Water" in the Carlsbad Project Operations and Water Conservation EIS Technical Appendix.

.A portion of AWA from FSID supplies may end up in Brantley Reservoir and become part of the Carlsbad Project supply, or the change in operations associated with this AWA option may cause additional depletions to the Carlsbad Project Supply. The impacts are not only a function of how much AWA ends up in Brantley Reservoir but also a function of how AWA affects the demand for bypasses to meet target flows associated with an alternative. As FSID returns decrease, the demand for bypasses increases. These two factors combined yield variability in the impacts of AWA between alternatives. Timing and annual volume of block releases will also affect net depletions to Carlsbad project supplies when considering AWA from FSID among alternatives. The effects of AWA from FSID on net depletions are summarized in Table 4 for the Taiban Constant and Acme Constant Alternatives. It can be concluded from the results in Table 4 that alternatives that move larger volumes of water by block release (such as Taiban Constant) demonstrate increased efficiency of transmission of AWA to Brantley Reservoir.

Table 4. Impact of AWA from FSID on Net Depletions to the Carlsbad Project Supply

Source for AWA	Average Annual Net Depletion (acre-feet)			
	Acme Constant	Additional Depletion from AWA with Acme Constant	Taiban Constant	Additional Depletion from AWA with Taiban Constant
No AWA	3,900	---	1,200	---
FSID (1500 acre-feet/year)	4,300	400	1,200	0
FSID (3000 acre-feet/year)	3,900	0	700	-500
FSID (9040 acre-feet/year)	4,000	100	900	-300

3.2 AWA from Upstream Acequias - PDL

Intermittency

Agreements may be reached for AWA with various upstream acequias along the reach from Santa Rosa Dam to PDL. The conveyance losses associated with this option would significantly reduce the benefit realized near Acme. In fact, model results indicate that the occurrence of intermittency near Acme would not be reduced as a result of AWA from upstream acequias. Also, depending on the alternative, AWA from this option may adversely impact the amount of time that target flows are met. The impacts are summarized in Tables 5 and 6 for the Taiban Constant and Acme Constant Alternatives, respectively for the Acme gage.

Table 5. Impact of AWA from Acequias with the Taiban Constant Alternative

AWA with Taiban Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
PDL (900 acre-feet/year)	3.3	4.4	-2.4
PDL (3000 acre-feet/year)	3.3	4.0	-1.2
PDL (4300 acre-feet/year)	3.3	3.6	-0.5

Table 6. Impact of AWA from Acequias with the Acme Constant Alternative

AWA with Acme Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
PDL (900 acre-feet/year)	2.5	2.5	2.4
PDL (3000 acre-feet/year)	2.5	2.6	6.5
PDL (4300 acre-feet/year)	2.5	2.3	10.7

Flow Exceedance

Flow Exceedance plots for AWA options utilizing water from upstream acequias are shown in Figures 3 and 4. Figure 3 shows the combinations of AWA from acequias with the Taiban Constant alternative and Figure 4 shows those combinations with the Acme Constant alternative. The Taiban Constant alternative shows slight detriments to slight improvements in some of the flow ranges. The Acme Constant alternative shows improvements in all flow ranges. This difference is likely due to the AWA water from PDL combined with the larger bypasses of Acme Constant. With Taiban Constant, these AWA amounts are consumed by the break through flows in the reaches between Sumner and Acme much more readily (due to the lower flow levels in the river) with the Taiban Constant alternative than they are with the Acme Constant alternative.

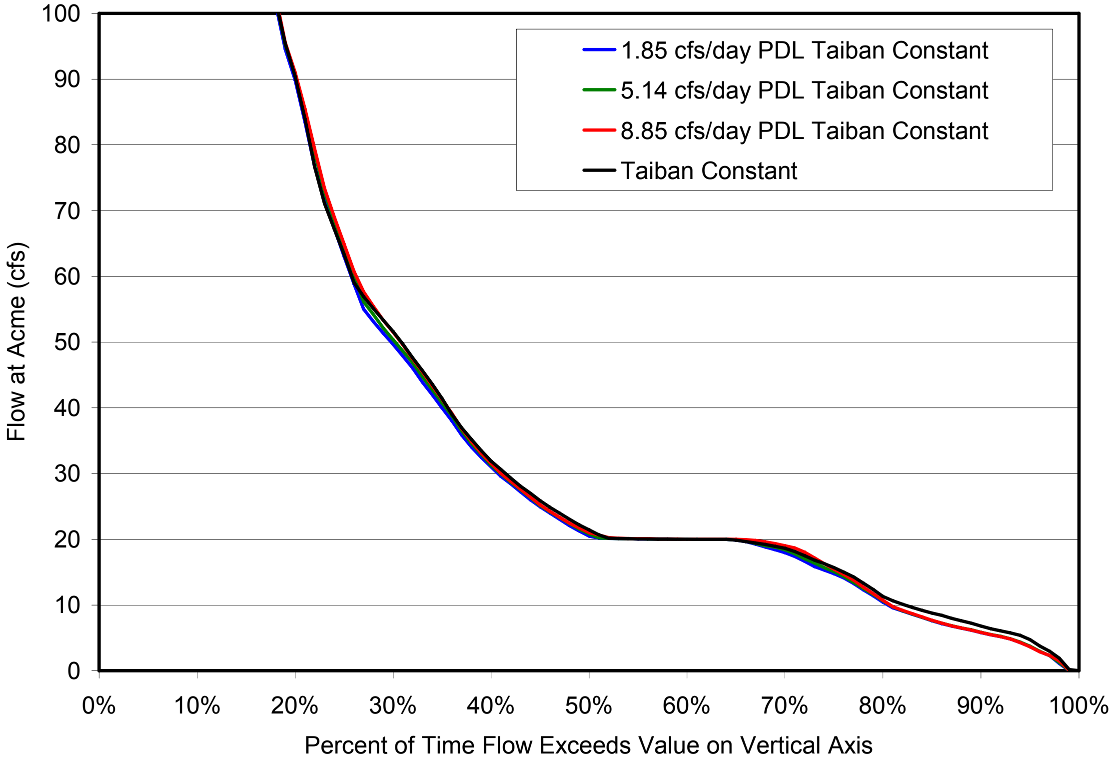

Figure 3. Flow Exceedance at Acme for the Taiban Constant Alternative with AWA from Upstream Acequias

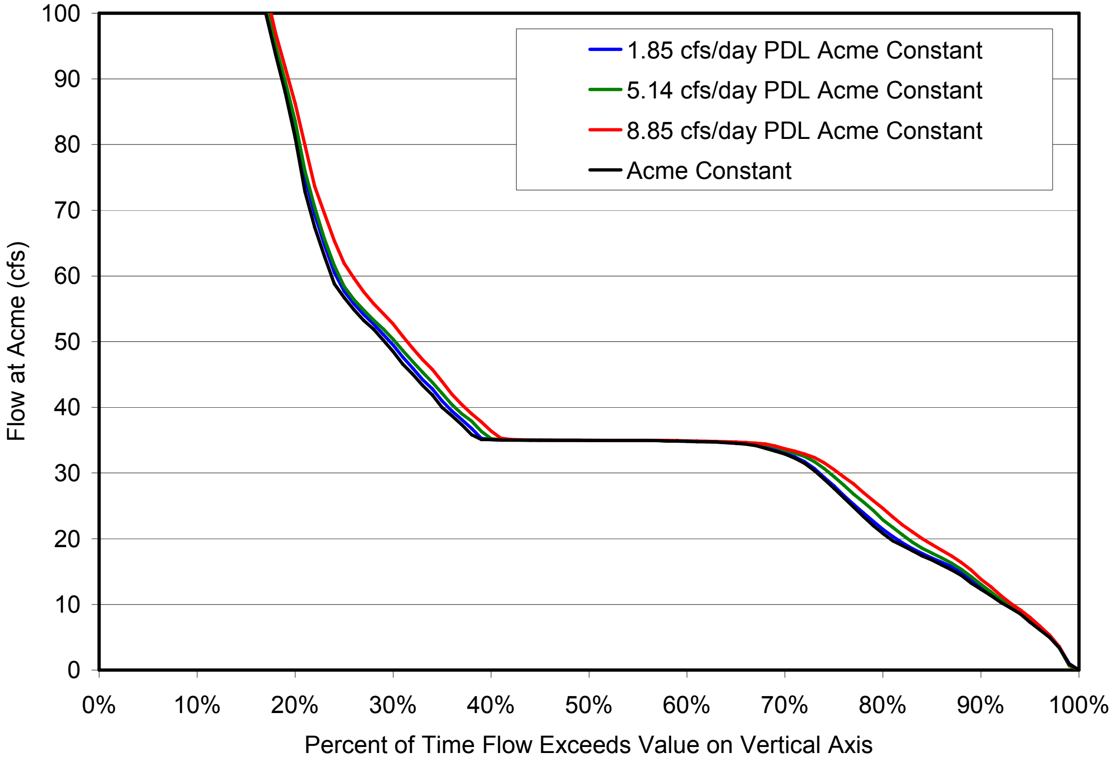

Figure 4. Flow Exceedance at Acme for the Acme Constant Alternative with AWA from Upstream Acequias

Net Depletions

AWA from upstream acequia districts would augment the Carlsbad Project Supply. Since all of the AWA from this source would be an effective gain to the river at the location of the source (i.e. the amount of water would not be effectively reduced based on return flows that would have been realized anyway as in the case of FSID), incidental benefits to the Carlsbad Project supply are always evident. The impacts of AWA from upstream acequia districts on net depletions are summarized in Table 7 for the Taiban Constant Alternative and Acme Constant Alternative.

Table 7. Impact of AWA from Acequia Districts on Net Depletions to the Carlsbad Project Supply

	Average Annual Net Depletion (acre-feet)			
AWA	Acme Constant	Additional Depletion from AWA with Acme Constant	Taiban Constant	Additional Depletion from AWA with Taiban Constant
No AWA	3,900	---	1,200	---
PDL (900 acre-feet/year)	3,700	-200	600	-600
PDL (3000 acre-feet/year)	3,200	-700	500	-700
PDL (4300 acre-feet/year)	3,200	-700	500	-700

3.3 AWA from Ft. Sumner Well Field

Intermittency

In the event that the Ft. Sumner Well Field is constructed and used to supplement in channel flows, there would be an expected decrease in the days of intermittency at the Acme gage for both the Taiban Constant and the Acme Constant Alternatives as detailed in Tables 8 and 9. Additionally, this AWA option lends a slight increase to the number of days per year that the flow target is met at the Acme gage.

Table 8. Impact of AWA from the Vaughn-Crockett Pipeline with the Taiban Constant Alternative

AWA with Taiban Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
Ft. Sumner Well Field	3.3	3.1	1.0

Table 9. Impact of AWA from the Vaughn-Crockett Pipeline with the Acme Constant Alternative

AWA with Taiban Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
Ft. Sumner Well Field	2.5	2.2	1.7

Flow Exceedance

Changes to the flow exceedance from the Ft. Sumner well field for the Taiban Constant and Acme Constant alternatives were imperceptible using a flow exceedance chart. For this reason, flow exceedance figures are not presented for this AWA option.

Net Depletions

The AWA from the Ft. Sumner Well Field adds enough water to the system to cause some small additional net depletions to the Carlsbad Project Supply. Most of the net depletion is due to differences in spills at Avalon Reservoir. Table 10 below summarized the results.

Table 10. Impact of AWA from Vaughn Crocket Pipeline on Net Depletions to the Carlsbad Project Supply

AWA	Average Annual Net Depletion (acre-feet)			
	Acme Constant	Additional Depletion from AWA with Acme Constant	Taiban Constant	Additional Depletion from AWA with Taiban Constant
No AWA	3,900	---	1,200	---
Vaughn Crockett Pipeline	4,000	100	1,000	200

3.4 AWA from Gravel Pit Pumping in the Ft. Sumner Area

Intermittency

The gravel pit in the Ft. Sumner area could be pumped to augment river flows, but this source would yield negligible results. Model simulations indicate that the available amount of water is too small to yield a significant change to flows near Acme. The effects of pumping from the

FSID Gravel Pit on the occurrence of intermittency and target flows near Acme are summarized in Tables 11 and 12.

Table 11. Impact of AWA from FSID Gravel Pit Pumping with the Taiban Constant Alternative

AWA with Taiban Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
Ft. Sumner Gravel Pit (10 acre-feet/day)	3.3	3.3	0.0
Ft. Sumner Gravel Pit (20 acre-feet/day)	3.3	3.3	0.0

Table 12. Impact of AWA from FSID Gravel Pit Pumping with the Acme Constant Alternative

AWA with Acme Constant	Average Days per Year of Intermittency at Acme (no flow)		Average Days per Year that the Flow at the Target Location was Increased
	Alternative	Alternative with AWA	Alternative with AWA
Ft. Sumner Gravel Pit (10 acre-feet/day)	2.5	2.2	0.2
Ft. Sumner Gravel Pit (20 acre-feet/day)	2.5	2.2	0.2

Flow Exceedance

Changes to the flow exceedance from the gravel pit pumping for the Taiban Constant and Acme Constant alternatives were also imperceptible using a flow exceedance chart. For this reason, flow exceedance figures are also not presented for this AWA option.

Net Depletions

The AWA from the gravel pit adds a small amount of water to the system. This results in a slight impact on net depletions to the Carlsbad Project supply, as portrayed by the results presented in Table 13.

Table 13. Impact of AWA from FSID Gravel Pit on Net Depletions to the Carlsbad Project Supply

	Average Annual Net Depletion (acre-feet)			
AWA	Acme Constant	Additional Depletion from AWA with Acme Constant	Taiban Constant	Additional Depletion from AWA with Taiban Constant
No AWA	3,900	---	1,200	---
Gravel Pit (10 acre-feet/year)	4,100	200	1,100	-100
Gravel Pit (20 acre-feet/year)	3,900	0	1,100	-100

In addition to the four modeled AWA options, Table 14 on the next page contains a qualitative assessment of hydrologic effects of AWA options that weren't modeled for the Carlsbad Operations EIS. This includes all options that were B-listed by the WOOG in their ranking process.

4.0 Conclusions

AWA options were modeled for four different water sources with the Taiban and Acme Constant alternatives. Results indicated that AWA options have little benefit to flow duration, intermittency, or Carlsbad Project water supplies. AWA from FSID generally worsens flow duration and intermittency due to the reduced return flows from FSID and because less total water is released below the dam than would be with the alternative alone. AWA from upstream acequias did not improve intermittency, but showed some improvements to flow duration for Taiban Constant, and showed improvements in nearly all low-flow ranges for Acme Constant. AWA from the Ft. Sumner Well Field showed slight improvements to intermittency and time meeting targets for both alternatives, but changes to flow exceedance were negligible. Improvements in intermittency for AWA Gravel Pit pumping showed slight (Acme Constant) to no improvement (Taiban Constant) with a negligible improvement in achieving targets and flow duration.

Table 14. Qualitative Assessment of Hydrologic Effects for AWA Options that were not Modeled for the Carlsbad Operations EIS

Additional Water Acquisition B-List Qualitative Impacts

Designation	Option Name	Logistics and Qualitative Impacts
F	Import Canadian River Water	Water would be piped into Pecos River system and bypassed through Sumner Reservoir. Water would directly benefit the PBNS. Water would accrue to river below Santa Rosa Dam. Water would need to be managed and accounted for to keep separate from CID supply.
A-3	Groundwater Right Purchase-FSPA	Purchase of water rights in Fort Sumner Pivot Area. Alone this option will have little effect on increasing flows for the PBNS, although the interaction of groundwater in these reaches is poorly understood.
A-3X	Groundwater Right Purchase-FSPA (add. 40% inflat.)	Purchase of water rights in Fort Sumner Pivot Area. Alone this option will have little effect on increasing flows for the PBNS, although the interaction of groundwater in these reaches is poorly understood.
B-3	Groundwater Right Lease-FSPA	Purchase of water rights in Fort Sumner Pivot Area. Alone this option will have little effect on increasing flows for the PBNS, although the interaction of groundwater in these reaches is poorly understood.
A-5	Water Right Purchase-Above Santa Rosa	Would create additional inflow into Santa Rosa Reservoir augmenting available bypass supply for PBNS. Measurement and apportionment of retired rights and wet water (vs. CID supply) would require administrative policy.
K	Renegotiate Compact--Forebearance	Would require agreement with State of New Mexico for CID to hold onto upstream supply (increased conservation storage and diversion amounts) in exchange for forbearance in the Red Bluff Irrigation District (to lessen state line compact obligation). Would require additional agreement between CID and BOR for forbearance exchange for AWA (pays for bypass water upfront).
G-1	Range and Lower Watershed Management (adj. river upland)	Would increase base flows into Pecos River and its tributaries. Impacts would accrue both above and below Acme, so PBNS habitat may realize part of the benefit. Very difficult to quantify true amount of salvaged water
G-2	Range and Lower Watershed Management (adj. river upland)	Would increase base flows into Pecos River and its tributaries. Impacts would accrue both above and below Acme, so PBNS habitat may realize part of the benefit. Very difficult to quantify true amount of salvaged water
C-3	On Farm Conservation-FSPA	Most likely little or no effect on Pecos River system in short-term. Long-term affects of curbing groundwater pumping in this area are poorly understood.
E-1	Riparian Veg. Control (Salt Cedar)	Water would accrue into Santa Rosa and Sumner or directly into Pecos in Upper Critical Habitat. Quantifying actual salvage amounts are very difficult. Benefit of salvaged water complicated by Pecos Compact which requires 1/2 of any federally funded salvage to be delivered to Texas.
A-5X	Water Right Purchase-Above Santa Rosa (add. 40% inflat.)	Would create additional inflow into Santa Rosa Reservoir. Measurement and apportionment of retired rights and wet water (vs. CID supply) would require administrative policy.
E-2	Riparian Veg. Control (Replace RO with CW)	Water would accrue into Santa Rosa and Sumner or directly into Pecos in Upper Critical Habitat. Quantifying actual salvage amounts are very difficult. Benefit of salvaged water complicated by Pecos Compact which requires 1/2 of any federally funded salvage to be delivered to Texas.
B-5	Water Right Lease-Above Santa Rosa	Would create additional inflow into Santa Rosa Reservoir augmenting available bypass supply for PBNS. Measurement and apportionment of retired rights and wet water (vs. CID supply) would require administrative policy.
C-5	On Farm Conservation-Above Santa Rosa	Will increase in stream flow and bypass supply for PBNS, but will require saved water is not diverted or turned back. Hard to measure and manage. Will require accounting to segregate saved water from CID supply.
G-6	Range and Upper Watershed Management (forest thinning)	Would cause increase in mostly headwater inflows on main stem Pecos and on tributaries. Very difficult to quantify amounts. Upstream diverters would likely divert additional amounts before they were realized in lower reservoirs.
H-1	Evaporation Suppression (old meth.)-Santa Rosa and Sumner	If feasible, would have a direct benefit to both PBNS and CID. Difficult to quantitatively measure gains in water.
D-3	Change Cropping Patterns-FSPA (Small Grain)	Most likely little or no effect on Pecos River system in short-term. Long-term affects of curbing groundwater pumping in this area are poorly understood.
H-3	Evaporation Suppression (old meth.)-Sumner	If feasible, would have a direct benefit to both PBNS and CID. Difficult to quantitatively measure gains in water.
G-3	Range and Lower Watershed Management (adj. river upland)	Would increase base flows into Pecos River and its tributaries. Impacts would accrue both above and below Acme, so PBNS habitat may realize part of the benefit. Very difficult to quantify true amount of salvaged water
D-5	Change Cropping Patterns-Above Santa Rosa (Small Grain)	Will increase in stream flow, but will require saved water is turned back or not diverted. Hard to measure and manage. Will require accounting to segregate saved water from CID supply.
G-5	Range and Upper Watershed Management (forest thinning)	Would cause increase in mostly headwater inflows on main stem Pecos and on tributaries. Very difficult to quantify amounts. Upstream diverters would likely divert additional amounts before they were realized in lower reservoirs.
G-4	Range and Upper Watershed Management (forest thinning)	Would cause increase in mostly headwater inflows on main stem Pecos and on tributaries. Very difficult to quantify amounts. Upstream diverters would likely divert additional amounts before they were realized in lower reservoirs.
H-2	Evaporation Suppression (old meth.)-Santa Rosa	If feasible, would have a direct benefit to both PBNS and CID. Difficult to quantitatively measure gains in water.
H-4	Evaporation Suppression (new meth.)-Santa Rosa and Sumner	If feasible, would have a direct benefit to both PBNS and CID. Difficult to quantitatively measure gains in water.
H-6	Evaporation Suppression (new meth.)-Sumner	If feasible, would have a direct benefit to both PBNS and CID. Difficult to quantitatively measure gains in water.
H-5	Evaporation Suppression (new meth.)-Santa Rosa	If feasible, would have a direct benefit to both PBNS and CID. Difficult to quantitatively measure gains in water.

5.0 References

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Technical Addendum to the:

Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

New Mexico-Texas Stateline Modeling and Post-Processing Report

January 2006

Prepared by Hydrosphere Resource Consultants, Inc.

HYDROSPHERE
Resource Consultants

TABLE OF CONTENTS

1.0 Introduction

As part of the Pecos River Carlsbad Project Water Operations and Water Supply Conservation NEPA Process, several resource indicators were developed for use in evaluating operational alternatives. This memo addresses the assumptions and methods used to compute impacts to one of those resource indicators, flow at the New Mexico-Texas Stateline, as well as summary results.

The State of New Mexico has obligations to deliver water to the New Mexico-Texas Stateline under the Pecos River Compact. While New Mexico may obtain a credit for over-delivery, it is not allowed to accrue a debt. Although the Compact itself is not indicated as a primary resource of interest as defined in the purpose and need for the EIS, it nevertheless is included as part of the cumulative impacts of the project, and may be a constraining influence on EIS alternatives and a driving force behind requirements for offsetting adverse impacts. Flows at the Texas-New Mexico Stateline are thus a resource of interest and model simulation results are evaluated to determine impacts to this resource.

2.0 Summary of Alternatives Modeling and Post-Processing

To evaluate the impacts of NEPA alternatives to reoperate Sumner Dam for the Pecos Bluntnose Shiner (PBNS), the Hydrology/Water Operations Work Group (HWG) modeled alternatives using the Pecos River Decision Support System (PRDSS) (Hydrology Work Group, 2003 and 2004; Hydrosphere, 2001 and 2005; Hydrosphere and Tetra Tech, Inc, 2003a and 2003b). The PRDSS consists of a RiverWare surface water model, two MODFLOW groundwater models, and an MSAccess-based output post-processor/data reformatter. After the PRDSS was run, model outputs were post-processed, saved in an MSAccess results database, and results for requested resources of interest distributed to EIS work groups. This document focus primarily on the portions of the PRDSS used to simulate the Pecos River from Avalon Reservoir to the Stateline.

3.0 Modeling Stateline Flows

Specific to Stateline flow modeling, a suite of three models and a data processor simulate groundwater and surface water hydrology and operations from Avalon Reservoir to the New Mexico-Texas Stateline. This suite includes the:

- Pecos River RiverWare Model;
- Carlsbad Area Groundwater Model (CAGW);
- The Red Bluff Accounting Model (RBAM); and
- Data Processing Tool (DPT).

Results are stored in an MSAccess database where additional post-processing occurs. Excel results files are dynamically linked to the results database for reporting.

The Pecos River RiverWare Model models diversions from Lake Avalon to the Carlsbad Irrigation District (CID) based on available surface water supplies and CID demand. RiverWare also computes conservation spills and seepage from Avalon Dam. Diversion and seepage values are processed for input to the CAGW groundwater model. Avalon conservation spills are input to the RBAM model.

Individual RiverWare surface water models (run on a daily timestep) and rulesets were created for each alternative (a summary alternative matrix presented in attachment A). Alternatives vary mostly by stipulations for flow targets in the PBNS Upper Critical Habitat and at two target gages. More specific details regarding how alternatives were modeled can be found in the EIS.

The Carlsbad Area Groundwater Model (CAGW) is a 2-layer MODFLOW model that simulates impacts of surface irrigation and well pumping in the Carlsbad area on gains to the Pecos River below Avalon Dam. Diversions to CID from Avalon are translated into components including transit losses, incidental depletions, consumptive irrigation requirements, and return flows. Surface water diversions are used to determine if supplemental well pumping to augment Carlsbad Project supply is required, and the magnitude and timing of the pumping. Seepage from Avalon contributes to the Carlsbad ground water system. Return flows, supplemental pumping and base inflows are then routed through the Carlsbad Basin groundwater system before entering the Pecos River.

The Red Bluff Accounting Model (RBAM) provides a monthly and annual analysis of deliveries to the New Mexico-Texas Stateline, incorporating data from both the CAGW and RiverWare models. It aggregates and applies a 5% transit loss to the daily conservation spills (from RiverWare) from Avalon Dam to the Pecos River. Avalon spills are then combined with the monthly seepage into the Pecos River from the Carlsbad area (from CAGW), other tributary inflows, wastewater treatment plant effluent, and miscellaneous depletions to estimate Stateline flows.

The Data Processing Tool (DPT) handles input/output processing for the movement of data between the RiverWare model, CAGW and RBAM. The DPT calculates well pumping in the basin based on monthly farm deliveries aggregated from RiverWare output. It also calculates other influences on the aquifer including irrigation return flows, delivery seepage, and precipitation recharge, and builds the .WEL and .RCH stress files for input into the CAGW MODFLOW Model (the CAGW model is run separately outside the DPT). The DPT then aggregates the CAGW modeled gains to the Pecos River to monthly values for input into RBAM. RBAM, which resides inside the DPT, uses these data to generate monthly flows at the New Mexico-Texas Stateline, and the DPT then exports the Stateline flows on an annual basis for incorporation into the post-processing database.

The Post-Processing Database stores results for all resource indicators and requested model outputs. Additional post-processing occurs in this database, which is linked dynamically to reporting files.

4.0 Components of Texas-New Mexico Stateline Flows

Within the current suite of models used to model the basin, Pecos River flows at the Texas-New Mexico Stateline are comprised of:

- Avalon Reservoir Conservation Spills (from RiverWare);
- Base inflows and return flows from the Carlsbad area (from CAGW);
- Other tributary inflows between Avalon Dam and the Red Bluff gage (from RBAM); and
- Delaware River Inflows (from RBAM)

Fixed Stateline Components

Other than gains estimated from the CAGW model and Avalon conservation spills from RiverWare, inflows to the Pecos River between Avalon and the Stateline do not change between NEPA alternatives. Data sources for these inflows are many and include: gage data, data backed out from gage data, and results of regression analyses. Fixed inflows include the following:

- Dark Canyon Arroyo;
- Black River;
- Waste Water Treatment Plant WWTP) Effluent; and
- Delaware River.

Black River inflows are calculated in the DPT as Black River above Malaga gaged flows minus Black River canal diversions. Additional details can be found in the Pecos River Data Processing Tool Report (PR DPT) (Hydrosphere, 2005).

Variable Stateline Components

Avalon conservation spills and CAGW gains are not fixed and are influenced by a variety of factors, which change according to operational alternative.

Avalon Conservation Spills: Under all NEPA alternatives, the only downstream releases from Avalon Dam are conservation spills. Spills may occur when an individual reservoir's conservation storage limit is exceeded or when the total Carlsbad Project storage is exceeded. The magnitude and frequency of spills may be influenced by operational changes, such as timing of block releases or bypass flows for Pecos Bluntnose Shiner habitat.
Under cumulative impacts, additional releases from Avalon for the "Settlement Agreement[9]" would allow the New Mexico Interstate Stream Commission to release their share of Carlsbad Project water rights from Avalon downstream to the Stateline under certain conditions. Settlement Agreement releases were not modeled for this EIS.

CAGW Gains: CAGW gains are affected by a variety of factors including CID demands and deliveries, supplemental well pumping, and groundwater baseflows. When Carlsbad Project surface water supplies are low, "supplemental pumping" of groundwater is used to supplement supplies. This causes additional depletions to the return flows from irrigation, as well as depletions to the native groundwater that would otherwise seep into the Pecos River. Return flows from CID and base inflows from the underlying aquifer contribute significantly to Pecos River flows below Lake Avalon.

5.0 Net Depletions to the "New Mexico-Texas Stateline Flows" Resource Indicator

Model simulation results are not intended to predict future hydrologic conditions; rather they predict differences in hydrologic conditions in the basin resulting from different management actions. The evaluation process involves simulating a "baseline" scenario (the Pre-91 Baseline alternative) as well as alternative scenarios that represent operational changes. This provides a baseline condition for the resource indicators against which impacts caused by changing operations may be evaluated. Basin operational rules are then modified to reflect each proposed alternative scenario. The "net depletions", or loss of water, under an alternative

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[9] Entered into on March 25, 2003 by the state of New Mexico, the New Mexico Interstate Stream Commission, the United States of America, the Carlsbad Irrigation District, and the Pecos Valley Artesian Conservancy District.

scenario as compared to the Pre-91 Baseline is used here to represent this change in the "value" of the resource. Net depletions are shown as positive numbers when there is an adverse impact. A negative net depletion signifies a gain in water under the proposed alternative scenario. Net depletions to Stateline flows are the decrease in flows at the New Mexico-Texas Stateline for an alternative in comparison to the Pre-91 Baseline model run which does not include bypasses for the fish.

Net depletions to Stateline flows are primarily impacted by changes to CAGW gains below Avalon Dam and changes to spills from Avalon Dam. If an alternative impacts the delivery of water to CID, CAGW gains are impacted. If an alternative affects the magnitude of spills from Brantley Dam (and Avalon Dam) as conservation or project storage limits are exceeded, Stateline flows are affected. Average annual net depletions to Stateline flows were determined for each alternative.

In modeling alternatives, RiverWare block release rules were not adjusted to reflect changes in operational policies which may occur as a result of bypasses. As a result, the timing of modeled spills may be unrealistically skewed. To eliminate large variations in spills between individual years, Carlsbad Project net depletions were "corrected". Modeled spills from Avalon Dam during that year were subtracted and the average annual spills were added. Net depletions to Stateline flow (corrected) are calculated as:

$$\mathbf{\begin{matrix}\text{Annual Corrected}\\ \text{Net Depletion to}\\ \text{Stateline Flows}\end{matrix} = \begin{matrix}\text{Annual Net}\\ \text{Depletion to}\\ \text{Stateline Flow}\end{matrix} - \begin{matrix}\text{Annual Net}\\ \text{Depletion to}\\ \text{Avalon Spills}\end{matrix} + \begin{matrix}\text{60 Year}\\ \text{Average Net}\\ \text{Depletion to}\\ \text{Avalon Spills}\end{matrix}}$$

Figure 1 shows Stateline net depletions before and after being "corrected" for the Taiban Constant alternative. Prior to being corrected, annual net depletions fluctuated greatly between years. By correcting net depletions annual values were smoothed. Average annual net depletions remain the same under both methodologies. All Stateline net depletions presented in the EIS are "corrected".

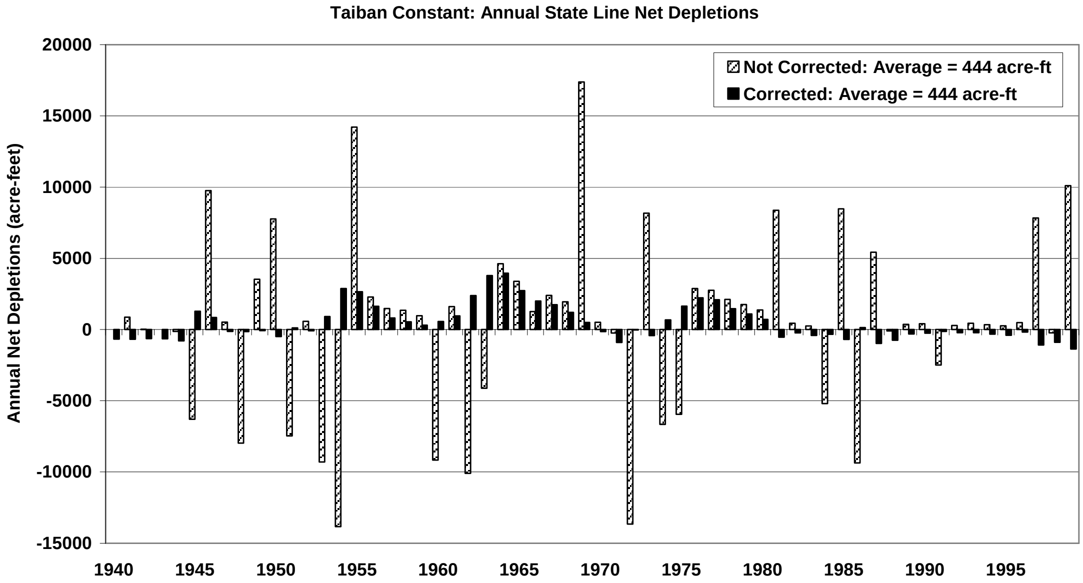

Figure 1. Comparison of annual “corrected” and “not corrected” Stateline net depletions

6.0 Bypass Operations Stateline Results

Figure 2 shows the average annual net depletions to Stateline flow results, rounded to the nearest 100 acre-feet, for bypass operations model simulations with additional results provided in Table 1. Figure 3 demonstrates the correlation between the average annual depletion and the effective Acme flow target[10]. The results show that alternatives with higher flow targets tend to exhibit higher net depletions. Acme Constant, Acme Variable and Taiban Variable HRS[11] alternatives exhibit the highest average annual net depletions to Stateline flows, whereas the Taiban Constant and Critical Habitat Alternatives yield the lowest net depletions.

Looking at the specific components of Stateline flows (Table 1), all bypass alternatives showed net depletions to CAGW gains. As Carlsbad Project supply decreases, supplemental pumping increases leading to lower return flows. Fewer diversions to CID also lead to smaller return flows from irrigated lands. These decreases were slightly offset by fewer spills for most alternatives, with the exception of No Action and Taiban Variable HRS.

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[10] The effective Acme flow target is the alternative's flow target expressed at Acme. For alternatives with Acme targets, this the flow target. For alternatives with flow targets at other locations, targets are converted to Acme flows taking river gains and losses into account.

[11] The Taiban Variable alternative has summer targets which vary. The alternative identified as Taiban Variable HRS has a summer target of 55 cfs. The MRS alternative has a summer target of 45 cfs and the LRS alternative has a summer target of 40 cfs.

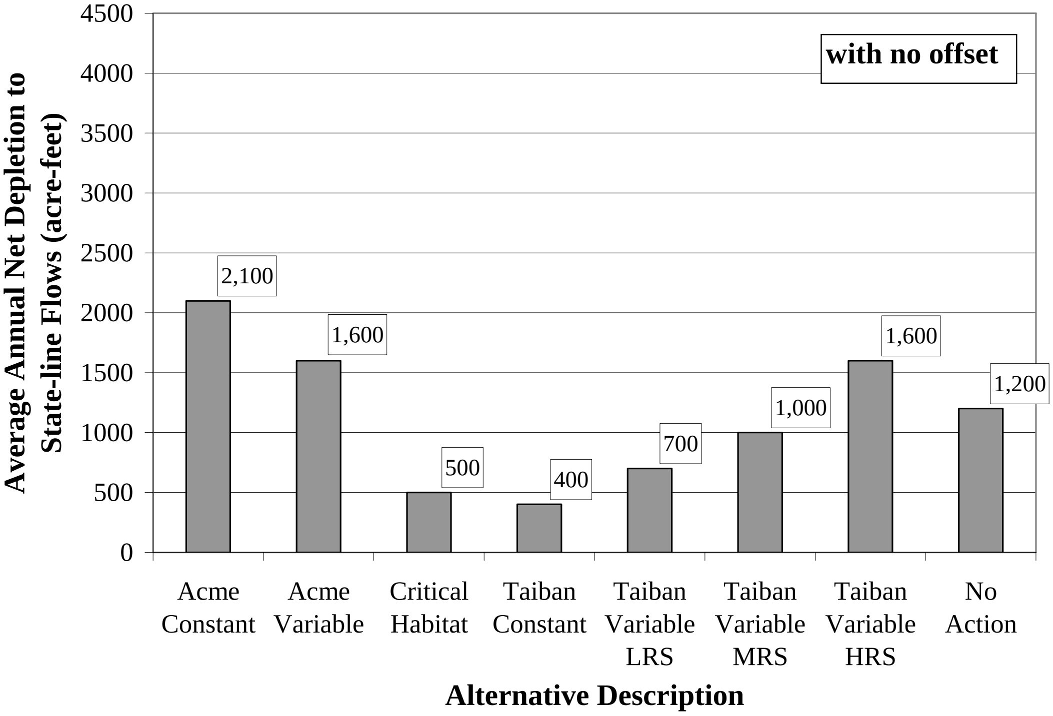

Figure 2. Average Annual Net Depletions to Stateline Flows for Each Alternative with No Water Offset

Table 1: Annual Stateline flow and selected component results

	Net Depletions to Stateline Flows and Components [1] (acre-feet/year)						
	60-year Averages			Max. and Min. Net Depletions to Stateline Flows			
Alternative / Baseline	Stateline Flows	CAGW Gains	Avalon Conservation Spills	Maximum Net Depletion to Stateline Flows	Maximum Occurs in Modeled Year	Minimum Net Depletion to Stateline Flows	Minimum Occurs in Modeled Year
Pre-91	NA	NA	NA	NA	NA	NA	NA
Acme Constant	2100	3000	-920	5400	1976	-1200	1941
Acme Variable	1600	2300	-720	4900	1976	-1000	1941
Critical Habitat	530	1100	-580	4000	1964	-1300	1999
Taiban Const.	440	1100	-660	4000	1964	-1400	1999
Taiban Var. LRS	690	1100	-400	4400	1964	-1100	1999
Taiban Var. MRS	1000	1300	-320	4600	1976	-770	1999
Taiban Var. HRS	1600	1400	210	5300	1964	-150	1950
No Action	1200	1200	13	3000	1975	-440	1941

[1] Results are presented with two significant figures; subsequently, summed components do not exactly match the totals.

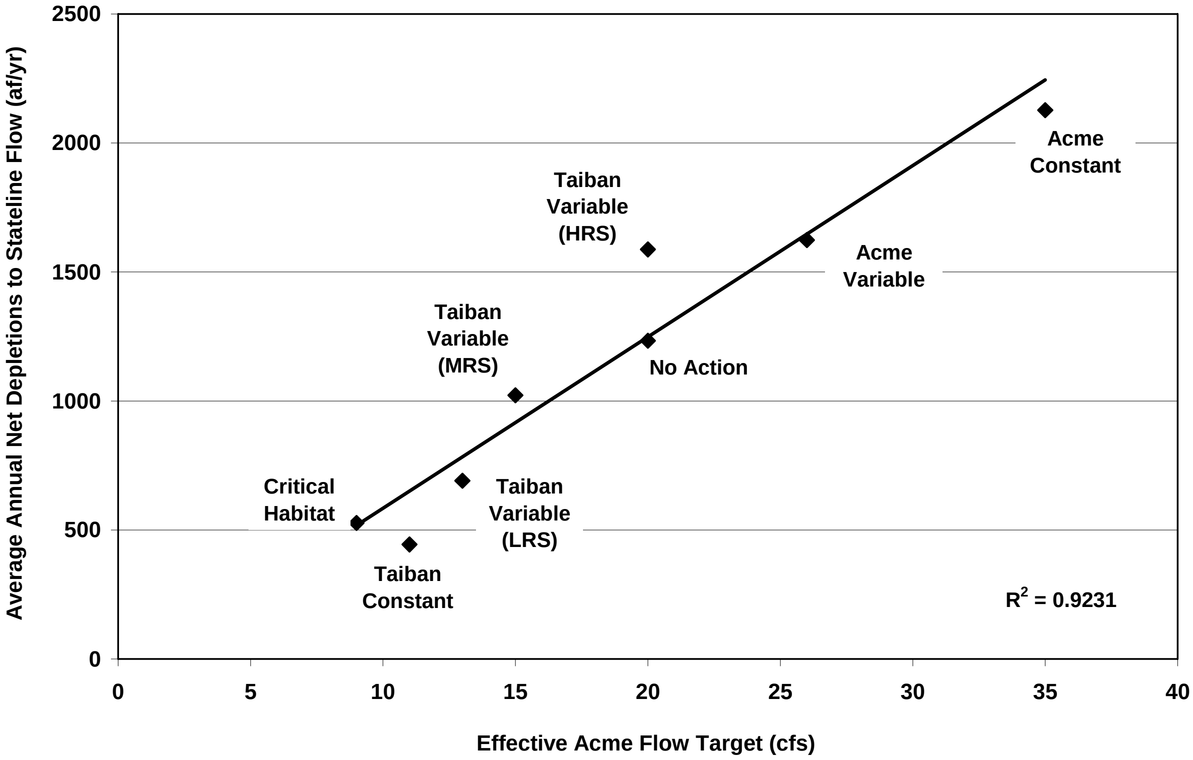

Figure 3. Average annual net depletions to Stateline flows as a function of effective Acme flow target.

7.0 Stateline Flows for Alternatives with Water Acquisition Options

One of the purposes of the Proposed Action is to conserve the Carlsbad Project water supply. Therefore, net depletions to the Carlsbad Project's supply caused by bypass operations to benefit the PBNS need to be "offset." Options for acquiring additional water (CPWA options[12]) were developed explicitly for the purpose of offsetting net depletions to the Carlsbad Project water supply caused by the re-operation of Sumner Dam for the Pecos bluntnose shiner.

7.1 Modeling Selected "A-List" CPWA Options to the Stateline

CPWA options were evaluated for how effective they were in offsetting net depletions to the Carlsbad Project. Regarding impacts on Stateline flows, generally, if an option offsets the net depletion to the Carlsbad Project supply, the net depletion at the Stateline would also be reduced. However, if the offset water source is directly from retirement of water rights within the Carlsbad Project or changes to CID cropping patterns, CAGW gains to the river are impacted. Additional spills may not make up for the decreases in CAGW gains downstream from Avalon Dam. For these reasons, offset options involving retirement of Carlsbad Project water rights or changes to CID cropping patterns were modeled to the Stateline.

To determine the effect of water offsets (CPWA) options on Stateline flows, the PRDSS was run to the Stateline for several A-list CPWA options in combination with three of the bypass

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[12] Carlsbad Project Water Acquisition options

operations alternatives (Taiban Constant, Acme Constant, and Pre-91 Baseline). Table 2 shows the combinations of fish alternatives and CPWA options which were evaluated in the “first tier” of model simulations. These CPWA options were selected as those most likely to show a significant impact to Stateline flows, and to provide a range of impacts within which other similar CPWA options would be expected to fall. To maximize potential impacts, CID 3,000 acre retirement options, rather than 1,500 acre scenarios, were modeled. Assumptions used to model these CPWA options to the Stateline are listed under “Modeling Assumptions/Notes” in Table 2. Note that water applied to acreage with new crop patterns (very low and medium water use) is assumed to be fully consumed so there are no return flows to the river from these lands.

Table 2. Water acquisition options modeled to the Stateline

Fish Alternative / CPWA Combo	Modeling Assumptions/Notes
Very Low Water Use CID Crop Pattern	Expected maximum net depletion of all CID crop CPWA options. Cropping pattern change applied to 25% (5,000 of 20,000 acres) of CID’s irrigated land. Reduction in consumptive irrigation requirements (CIR) is assumed to be fully consumed by new crops. Main/lateral losses are accounted for, but there are no on-farm incidental depletions or return flows. Delivery efficiency is unchanged. Lands under very low water use crops are not irrigated by supplemental wells.
Medium Water Use CID Crop Pattern	Expected minimum net depletion of all CID crop CPWA options. Cropping pattern change applied to 25% (5,000 of 20,000 acres) of CID’s irrigated land. Reduction in consumptive irrigation requirements (CIR) is assumed to be fully consumed by new crops. Main/lateral losses are accounted for, but there are no on-farm incidental depletions or return flows. Delivery efficiency is unchanged. Lands under medium water use crops are not irrigated by supplemental wells.
3000 CID acres retired (actual only)	Actual irrigated acreage reduced from 20,000 acres to 17,000 acres, with no reduction in allotment acreage (25,055 acres). Retired lands are not irrigated by supplemental wells.
3000 CID acres retired (actual, and entitlement by constant)	Actual irrigated acreage is reduced from 20,000 acres to 17,000 acres, with a reduction in allotment acreage from 25,055 to 22,055 acres. Retired acreage water is redistributed to other irrigators. Retired lands are not irrigated by supplemental wells.

After the RiverWare model was run[3] for the specified CPWA options, the water diverted to new crops was subtracted from total CID diversions in the DPT. The remaining diversions were applied to acreage under the original crop pattern. Because water applied to new crop patterns was assumed to be fully consumed and no supplemental pumping occurred on new crop acreage, this water was not considered when determining CAGW gains. Supplemental pumping was calculated by comparing CID deliveries (diversions minus canal losses) to lands under the original crop pattern to the unmet allotment entitlement. The CAGW model was then run using those surface water and pumping stresses, and the modeled stream gains generated by CAGW were run through the Red Bluff Accounting Model to estimate Stateline Flows.

7.2 CPWA Stateline Modeling Results

Table 3 shows the average annual net depletions (rounded to two significant digits) to Stateline flows and primary components for the CPWA options which were modeled to the Stateline. Net Depletions to Stateline flows, Avalon spills and CAGW gains were calculated by subtracting CPWA options results from the Pre-91 Baseline results. Gains to Stateline flow due to offsets were calculated as the alternative’s net depletion (e.g., Acme Constant with bypass operations

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[3] For specifics on RiverWare modeling of CPWA options, see the Pecos River RiverWare Model Offset Modeling Documentation Report (Tetra Tech, 2005)

only) minus the net depletion for the alternative’s CPWA options (e.g., Acme Constant Very Low Water Use CID Crop Pattern).

Table 3. CPWA Offset Modeling: Stateline Results

CPWA Offset Modeling: Stateline Results[1]				
	Average Annual Net Depletions (AF/yr)			Gains to Stateline Flow Due to Offset
Alternative and CPWA Option	Stateline Flow	Avalon Spills	CAGW Return Flows	
Acme Constant (without offset--used for offset determination):	2100	-920	3000	NA
Taiban Constant (without offset--used for offset determination):	440	-660	1100	NA
Pre-91(without offset--used for offset determination):	NA	NA	NA	NA
Acme Constant w/L-3 Very Low Water Use CID Crop Pattern:	-220	-4900	4400	2300
Taiban Constant w/L-3 Very Low Water Use CID Crop Pattern:	-2200	-5100	2700	2600
Pre-91 w/L-3 Very Low Water Use CID Crop Pattern:	-3100	-6500	3000	3100
Acme Constant w/L-4 Medium Water Use CID Crop Pattern:	3200	-2500	5600	-1100
Taiban Constant w/L-4 Medium Water Use CID Crop Pattern:	1300	-2700	3900	-840
Pre-91 w/L-4 Medium Water Use CID Crop Pattern:	830	-2900	3600	-830
Acme Constant w/3000 CID acres retired (actual only):	-17	-3600	3400	2100
Taiban Constant w/3000 CID acres retired (actual only):	-2300	-4500	2000	2700
Pre-91 w/3000 CID acres retired (actual only):	-2900	-4800	1700	2900
AC w/3000 CID acres retired (actual, and entitlement by constant):	-900	-2500	1500	3000
TC w/3000 CID acres retired (actual, and entitlement by constant):	-3000	-2900	-210	3500
Pre-91 w/3000 CID acres retired (acutal, and entitlement by constant):	-3500	-3200	-450	3500

[1] Results are only presented with two significant figures; subsequently, summed components do not exactly match the totals presented in this table.

When looking at results, it is the CPWA option’s relative impact on spills and CAGW gains that determines whether there is a depletion to Stateline flows. The very low water use CID crop pattern and both land retirement options all resulted in increased Stateline flows. The medium water use CID crop pattern options are the only CPWA options which led to net depletions to Stateline flows. For the medium water use crop pattern options increases in spills were not sufficient to offset decreases in CAGW gains. Compared to the very low water use crop pattern CPWA options (which saw increases in Stateline flows), more water was diverted to medium water use crop pattern acreage and fully consumed, leaving less available in storage for future diversions or to spill.

CID land retirement options positively affected average annual Stateline flows, with increases ranging from 17 acre-ft/year for the Acme Constant w/3000 CID acres retired (actual only) option to 3,500 acre-ft/year for the Pre-91 Baseline w/3000 CID acres retired (actual, and entitlement by constant) option. Land retirement options where the total irrigated acreage was also reduced (“actual, and entitlement by constant” options) led to slightly greater Stateline flows than for land retirement options where the irrigated acreage was not reduced (“actual only” options). Spills from Avalon reservoir increased under all land retirement options, with greater increases for “actual only” options. Water from retired lands was not redistributed to other irrigators for “actual only” options leaving more water in storage and increasing the likelihood of a spill. Related to this are the net depletions to CAGW gains for all “actual only” retirement options. Less water was applied to irrigated lands so less water returned. All of the “actual, and entitlement by constant” options showed net increases to CAGW gains. This is because water from retired lands was redistributed and allocated to other irrigators which led to slight increases in gains.

Within each set of results (without offset, very low water use crop pattern, medium water use crop pattern, “actual only” retirement, and “actual, and entitlement by constant” land retirement) there are consistent relationships between the Pre-91 Baseline, Acme Constant and Taiban Constant alternatives. Increases to Stateline flows are smallest for the Acme Constant and greatest for Pre-91 Baseline options. Though net depletions are positive for medium water use crop pattern options, this pattern of less water at the Stateline for the Acme Constant alternative, followed by Taiban Constant and the Pre-91 Baseline alternatives persists.

8.0 References

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ATTACHMENT A: Summary Alternative Matrix

Carlsbad Project Water Operations and Water Supply Conservation EIS Alternatives												
	{-----------------Range of Flows ----------------------}						{----------------------------------Block Releases-------------------------------}					
	{-----Dry-----}		{-----Average-----}		{---Wet---}							
Alternative Designation	**Winter Target**	**Summer Target**	**Winter Target**	**Summer Target**	**Winter Target**	**Summer Target**	**Duration**	**Frequency**	**Magnitude**	**Ramp Down**	**Delivery**	**Time of Year**
Taiban Constant	35 cfs @ Taiban	35 cfs @ Taiban. Use pumps to prevent intermittency @ Acme	35 cfs @ Taiban	35 cfs @ Taiban. Use pumps to prevent intermittency @ Acme	35 cfs @ Taiban	35 cfs @ Taiban. Use pumps to prevent intermittency @ Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Taiban Variable	35 cfs @ Taiban	45cfs, -5, +10 @Taiban.	35 cfs @ Taiban	45cfs, -5, +10 @Taiban.	35 cfs @ Taiban	45cfs, -5, +10 @Taiban.	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Acme Constant	35 cfs Acme	35 cfs Acme	35 cfs Acme	35 cfs Acme	35 cfs Acme	35 cfs Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Acme Variable	35 cfs Acme	12 cfs Acme	35 cfs Acme	24 cfs Acme	35 cfs Acme	48 cfs Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
Critical Habitat	35 cfs Taiban Minimum	Critical Habitat Kept Wet; Avoid Intermittency @ Acme	35 cfs Taiban Minimum	5 cfs Acme	35 cfs Taiban Minimum	10 cfs Acme	15 day max	On CID demand, but space out as long as possible	On CID demand	None	Maximum Efficiency	On CID demand – avoid releases during 6 weeks around August 1st
No Action (Current Operations, 2003-2006 Biological Opinion)	35 cfs Acme	Upper Critical Habitat Kept Wet; Avoid Intermittency @ Acme	35 cfs Acme	20 cfs Acme	35 cfs Acme	35 cfs Acme	15 day max at peak. 65 days per year.	Space out to 14 + days apart	1200 cfs	None	Maximum Efficiency	No winter. On CID demand

Notes:

Reflects screening by the Alternatives Workgroup on 9/18/03 with 9/24/03 input from the Biology Workgroup and changes from 12/04/03 meeting.

Screening focused on flows and releases. Specific habitat restoration and conservation measures were not evaluated.

Unless specified differently in an alternative, all alternatives would have the following actions incorporated: (Some may require additional project-specific NEPA analysis)

- ✓ Offset all depletions through actions and priorities developed by the WOOG Group.
- ✓ Establishment and management of a conservation pool in Fort Sumner and Santa Rosa Reservoirs.
- ✓ Creation of a management plan addressing monitoring of the flow targets and establishing procedures, mitigative actions and sources of water available in case flow targets are threatened.
- ✓ Execution of an agreement document among the agencies governing the conservation pool and adaptive management plan

The following conservation actions would be considered by the appropriate agencies: (Some may require additional project-specific NEPA analysis)

- ✓ Continue to develop wells and pumping infrastructure to respond for the need to supplement flows in the short-term.
- ✓ Continue to remove non-native riparian vegetation.
- ✓ Restore natural channels to provide better riparian habitat.

*Net Depletions are calculated by comparing to historic, pre-fish operations

Technical Addendum to the:

Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

Roswell Artesian Basin Ground Water Model Technical Report

January 2006

Prepared by Hydrosphere Resource Consultants, Inc.

HYDROSPHERE
Resource Consultants

1.0 INTRODUCTION

Modeling of groundwater in the Roswell Artesian Basin was performed for support of NEPA alternatives impact analysis. This document provides a description of that modeling effort, focusing on:

- Identification and description of the numerical model used in the analysis
- Key modeling assumptions for both the baseline model, as well as the Carlsbad Project water acquisition option that involved both retirement of groundwater rights in the Roswell basin and development of a well field to augment Pecos River flows, and
- Resource indicators evaluated.

For additional information about the Roswell Artesian Basin Groundwater Model (RABGW) refer to the Roswell Artesian Basin Groundwater Model Documentation (Hydrosphere, 2003).

2.0 RABGW MODEL

For the NEPA alternatives impact analysis, the 2004 release of the S. S. Papadopolus & Associates (SSPA) historical (1900-2001) RABGW model was the starting point for developing the 60-year model used for NEPA scenarios. The RABGW model was developed in MODFLOW, the general groundwater modeling code developed by the USGS.

The RABGW model has its origin in the work of Ms. Amy Lewis, who spent several years (including work on her MS thesis at New Mexico Tech) compiling Roswell basin hydrogeologic data and information and working on the model. In 1995, working for DB Stephens & Associates, Lewis published a “Comprehensive Review and Model of the Hydrogeology of the Roswell Basin” (DBS&A, 1995). Known as the “Lewis Model” by the Office of the State Engineer (OSE) employees, Ms. Lewis’ product was a two-layer MODFLOW-based model that simulated flow in both the shallow alluvial and the deep artesian aquifer for the time period between 1967 and 1990. Since that time, Keyes (2001) of the OSE enhanced the Lewis model by refining the calibration, modifying recharge sources boundary conditions, and compiling historic pumping files all the way back to 1900. Most recently, the SEO contracted with SSPA to refine and improve the model further by adding a third layer that represents the confining bed between the shallow and deep aquifers, improving the treatment of evapotranspiration, and extending the end of the simulation period from 1990 to 2001.

3.0 MODELING ASSUMPTIONS FOR IMPACT ANALYSIS

The NEPA alternatives analyses for the Carlsbad Operations EIS involves numerous assumptions and adaptations from the historical model. The overarching assumption is that conditions in the future are best represented by current conditions in the Roswell Basin, as represented by the period from 1990 through 2000. With this global assumption understood, one can begin to identify and develop particular assumptions required to implement the global assumption.

Particular assumptions adopted include:

- A 60-year simulation period, with the historical hydrology from 1940 through 2000 used to provide the hydrological inputs. This assumption was also made for the RiverWare model which the RABGW model is linked to.
- To honor the global assumption that the 1990s level of development in the basin are representative of expected future conditions, adjustments to the historical evapotranspiration (ETS), river (RIV), and well (WEL) input files were made as described in detail in separate sections below.
- Using January 1, 2000 modeled heads as an initial condition

As noted in the second bullet above, several changes had to be made to the historical model inputs for NEPA use. The existing MODFLOW2000 input files had to be modified to represent the 60-year time period. The hydrologic conditions from the time period 1/1/1940 to 12/31/1999 were chosen, and the MODFLOW2000 input files DIS, RCH, ETS, DRN, OC, WEL, and RIV were modified to represent this time period. Additionally, the January 1, 2000 heads were extracted from the historical model output and the BAS file was modified to use them as initial head conditions for the 60-year NEPA model.

3.1 ETS Input File Changes

Assumptions on how to treat evapotranspiration in MODFLOW2000 are addressed in the ETS input file. As described above, one exception related to the historical hydrology inputs is that the evapotranspiriation (ET) represented in the historical calibration model will not be used. Prior to 1950 in the SSPA historical model a multiplier was used to properly simulate long-term changes in the amount and area of groundwater ET. During that period, there was a great deal of ponding of water from flowing artesian wells which led to greatly enhanced ET compared to current conditions. To account for this fact in the historical calibration model, SSPA (2003) applied an ET enhancement factor to the model. This magnitude of ET has not occurred for several decades, nor is it ever expected to occur again. Given that the NEPA 60-year model scenarios were to be representative of current and proposed future conditions, the ET multipliers for the 1940 to 1950 time period were removed to be consistent with post-1950 conditions.

3.2 RIV Input File Changes

In the RABGW model, groundwater interactions with the Pecos River (including McMillan and Brantley reservoirs) are addressed in MODFLOW's RIV input file. The historical RABGW model had a monthly varying Brantley stage from 1/1/1989 when Brantley came online through 9/30/2001. The RIV file needed to be changed such that Brantley was operated for the entire 60-year simulation to be representative of the current and future scenario conditions. A sensitivity analysis was done to determine the most appropriate method for extrapolating Brantley stage for the 60 year simulation time period. Four separate model runs were made for the 1989-2001 time period using four different approaches for treating the Brantley stage:

- the original monthly stage values,
- a yearly average stage,
- a monthly average stage (i.e. all 13 years Jan, Feb, etc. values were averaged), and
- an overall average stage.

As the Acme to Artesia baseflows are the primary resource indicator for the NEPA analysis, the difference in baseflows was used to determine which approach of these four approaches to simulating Brantley stage was best. Figure 1 shows the resultant baseflows for the four approaches. Table 1 is a summary of the average difference between the baseflows for the three proposed methods and the actual monthly varying baseflows. All three scenarios had an average difference in baseflows of less than 3 acre-feet/year. Given these results, the overall average stage was chosen and implemented in the NEPA 60-year model due to its simplicity and the lack of model sensitivity.

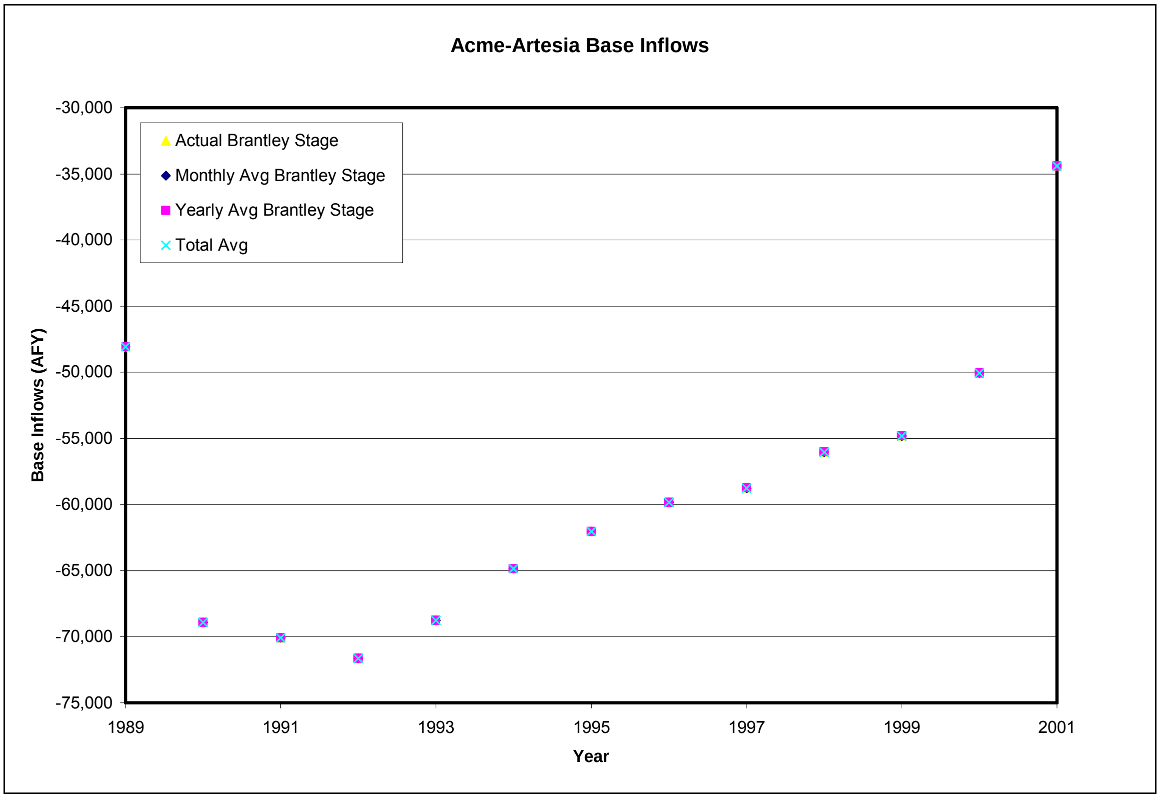


Figure 1. Annual base inflows for Brantley stage sensitivity analysis.

Table 1. Average annual difference in computed base inflows for Brantley stage sensitivity analysis; each column compares baseflows computed using actual monthly stage to stage computed as average monthly, average annual, and overall total average over 12-yr period of record.

Average Difference in Base Inflows (AFY)		
(Actual-Monthly)	(Actual-Yearly)	(Actual-Total)
2.90	0.02	2.82

3.3 WEL Input File Changes

In MODFLOW2000, well pumping is specified through the WEL input file. Pumping in the Roswell Basin is the key anthropogenic stress to the hydrological system, and is also one of the model inputs that may experience perturbations in future management alternatives considered in the EIS.

3.3.1 Historical Pumping

Historical pumping in the Lewis model was compiled from available data for the 1967 through 1990 period. Complete metered data on well pumping was only available after 1966. The Keyes model expanded the historical pumping data back to 1900. The historic annual pumping rates prior to 1966 were estimated from information in Mower (1960). In the Keyes model, annual pumping was simulated from 1900 through 1929, after which the model became seasonal with six-month stress periods as in the Lewis model. The irrigation season six-month stress period includes April 1 through September 30 and is sometimes referred to with the word “summer”. The non-irrigation season runs from October 1 to the end of March and was also sometimes referred to as the “winter” season. Pre-1967 simulated seasonal pumping percentages for the shallow aquifer were distributed to 98.7% in the summer and 1.3% in the winter, and percentages for the artesian aquifer were distributed to 95.8% in the summer and 4.2% in the winter. The estimated historical pumping was later updated by the SEO for the period 1989 to 1998 and by SSPA with data provided by the SEO for the period 1990 to 2001. The SSPA enhancements also included applying pre-1930 pumping to the summer 6-month stress period. Figure 2 shows the estimated annual historical pumping in the basin from 1900 through 2000 as simulated in the RABGW model.

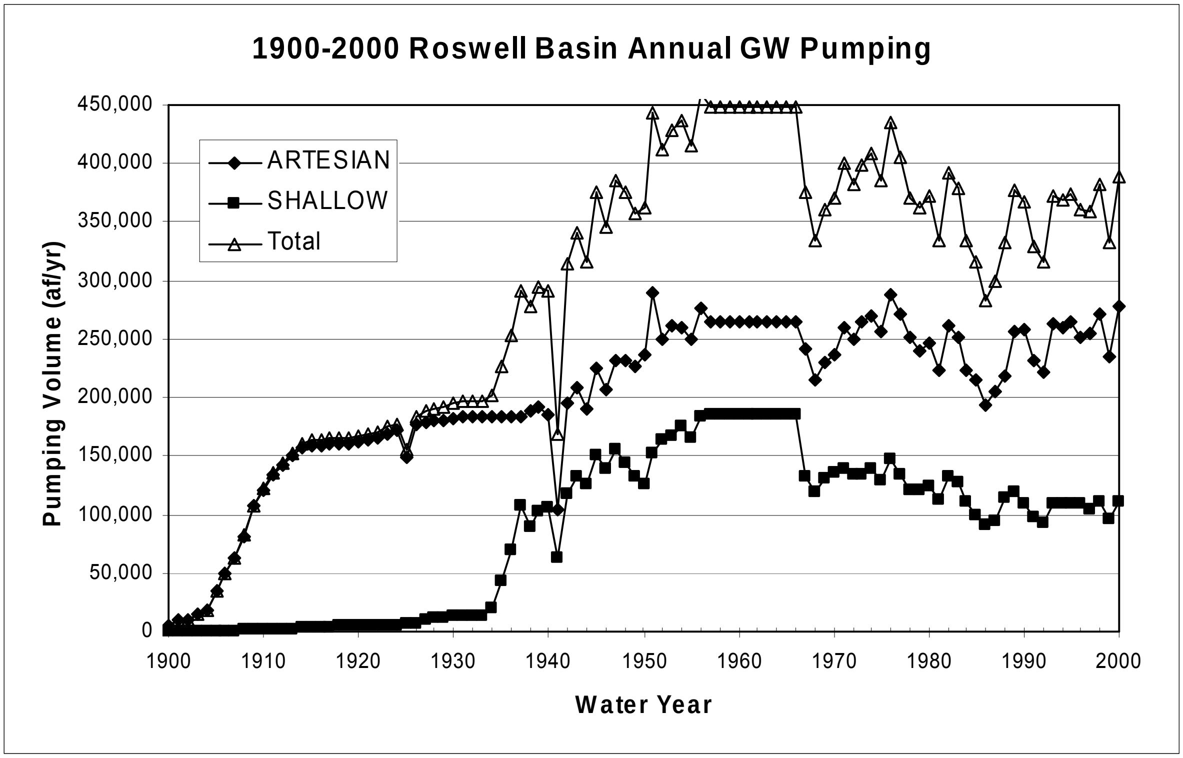


Figure 2. Estimated historical pumping from the Roswell Basin aquifers.

3.3.2 Return Flows

Annual return flows were computed as described by Keyes (2001) using the same method originally employed in the Lewis model: 33% of the total irrigation pumping in any given cell is returned to the uppermost active layer. Return flows from surface water irrigation is distributed only to lands irrigated with surface water (e.g., Hagerman Irrigation Company lands; see p. 5-42 and Fig. 5-23 in DBS&A, 1995). Return flows were simulated as uniformly returning at the same rate for both summer and winter seasons.

3.3.3 NEPA Baseline Pumping

For the NEPA analyses, EIS alternatives were simulated for a 60-year simulation period, with most hydrological inputs taken from the 1940 though 2000 historical record and initial conditions based on January 2001 observations. However, pumping from the Roswell basin aquifers exhibited significant evolution of that historical period (Figure 2), and the historical pumping record is not anticipated to reflect future pumping conditions in the basin. For example, the period between 1900 and the mid-1970s saw explosive growth in pumping from an initial value of near-zero to its maximum historical values on the order of 450,000 af/year during the drought periods of the 1950s and 1970s.

The 60-year baseline pumping was developed based on the guiding principle that the most recent (1991 through current) conditions are most representative of expected future conditions. As illustrated in Figures 3 and 4, the 60-year baseline pumping is changed from the historic such that:

- The pre-1967 artesian pumping is based on the correlation between post-1967 pumping and precipitation (Fig. 3). This is due to the fact that pumping prior to 1967 was inferred from ancillary data (as there was no metering of wells), and that total pumping in the basin was still on a growth trajectory during the period from 1940 through the 1950s.
- The shallow pumping is based on the correlation between 1991-2000 artesian and shallow pumping (Fig. 4), due to the fact that shallow pumping in this period was reduced in conjunction with water rights retirement efforts by Pecos Valley Artesian Conservancy District (PVACD) and the New Mexico Interstate Stream Commission (NMISC) in the late-1980s and early-1990s.

From the regressed lines associated with these correlations, we can develop a new time series of total pumping for the 60-yr baseline period; Figure 5 shows the total baseline pumping developed using this approach compared to the estimated historical pumping in the basin.

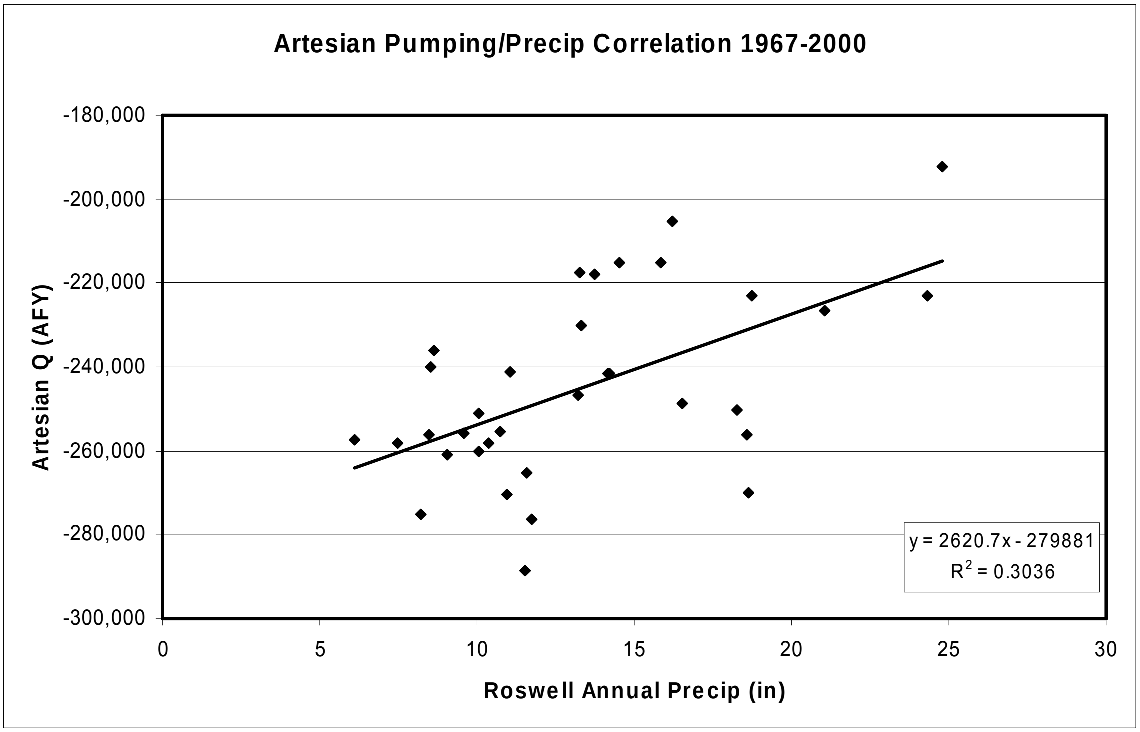


Figure 3. Correlation between post-1967 artesian pumping and precipitation.

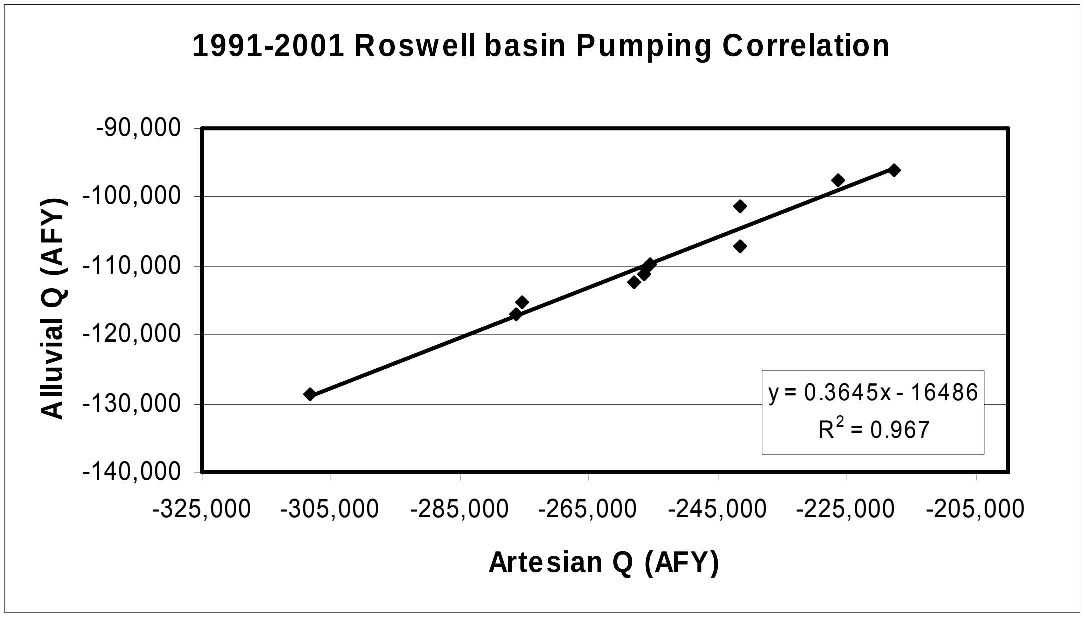


Figure 4. Correlation between 1991-2000 artesian and shallow pumping.

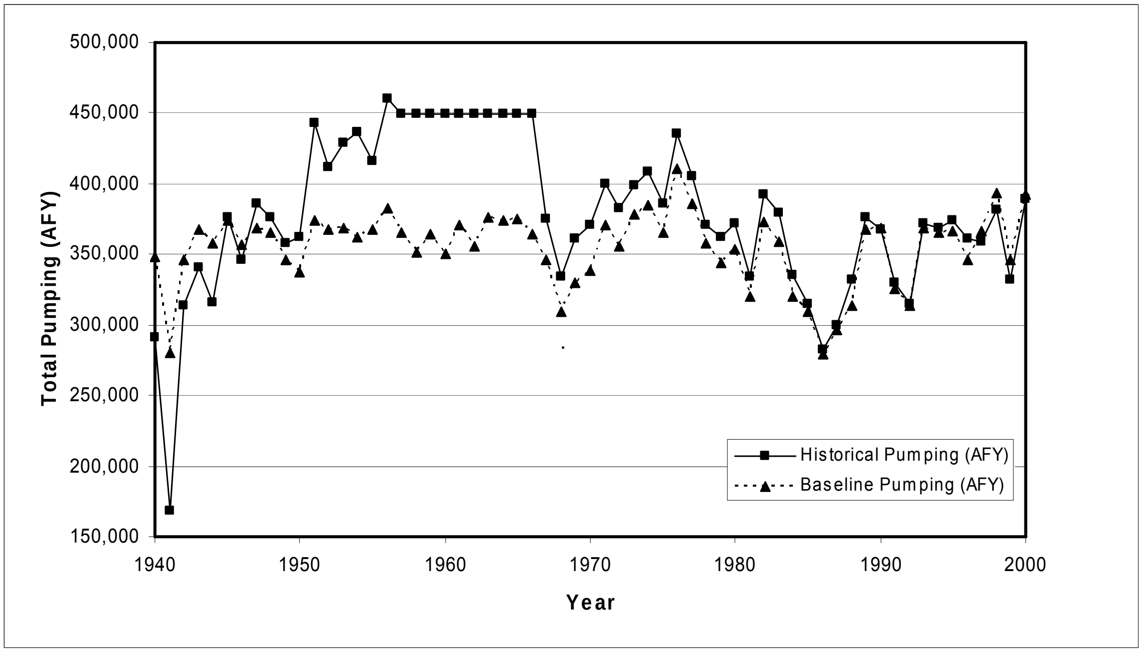


Figure 5. Total baseline and historical pumping for 60 year period.

To implement the basin-wide pumping changes to each grid cell in the model domain, the estimated historical pumping in each cell is adjusted using a time-varying scaling factor, S_b. The scaling factor is computed for each year as the ratio of the total pumping volume in the future baseline case, $V_{baseline}$, to the historical pumping volume, $V_{historic}$:

$$S_b = \left[\frac{V_{baseline}}{V_{historic}} \right] \qquad \text{(Eq. 1)}$$

Thus the total pumping for each year in the baseline model is simply S_b times $V_{historic}$, and the pumping in each grid cell is:

$$Q_{pump}^{baseline} = Q_{pump}^{historic} S_b \qquad \text{(Eq. 2)}$$

Return flows are also adjusted based on a scaling constant. The new return flows are applied only to existing return flow cells. All return flows are applied in the uppermost active model layer.

This pumping baseline was applied to all EIS alternatives, as groundwater operations were specified to be the same across all alternative. Only for the CPWA Augmentation Well Field Option did simulated pumping deviate from this baseline. In that case, pumping was adjusted at the locations of the proposed well fields, with a pumping schedule for the well field dictated by the RiverWare model-estimated depletions associated with bypass operations to meet the flow targets for each alternative (see next section).

3.3.4 NEPA CPWA Well Field Alternatives Pumping

The Carlsbad Project water acquisition (CPWA) well field option considered changes in pumping associated with water rights retirement and pumping to augment Pecos River flows ("augmentation pumping") and thus offset depletions caused by Sumner bypasses to meet flow targets. The modeled CPWA well field operations described here were implemented with the Acme Constant and Taiban Constant alternatives. Pumping associated with these future scenarios was developed using the 60-year baseline pumping distribution and multipliers calculated (similarly to Eqn. 1) from augmentation pumping and water rights retirement spreadsheets. For example, if 10% of the irrigated land in the basin is subject to retirement, then a pumping multiplier of 0.9 could be applied uniformly across the basin.

The particular water rights retirement and augmentation pumping scheme involved in the CPWA well field scenarios included:

- *the retirement of 10,000 acre-feet of consumptive use retirement in PVACD, with 73% of the acres irrigated by the deep artesian aquifer and 27% of the retired acreage irrigated by pumping from the shallow alluvial aquifer*. Water Rights Retirement was applied uniformly to all existing pumping and return flow cells (except Western Boundary Recharge cells, as this component of recharge is treated through the WEL file).
- *the well fields were assumed to have an annual pumping capacity of 12,100 AF/year or 33.14 AF/day. The Pecos River RiverWare model was used to compute the initial pumping amounts (see p. C-4 of the Offset Modeling Technical Appendix)*. Specific locations were identified for augmentation pumping from the proposed Seven Rivers and Buffalo Valley well fields, and direct adjustments to the pumping input file were applied to these specific locations. No return flows were applied from augmentation pumping. Figure 6 shows the augmentation pumping time series used for modeling the CPWA well field options with alternatives.

The decreased pumping resulting from the water rights retirement is used to develop a net change in pumping from the baseline. These values are then utilized in conjunction with the baseline pumping and multipliers to scale prescribed pumping and return flows in the model using a time-varying scaling factor, S_{retire}. The scaling factor is computed for each year as the ratio of the total pumping volume in the future for the retirement case, V_{retire}, to the historical pumping volume, $V_{baseline}$:

$$S_{retire} = \left[\frac{V_{retire}}{V_{baseline}} \right] \qquad \text{(Eq. 3)}$$

Thus the total pumping for each year in the baseline model is simply S_{retire} times $V_{baseline}$, and the pumping in each grid cell is:

$$Q_{pump}^{retire} = Q_{pump}^{baseline} S_{retire} \qquad \text{(Eq. 2)}$$

Return flows are also adjusted based on a scaling constant. The new return flows are applied only to existing return flow cells. All return flows are applied in the uppermost active model layer.

This results in a new water rights retirement - augmentation well field WEL input file for the RABGW MODFLOW model. The initial monthly augmentation pumping amounts computed using the Pecos River RiverWare model were put into units of ft^3/day and added to the water rights retirement well input file as 10 wells in the location of the proposed well field with evenly distributed pumping. Figure 7 shows the historical pumping together with baseline and action-alternative pumping for these scenarios.

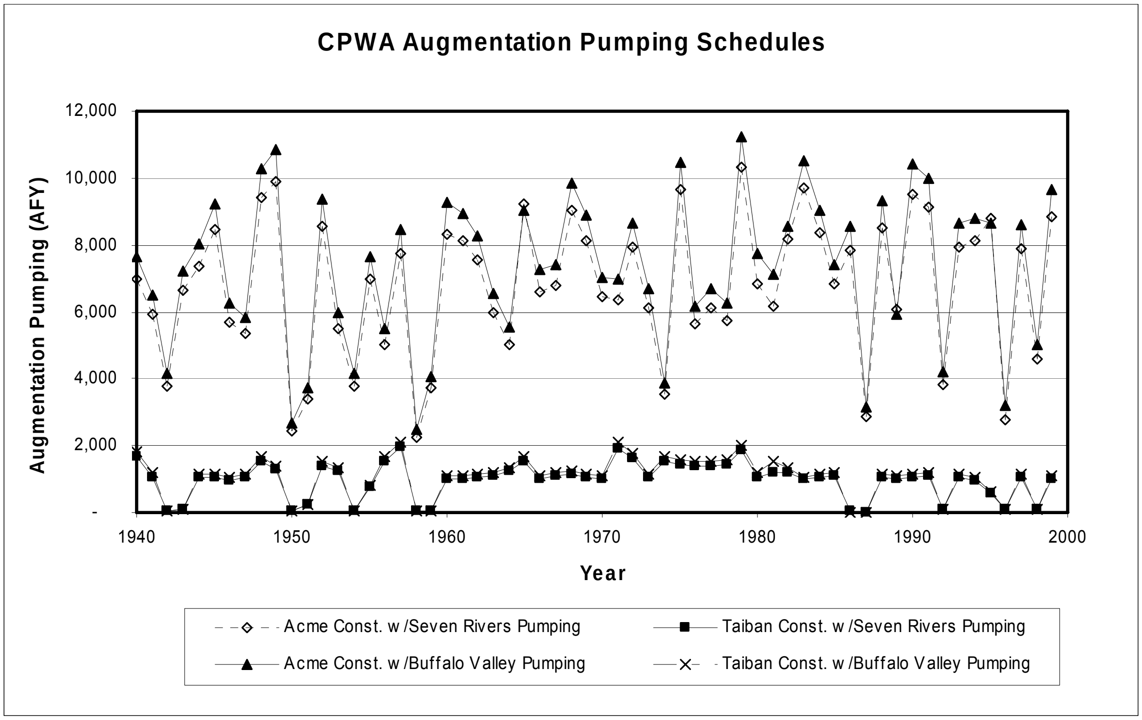


Figure 6. Augmentation pumping schedules for the CPWA well field scenarios.

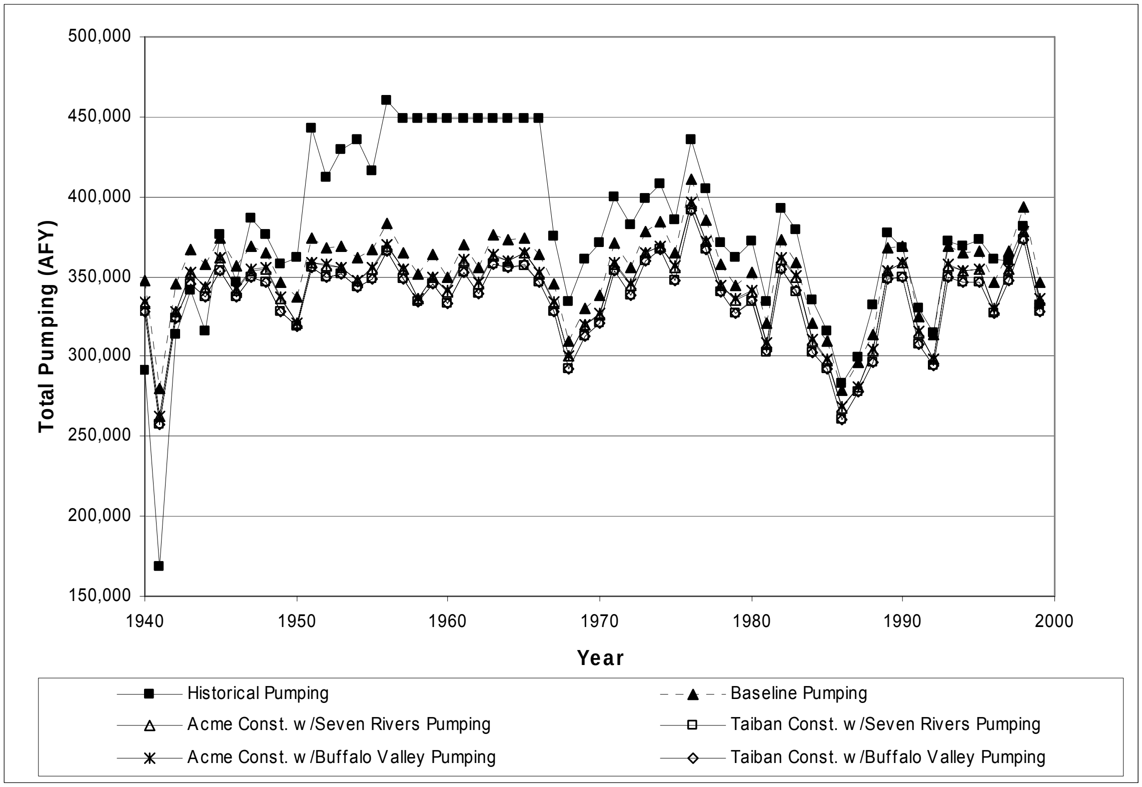


Figure 7. Total pumping for the historical, baseline, and CPWA well field scenarios.

4.0 RESOURCE INDICATORS FOR IMPACT ANALYSIS

Two resource indicators were employed to assess impacts to the basin from the EIS alternatives, aquifer storage and base inflows to the Pecos River**.**

4.1 Aquifer Storage

While well hydrographs can provide insight into the impacts of pumping changes in the basin on the water elevations at a few selected locations, a broader measure of the impact to the aquifers resulting from changes in the pumping regime is the aquifer storage. Figure 8 shows the aquifer storage for the shallow alluvial and deep artesian aquifers for the baseline and CPWA well field scenarios.

4.2 Base Inflows to the Pecos River

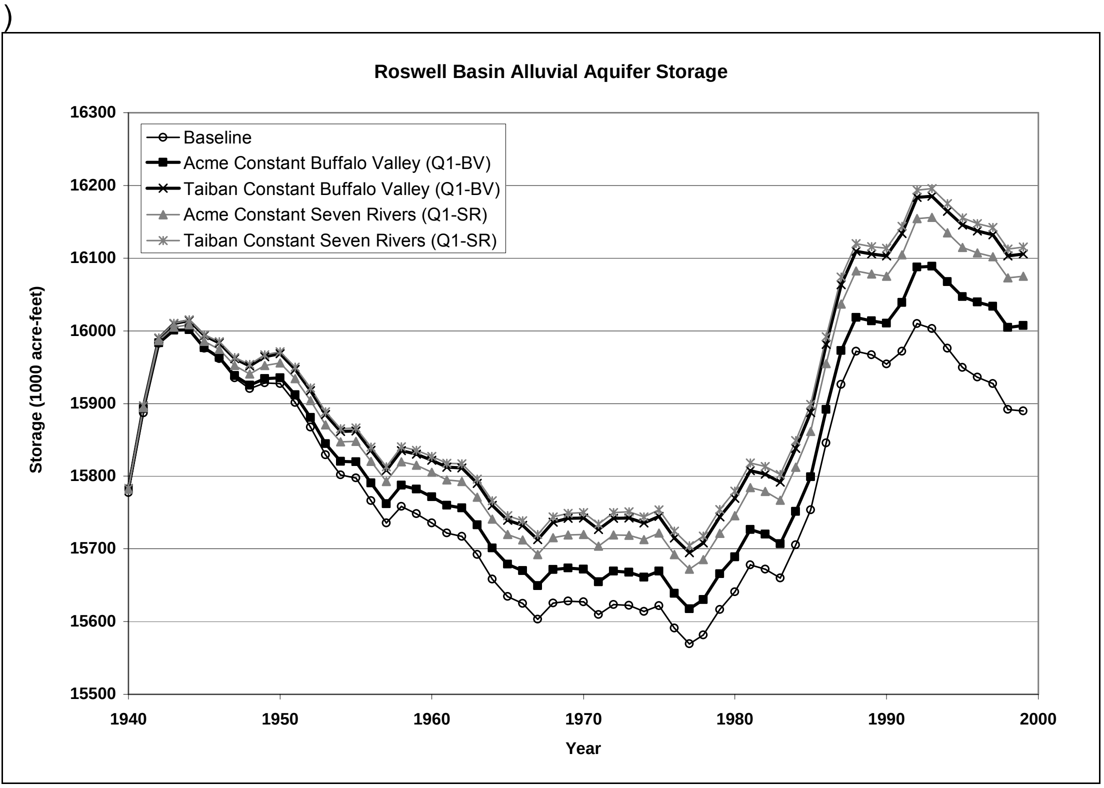
The base inflows to the river for the Acme to Artesia reach represent one of the key performance indicators of impacts of operational changes in Roswell Basin pumping on the system. Based on historical gage flow records, the Acme to Artesia reach has consistently experienced baseflow gains over the period of record, although it has varied significantly over the years as described in the next paragraph. The Artesia to Brantley reach, on the other hand, exhibits interannual variability between gaining and losing conditions (generally in the range between 6,000 af/yr loss and 500 af/yr gain). Thus, it is the Acme to Artesia reach that was selected as the resource indicator of interest.

To illustrate the importance of the Acme to Artesia baseflow resource indicator, note that under predevelopment conditions, base inflows to the river approached 100,000 af annually, and that groundwater pumping has reduced annual amounts to values on the order of 20,000 to 30,000 af per year (Fig. 9).

For the CPWA Roswell Basin groundwater option, reductions in groundwater pumping associated with water rights retirement will accrue to the river (as increased base inflows) over time, and those increased base inflows will be captured in Brantley Reservoir. Conversely, the augmentation well field pumping associated with this potion will reduce base inflows to the Pecos. Because the amount of consumptive-use retirement exceeds the average CPWA well field pumping, there will be a net increase in baseflows under this CPWA option. This is clearly illustrated in Figure 10, which shows the time series of annual base inflows for the baseline and CPWA well field scenarios. Note that in a permutations of this CPWA option, Acme to Artesia baseflows to the river increase over the baseline. The Acme Constant – Buffalo Valley well field permutation stands apart from the other permutations for this CPWA option, due the fact that the Acme Constant alternative requires greater augmentation pumping (Figure 6) in conjunction with the fact that the Buffalo Valley well field is located immediately adjacent to the Acme-Artesia reach (whereas the Seven Rivers well field is located immediately adjacent to Brantley below Artesia).

Finally, given CID's overall efficiency and the fact that return flows from CID enter the river below Carlsbad, nearly 50% of this net increase in base inflows (as well as increases in river flows due to the augmentation well field pumping) above Brantley can ultimately be realized as Pecos Compact stateline deliveries.

A.)



B.)

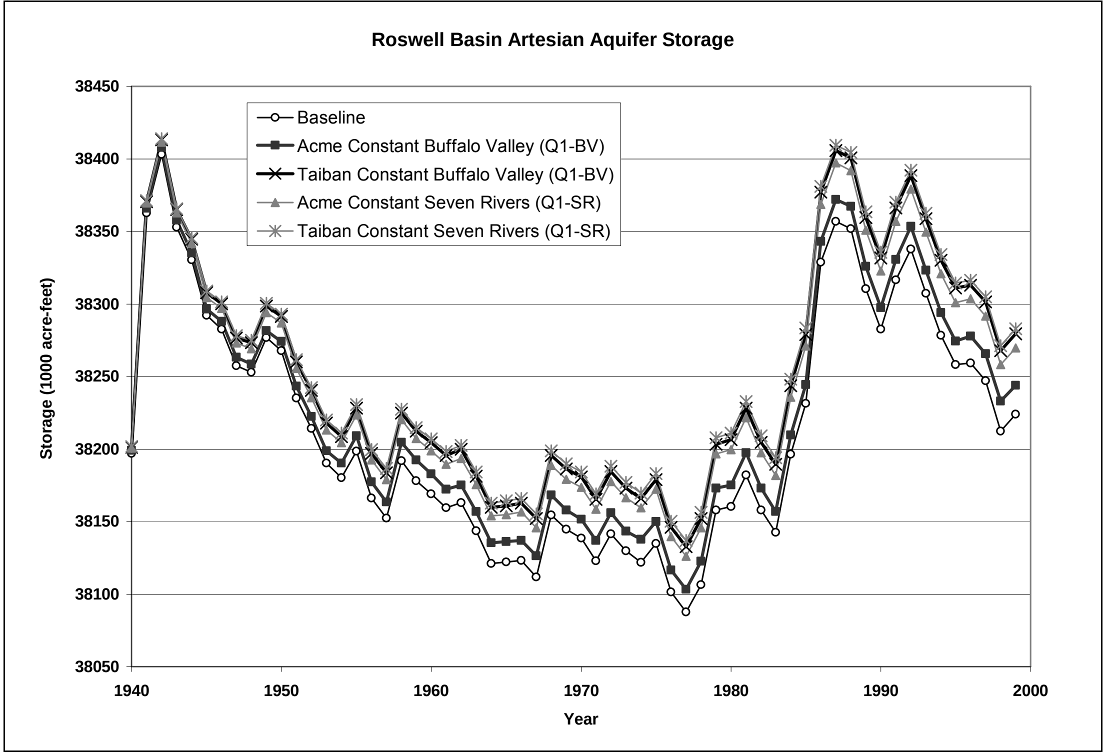
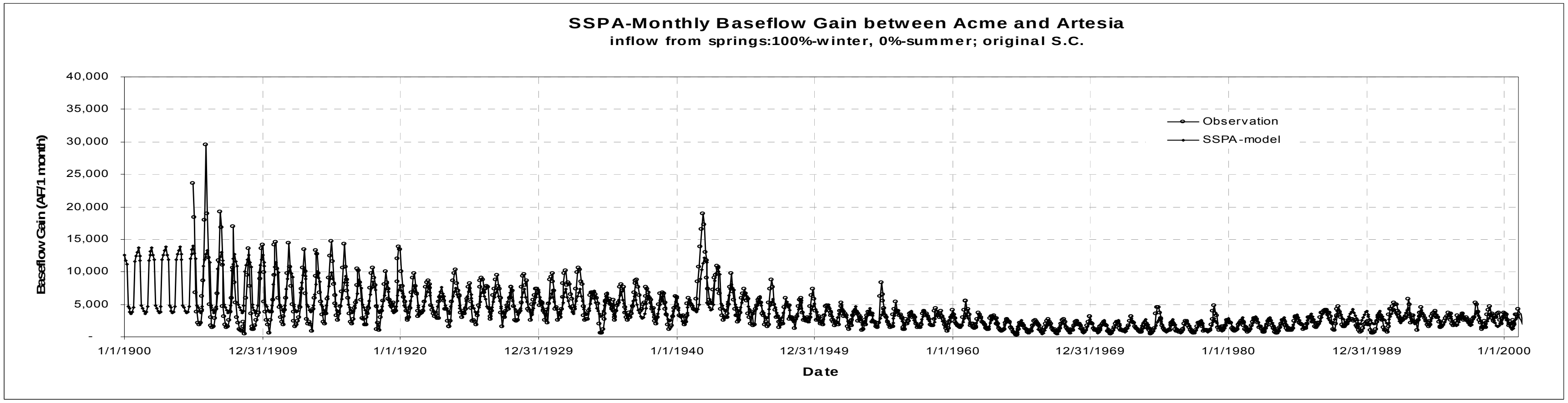


Figure 8. Storage for the Baseline and CPWA scenarios for the A.) Alluvial and B.) Artesian aquifers.

A.)



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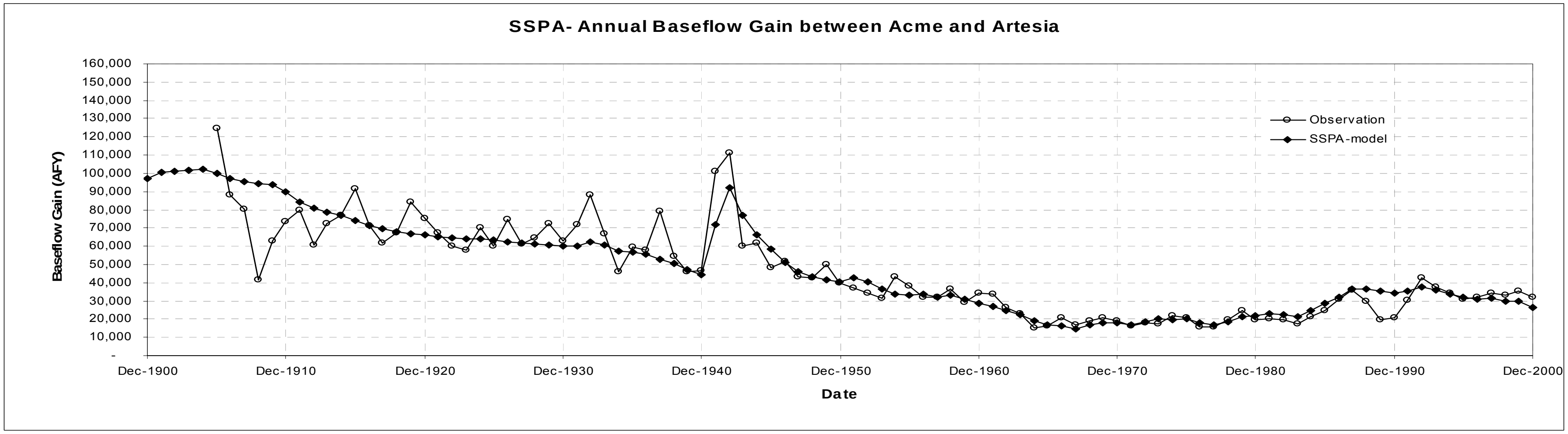

Figure 9. Observed and computed baseflow gain A) monthly and B) annual (from SSPA, 2003)

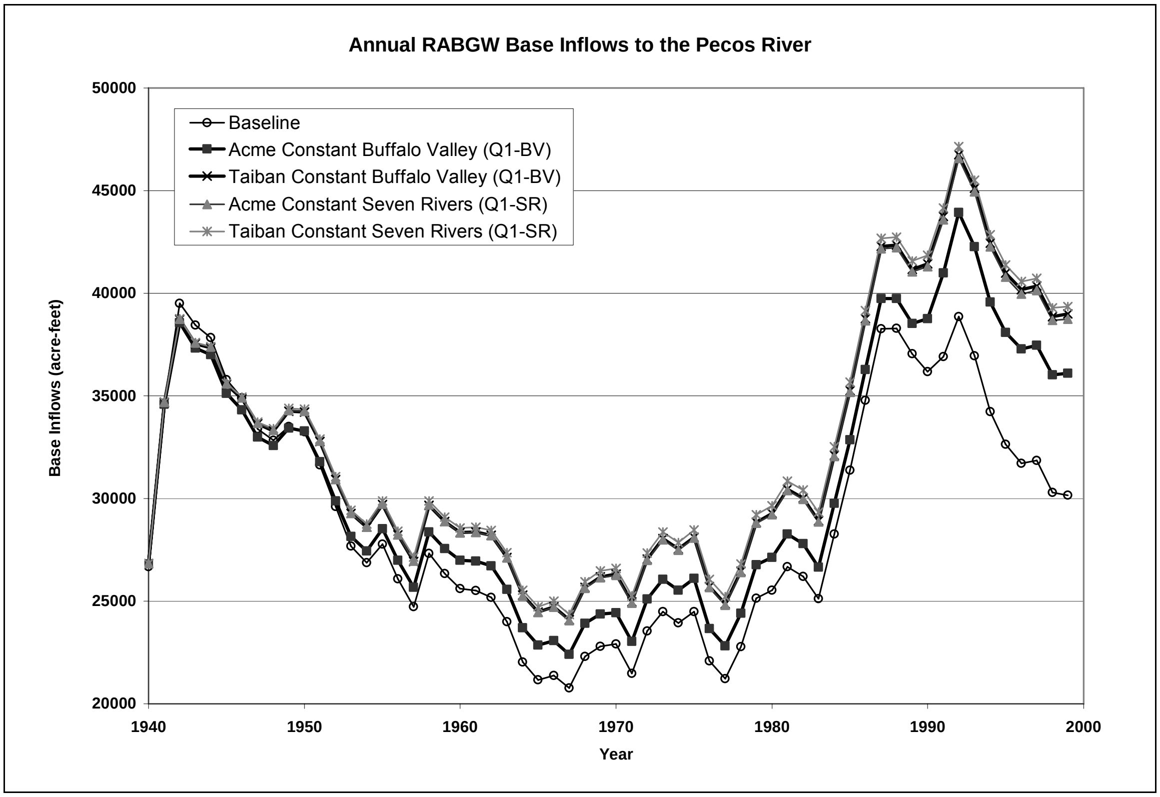

Figure 10. Annual base inflows for the Baseline and CPWA scenarios.

5.0 SUMMARY AND CONCLUSIONS

This document summarizes the groundwater modeling approach, assumptions, and results for evaluating the impacts of the EIS alternatives on groundwater resources in the Roswell Basin. None of the alternatives contemplated changes in groundwater pumping operations in the Roswell Basin, with the exception of the CPWA well field option that involved both retirement of groundwater rights, as well as development of a well field to pump groundwater to the river to help offset depletions that results from re-operations associated with the alternatives. The modeling results show that both aquifer levels and baseflows to the Pecos River increase for the CPWA well field option compared to the baseline.

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Technical Addendum to the:
Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement
Analysis of Intermittency

January 2006

Prepared by Hydrosphere Resource Consultants, Inc.

HYDROSPHERE
Resource Consultants

1.0 INTRODUCTION

This memorandum summarizes findings regarding intermittency trends and confidence interval calculations with respect to RiverWare model predicted and United States Geological Survey (USGS) actual gage flow. A summary of the calculations performed and an overview of the results are provided.

RiverWare model predicted or *model flow* refers to modeled river flow as output from the RiverWare model, which consists of daily model predicted values of Pecos River flow from January 1940 to December 1999. *USGS actual gage* or *gage flow* refers to stream flow data obtained from the USGS website for the relevant gage. Within this memorandum, the following gages are discussed:

- Acme gage, located along the Pecos River near river mile (RM) 600, approximately 106 miles downstream from Sumner Dam and approximately 26 river miles below the end of the Pecos Bluntnose Shiner (PBNS) upper critical habitat.
- Dunlap gage, located at RM 638.9, approximately 28 miles above the end of the upper critical habitat.

This memorandum includes descriptions of major tasks in three sections:

- Acme Gage
    - Confidence Intervals
    - Probability of Intermittency
- Dunlap Gage
    - Confidence Intervals
    - Probability of Flow Range
- Intermittency Trends by Hydrologic Season
    - Acme Intermittency
    - Length of Acme Intermittency

2.0 ACME GAGE

This section summarizes findings regarding confidence intervals with respect to RiverWare model predicted flow at Acme gage for the historical (calibration) model. Also, residual distributions are applied to estimate the expected probability of flow intermittency at the Acme gage.

This summary includes descriptions of two major tasks:

- Section 2.1 Confidence Intervals
    - Confidence interval calculations using the original model, gage, and residual data, and assuming a normal distribution.
    - A check of the above method using a random number generator and lookup table. This synthetically generated data set was then examined statistically and confidence intervals were calculated.
    - Confidence interval calculations using the original model, gage, and residual data, and assuming a lognormal distribution.
- Section 2.2 Probability of Intermittency
    - Probability of intermittency calculations.

2.1 Confidence Intervals

When dealing with “real” data sets, a statistical analysis including calculation of confidence intervals can be useful in giving an estimated range of values which is likely to include the unknown parameter, based on historical data. The width of the confidence interval gives an indication of how certain you are about the unknown parameter. Confidence intervals may be calculated at different percentage levels, the most common being percentage being 95% confidence.

2.1.1 Basic Statistics and Confidence Intervals (assuming a normal distribution of data)

RiverWare model predicted and USGS gage flow data from the Acme gage were used to calculate confidence intervals of model residuals. The model residual is defined as the model flow minus the gage flow; a negative residual corresponds to a case where the gage flow was larger than the model flow.

Basic statistics for residuals were calculated for defined modeled flow ranges for the Acme gage (for bins of 0-4, 4-8, 8-16, 16-25, 25-35, 30-40, 35-45, and 45-60 cfs). The statistics included total number of data points (N), sample mean (x), variance (σ^2), and standard deviation (σ).

Confidence intervals were calculated based on the assumption that the residuals have a normal distribution. Two different approaches, the Gaussian and Student-t, were used.[13] Results from the Student-t approach are presented, since both methods produced similar results with the large sample size. *Table 1* summarizes the statistics of each flow range and associated confidence interval that was calculated.

The following procedure was used (from Moore and McCabe, 2003; Ang and Tang, 1975):

- The original data (model flow, gage flow, and residual) was separated into bins based on model flow.
- Basic residual statistics (N, x, σ^2, and σ) were calculated for each bin.
- The appropriate t-critical value (t*), based on the desired level of confidence, was looked up in a table.
- The confidence interval for the estimated mean residual was calculated using the following equation:

$$CI = \left(\sigma / \sqrt{N} \right) \times t^* \qquad \textit{Equation 1}$$

Table 1. Summary statistics and confidence intervals of residuals calculated for modeled flow ranges at the Acme gage. Negative values indicate that gage flows are higher than model flows.

Modeled Flow Range (cfs)	Total number of data points, *N*	Mean Residual, *x* (cfs)	Variance, σ^2 (cfs^2)	Standard Deviation, σ (cfs)	95% Confidence Interval (+/- cfs)	99% Confidence Interval (+/- cfs)
0-4	3,503	-11.2	825.8	28.7	0.98	1.31
4-8	2,136	-8.6	780.9	27.9	1.22	1.63
8-16	3,854	-5.6	707.4	26.6	0.87	1.16
16-25	2,663	-4.4	654.5	25.6	1.00	1.34
25-35	1,716	-3.8	951.8	30.9	1.51	2.01
30-40	1,369	-1.3	757.3	27.5	1.50	2.01
35-45	1,098	-2.1	822.6	28.7	1.75	2.34
45-60	997	-8.1	1451.7	38.1	2.44	3.26

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[13] As a general note on calculating confidence intervals, the Student-t method *must* be used when dealing with small samples (those of size 30 or below). For larger sample sizes, the Gaussian method as an approximation to the Student-t confidence interval is appropriate. The difference between the methods arises from the t-critical value which is used, or t*.

2.1.2 Synthetically Generated Residual Data Set

A data set of residuals for the 0-4 cfs modeled flow range was synthetically generated in order to perform a check of the above calculations. The following procedure was used:

- A uniform random number was generated between 1 and N. This was done N times (3,503 in this case) so that the generated data set was the same size as the original.
- The lookup function in Microsoft Excel was used to find the original residual ranking corresponding to this randomly generated number. This original residual was then added to the synthetically generated residual set until all the randomly generated numbers were expended.
- Basic statistics for this generated residual data set were calculated using the same procedure described in Section 2.1.1.

For the sake of time and efficiency, only one modeled flow range was examined. The 0-4 cfs modeled flow range was chosen because this is the most critical range to understand when evaluating modeled intermittency frequency, which is most likely to occur in this flow range. Resulting statistics and confidence intervals are very similar to that of the original data set (*Table 2*).

Table 2. Summary statistics and confidence intervals of residuals calculated for generated residual data.

Flow Range (cfs)	Total number of data points, *N*	Mean Residual (cfs)	Variance (cfs^2)	Standard Deviation, σ (cfs)	95% Confidence Interval (+/- cfs)	99% Confidence Interval (+/- cfs)
0-4	3,503	-11.5	925.5	30.4	1.04	1.39

2.1.3 Basic Statistics and Expanded Confidence Intervals (assuming a lognormal distribution of data)

Considering the possibility that the residual data may not be normally distributed, a closer inspection revealed that the data was in fact skewed to the left, and appeared to have a lognormal distribution (*Figure 1*). Generally speaking, many of the residuals fell along a “tail” to the left (negative), which corresponds to gage flow larger than model.

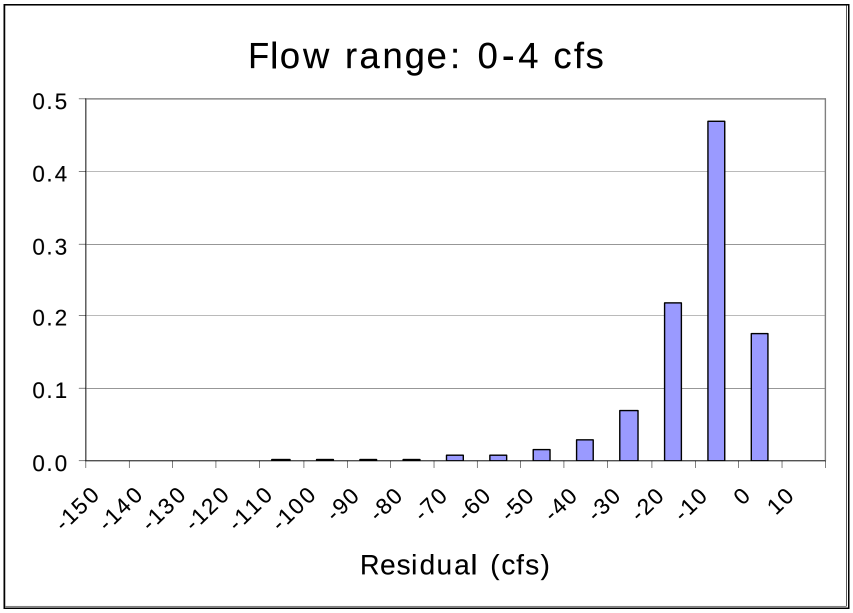


Figure 1. Histogram of model residual data illustrating the lognormal distribution which is skewed to the left. Note that not the entire graph is not shown in this figure; the actual minimum and maximum residual of the original data set were -845.7 and 4.0 cfs, respectively.

Basic statistics were calculated for the 0-4 cfs flow range. The lowest 8 residual values (0.02% of the data set) were not used in the calculations, as they were determined to be outliers. *Table 3* summarizes the statistics of the 0-4 cfs flow range. The median is higher than the mean of the data set, which typically indicates a skewed data set. The results are similar to the above analysis which assumed a normal distribution (*Table 2*), but these statistics provide a better representation of the data given the clear skewness of the distribution (Figure 1).

Table 3. Summary statistics of residuals calculated for log transformed residual data at the Acme gage, 0-4 cfs modeled flow range.

Modeled Flow Range (cfs)	Total number of data points, *N*	Mean (cfs)	Median (cfs)	Variance (cfs^2)	Standard Deviation, σ (cfs)
0-4	3,795	-10.1	-5.9	317.3	17.8

The Student-t method was used to calculate *confidence intervals* at a wide range of levels. The confidence interval at 50% confidence is +/- 1.23 cfs; at 99.9% confidence, the interval is +/- 2.92 cfs (*Table 4*). Keeping in mind that the total range of data is 837 cfs, the calculated confidence intervals are relatively small. *Figure 2* is a graphic representation of the magnitude of confidence intervals at various levels of confidence in the form of a probability distribution function (PDF) for the Confidence Interval Model. As expected, both *Table 4* and *Figure 2* show that at high levels of confidence, the corresponding confidence interval is larger than at low levels of confidence.

Table 4. Range of confidence levels and corresponding intervals for log transformed residual data in the 0-4 cfs modeled flow range.

Confidence Level (%)	10	20	30	40	50	60	70	80	90	95	99	99.9
+/- cfs	0.40	0.76	0.96	1.12	1.23	1.29	1.37	1.48	1.66	1.84	2.26	2.92

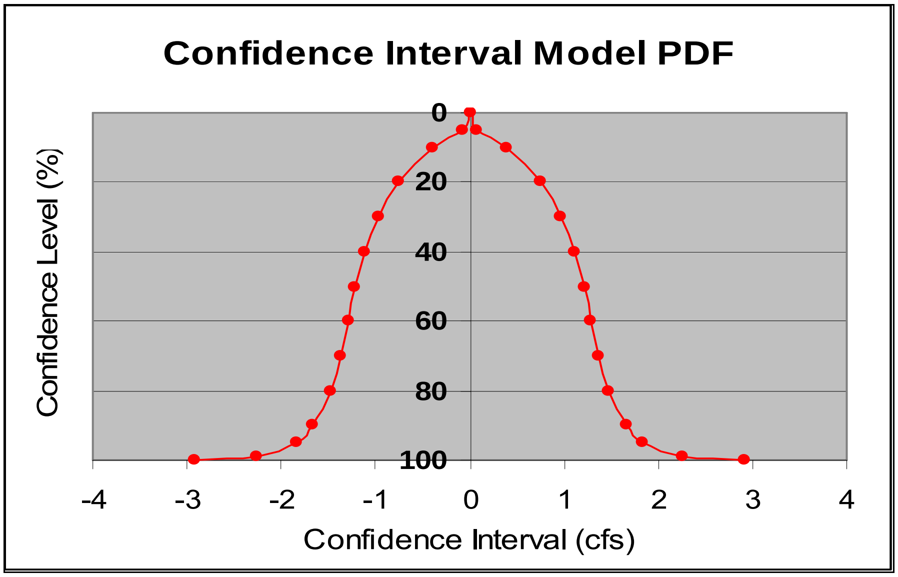


Figure 2. Probability distribution function (PDF) to graphically illustrate mean log-transformed residual confidence interval ranges at varying levels of confidence in the 0-4 cfs flow range. The y-axis corresponds to the confidence level, in %; the x-axis corresponds to the magnitude of the associated confidence interval, in cfs. For data used to create graph, see *Table 4*.

2.2 Probability of Intermittency

The probability of intermittency occurring is of particular interest since avoiding intermittency in parts of the Pecos River is crucial in maintaining the critical habitat for the PBNS. The Acme gage is located approximately 26 river miles below the end of the upper critical habitat, and it has historically shown intermittency approximately 10% of the time over its period of record. Comparing the gage records to the calibration model predicted flows provides a basis for projecting intermittencies for the future under the various EIS alternatives. In other words, there are times when the gage showed zero flow that the calibration model predicts flow, and conversely there are times when the model predicts zero flow but the gage showed flow. Thus prediction of intermittency is more complicated than simply considering model-predicted zero flows, and conditional probability approaches are required. To address this question, the raw residual data analyzed above is also directly applied to estimate the intermittency probability as described below.

2.2.1 Conditional Probability of Zero Gage Flow

Probability of intermittency was estimated based on the empirical model residuals for flow at the Acme gage using a conditional probability approach (Moore and McCabe, 2003; Ang and Tang, 1975). In essence, conditional probability theory states that the probability of some event X can be computed as the product of the probability of X given the occurrence of Y times the probability of event Y:

$$P(X) = P(X \mid Y) \times P(Y) \qquad \textit{Equation 2}$$

P(X), *P(X|Y)*, and *P(Y)* as they are used for this application are defined in the following section.

For this application, three key variables were defined:

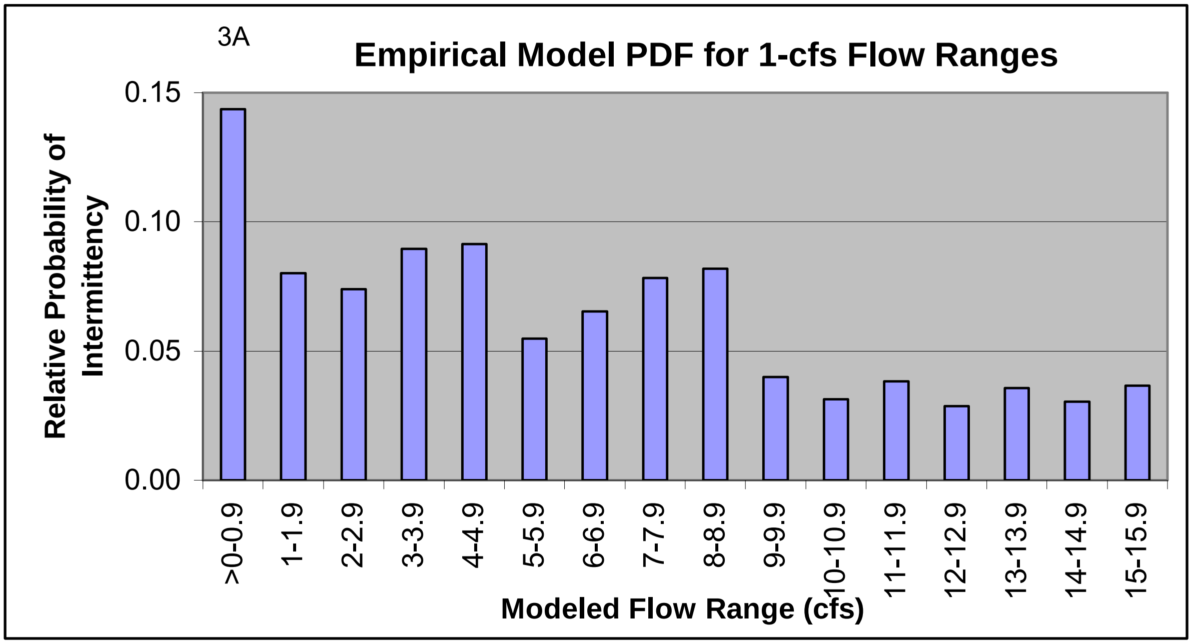
- the total number of predicted daily flows (*N*);
- the number of data points in each defined flow range (*N1*); and
- the number of times when gage flow was 0 cfs in each specified modeled flow range (*N2*).

The conditional probability of intermittency at the Acme gage given model flow within a specific range (*P2=P (X|Y)*) is calculated as *N2/N1* (*Table 5*). From these results, a PDF can be developed (*Figure 3*) that is similar to that presented for the Confidence Interval Model in *Figure 2*. This graph assumes that the probability associated with non-intermittency is one minus the conditional probability of intermittency. The graph illustrates that at lower model flow ranges, the probability of zero gage flow is higher than at higher flow ranges. The conditional probability of intermittency will approach zero as the model flow range increases, as illustrated by *Figure 3B*.

This empirical probability analysis can be used to compute the total probability of intermittency. The probability of flow within the specified range (*P1*) was calculated by *N1/N*. The conditional probability of zero gage flow within the specified range (*P2*) for each alternative is assumed to be the same as for the original Acme Gage Empirical Model, which is described in the preceding paragraph. The probability of intermittency (*P3*) can then be calculated as *P1*P2*.

Table 5. Summary of expected probability of gage flow equal to 0 cfs for various ranges of model flow. Results refer to examination of the actual residual data set. Total number of data points (*N*) is 21,914.

		Empirical Model, ACME Gage; N= 21,914				
Model Flow (cfs)	Expected Gage Flow (cfs)	*N1* Data points in the specified Model Flow range	*N2* Occurrences of Gage Flow = 0 cfs	*P1* Probability of model flow within range	*P2* Conditional Probability of gage flow =0 cfs	*P3* Probability of Intermittency given Model Flow within range
				N1 / N	*N2 / N1*	*P1 * P2*
Broader Flow Ranges:						
0	0	1227	267	0.06	0.22	0.01
>0-3.9	0	2270	445	0.10	0.20	0.02
4-7.9	0	2132	333	0.10	0.16	0.02
8-15.9	0	3854	371	0.18	0.10	0.02
16-24.9	0	2663	228	0.12	0.09	0.01
25-34.9	0	1716	163	0.08	0.09	0.01
35-44.9	0	1098	60	0.05	0.05	0.003
45-59.9	0	997	29	0.05	0.03	0.001
>60	0	5957	4	0.27	0.001	0.0002
1 cfs-Interval Flow Ranges:						
>0-0.9	0	625	165	0.03	0.26	0.01
1-1.9	0	497	92	0.02	0.19	0.004
2-2.9	0	548	85	0.03	0.16	0.004
3-3.9	0	600	103	0.03	0.17	0.005
4-4.9	0	552	105	0.03	0.19	0.005
5-5.9	0	492	63	0.02	0.13	0.003
6-6.9	0	542	75	0.02	0.14	0.003
7-7.9	0	546	90	0.02	0.16	0.004
8-8.9	0	565	94	0.03	0.17	0.004
9-9.9	0	519	46	0.02	0.09	0.002
10-10.9	0	463	36	0.02	0.08	0.002
11-11.9	0	545	44	0.02	0.08	0.002
12-12.9	0	499	33	0.02	0.07	0.002
13-13.9	0	442	41	0.02	0.09	0.002
14-14.9	0	427	35	0.02	0.08	0.002
15-15.9	0	394	42	0.02	0.11	0.002



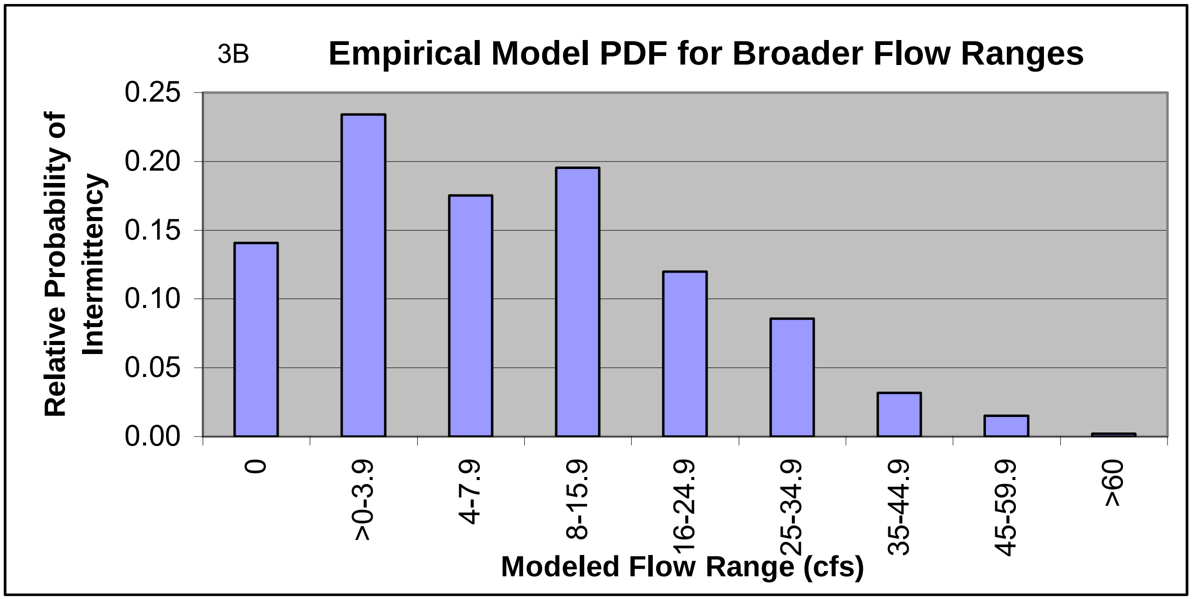


Figure 3. Empirical PDF (probability density function) to graphically illustrate intermittency probability distributed across all modeled flow ranges associated with intermittency. The y-axis corresponds to the relative probability of intermittency and the x-axis corresponds to the modeled flow range. For data used to create graphs, see *Table 5*.

2.2.2 Total Probability of Intermittency

Finally, to get the total probability of intermittency, the probability of gage flows greater than zero when the model is predicting zero flow is subtracted from *P3*:

$$P_{total}(X) = P(X \mid Y)P(Y) - P(Z \mid Y_0) \qquad \textit{Equation 3}$$

X = intermittency at gage
Y = Range min < Q model < Range max
Z = Q gage > 0 cfs
Y_0 = Q model = 0 cfs

The probability of non-zero gage flow (considered to be greater than 0.98 cfs based on the computed confidence interval) when model flow is equal to 0 cfs is constant for all alternatives, and was computed to be 4.2%.[14] Thus, the total probability of intermittency for each alternative was calculated as the sum of the intermittency probabilities over the individual flow range probabilities minus the probability of gage flow greater than 0 when model flow is equal to 0 cfs.

These calculations were undertaken for each of the EIS alternatives, for both the Bypass Alternatives and the Alternatives with all the Additional Water Needed (AWN) added to the river system; results are shown in *Table 6*.

2.3 Summary of Acme Gage Analysis

Basic statistics and Student-t confidence intervals were calculated for defined flow ranges based on a normal distribution of the historical model residual data for the Acme gage. A closer inspection of residual data corresponding to model flow of 0-4 cfs revealed a lognormal distribution that is skewed to the left (gage flow is more commonly larger than model flow). The range of confidence intervals for the log-transformed data ranged from +/- 0.40 to 2.92 cfs corresponding to confidence levels of 10 to 99.9 %, respectively. The intervals are relatively small for all low flow ranges examined, even when considering high levels of confidence.

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[14] For the 0-4 cfs flow range, the calculated 95% confidence interval was 0.98 cfs. The probability of non-zero flow when modeled flow is zero is 4.2% as derived from the calibration model, and it is thus constant across all alternatives.

Table 6. Probability of intermittency (*P3*) for particular broader flow ranges and *Total Probability of Intermittency* for each Bypass Alternative and Alternative with all AWN added based on empirical model relationships. For a detailed description of the variables (*N*, *N1*, *P1*, *P2*, and *P3*) and how they were calculated, see text. n/c indicates that the value was not calculated here, as it was obtained from historical calibration model (both *P2* and probability of non-zero gage flow when modeled flow is zero).

		No Action w/6week; N= 21,915				No Action w/o 6week; N= 21,915			
	Model Flow (cfs)	*N1*	*P1*	*P2*	*P3*	*N1*	*P1*	*P2*	*P3*
			N1 / N	n/c	*P1 * P2*		*N1 / N*	n/c	*P1 * P2*
BYPASS ALTERNATIVES	*Broader Flow Ranges:*								
	0	193	0.01	0.22	0.002	205	0.01	0.22	0.002
	>0-3.9	651	0.03	0.20	0.006	637	0.03	0.20	0.006
	4-7.9	1513	0.07	0.16	0.011	1629	0.07	0.16	0.012
	8-15.9	2228	0.10	0.10	0.010	2191	0.10	0.10	0.010
	16-24.9	2572	0.12	0.09	0.010	2625	0.12	0.09	0.010
	25-34.9	5084	0.23	0.09	0.022	5159	0.24	0.09	0.022
	35-44.9	2440	0.11	0.05	0.006	2405	0.11	0.05	0.006
	45-59.9	1828	0.08	0.03	0.002	1805	0.08	0.03	0.002
	>60	5406	0.25	0.00	0.0002	5259	0.24	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.028				0.029
ALTERNATIVES WITH ALL AWN ADDED	*Broader Flow Ranges:*								
	0	147	0.01	0.22	0.001	158	0.01	0.22	0.002
	>0-3.9	468	0.02	0.20	0.004	489	0.02	0.20	0.004
	4-7.9	1253	0.06	0.16	0.009	1336	0.06	0.16	0.010
	8-15.9	1513	0.07	0.10	0.007	1377	0.06	0.10	0.006
	16-24.9	2868	0.13	0.09	0.011	2925	0.13	0.09	0.011
	25-34.9	1132	0.05	0.09	0.005	1165	0.05	0.09	0.005
	35-44.9	7152	0.33	0.05	0.018	7252	0.33	0.05	0.018
	45-59.9	1902	0.09	0.03	0.003	1885	0.09	0.03	0.003
	>60	5480	0.25	0.00	0.0002	5328	0.24	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.016				0.017

Table 6, continued.

		Pre-91 Baseline; N= 21,915				Acme Constant; N= 21,915			
	Model Flow (cfs)	*N1*	*P1*	*P2*	*P3*	*N1*	*P1*	*P2*	*P3*
			N1 / N	n/c	*P1 * P2*		*N1 / N*	n/c	*P1 * P2*
BYPASS ALTERNATIVES	*Broader Flow Ranges:*								
	0	263	0.01	0.22	0.003	147	0.01	0.22	0.001
	>0-3.9	889	0.04	0.20	0.008	367	0.02	0.20	0.003
	4-7.9	2897	0.13	0.16	0.021	691	0.03	0.16	0.005
	8-15.9	4346	0.20	0.10	0.019	1856	0.08	0.10	0.008
	16-24.9	3691	0.17	0.09	0.014	2017	0.09	0.09	0.008
	25-34.9	1603	0.07	0.09	0.007	7077	0.32	0.09	0.031
	35-44.9	982	0.04	0.05	0.002	2735	0.12	0.05	0.007
	45-59.9	1709	0.08	0.03	0.002	1840	0.08	0.03	0.002
	>60	5535	0.25	0.00	0.0002	5185	0.24	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.036				0.025
ALTERNATIVES WITH ALL AWN ADDED	*Broader Flow Ranges:*								
	0		0.0		0.0	0	0.00	0.22	0
	>0-3.9		0.0		0.0	2	0.00	0.20	0.00002
	4-7.9		0.0		0.0	1	0.00	0.16	0.00001
	8-15.9		0.0		0.0	3	0.00	0.10	0.00001
	16-24.9		0.0		0.0	5	0.00	0.09	0.00002
	25-34.9		0.0		0.0	2177	0.10	0.09	0.009
	35-44.9		0.0		0.0	12275	0.56	0.05	0.031
	45-59.9		0.0		0.0	1967	0.09	0.03	0.003
	>60		0.0		0.0	5485	0.25	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					no data				0.042
	Cumulative Probability of Intermittency:								
					no data				0.001

Table 6, continued.

		Acme Variable; N= 21,915				Critical Habitat; N= 21,915			
	Model Flow (cfs)	*N1*	*P1*	*P2*	*P3*	*N1*	*P1*	*P2*	*P3*
			N1 / N	n/c	*P1 * P2*		*N1 / N*	n/c	*P1 * P2*
BYPASS ALTERNATIVES	*Broader Flow Ranges:*								
	0	150	0.01	0.22	0.001	234	0.01	0.22	0.002
	>0-3.9	460	0.02	0.20	0.004	690	0.03	0.20	0.006
	4-7.9	870	0.04	0.16	0.006	1865	0.09	0.16	0.013
	8-15.9	3042	0.14	0.10	0.013	2809	0.13	0.10	0.012
	16-24.9	2606	0.12	0.09	0.010	6278	0.29	0.09	0.025
	25-34.9	4941	0.23	0.09	0.021	1699	0.08	0.09	0.007
	35-44.9	2570	0.12	0.05	0.006	1050	0.05	0.05	0.003
	45-59.9	1928	0.09	0.03	0.003	1681	0.08	0.03	0.002
	>60	5348	0.24	0.00	0.0002	5609	0.26	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.025				0.030
ALTERNATIVES WITH ALL AWN ADDED	*Broader Flow Ranges:*								
	0	0	0.00	0.22	0	187	0.01	0.22	0.002
	>0-3.9	2	0.00	0.20	0.00002	498	0.02	0.20	0.004
	4-7.9	5	0.00	0.16	0.00004	1965	0.09	0.16	0.014
	8-15.9	3265	0.15	0.10	0.014	2860	0.13	0.10	0.013
	16-24.9	2738	0.12	0.09	0.011	6353	0.29	0.09	0.025
	25-34.9	1055	0.05	0.09	0.005	1696	0.08	0.09	0.007
	35-44.9	6442	0.29	0.05	0.016	1058	0.05	0.05	0.003
	45-59.9	2896	0.13	0.03	0.004	1685	0.08	0.03	0.002
	>60	5512	0.25	0.00	0.0002	5613	0.26	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.008				0.029

Table 6, continued.

		Taiban Constant; N= 21,915				Taiban Variable (55 cfs); N= 21,915			
	Model Flow (cfs)	*N1*	*P1*	*P2*	*P3*	*N1*	*P1*	*P2*	*P3*
			N1 / N	n/c	*P1 * P2*		*N1 / N*	n/c	*P1 * P2*
BYPASS ALTERNATIVES	*Broader Flow Ranges:*								
	0	196	0.01	0.22	0.002	137	0.01	0.22	0.001
	>0-3.9	732	0.03	0.20	0.007	489	0.02	0.20	0.004
	4-7.9	1930	0.09	0.16	0.014	910	0.04	0.16	0.006
	8-15.9	2731	0.12	0.10	0.012	3781	0.17	0.10	0.017
	16-24.9	6278	0.29	0.09	0.025	6388	0.29	0.09	0.025
	25-34.9	1698	0.08	0.09	0.007	1978	0.09	0.09	0.009
	35-44.9	1039	0.05	0.05	0.003	1075	0.05	0.05	0.003
	45-59.9	1668	0.08	0.03	0.002	1667	0.08	0.03	0.002
	>60	5643	0.26	0.00	0.0002	5490	0.25	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.030				0.026
ALTERNATIVES WITH ALL AWN ADDED	*Broader Flow Ranges:*								
	0	0	0.00	0.22	0	0	0.00	0.22	0
	>0-3.9	859	0.04	0.20	0.008	2	0.00	0.20	0.00002
	4-7.9	1963	0.09	0.16	0.014	5	0.00	0.16	0.00004
	8-15.9	2587	0.12	0.10	0.011	4187	0.19	0.10	0.018
	16-24.9	6434	0.29	0.09	0.025	5923	0.27	0.09	0.023
	25-34.9	1715	0.08	0.09	0.007	3252	0.15	0.09	0.014
	35-44.9	1043	0.05	0.05	0.003	1289	0.06	0.05	0.003
	45-59.9	1666	0.08	0.03	0.002	1719	0.08	0.03	0.002
	>60	5648	0.26	0.00	0.0002	5538	0.25	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.029				0.020

Table 6, continued.

		Taiban Variable (40 cfs); N= 21,915				Taiban Variable (45 cfs); N= 21,915			
	Model Flow (cfs)	*N1*	*P1*	*P2*	*P3*	*N1*	*P1*	*P2*	*P3*
			N1 / N	n/c	P1 * P2		N1 / N	n/c	P1 * P2
BYPASS ALTERNATIVES	*Broader Flow Ranges:*								
	0	187	0.01	0.22	0.002	176	0.01	0.22	0.002
	>0-3.9	597	0.03	0.20	0.005	514	0.02	0.20	0.005
	4-7.9	2055	0.09	0.16	0.015	2053	0.09	0.16	0.015
	8-15.9	2737	0.12	0.10	0.012	2807	0.13	0.10	0.012
	16-24.9	6303	0.29	0.09	0.025	6370	0.29	0.09	0.025
	25-34.9	1709	0.08	0.09	0.007	1751	0.08	0.09	0.008
	35-44.9	1043	0.05	0.05	0.003	1048	0.05	0.05	0.003
	45-59.9	1693	0.08	0.03	0.002	1609	0.07	0.03	0.002
	>60	5591	0.26	0.00	0.0002	5587	0.25	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.030				0.030
ALTERNATIVES WITH ALL AWN ADDED	*Broader Flow Ranges:*								
	0	0	0.00	0.22	0	0	0.00	0.22	0
	>0-3.9	27	0.00	0.20	0.0002	5	0.00	0.20	0.00004
	4-7.9	2627	0.12	0.16	0.019	1844	0.08	0.16	0.013
	8-15.9	2527	0.12	0.10	0.011	3002	0.14	0.10	0.013
	16-24.9	6550	0.30	0.09	0.026	6344	0.29	0.09	0.025
	25-34.9	1831	0.08	0.09	0.008	2412	0.11	0.09	0.010
	35-44.9	1053	0.05	0.05	0.003	1080	0.05	0.05	0.003
	45-59.9	1700	0.08	0.03	0.002	1622	0.07	0.03	0.002
	>60	5600	0.26	0.00	0.0002	5606	0.26	0.00	0.0002
	Probability of gage flow >0 cfs when mod flow =0 cfs:								
					0.042				0.042
	Cumulative Probability of Intermittency:								
					0.027				0.025

Additionally, more than half of the time, actual gage flow will be higher than the RiverWare model predicted flow for the same time (i.e., the mean and median residual are less than 0 cfs).

The predicted probability of intermittency was examined by using an empirical model based on the raw residuals (model minus gage flow). With this model, the probabilities of intermittency (zero gage flow) within specified flow ranges for the historical (calibration) model were calculated. Empirical results were used to extrapolate conditional cumulative probability of intermittency within specific flow ranges for all of the EIS Bypass Alternatives and Alternatives with all AWN added. Overall, the cumulative probability of intermittency ranges from 0.10% to 3.6%. The probability of intermittency for the Bypass Options is generally higher than the probability of intermittency for Alternatives with all AWN added since available supply is not an issue for the latter. Results for the Bypass Alternatives indicate that the probability of intermittency is lowest for the Acme alternatives (less than 2.5%), and is highest in the case of the Pre-91 Baseline alternative (3.6%). Results for Alternatives with all AWN added indicate the probability of intermittency is lowest for the Acme alternatives (0.1 to 0.8%) and highest for the Critical Habitat alternative (2.9%).

Finally, when viewing these intermittency probabilities, it should be recognized that the empirical probability model employed conditional distributions based on the historical calibration model. In the RiverWare rules for the historical model, which are designed to reflect a decision process of the human operators, there is no accounting for a bias by the operator to avoid flow intermittencies at Acme. Therefore, it is likely that the computed intermittencies overstate what the actual expected intermittency will be, given that in the future the dam operators will include avoiding intermittency at Acme gage as one of their decision criteria.

3.0 DUNLAP GAGE

This section summarizes the findings regarding confidence intervals with respect to RiverWare model predicted flow at Dunlap gage for the historical (calibration) model. The probability of model and gage flow within specific ranges is also calculated.

This summary includes descriptions of two major tasks:

- Section 3.1 Confidence Intervals
    - Confidence interval calculations for Dunlap gage using the original model, gage, and residual data, and assuming a normal distribution.
- Section 3.2 Probability Calculations
    - Calculated probability of flow within a given range.

For the Dunlap gage, USGS daily stream flow data is available for the time period of August 20, 1993 to September 30, 2002. During this time, the lowest measured gage flow is 0.19 cfs. Modeled stream flow data for the calibrated RiverWare model is available for the time period January 1940 to December 1999. During the time of overlap analyzed (August 20, 1993 to December 1999), the model predicted river flow is not intermittent at any time, nor has the observed gage flow ever shown intermittency.

3.1 Confidence Intervals

RiverWare model predicted and USGS actual gage flow data from the Dunlap gage was used to calculate statistics and confidence intervals of model residuals. The model residual is defined as the model flow minus gage flow; a negative residual corresponds to a case where the gage flow was larger than the model flow.

Basic statistics for residuals were calculated for each of the defined model flow ranges for the Dunlap gage (for bins of 0-4, 4-8, 8-16, 16-25, 25-35, 30-40, 35-45, and 45-60 cfs). The statistics included total number of data points (N), sample mean (x), variance (σ^2), and standard deviation (σ).

Confidence intervals were calculated using the Student-t method and based on the assumption that the residuals have a normal distribution. The procedure used was adapted from Moore and McCabe (2003) and Ang and Tang (1975). For details, see Section 2.1.1. *Table 7* summarizes the statistics of each flow range and associated confidence interval that was calculated. Results of the calculated mean residual indicate that for most flow ranges (less than 60 cfs), the model flow under predicts actual gage flow; for flow greater than 60 cfs, the model tends to over predict flow.

Table 7. Summary statistics and Student-t confidence intervals of residuals calculated for modeled flow ranges at the Dunlap gage. Negative values indicate that gage flows are higher than model flows.

Flow Range (cfs)	Total number of data points, *N*	Mean Residual, *x* (cfs)	Variance, σ^2 (cfs^2)	Standard Deviation, σ (cfs)	95% Confidence Interval (+/- cfs)	99% Confidence Interval (+/- cfs)
0-4	n/d	n/d	n/d	n/d	n/d	n/d
4-8	10	-16.8	409.4	20.2	14.47	20.79
8-16	85	-21.9	6495.6	80.6	17.48	23.25
16-25	403	-32.7	14153.0	119.0	11.62	15.27
25-35	500	-16.3	1631.8	40.4	3.54	4.65
30-40	342	-20.0	2354.7	48.5	5.14	6.76
35-45	381	-21.8	2117.2	46.0	4.62	6.07
45-60	254	-22.5	1221.4	34.9	4.30	5.65
>60	692	26.3	12816.7	113.2	8.44	11.09

3.2 Probability of Flow Range

The probability of intermittency occurring is of particular interest since avoiding intermittency in parts of the Pecos River is crucial in maintaining the critical habitat for the PBNS. Crockett Draw is important in maintaining flow for the PBNS in that it is located at the end of the upper critical habitat at river mile 610.4; however, the Pecos River has no gage in this location. The Dunlap gage is located near Crockett Draw at river mile 638.9, approximately 28 miles upstream of the end of the upper critical habitat.

An additional interest is the probability of flow within a given range. Flows at the Dunlap gage tend to be higher relative to the Acme gage (Section 2.0) and historically the gage has never recorded intermittency. *Table 8* gives the empirical probabilities of gage and model flow occurrences within given ranges. Results indicate that the model generally predicts a higher probability of flow at flow ranges less than 60 cfs and under predicts the probability of flow greater than 60 cfs.

Table 8. Probability of gage and model flow within given flow ranges at the Dunlap gage.

Flow Range (cfs)	Gage flow within specified flow range (No. of occurrences)	Probability of gage flow within specified flow range	Model flow within specified flow range (No. of occurrences)	Probability of model flow within specified flow range
0	0	0	0	0
>0-3.9	0	0	0	0
4-7.9	7	0.003	10	0.004
8-15.9	159	0.07	85	0.04
16-24.9	160	0.07	403	0.17
25-34.9	225	0.10	500	0.22
35-44.9	249	0.11	381	0.16
45-59.9	420	0.18	254	0.11
>60	1105	0.48	692	0.30

Figure 4 is an exceedence curve for model and gage flow at the Dunlap gage for the entire range of observed and modeled flows. The graph illustrates that at flows less than 250 cfs, gage flow is usually higher than model flow. Between 250 and 850 cfs, trends in model and gage flow are similar. At flow ranges greater than approximately 850 cfs, the opposite occurs and model flow is generally greater than actual flow. For the case of gage flow, 58 cfs flow is exceeded 50% of the time; for the model flow, 39.94 cfs is exceeded 50% of the time. *Figure 5* is a scatterplot of gage versus model data, and confirms the pattern of model flow being generally lower than gage flow. This tendency of the model to underpredict flow has important implications when using the model to evaluate potential intermittency along the Pecos River.

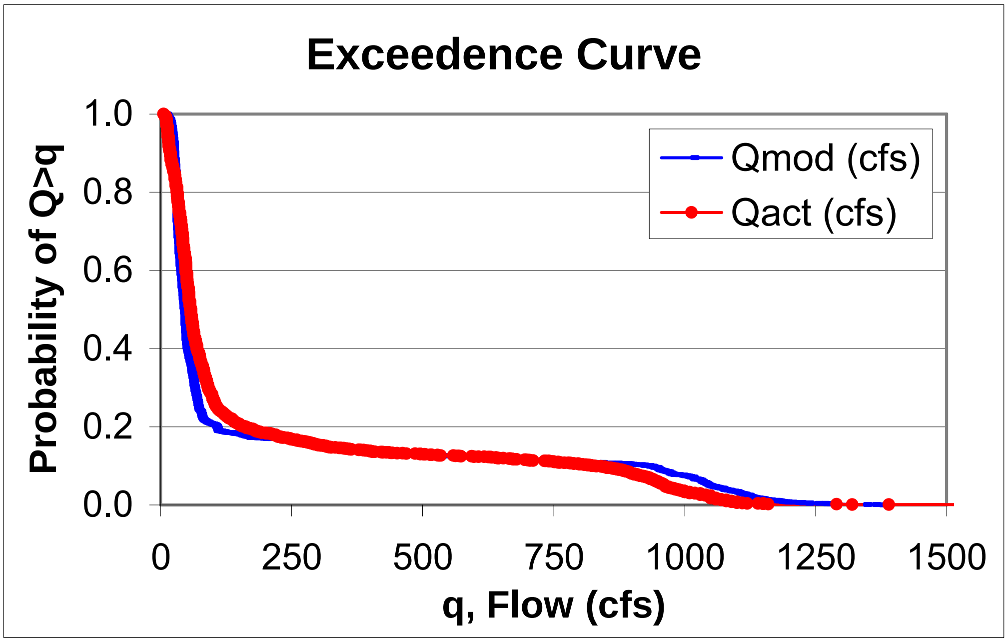

Figure 4. Probability of flow for RiverWare modeled (Qmod) and actual gage (Qact) flow at the Dunlap gage.

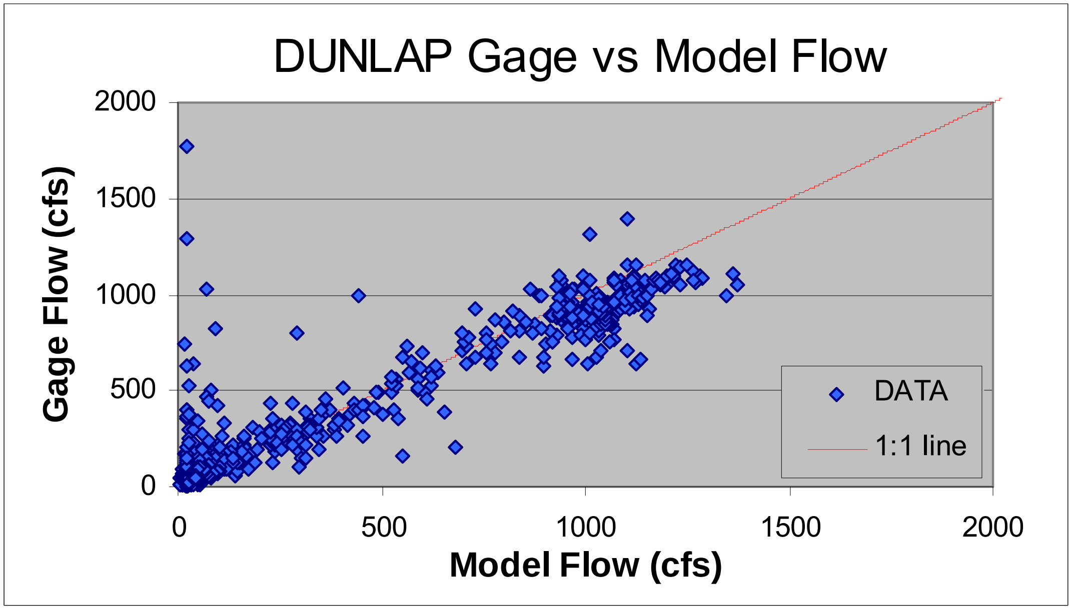

Figure 5. Scatterplot of flow for actual gage (Qact) and RiverWare modeled (Qmod) at the Dunlap gage.

3.3 Summary of Dunlap Gage Analysis

Basic statistics and Student-t confidence intervals were calculated for defined flow ranges based on a normal distribution of the historical model residual data for the Dunlap gage. More than 60% of the time, actual gage flow will be higher than RiverWare model predicted flow (residuals are less than 0 cfs). The range of 95% and 99% residual confidence intervals ranged from +/- 3.54 to 17.48 and +/- 4.65 to 23.25 cfs, respectively. The intervals are relatively large for all low flow ranges examined, and demonstrate no pattern with increasing or decreasing flow ranges.

The probability of flow within a given range indicates that gage flow at the Dunlap gage is greater than 60 cfs nearly 50% of the time, and greater than 25 cfs 85% of the time. Model flow is greater than 60 cfs 30% of the time, and greater than 25 cfs nearly 80% of the time. For most flow ranges, the RiverWare model predicted flow is lower than actual gage flow.

4.0 INTERMITTENCY TRENDS BY HYDROLOGIC SEASON

This section summarizes findings regarding length and occurrence of intermittency at Acme gage. The results of this analysis are compared by alternatives and by hydrologic season.

This summary includes descriptions of two major tasks:

- Section 4.1 Acme Intermittency
    - Calculation of the percent of the time that intermittency occurs at Acme.
    - Comparison by wet, average, or dry hydrologic season.
- Section 4.2 Length of Acme Intermittency
    - Tabulated length and count of intermittent periods.
    - Comparison by wet, average, or dry hydrologic season.

The nine alternatives considered include: No Action, Pre-91 Baseline, Acme Constant, Acme Variable, Critical Habitat, Taiban Constant, Taiban Variable HRS, Taiban Variable LRS, and Taiban Variable MRS. The determination of dry, average, and wet years (or hydrologic season) is based on effective Brantley storage along with the Palmer Drought Severity Index, as described in the 2003-2006 Fish and Wildlife Service biological opinion. An annual assessment is usually made with the possibility of adjustment throughout the irrigation season (Chapter 2 of EIS, June 2006).

4.1 Acme Intermittency

RiverWare output is daily for the time period from January 1940 to December 1999, for a total of 21,915 data points. The data used for analysis contains RiverWare model predicted flow data for all alternatives for days when Acme was intermittent, by hydrologic season. All days with intermittency were during summer months except for the Pre-91 Baseline.

Probability of intermittency, or zero flow, was calculated at Acme gage for each of the nine alternatives by hydrologic season (dry, average, or wet). *Table 9* shows the results numerically, and *Figure 6* provides a graphical illustration. During wet years, there is no occurrence of intermittency at Acme. The percent of intermittency for average years ranges from 0.10 to 0.21 % for all alternatives. As expected, the percent of intermittency during dry years is higher than wet or average, and ranges from 0.5 to 1.0 %.

Table 9: Percent intermittency for flow at Acme for each of the nine alternatives based on 21,915 total data points for the 60-year RiverWare model period.

	% Intermittency		
	DRY	**AVERAGE**	**WET**
No Action	0.77%	0.16%	0.00%
Pre-91 Baseline	1.00%	0.20%	0.00%
Acme Constant	0.50%	0.17%	0.00%
Acme Variable	0.52%	0.17%	0.00%
Critical Habitat	0.86%	0.21%	0.00%
Taiban Constant	0.69%	0.20%	0.00%
Taiban Var HRS	0.52%	0.10%	0.00%
Taiban Var LRS	0.65%	0.20%	0.00%
Taiban Var MRS	0.62%	0.18%	0.00%

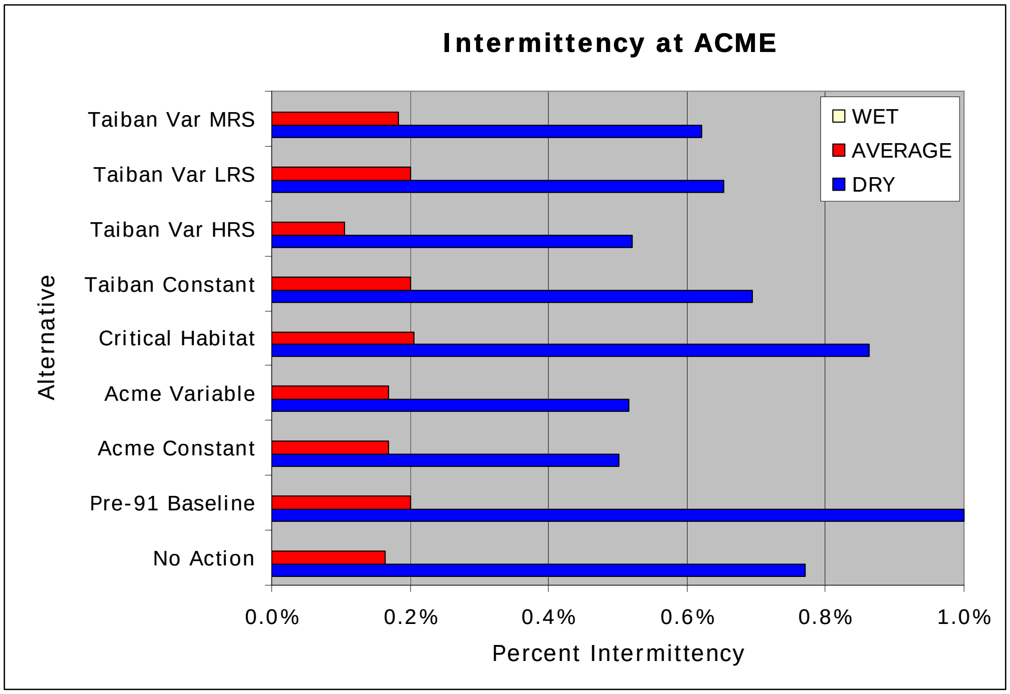

Figure 6: Bar graph showing the percent of the time that flow at Acme gage is intermittent (x-axis). Results are presented in terms of nine alternatives, located along the y-axis, and by hydrologic season (average or dry; there are no occurrences of intermittency at Acme during a wet hydrologic season). Data used to construct this figure is shown in *Table 9*.

4.2 Length of Acme Intermittency

Length of intermittency at Acme was determined for each of the nine alternatives by hydrologic season (dry, average, or wet). Length of intermittency was separated into 3 lengths: 1 to 5 days, 6 to 10 days, or more than 10 days. The results from this analysis are presented in *Table 10* and *Figure 7*. During average years, intermittent periods lasting 1 to 5 days and 6 to 10 days occur a maximum of one time throughout the period modeled for all alternatives; intermittent periods lasting more than 10 days occur one to two times for all alternatives. Dry years show a trend of longer periods of intermittency which also occur more often. Periods of intermittency lasting 1 to 5 days occur a minimum of 3 times for the Acme Constant alternative and a maximum of 12 times for the Critical Habitat alternative; periods lasting 6 to 10 days occur a minimum of 5 times (Taiban Variable LRS alternative) and a maximum of 8 times (Pre-91 Baseline); periods lasting more than 10 days occur a minimum of 3 times (Taiban Variable MRS and Taiban Variable HRS alternatives) and a maximum of 7 times (Pre-91 Baseline).

Table 10: Number of intermittent periods at Acme for each of the nine alternatives and length of intermittency, based on 21,915 total data points for the 60-year RiverWare model period.

	Number of Intermittent Periods	**Length of Intermittency**		
		1-5 days	**6-10 days**	**>10 days**
DRY	20	10	5	5
AVG	3	1	1	1
WET	0	0	0	0
DRY	26	11	8	7
AVG	4	1	1	2
WET	0	0	0	0
DRY	12	3	5	4
AVG	3	1	0	2
WET	0	0	0	0
DRY	14	5	5	4
AVG	3	1	0	2
WET	0	0	0	0
DRY	24	12	7	5
AVG	4	1	1	2
WET	0	0	0	0
DRY	19	10	5	4
AVG	4	1	1	2
WET	0	0	0	0
DRY	12	4	5	3
AVG	3	1	1	1
WET	0	0	0	0
DRY	15	7	4	4
AVG	4	1	1	2
WET	0	0	0	0
DRY	15	5	7	3
AVG	3	0	1	2
WET	0	0	0	0

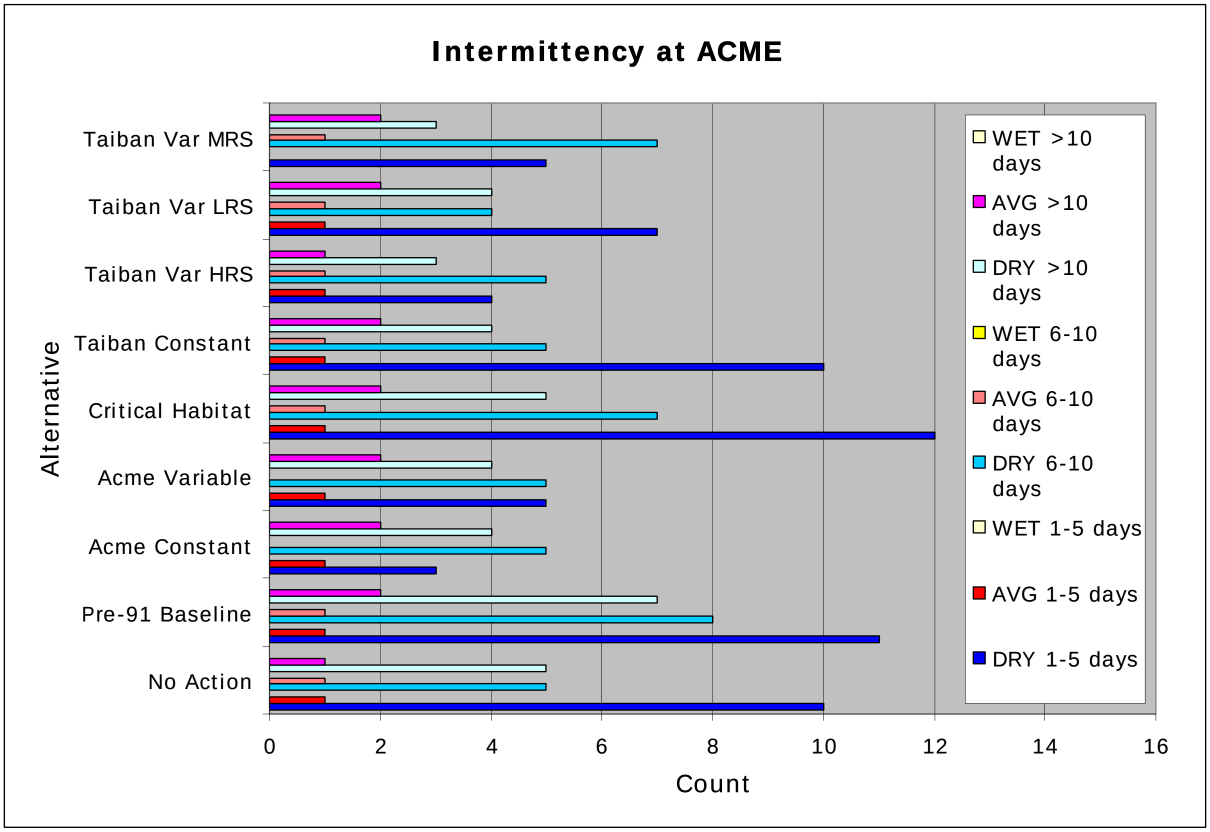

Figure 7: Bar graph showing the number of times that flow at Acme gage is intermittent (x-axis) and the length of intermittency. Results are presented in terms of nine alternatives, located along the y-axis, and by hydrologic season (average or dry; there are no occurrences of intermittency at Acme during a wet hydrologic season). Data used to construct this figure is shown in *Table 10*.

4.3 Summary of Intermittency Trends by Hydrologic Season

Intermittency at Acme gage is not common, and it occurs less than 1 % of the time when considering all alternatives for the RiverWare model predicted flows from January 1940 to December 1999. There are no occurrences of intermittency during wet years. Intermittency is more common during dry than during average years. Generally speaking, intermittency occurs nearly three times as often during dry years.

During average years, periods of intermittency at Acme gage are infrequent. During dry years, periods of intermittency occur more often and it is more likely that they will last for a longer period of time.

When analyzing intermittency along the Pecos River for the PBNS, it is important to look not only at the total percent of intermittency, but also at the length of these intermitteny periods.

Comparing intermittency by season helps us to better understand the trends. It will also enable better planning for management of the Pecos River to avoid such intermittency.

5.0 REFERENCES

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Geomorphology Memorandum

For the Pecos River Carlsbad Project
Water Supply and Conservation EIS

Written by: Alaina Briggs, P.E.

January 2006

TETRA TECH, INC.

1.0 INTRODUCTION

This memorandum is intended to supplement the information being presented in the Carlsbad Project Water Operations and Water Supply Conservation Supply EIS.

An overview of the geomorphology of the river, with particular attention to the section from Sumner Reservoir to Brantley Reservoir is summarized in this memo. In addition, this memo provides detailed descriptions of ten locations where observations were made and cross section surveys were conducted during a field visit in February of 2005. A discussion on the prediction of channel geometry for the different alternatives described in the EIS is also included.

As part of this effort, documents regarding the Pecos River geomorphology were reviewed, a field visit was conducted to observe current conditions, and previously established cross sections were surveyed and photographed. The cross section surveys and photographs help to compare changes that have occurred at specific locations within the system and lend to conclusions regarding trends of the overall reaches. In addition, calculations were made to estimate the approximate channel geometry (width and depth) that may result from the different Sumner Dam reoperation alternatives.

2.0 OVERVIEW

The geomorphology of the Pecos River system is different today than it was at the turn of the last century. Changes to the hydrology, including the construction of reservoirs, regulation of flows, changes to sediment transport mechanisms and changes to the ground water systems, have all affected the river system. Additional anthropogenic influences such as channelization and straightening of the river have also had a large impact on the geomorphology.

Today, two sections of the river between Sumner and Brantley Reservoirs have been designated Critical Habitat for the Pecos bluntnose shiner (PBNS), *Notropis simus pecosensis*. The upper critical habitat stretches approximately 58 river miles from upstream of the Taiban Creek-Pecos River confluence to immediately downstream of the Crockett Draw-Pecos River confluence. The lower critical habitat extends approximately 35 miles from just upstream of the New Mexico Highway 31 Bridge to downstream of the USGS Near Artesia gaging station. (U.S. Fish and Wildlife Service, 2002).

The Pecos River in the area of the upper critical habitat is in significantly better geomorphic condition for PBNS conservation than the lower critical habitat. From Sumner Reservoir to approximately the USGS Acme gaging station, the channel exhibits relatively good floodplain connectivity, meanders within the floodplain, and has riffle / pool sequences with point bars and macroforms, all factors that lend to diverse aquatic habitat. The much of the vegetation in the upper reaches consists of willows, sedges, grasses, and occasional tamarisks. Photo #1 is an aerial photo in the vicinity of the USGS Acme gaging station.

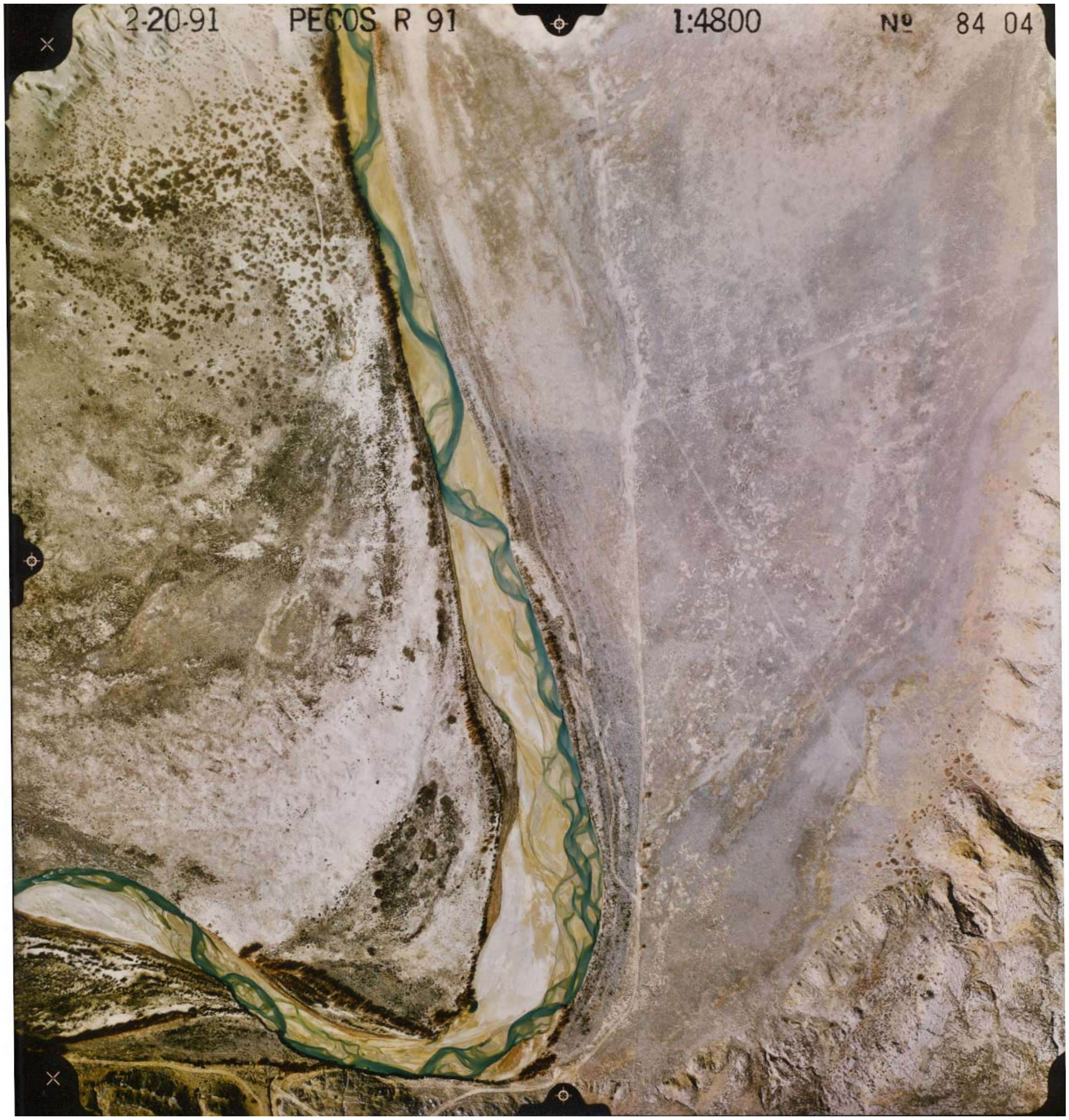

Photo #1. Aerial view of the Pecos River in the area of the USGS Acme gaging station (Photo taken February 20, 1991).

In contrast to the favorable geomorphic conditions in the upper critical habitat, the river in the lower critical habitat has been channelized in many locations. The channel in some sections, such as near the USGS Artesia gaging station and all through the Kaiser reach, was channelized for better conveyance. This channelization was subsequently fortified by the non-native invasive tamarisks trees that densely vegetate the banks, providing erosion resistance and ensuring no or limited channel migration. These areas have virtually no sinuosity, are lined with dense mature tamarisks, and have low width to depth ratios. Photo #2 shows an aerial view of the Pecos River in the area near the USGS Artesia gaging station.

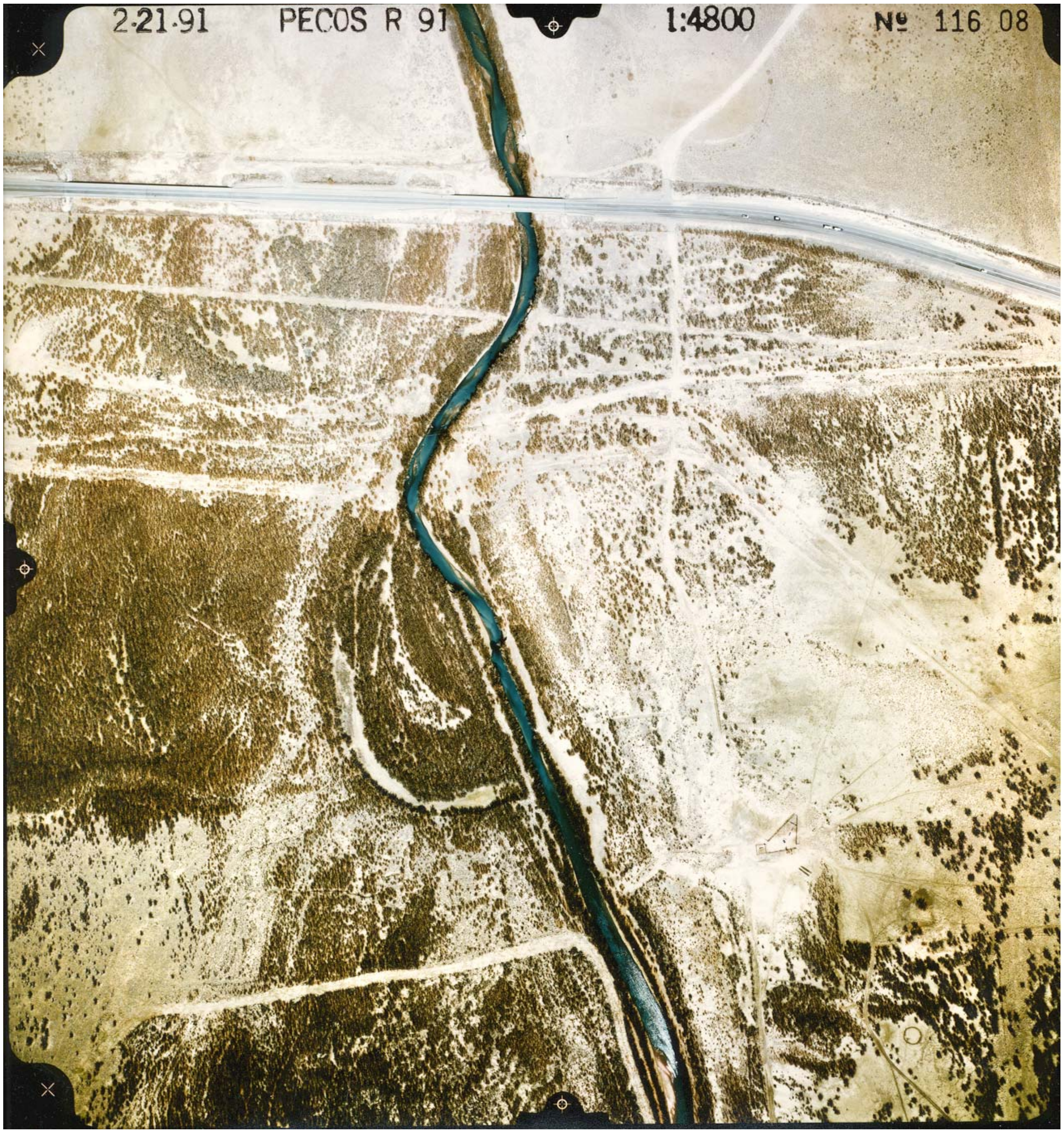

Photo #2. Aerial photograph of the Pecos River in the area near the USGS Artesia gaging station (Photo taken February 21, 1991).

Table 1 contains a summary of geomorphic parameter results taken from the Tetra Tech 2001 report. In the table, sinuosity is a measure of the relative amount of the curvature in the river system compared to the valley length, or river reach length divided by valley length. Also shown in the table is entrenchment ratio, which is the width of the current floodplain, divided by the bankfull width of the channel. In addition, the width to depth ratio (bankfull width divided by maximum depth in the thalweg at bankfull discharge) is shown along with measured channel slopes and water surface slopes.

Table 1. Geomorphic Parameters

Location	Sinuosity	Entrenchment Ratio	Width / Depth Ratio	Channel Slope (ft/ft)	Water Surface Slope (ft/ft)
Taiban	1.6	4.1	44	0.0007	0.0010
Dunlap	1.1	3.5	85	0.0020	0.0008
Above Acme	1.1	3.8	106	0.0007	0.0007
Acme	1.5	3.0	69	0.0008	0.0006
Dexter	1.0	2.2	17	0.0003	0.0004
Lake Arthur	2.3	1.3	21	0.0005	0.0005
Artesia	1.2	1.6	15	0.0012	0.0005

While performing the cross section surveys, it was observed that in the lower reaches (downstream of the Highway 380 bridge), channelized cross section fines and sands had accumulated in the overbank areas close to the channel in the tamarisk stands. This indicates that when flows do overtop the channel, the water is immediately slowed due to the dense vegetation and the sediment falls out of suspension and deposits along the banks. This process increases the height of the bank, further entrenching the channel.

During the February 2005 field trip, it was also observed that non-native vegetation eradication efforts have taken place on most public lands between Sumner and Brantley Reservoirs. Most tamarisks appeared to have been chemically treated and some had been cut. The impact on the channel will depend on the success of the eradication efforts. It is possible that with the removal of the tamarisks, the banks will lose some of the stability provided by the dense root systems and begin to erode naturally. If successful, eventually the channel may begin to meander in the historic floodplain and regain more natural sinuosity and channel geometry.

3.0 FIELD RECONNAISSANCE

A field reconnaissance and survey was conducted by Alaina Briggs, Tomas Stockton and Craig Boroughs from February 7 through 10, 2005. The purpose of the trip was two-fold: to make geomorphic observations and to perform tag line and level surveys at previously established cross sections.

A total of ten cross sections were surveyed during the field visit. The cross sections surveyed include: ST-2 Railroad Bridge, ST-3 Fort Sumner Park, ST-4 Taiban, TA-0.5 Dunlap, TA-2 Above Acme, TA-4 Near Acme, AA-1 Highway 380 Bridge, AA-1.5 Dexter Bridge, AA-3 Lake Arthur, and AA-4 Artesia. The cross sections are plotted along with previous surveys and are shown in Section 7 following the reference section at the end of the document.

Pictures were taken during the field trip and are used in this study for comparison with photographs taken as part of previous data collection efforts (September 1995 and April and May of 2000). Many of the photographs taken on the field trip are shown in the discussions below; additional pictures were included in an appendix in the original version of this document, but were removed from this version. The following sections detail the observations and survey results at the individual locations.

3.1 Pecos River below Sumner Reservoir

Photo #3 shows the Sumner Dam and outlet works. The picture was taken from the left bank looking upstream. (Left and right sides of the river are defined when looking downstream.) In this area, the channel is confined to a narrow floodplain within steep canyon walls as observed on the right side of the channel in this photo.

Photo #3. Sumner Dam and Outlet works

Photo #4 was taken from the same location as #3, viewing the river downstream of Sumner Dam. The USGS Fort Sumner gaging station and weir can be seen as well as the floodplain with willows along the banks and brush and cottonwood trees further upland.

Photo #4. Looking downstream at the USGS Fort Sumner gaging station.

Photo #5 was taken from the top of the right bank looking downstream and across the floodplain. This area is approximately 2,500 feet downstream of the Fort Sumner Diversion structure, half way between the diversion structure and the railroad bridge near Fort Sumner. The channel may have been straightened in this area, however, point bars and eroding banks indicate normal active geomorphic processes are occurring and the channel may eventually regain more sinuosity. A remnant bank can be seen in the left overbank. There are some tamarisks in this stretch of the river, especially along the left bank. However, eradication efforts were observed all along the river from Sumner to Brantley on public lands. The tamarisks appeared to have been sprayed, and some cut. Most appeared dead or dying (as evident from the brittle branches) although it was somewhat difficult to determine the extent as observations were made during the dormant season.

Photo #5. Taken 2500 feet downstream of the Fort Sumner Diversion Structure looking downstream.

3.2 ST-2 Railroad Bridge

The river in this area appears to be relatively stable with little to no changes observed in the cross section geometry when comparing the current survey with the one conducted in 1995. (See Section 7). The banks are low, indicating good geomorphic connectivity with the floodplain and the vegetation is primarily willows and sedges with some scattered mature cottonwoods in the floodplain. Photo #6 was taken at cross section ST-2 Railroad Bridge, from the right bank looking downstream at the channel, bridge, and right bridge abutment.

Photo #6. Looking downstream from the right bank at the ST-2 Railroad Bridge cross section.

3.3 ST-3 Fort Sumner Park

The river in the area of this cross section has been recently altered by heavy machinery. In looking at the cross section plot comparing 1995 to 2005 surveys, the left channel has filled slightly and the right channel has degraded. However, it is difficult to determine what extent was caused naturally and what was caused by machinery. The channel appears to have been reworked to facilitate vehicle crossings during low flow. Additionally it appears that some of the bars have been reworked and leveled out as well. Photo #7 was taken from the left end point looking towards the right end point (the right end point was missing), note the large tire tracks.

Photo #7. At cross section ST-3 Fort Sumner Park, from the left end point looking towards the right end point.

3.4 ST-4 Taiban Gage

The Pecos River near the Taiban gage is in a natural, relatively undisturbed state. The floodplain in this area is very wide and the channel exhibits natural meandering and sinuosity. The vegetation is primarily willows and grasses with some tamarisks. The cross section has experienced relatively little change since 1995 with the exception of some bank erosion along the right bank.

Photos 8 and 9 both show the Taiban gage. Photo 8 was taken in 2000 when most of the flow was along the left bank. During these periods, the gage can be assumed to be effective in determining discharge. The opposite is true in Photo 9 where the flow is more on the right side of the channel and the area around the gage is dry. This likely interferes with the accuracy of the gage under low flow conditions.

Photo #8. USGS Taiban gage photographed in 2000.

Photo #9. USGS Taiban gage photographed in 2005.

3.5 TA-0.5 Dunlap Site

Comparing the February 2005 survey with previous surveys, the cross section at TA-0.5 Dunlap has experienced relatively little change since the 1995 survey. A thalweg on the right side of the channel has filled slightly and a center bar has degraded slightly, both indications of natural channel migration. The banks have remained stable, especially on the left where the bank is a steep cliff due to a local fault.

Photo #10. Near cross section TA-0.5 looking upstream, taken in 2000.

Photo #11. Photo from the left bank at TA-0.5 Dunlap looking upstream; picture taken in 2005.

3.6 TA-2 Above Acme

The river at TA-2 Above Acme is in good geomorphic shape. Some shifting of the bed is observed from the cross section plot as is natural, especially in alluvial channels such as the Pecos River. Photo #12 shows the channel in 2000, with bars and macroforms observed in the main channel. Photo #13 was taken in a similar location. The bed of the channel is similar and some scattered tamarisks can be seen on the banks.

Photo #12. Above Acme USGS gage site looking upstream at active outer bank erosion, taken in 2000.

Photo #13. Photo taken at the Above Acme site, left bank looking upstream, taken in February 2005.

3.7 TA-4 Acme Gage

The river in the area of the Acme gage is located against a bluff on the right side of the floodplain. This portion of the river has some tamarisks along the banks with primarily wide open floodplain as can be observed in photos 14 and 15. Meandering occurs naturally here, the river in this reach has not been channelized or armored.

The cross section plot (Shown on page H-34) for TA-4 shows that there has been little change to the cross section since 1995 with the exception of some normal shifting of the thalweg from the right to the left side of the channel.

Photo #14. Looking at the Acme gage crossing and the left floodplain, taken in 2000.

Photo #15. Looking at the Acme gage site and the left floodplain, taken in 2005.

3.8 AA-1 Highway 380 Bridge

The river in the vicinity of the Highway 380 bridge is very uniform and appears to have been channelized. As can be seen in Photo #16, the channel banks are lined with dense tamarisks further ensconcing the channel in place. Deposition has occurred at this cross section since the 1995 survey. An average of 2 feet of deposition in the main channel and 1 foot in the overbanks is seen on the cross section plot. This section was not surveyed in 2000, and therefore there are no photographs to use for comparison.

Photo #16. Looking upstream from the center of the channel at AA-1 Highway 380 cross section.

3.9 AA-1.5 Dexter Gage

The cross section at the USGS Dexter gaging station is very similar to the Highway 380 cross section. The channel in this area is also very uniform, very straight and lined with dense tamarisks. Photos #17 and #18 show the channel looking upstream. The photos were taken at different times of the year, and show the difference of the vegetation during dormant and active seasons.

Deposition has also occurred at this cross section, with an average of 1 foot in the channel and roughly 0.5 feet in the overbanks between 1995 and 2005.

Photo #17. From the center of the channel at the Dexter gage looking upstream, taken during 2000.

Photo #18. From the center of the channel at the Dexter gage looking upstream, taken during 2005.

3.10 AA-3 Lake Arthur Gage

The cross section at the Lake Arthur gage has experienced some degradation in the past 5 years. The left side of the channel has degraded up to 2.5 feet. The channel in this reach is also very uniform with steep, stable banks and limited sinuosity. Comparing the two photos below (one taken in 2000 and the other in 2005), it is apparent that little change has occurred in the channel shape and in the vegetation on the banks.

Photo #19. Looking upstream at the USGS Lake Arthur gage, taken in 2000.

Photo #20. Looking upstream at the USGS Lake Arthur gage, taken in 2005.

3.11 AA-4 Artesia

The cross section at Artesia is relatively stable, with some deposition occurring on the right bank over the last 10 years. The channel is very uniform, with little sinuosity or diversity in aquatic habitat. Comparing the two photos below (taken 5 years apart), it is apparent that little change has occurred in the channel shape and in the vegetation on the banks.

Photo #21. Looking upstream from below the bridge near Artesia (cross section AA-4 is just upstream of the bridge), photo taken in 2000.

Photo #22. Looking downstream from the Artesia cross section (AA-4) at the bridge near Artesia, photo taken in 2005.

4.0 CHANNEL GEOMETRY PREDICTION

In 2003, Tetra Tech, Inc. performed a study for the Bureau of Reclamation on the Pecos River. The study involved determining a way to predict channel geometry based on dominant or effective discharge[15].

In the 2003 study, cross section information from an undisturbed portion of the Pecos River in the Bitter Lake National Wildlife Refuge was used to generate hydraulic information using HEC-RAS (USACE, 2002). The hydraulics were in turn used to estimate sediment transport rates for the known range of flows for the Acme gage. For each discharge rate, a corresponding sediment transport rate was estimated. The frequency of the discharge was determined by creating bins of flow and performing a histogram analysis. From the frequency, the probability of occurrence was calculated. The probability of occurrence is multiplied by the sediment transport rate for a representative discharge for each bin and divided by the size of the corresponding bin since the bins are not all of equal size. The result is referred to as the incremental sediment transport rate that has units of tons/day/cfs. The discharge that corresponds to the highest incremental sediment discharge rate is the dominant discharge. Table 2 below shows an example of the calculations.

This process was used in the 2003 study to determine the dominant discharge for the flows at Acme based on three scenarios unrelated to the current EIS alternatives. The three scenarios were selected to demonstrate the effects of vastly different operating conditions.

With the dominant discharge known, the coefficients for the channel geometry prediction equations (shown below) were determined, thus calibrating the equations for the area of the study.

Three sub-reaches were defined in the 2003 study and the equations determined for each reach are:

Reach 1: $W = 3.98\ Q_d^{\ 0.5}$ $D = 0.138\ Q_d^{\ 0.4}$
Reach 2: $W = 3.54\ Q_d^{\ 0.5}$ $D = 0.135\ Q_d^{\ 0.4}$
Reach 3: $W = 4.39\ Q_d^{\ 0.5}$ $D = 0.154\ Q_d^{\ 0.4}$

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[15] "The dominant or effective discharge is defined as the single discharge (resulting from a range of flows) at which the sediment transport capacity multiplied by the frequency of occurrence (incremental sediment transport rate) yields the largest portion of sediment transported by the system relative to other flows (Thorne, 1997)." Tetra Tech, 2003

Table 2. Calculation of Dominant Discharge for Acme Constant with Bypass Flows Only

				Acme Constant				
Sediment Transport Rates (tons/day)						*Incremental Transport Rate (tons/day/cfs)*		
				Frequency	*Probability*	*Reach 1*	*Reach 2*	*Reach 3*
Discharge (cfs)	Reach 1	Reach 2	Reach 3					
0	0	0	0	147	0.0067			
7	2	1	2	1515	0.0691	0.01	0.01	0.01
14	7	7	6	2571	0.1173	0.08	0.08	0.07
24	18	17	15	1623	0.0741	0.13	0.13	0.11
35	33	32	30	8388	0.3828	1.28	1.24	1.13
45	51	49	45	1284	0.0586	0.30	0.28	0.26
55	72	67	63	1203	0.0549	0.40	0.37	0.35
65	96	86	83	473	0.0216	0.21	0.19	0.18
75	122	108	106	300	0.0137	0.17	0.15	0.14
85	151	132	130	336	0.0153	0.23	0.20	0.20
95	181	157	156	346	0.0158	0.29	0.25	0.25
105	213	183	183	267	0.0122	0.26	0.22	0.22
115	246	212	212	206	0.0094	0.23	0.20	0.20
125	282	241	243	155	0.0071	0.20	0.17	0.17
135	314	272	275	104	0.0047	0.15	0.13	0.13
145	352	303	308	108	0.0049	0.17	0.15	0.15
155	392	336	341	88	0.0040	0.16	0.13	0.14
165	434	370	376	71	0.0032	0.14	0.12	0.12
175	476	405	413	71	0.0032	0.15	0.13	0.13
185	520	441	451	60	0.0027	0.14	0.12	0.12
195	565	478	490	50	0.0023	0.13	0.11	0.11
245	815	673	698	359	0.0164	0.13	0.11	0.11
346	1407	1153	1188	308	0.0141	0.20	0.16	0.17
447	2111	1718	1759	182	0.0083	0.18	0.14	0.15
548	2910	2358	2381	169	0.0077	0.22	0.18	0.18
648	3787	3058	3048	110	0.0050	0.19	0.15	0.15
748	4739	3815	3744	170	0.0078	0.37	0.30	0.29
849	5762	4644	4474	184	0.0084	0.48	0.39	0.38
949	6681	5539	5210	287	0.0131	0.87	0.73	0.68
1025	7965	6621	5661	346	0.0158	**2.52**	**2.09**	**1.79**
1075	8569	7147	5996	118	0.0054	0.92	0.77	0.65
1125	9172	7673	6331	42	0.0019	0.35	0.29	0.24
1175	9776	8199	6666	23	0.0010	0.21	0.17	0.14
1224	10376	8723	6999	18	0.0008	0.17	0.14	0.12
1250	10684	8991	7169	0	0.0000	0.00	0.00	0.00
1275	10985	9254	7337	17	0.0008	0.17	0.15	0.11
1325	11586	9778	7670	12	0.0005	0.13	0.11	0.08
1375	12189	10304	8005	9	0.0004	0.10	0.08	0.07
1449	13085	11085	8501	30	0.0014	0.18	0.15	0.12
1732	16760	14369	10249	54	0.0025	0.08	0.07	0.05
2236	24118	21252	13882	24	0.0011	0.05	0.05	0.03
2739	30614	29309	17528	12	0.0005	0.03	0.03	0.02
3122	36377	35996	20251	7	0.0003	0.05	0.05	0.03
3373	40147	39463	21519	6	0.0003	0.04	0.04	0.02
3742	47589	49934	31210	5	0.0002	0.02	0.02	0.01
4472	62539	75418	44512	21	0.0010	0.06	0.07	0.04
6124	103028	95210	87393	23	0.0010	0.04	0.04	0.04
8660	183270	163647	144024	4	0.0002	0.01	0.01	0.01
12247	334094	316315	298536	5	0.0002	0.02	0.01	0.01
17321	622079	565064	508048	2	0.0001	0.01	0.01	0.01
24495	1178727	1135399	1092072	2	0.0001	0.01	0.01	0.01
			MORE	0				
			TOTAL	21915	1.0000			

*4.**1 Bypass Flows Only***

For this study, the dominant discharge, Q_d, for each of the EIS alternatives was determined and entered into these equations. The goal of this exercise was to determine if the different alternatives would result in different channel geometry in the long run.

The dominant discharge for the bypass only EIS alternatives was a fairly straight forward calculation. First, a range of discharge values that encompassed all flows for the Acme gage (values were determined from RiverWare model output) were determined. Next, the range was broken down into a series of bins. The flow record for the modeled Acme gage was then separated into bins and the frequency of each flow (the median flow value represented by the bin) was determined. The probability of occurrence was calculated based on the frequency and the total number of occurrences. The sediment transport rate for each flow value was determined as part of the 2003 study. This value was multiplied by the probability of occurrence. The largest value determined by this product represents the dominant discharge. The results of the “bypass only” flows are shown in Table 2.

The results showed little to no variation in the dominant discharge among alternatives with bypass water only, as shown in Table 4. Note that the values depicted in Table 4 are the median values of the bins used to define ranges of flows. In this case, 1,075 cfs is the median of the range from 1,050 to 1,100 cfs, likewise, 1,000 – 1,050 cfs is the range that encompasses 1,025 cfs.

In addition to the analysis of the alternatives that used bypass flows only, another set of alternatives that added all the required water to meet all the Pecos blutnose shiner’s (PBNS) needs (defined as targets in the alternatives) was analyzed as well. This second set of alternatives, dubbed “with Carlsbad Project supply” represents the scenario where water would be released from Sumner Reservoir to supplement bypass flows, therefore decreasing the water available for Carlsbad Project supply.

4.2 With Carlsbad Project Supply

The determination of the dominant discharge for the “with Carlsbad Project supply” was a bit more complicated. As part of the EIS process, a “mini-model” was executed to determine the amount of water needed each year (1940 – 1999) to meet the additional water needs of the PBNS not met by the bypass flows alone. The “mini-model” spanned from Sumner to Acme, but did not extend downstream as far as Brantley Reservoir. The results therefore contain block releases from Sumner Dam as they would have occurred in the bypass only scenario. However, it is likely that some of the water released for the PBNS would reach Brantley Reservoir and decrease the need for block releases from Sumner Reservoir.

In order to alter the available information to more accurately represent the “with Carlsbad Project supply” condition, the amount of water need for the PBNS was determined for each year. This volume was then subtracted from the volume of water discharged out of Sumner Dam in block releases and the flow frequencies were recalculated. The number of days of block releases for the bypass only and for the “with Carlsbad Project supply” are shown in Table 3. As can be seen, there is not a very large difference between the two scenarios. The exception is the Acme Constant alternative which has a decrease of 270 days in block releases for the “with CID supply” scenario.

Results for the dominant discharge for the "with Carlsbad Project supply" scenario are shown in Table 4. As can be seen, the changes in the block release flow values are not large enough to make a difference in the dominant discharge.

Table 3. Number of Days of Block Releases During Period of Study (1940 – 1999)

	Acme Constant	Acme Variable	Taiban Constant	Taiban Variable 55 cfs	Taiban Variable 40 cfs	Taiban Variable 45 cfs	Critical Habitat	No Action
Bypass Only	650	660	750	725	750	740	750	750
With Carlsbad Project Supply	380	510	730	605	710	675	730	670

Table 4. Dominant Discharge (cfs)

	Alternative								
	Pre-91	Acme Constant	Acme Variable	Taiban Constant	Taiban Variable 55 cfs	Taiban Variable 40 cfs	Taiban Variable 45 cfs	Critical Habitat	No Action
Bypass Only	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025
With Carlsbad Project Supply	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025	1,025

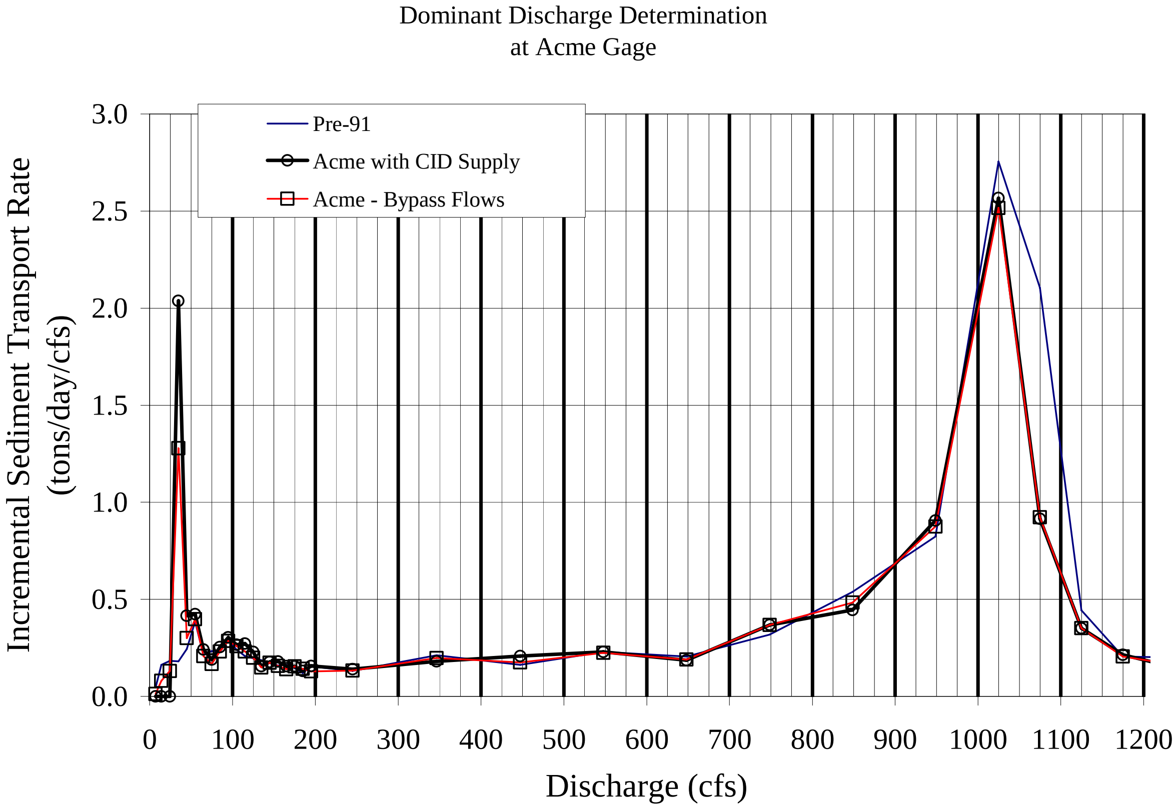

Figure 1. Graph of Dominant Discharge for Pre-91, Bypass Flows and With Carlsbad Project Supply conditions at the Acme gage for the Acme Constant Alternative.

Figure 1 shows the incremental sediment transport rate versus the discharge for bypass operations under the alternatives and the Pre-91 baseline. From this figure, it can be seen that the dominant discharge for the Pre-91 condition is 1,025 cfs. This is the value that corresponds to the highest incremental sediment transport rate, approximately 2.76 tons/day/cfs. Likewise, the dominant discharge for the Acme Constant alternative with Bypass Flows only and the Acme Constant alternative with unlimited use of Carlsbad Project Water is 1,025 cfs, corresponding to an incremental sediment transport rate of approximately 2.57 tons/day/cfs. This slightly lower incremental transport rate is essentially due to the block release constraints imposed by the alternatives.

Using the average of the three reaches and putting in a range of dominant discharge values, Figure 2 was created. This demonstrates how the channel width and depth are expected to decrease with decrease in dominant discharge.

Using the channel geometry equations and the results listed in Table 3, the channel width and depth under Pre-91 and alternative operation conditions could be expected to average 127 feet and 1.8 feet, respectively. Although the results show no change between the alternatives and the baseline, Figure 1 indicates that additional reductions in block flows (beyond Acme Constant using all of CID's supplies) and subsequent redistribution of those flows in the target ranges considered by the alternatives may cause the channel to change shape. For example, if the higher flows were reduced further and the dominant discharge dropped to 45 cfs, the channel width prediction would be 27 feet and the depth would be 0.6 feet.

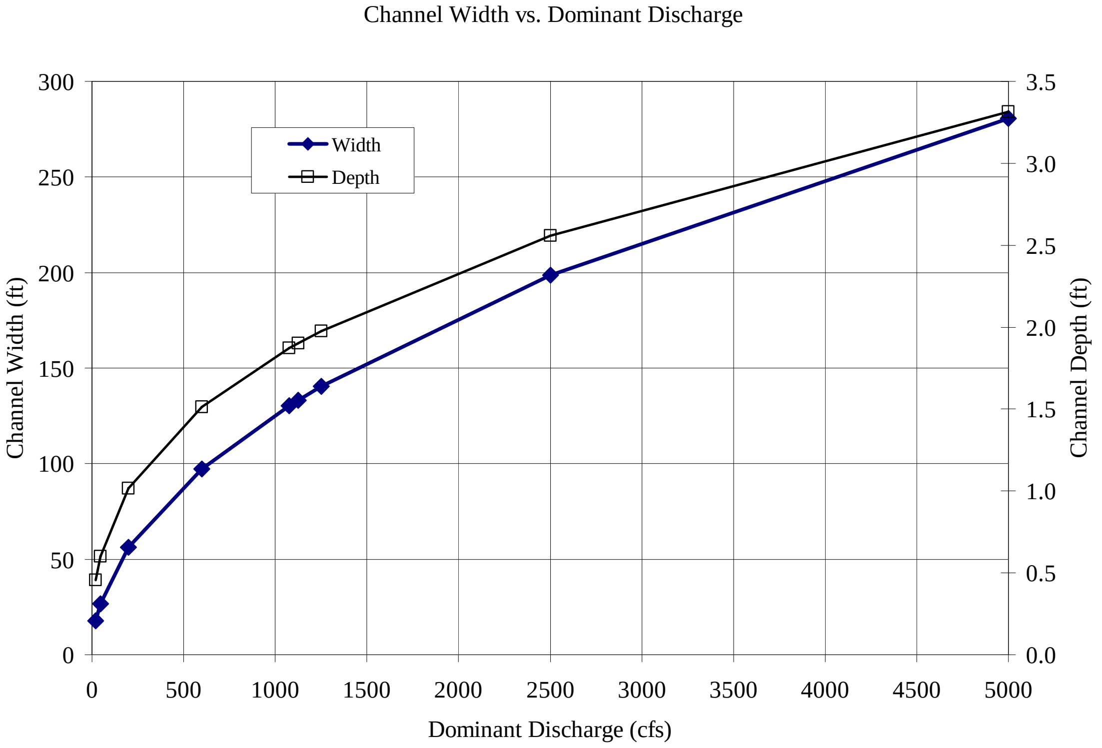

Figure 2. Predicted Channel Width and Depth versus Dominant Discharge

5.0 CONCLUSIONS

The Pecos River between Sumner and Brantley Reservoir has widely varied geomorphology and aquatic habitat conditions. The upper critical habitat is in a section of the river that has not been as dramatically altered as is the case in the lower critical habitat. The upper portions, from Sumner Reservoir to roughly the Acme gage, has been affected by the changes to hydrology, diversion structures, return flows, etc.; however, some natural characteristics such as good floodplain connectivity and channel shape still exist. In the lower portions of the river, previous channelization efforts have caused the channel to become very canal like, held in place with dense, mature tamarisks.

The channel geometry prediction equations show that with lower dominant discharges, a decrease in channel width and depth can be expected. Based on the results of the modeling efforts for the different alternatives and scenarios, a large change would not be expected in the channel geometry. However, should the block releases be lowered or eliminated altogether, a bigger impact on the channel is to be expected as demonstrated in Figure 2.

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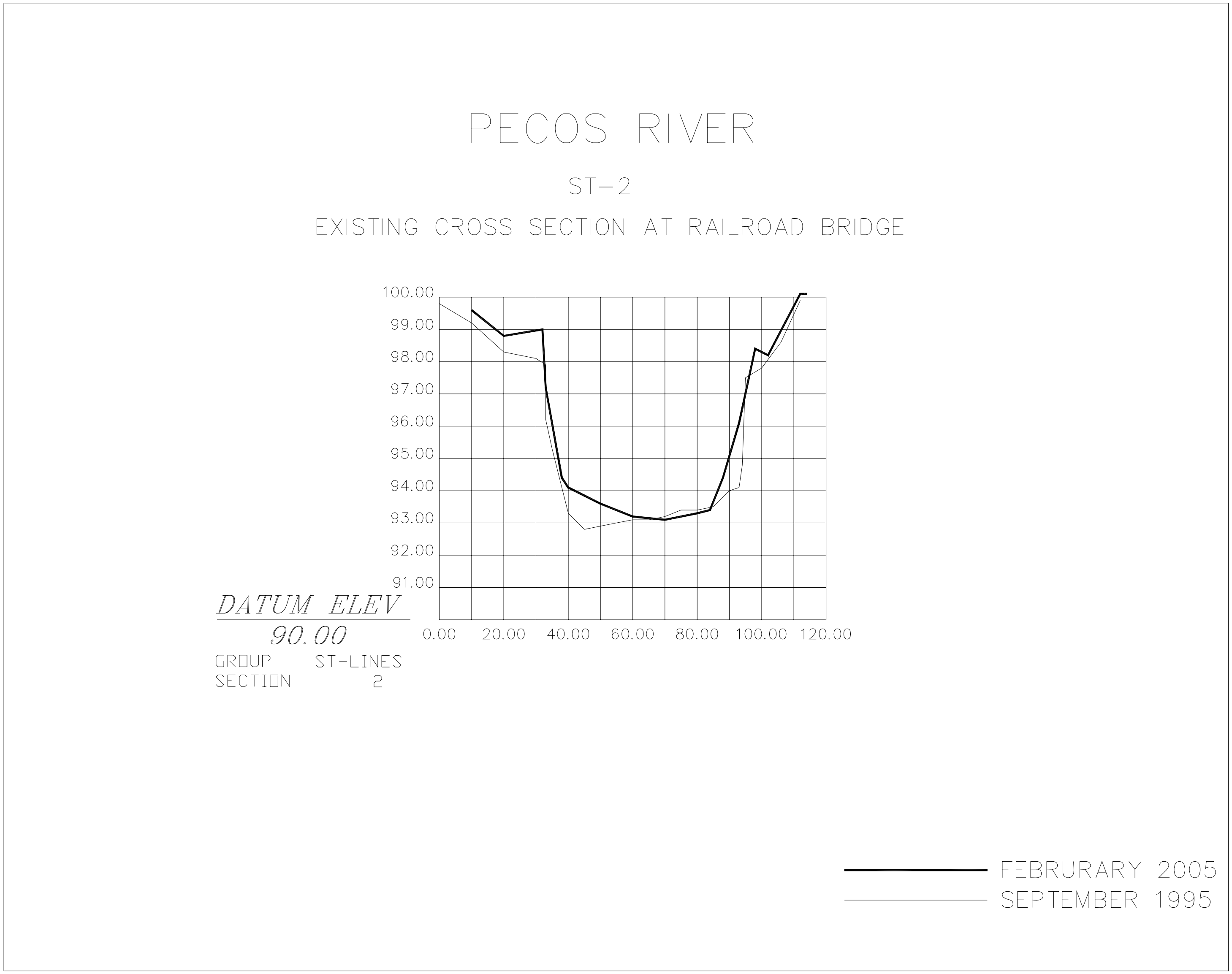
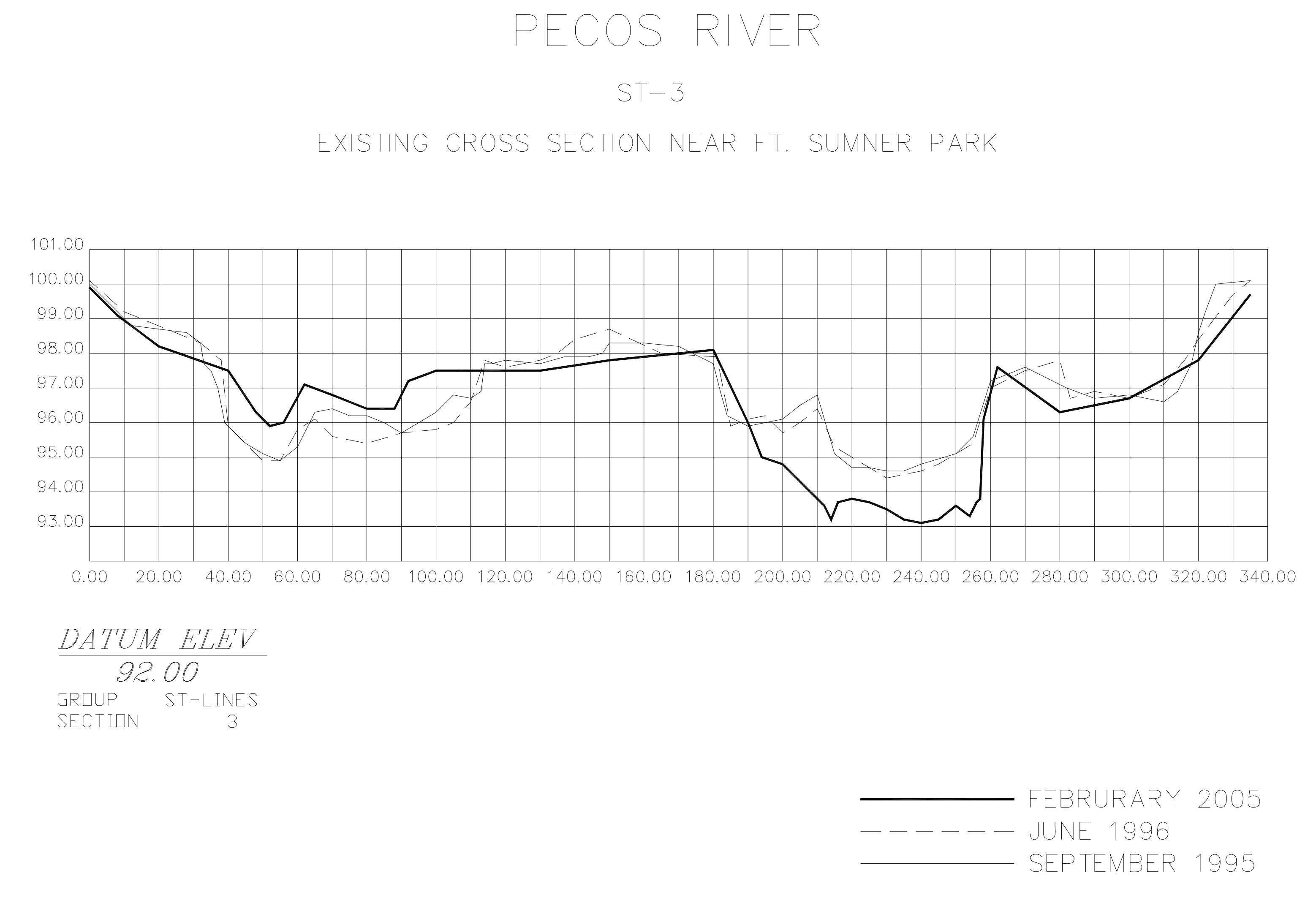
7.0 CROSS SECTION PLOTS 2005 DATA COLLECTION


PECOS RIVER

ST-2

EXISTING CROSS SECTION AT RAILROAD BRIDGE



PECOS RIVER

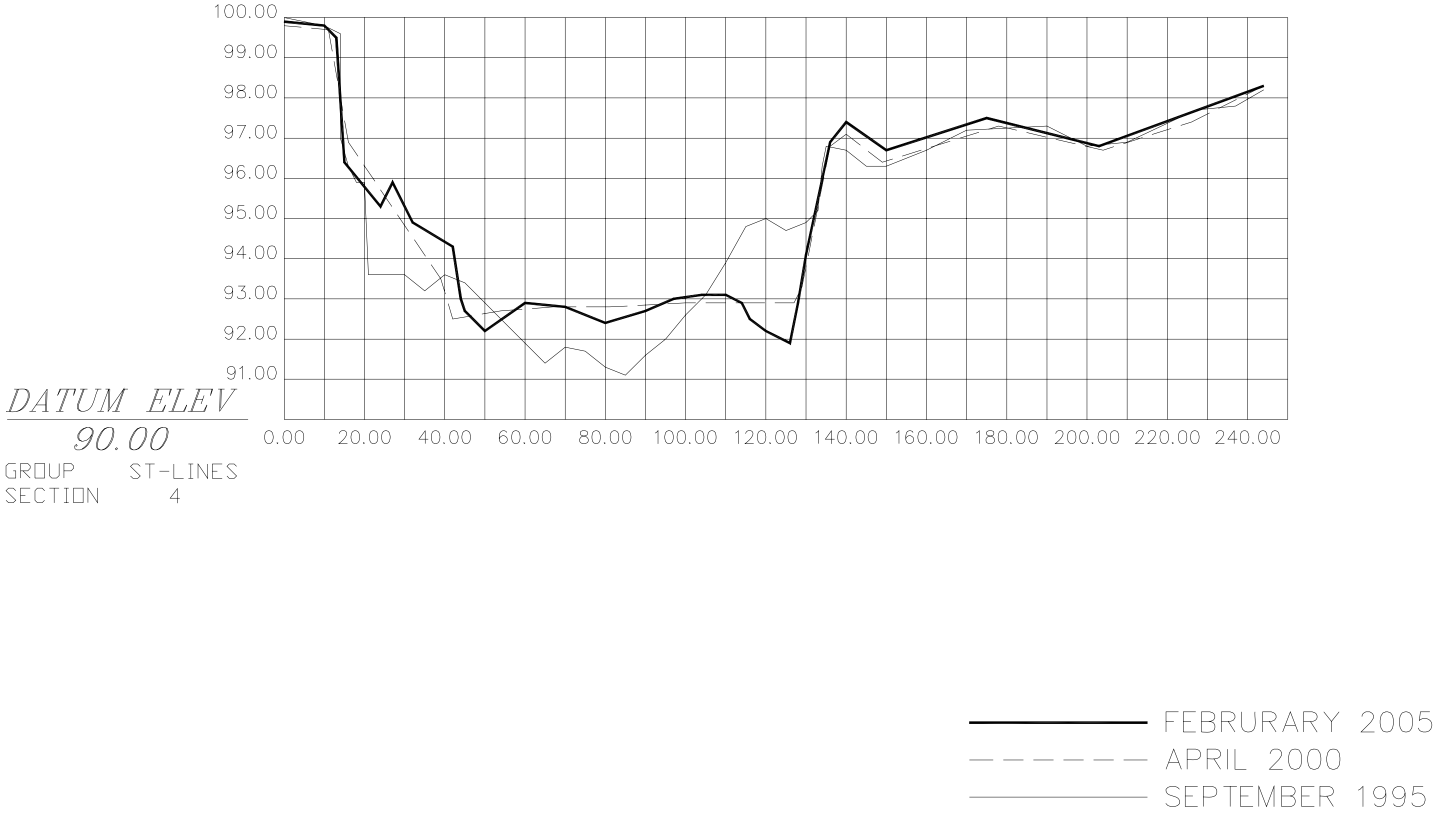
ST-3

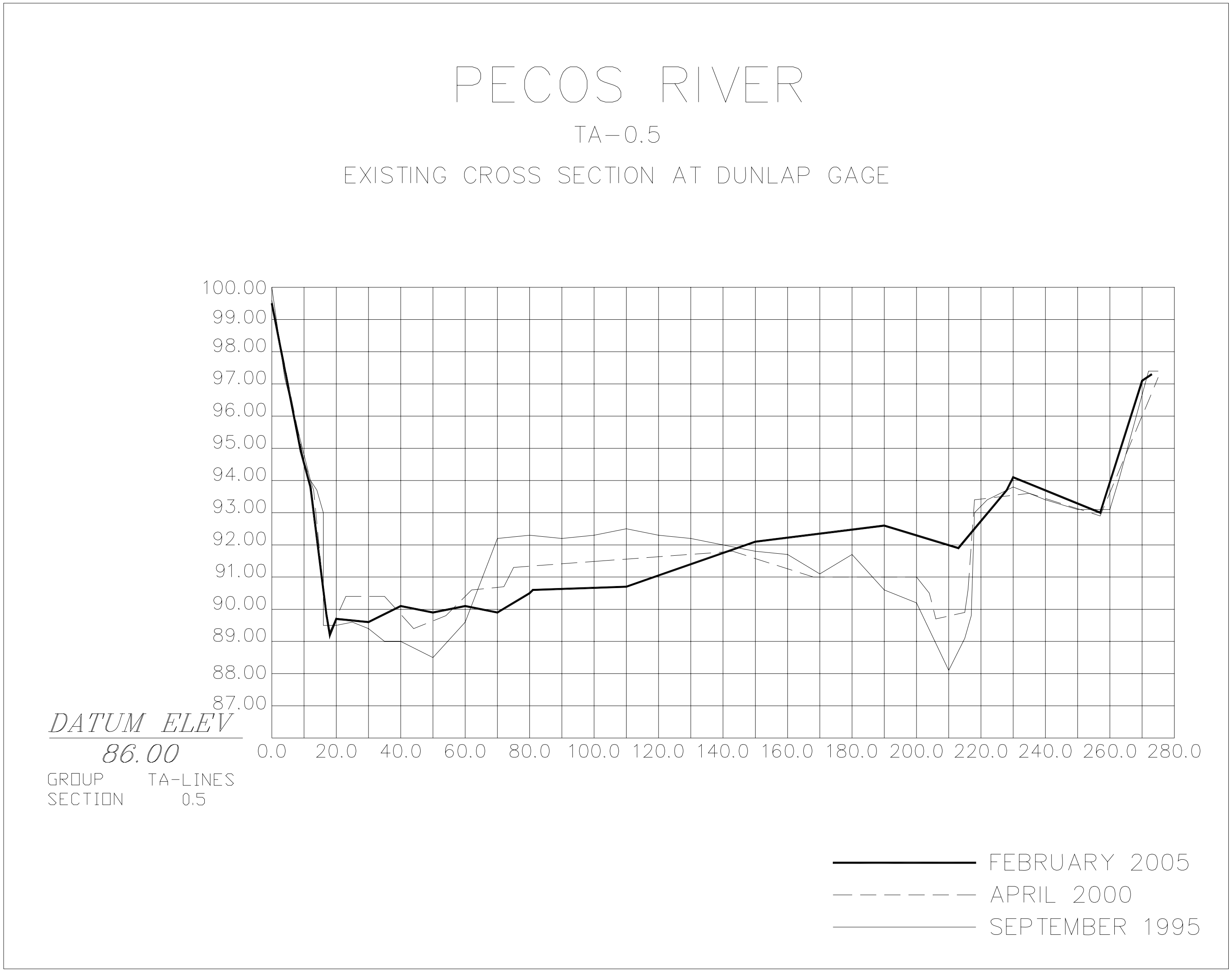
EXISTING CROSS SECTION NEAR FT. SUMNER PARK

PECOS RIVER

ST–4

EXISTING CROSS SECTION AT TAIBAN GAGE




PECOS RIVER
TA–0.5
EXISTING CROSS SECTION AT DUNLAP GAGE
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99.00
98.00
97.00
96.00
95.00
94.00
93.00
92.00
91.00
90.00
89.00
88.00
87.00
DATUM ELEV
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20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
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220.0
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260.0
280.0
GROUP TA-LINES
SECTION 0.5
FEBRUARY 2005
APRIL 2000
SEPTEMBER 1995

PECOS RIVER

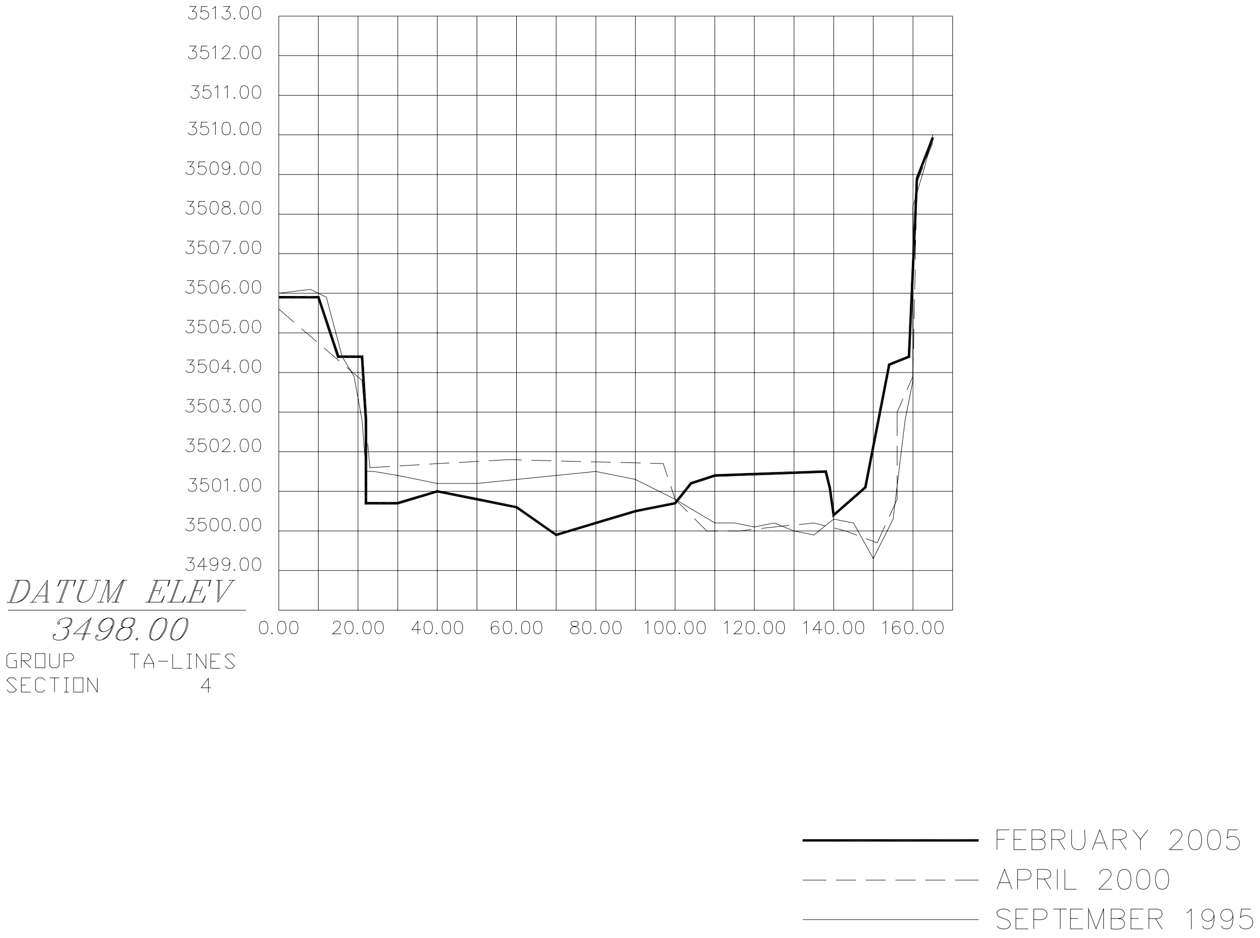
TA−2

EXISTING CROSS SECTION AT ABOVE ACME GAGE

PECOS RIVER

TA-4

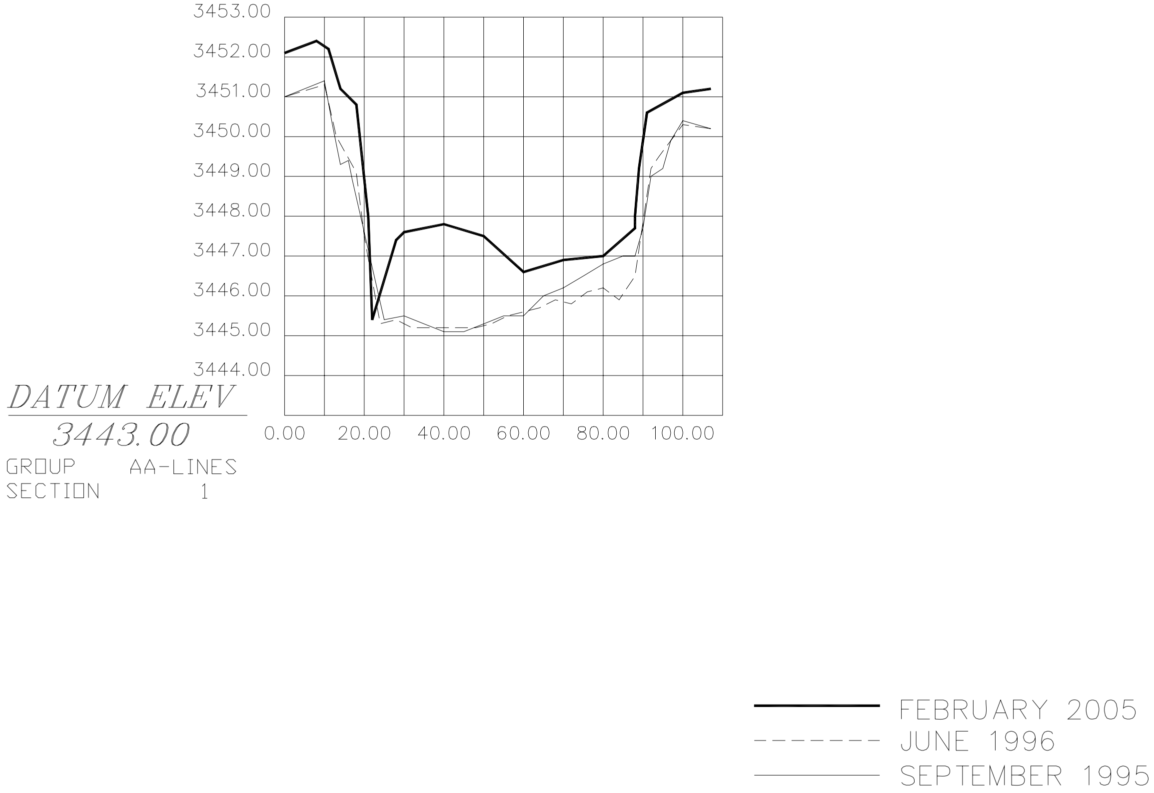
EXISTING CROSS SECTION AT ACME GAGE

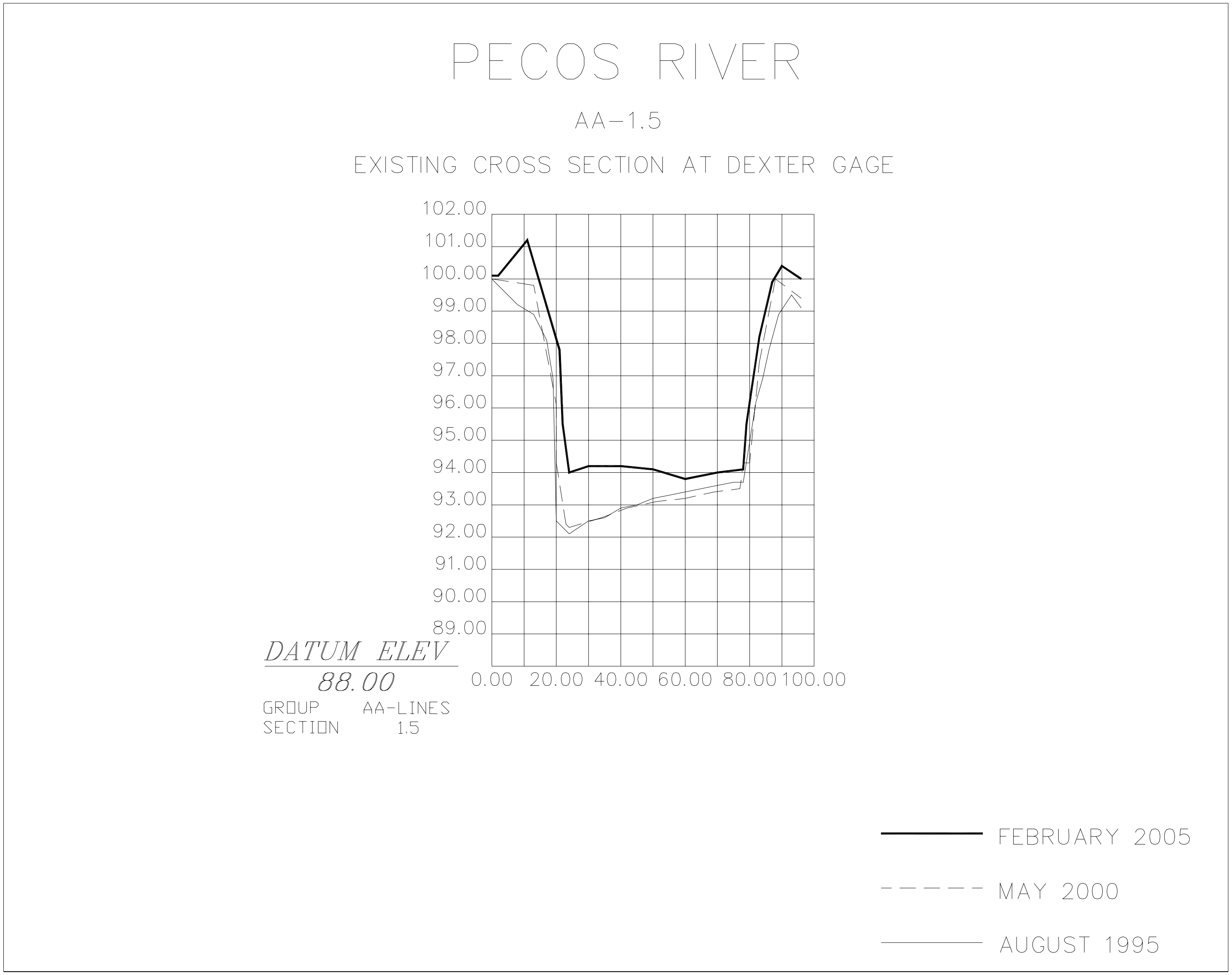


PECOS RIVER

AA-1

EXISTING CROSS SECTION AT HIGHWAY 380 BRIDGE





PECOS RIVER

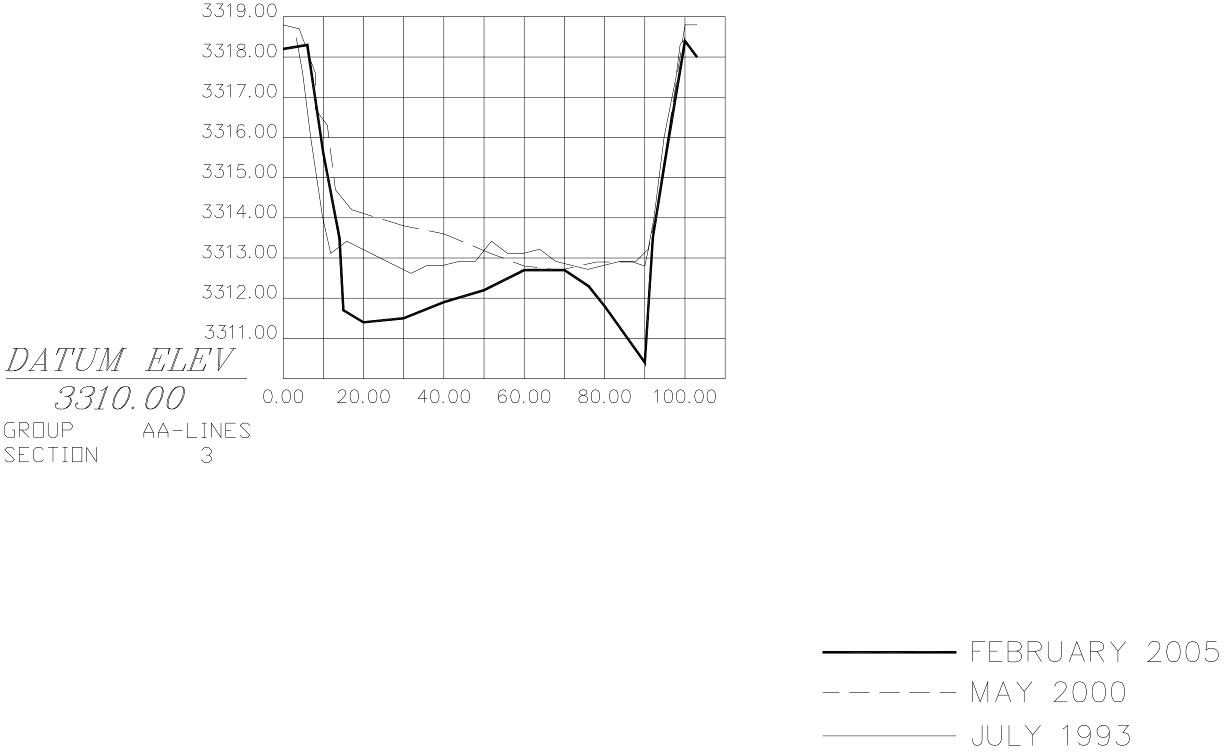
AA−1.5

EXISTING CROSS SECTION AT DEXTER GAGE

PECOS RIVER

AA-3

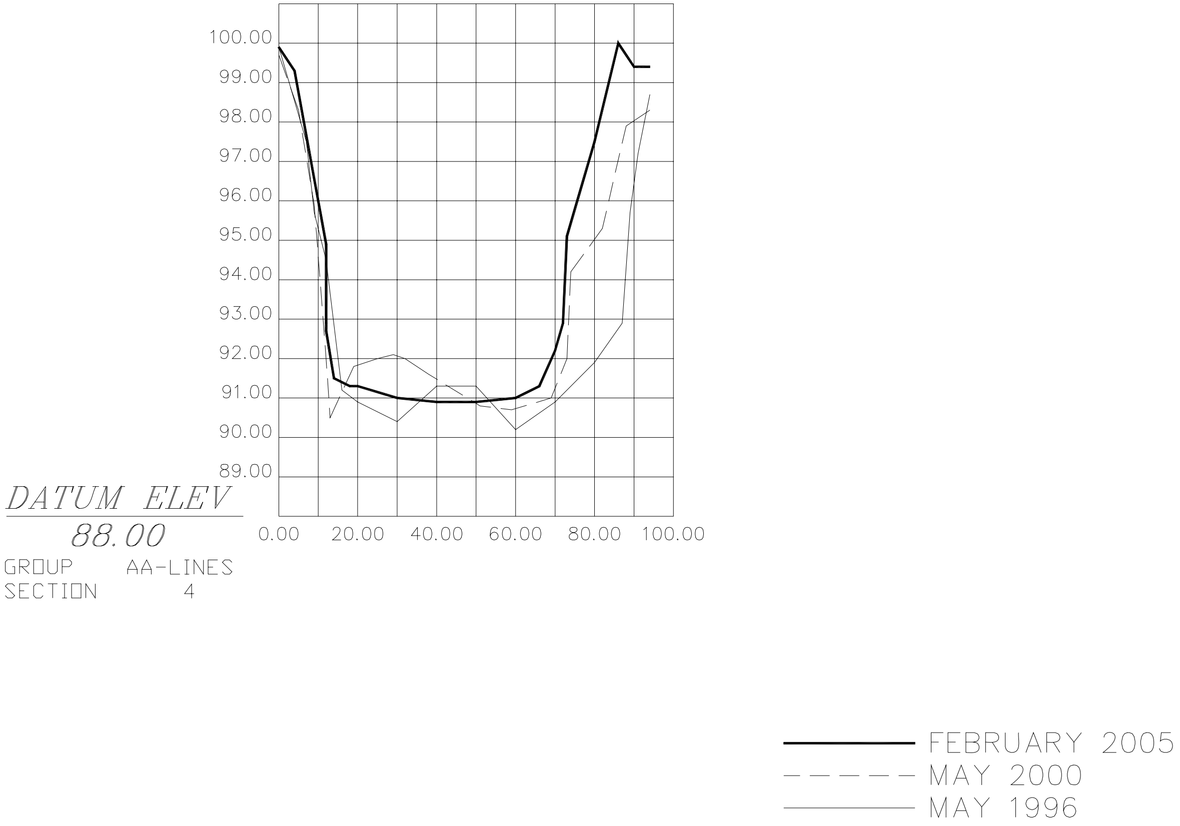
EXISTING CROSS SECTION AT LAKE ARTHUR GAGE



PECOS RIVER

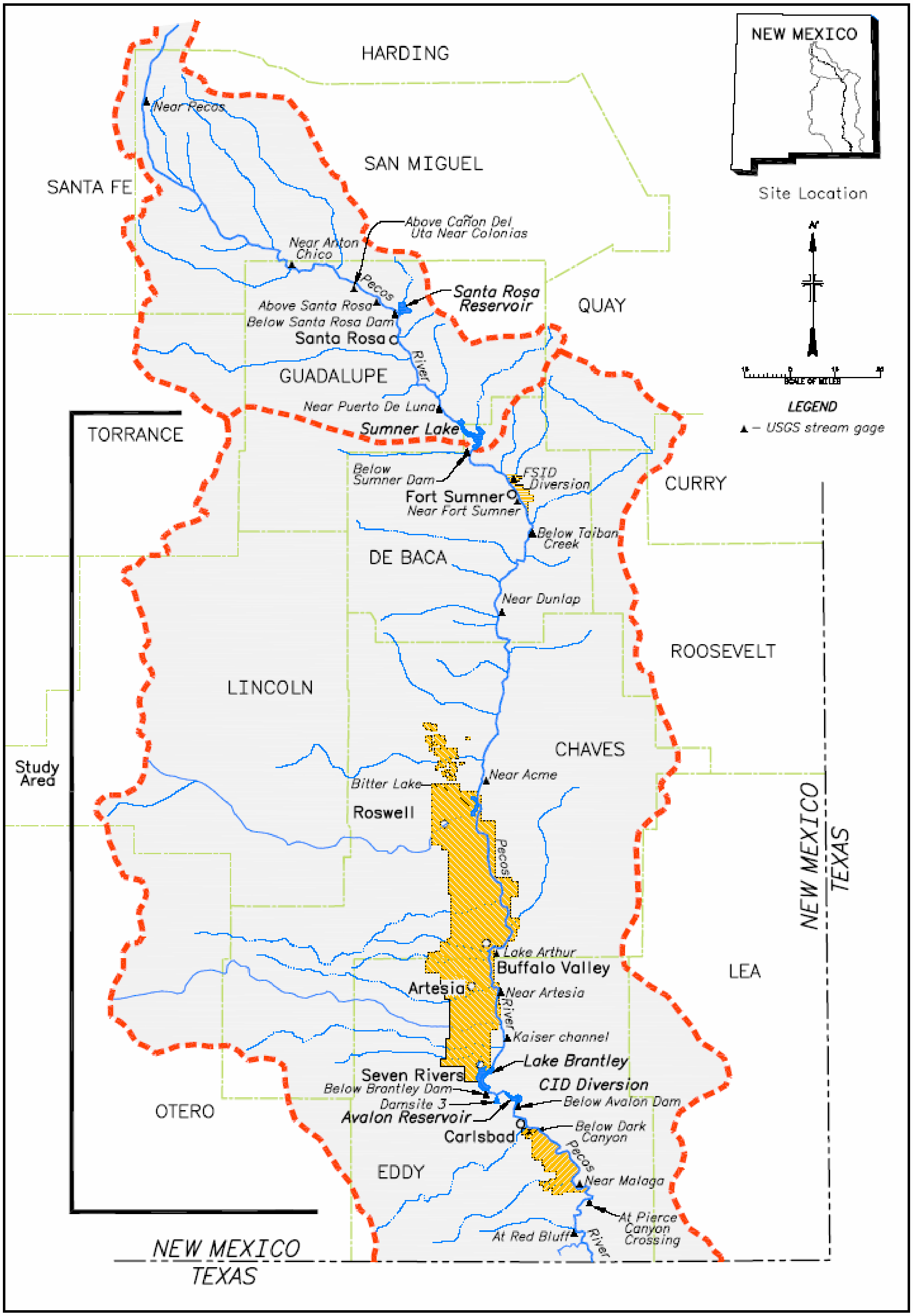
AA-4

EXISTING CROSS SECTION AT ARTESIA GAGE



Appendix 4

Water Quality



Map 1: Map of the Pecos River Basin in New Mexico showing stream gage locations

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Water Quality Appendix

This section will present data on existing water quality in the Pecos River basin from Santa Rosa Lake to north Texas. Data for the description were retrieved from the U.S. Geological Survey's (USGS) National Water Information System (NWIS). There are water quality data available for 14 long-term USGS gages in the basin. To define the existing water quality of the basin, only data collected since storage began behind Brantley Dam in August 1988 were used. This restriction of the period of record eliminated 3 of the gages that were discontinued prior to the closure of Brantley Dam. The gages that were eliminated included those at Pecos (ended 1970), Sumner Dam (ended 1988), and Carlsbad (ended 1987).

Pecos River

Basin-wide Water Quality

The water quality of the Pecos River basin has been recently described by the New Mexico Water Quality Control Commission (NMWQCC, 2002a) in their 305(b) Report. This initial description is works from the summary in that report.

The headwaters are pristine with one exception, the abandoned Pecos (Terrero) Mine near the mouth of Willow Creek. Although the remainder of the basin is by no means pristine, it is supportive of its designated beneficial uses. The listed causes of nonsupport in the mainstem of the Pecos River as shown in NMWQCC (2002a) in the study area include:

> metals (most frequently aluminum, but also including mercury, primarily in lakes), turbidity, nutrients, pathogens, dissolved oxygen, stream bottom deposits, and total ammonia from municipal point sources, temperature, and conductivity.

This description will focus on the factors that can be affected by the operations of the Project and changes in those operations. These include total dissolved solids (TDS), *i.e.* specific conductance, metals, and siltation. Data to be used are summarized in Attachment 1, which also includes water quality standards and a comparison to the standards for each of the gages in the Pecos Basin within the Project area.

Figure 1 shows the median along with the 25th and 75th percentile specific conductance of the Pecos River from above the study area to a point beyond its southern end. Specific conductance is a measure of the ability of water to conduct electricity and is proportional to the dissolved solids (electrolytes) concentration in water. All of the data summarized in Figure 1 are based on the periods shown at the top of the summary tables in Attachment 1; this includes the period since the closure of Brantley Dam. The EC for the farthest upstream site, the Santa Rosa Lake inflow, is in the range of 390 to 895 µS/cm. The median EC and the spread between the 25th and 75 percentiles then increases to the site near Artesia. There is a subsequent decrease in both the median and the spread at the site below Brantley Dam, with a further decrease at the Dark

Canyon gage. The initial decrease is a reflection of the mixing of dilute and concentrated inflows that occurs within the reservoir. The net effect is a more uniform water quality over time. The additional decrease at the Dark Canyon gage reflects the influence of base flow from the relatively pristine Capitan Reef aquifer, as well as tributary inflows from the Guadalupe Mountain watersheds. Flow at the Dark Canyon gage also shows even less variation in specific conductance than the Brantley Reservoir release. NMWQCC (2002) indicates that the river in the reach upstream from the Dark Canyon gage is located is frequently dry; water at the gage on such occasions would consist of local gains from base flow.

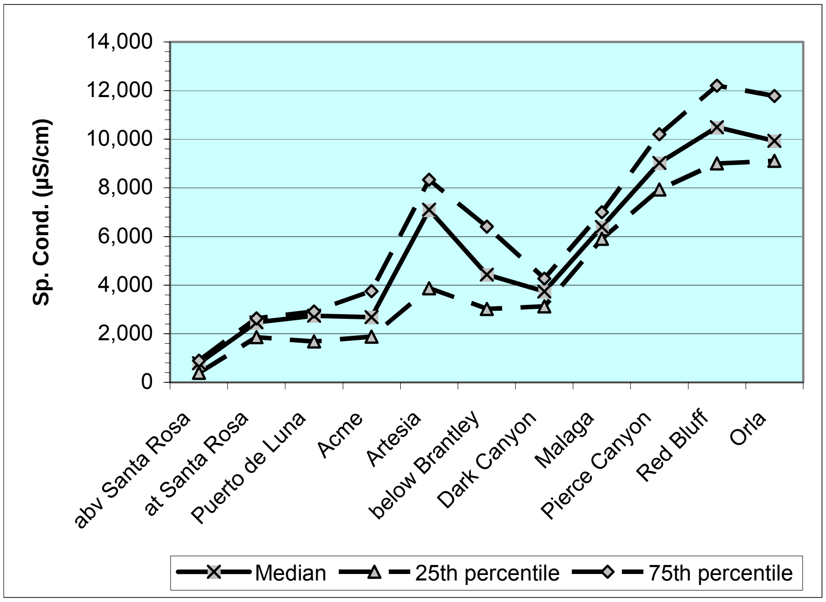


Figure 1: Specific conductance in the Pecos River basin between the Santa Rosa Lake inflow and Orla, Texas

Table 1 summarizes the results of a regression analysis of the flow and specific conductance data for each of the gages shown on Figure 1. The r^2-values in Table 1 reflect the relationships described above for the data in the plots. The lowest r^2-values are those for the Brantley outflow and the gage at Dark Canyon. Both the influence of a reservoir and the overwhelming predominance of base flow would reduce the influence of flow in determining the specific conductance. The relationship between flow and specific conductance reflects either the seasonal variation due to low specific conduc-

Table 1. Logarithmic regressions of specific conductance on flow at 11 sites on the Pecos River

Location	r^2	Slope	Intercept	n	F	Prob. > F
above Santa Rosa	0.6943	-0.394626	8.047279	53	115.81	< 0.000001
at Santa Rosa	0.7073	-0.331327	8.304622	42	96.68	< 0.000001
Puerto de Luna	0.6904	-0.516690	10.135504	51	109.27	< 0.000001
Acme	0.5729	-0.228936	8.809516	39	49.63	< 0.000001
Artesia	0.7408	-0.465102	10.831268	52	142.87	< 0.000001
Brantley	0.2314	-0.147210	8.980483	42	12.04	0.001259
Dark Canyon	0.0898	-0.061015	8.367093	76	7.30	0.008527
Malaga	0.6214	-0.253799	9.781035	77	123.12	< 0.000001
Pierce Canyon Crossing	0.7652	-0.444435	10.93416	78	247.74	< 0.000001
Red Bluff	0.8069	-0.357685	10.749378	33	129.50	< 0.000001
Orla	0.4333	-0.097887	9.609246	55	40.53	< 0.000001

tance during spring snow melt runoff, the dilution of higher base-flow concentrations of dissolved solids by storm runoff, or a combination of both. In the case of a reservoir release, the dilution occurs in the reservoir; in the case of base flow, there is no dilution. Both cases show those influences in a lower r^2 for their specific conductance on flow regressions.

As can be seen in the tables in Attachment 1, there are no water quality standards for specific conductance anywhere in the Pecos basin. However, beginning with the gage at Puerto de Luna and continuing to Orla, with the lone exception of the Brantley release, there are standards for TDS, chloride, and sulfate.

Figure 1 shows 2 peaks in specific conductance in the Pecos Basin. The first peak occurs at Artesia and the second at the Red Bluff gage. The first peak in specific conductance reflects the effect of what is an apparent large salt load between the Acme and Artesia gages. This effect will be explored in more detail later in the Sumner Dam release section of this description. The second peak is the culmination of a gradual increase that begins at Malaga. These peaks in specific conductance are accompanied by a change in the composition of the dissolved solids in the river. These changes are shown on Figure 2, which presents plots of the percent composition of the cations and anions at each gage in the river.

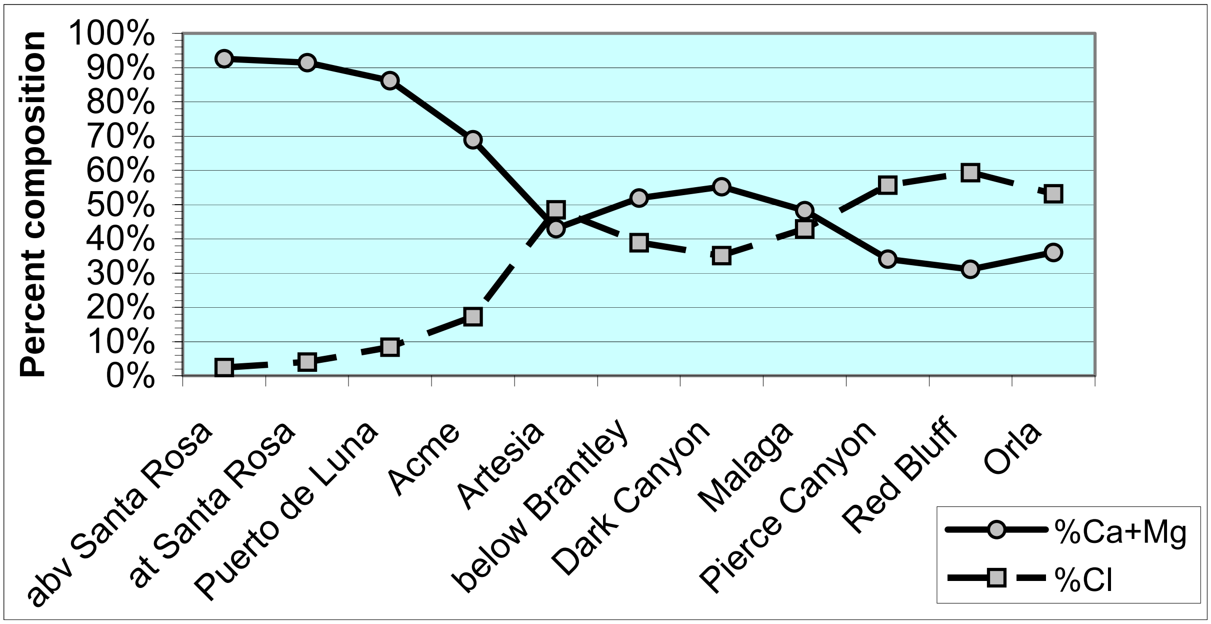


Figure 2: Median percent composition of cations and anions between the Santa Rosa inflow and Orla, Texas

The percent calcium plus magnesium (%Ca+Mg) on Figure 2 represents the percentage of the alkaline earth elements in the total cations, which also include the alkali elements, sodium and potassium (Na+K). Consequently, an decrease in the %Ca+Mg such as that which occurs between Santa Rosa and Artesia, could reflect either an increase in Na+K or a decrease in Ca+Mg. The specific conductance appears to remain fairly constant between the gage below Santa Rosa Lake and Acme, which would favor the loss of Ca+Mg. The pH is relatively high (see Attachment 1) and near or above 8.3, the saturation point of calcite ($CaCO_3$). This factor would favor the loss of Ca+Mg through calcite precipitation. Alternatively, at Artesia the specific conductance increases (Figure 1), which would favor an increase in Na+K, as has been documented in an earlier study by Mower *et al.* (1964). The decrease in the %Ca+Mg downstream from Dark Canyon (Figure 2) is caused by a documented loading of brine (specifically, NaCl) near Malaga (Kunkler, 1980).

The change in the anionic composition of the water adds confirmation to the above. There is an increase in the percent chloride (%Cl) between Santa Rosa and another beginning at Malaga. Unlike the %Ca+Mg, the %Cl does not represent the percentage in the total anions. The %Cl is only based on the sum of the chloride and sulfate concentrations, while the total anions would also include the carbonates. The carbonates were not included because there are no data at many of the stations, including the stations below Brantley, Dark Canyon, Malaga, and Pierce Canyon Crossing. Because of the lack of data on carbonates, these stations also do not have TDS data. But based on the data that are included on Figure 2, each decrease in the %Ca+Mg is accompanied by an increase in the %Cl, and *vice versa*. This factor further supports the increased loading of NaCl as the main factor in changing the ionic composition of the water as it proceeds downstream.

Table 2 shows a statistical comparison, based on Kruskal-Wallis tests, of the specific conductance of adjacent sites. There are significant differences among all of the adjacent sites, except for the Puerto de Luna to Acme and Red Bluff to Orla couples. To see the more dramatic changes, double-digit X^2-values can be used as a flag. Double-digit X^2-values occur in the following reaches: above Santa Rosa to at Santa Rosa, Acme to Artesia, Dark Canyon to Malaga, and Malaga to Pierce Canyon Crossing (Table 2). All of these reaches were noted in the discussion of Figure 1 with the exception of the first reach, which essentially encompasses Santa Rosa Lake. The median specific conductance values shown in Table 2 show an increase from around 800 µS/cm to about 2,400 µS/cm in the Santa Rosa Lake reach of the Pecos River. In the Acme to Artesia reach, the median specific conductance increases from about 2,700 to over 7,000 µS/cm. Below this reach, there is a decrease in specific conductance as was described above. The last of the large increases occurs between Dark Canyon and Malaga, where the median specific conductance increases from a little over 3,700 to 6,400 µS/cm, followed by a further increase to about 9,000 µS/cm between there and Pierce Canyon Crossing.

It was noted above that specific conductance is a surrogate for TDS. It was also noted above that there were no TDS data at a number of the sites. The relationships between TDS and specific conductance for the 6 sites from which there are TDS data are shown

Table 2. Comparison of specific conductance between adjacent sites (1988-2001)

Sites		Sp. Cond. (µS/cm)		n 1	n 2	X^2	Prob. > X^2
Upstream (1)	Downstream (2)	Median 1	Median 2				
above Santa Rosa	at Santa Rosa	791	2,425	55	46	35.830	< 0.000001
at Santa Rosa	P. de Luna	2,425	2,740	46	51	8.026	0.004611
P. de Luna	Acme	2,740	2,680	51	39	3.373	0.066292
Acme	Artesia	2,680	7,100	39	53	31.249	< 0.000001
Artesia	Brantley	7,100	4,430	53	45	9.048	0.002630
Brantley	Dark Canyon	4,430	3,735	45	79	5.055	0.024554
Dark Canyon	Malaga	3,735	6,400	79	79	92.634	< 0.000001
Malaga	Pierce Canyon Xing	6,400	9,030	79	79	60.676	< 0.000001
Pierce Canyon Xing	Red Bluff	9,030	10,500	79	34	7.608	0.005809
Red Bluff	Orla	10,500	9,910	34	55	0.281	0.596038

in Table 3. There are very good relationships, *i.e.* r^2 greater than 0.9, at 4 of the 6 sites. sites. The r^2 of the regressions are between 0.8 and 0.9 at the remaining 2 sites. The slopes of the regression equations range from 0.638 and 0.814 (Table 3). Hem (1985) notes that the range of slopes in his report was between 0.54 to 0.96, and that higher values represent waters high in sulfate. The slopes of the regressions show a decreasing slope from generally about 0.8 upstream from Sumner Lake to about 0.6 closer to the state line (Table 3). This decreasing trend in the regression generally agrees with the increasing chloride (decreasing sulfate) trend shown on Figure 2.

Table 3. Regressions of TDS on EC at 6 sites on the Pecos River

Location	r^2	Slope	Intercept	n	F	Prob. > F
above Santa Rosa	0.9300	0.773884	21.541022	34	425.26	< 0.000001
Puerto de Luna	0.8198	0.814004	221.344747	48	209.21	< 0.000001
Acme	0.9386	0.678344	235.081545	36	519.99	< 0.000001
Artesia	0.9471	0.650341	296.639521	48	824.34	< 0.000001
Red Bluff	0.9637	0.708482	-569.268181	29	716.81	< 0.000001
Orla	0.8727	0.638375	515.976343	46	301.70	< 0.000001

Based on the earlier comparisons, it is obvious that there are many more specific conductance observations than there are TDS samples. The specific conductance can be used to generate TDS data using a regression relationship. Figure 3 shows a regression relationship between TDS and specific conductance using all of the available data collected since September 1988 at all of the stations in the Pecos Basin. The regression relationship is 98 percent accurate in generating TDS data from specific conductance observations. The slope of the regression line is intermediate between those shown for stations between Acme and Orla and overestimates the lower TDS values found in the basin defined by the first 2 regressions in Table 3. At the scale of Figure 3, the overestimates are not obvious but amount to about a factor of 2 for TDS less than 1000 mg/L.

To better estimate the lower TDS concentrations at sites in the basin above Sumner Lake, the data set was subdivided based on the location relative to Sumner Lake. The resulting 2 regressions are plotted on Figure 4. The major difference between the 2

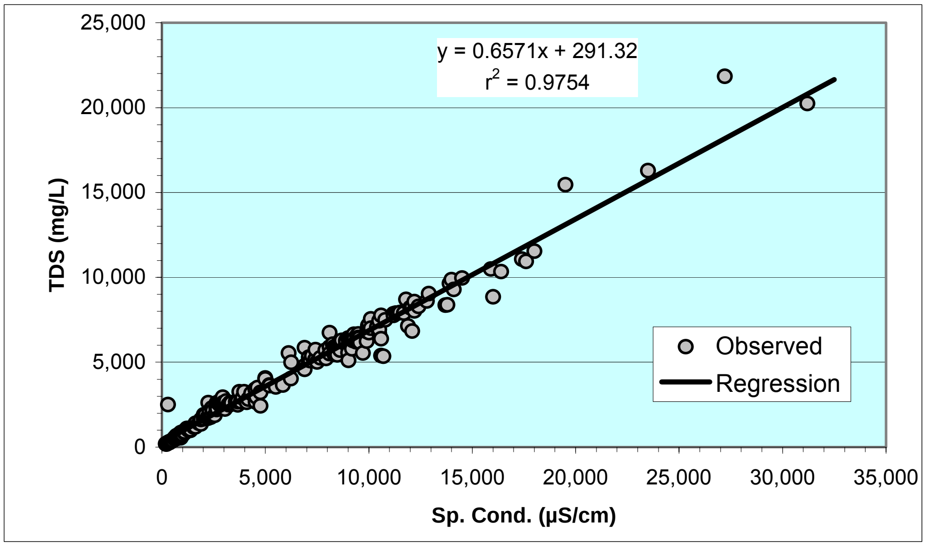


Figure 3: Relationship between TDS and specific conductance based on combined basin-wide data

regression approach as opposed to the single regression has to do with the predicted TDS at lower values of specific conductance. The single basin-wide regression shown on Figure 3 overpredicts the TDS in the upper basin at the gage above Santa Rosa by several hundred mg/L; the data from above Santa Rosa have specific conductance readings less than 1000 µS/cm. This result is better illustrated by the trend lines on Figure 5, which shows plots of the predicted TDS concentrations from the “Above Sumner” regression and the “Basin-wide” regression against the observed TDS. The reason for the difference is inherent in the least squares regression calculation in that greater weight is given to the larger values. Smaller values do not contribute as much to the sum of squares and residuals tend to be smaller.

In the case of the regression derived from the data from below Sumner Lake, the predicted values show little difference from those from the basin-wide regression. This is illustrated on Figure 6, which shows similar plots for the “Below Sumner” regression and the “Basin-side” regression to those shown on Figure 5. The predicted values from the “Below Sumner” and “Basin-wide” regressions are nearly overlain on the plot. The degree of overlap is so great that the size of the trend line and the dots representing the predicted TDS values from the “Below Sumner” regression had to be enlarged in order to make them show on the plot.

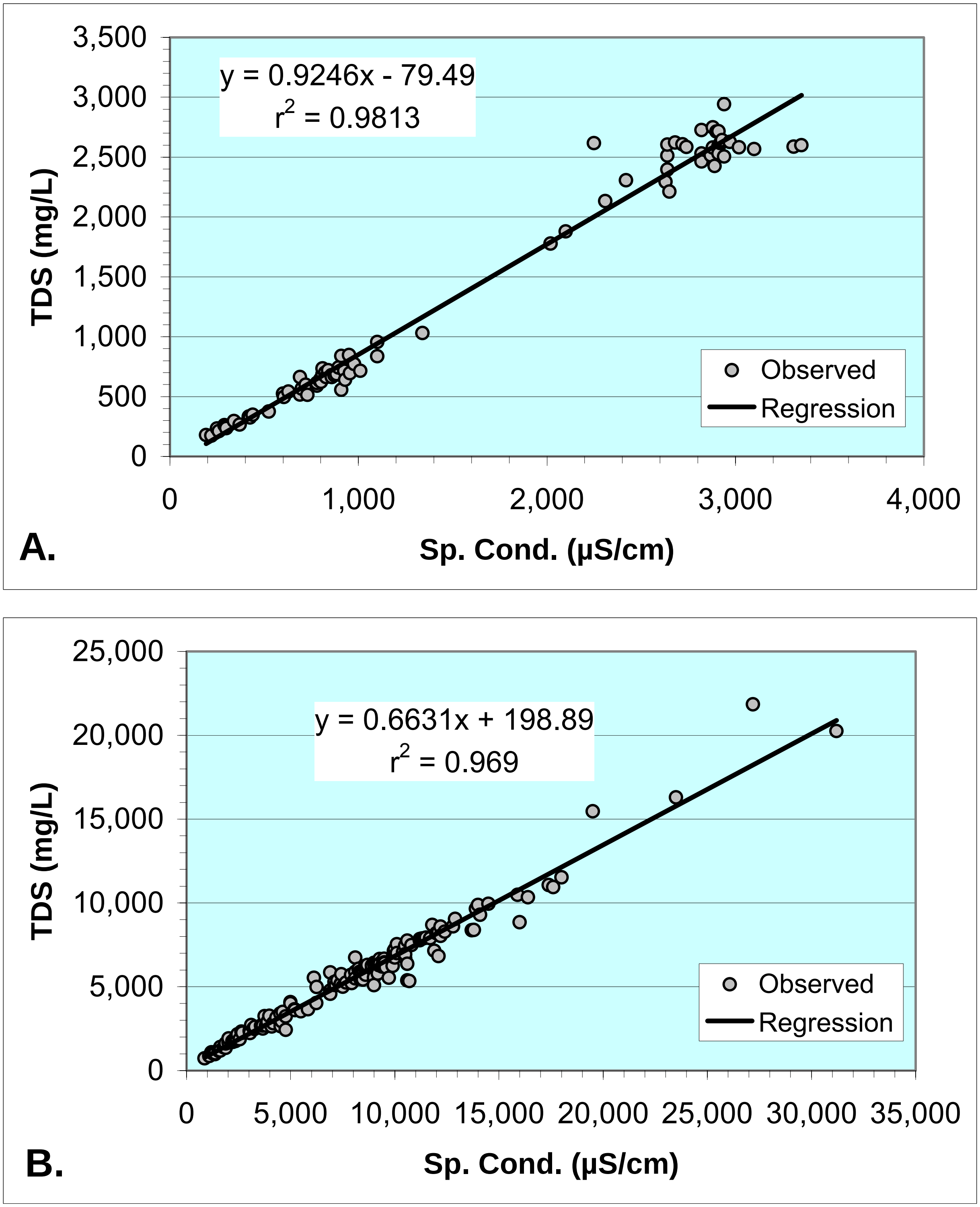


Figure 4: Regressions of TDS on specific conductance for sites above and below Sumner Lake: **A.** above Sumner Lake; **B.** below Sumner Lake

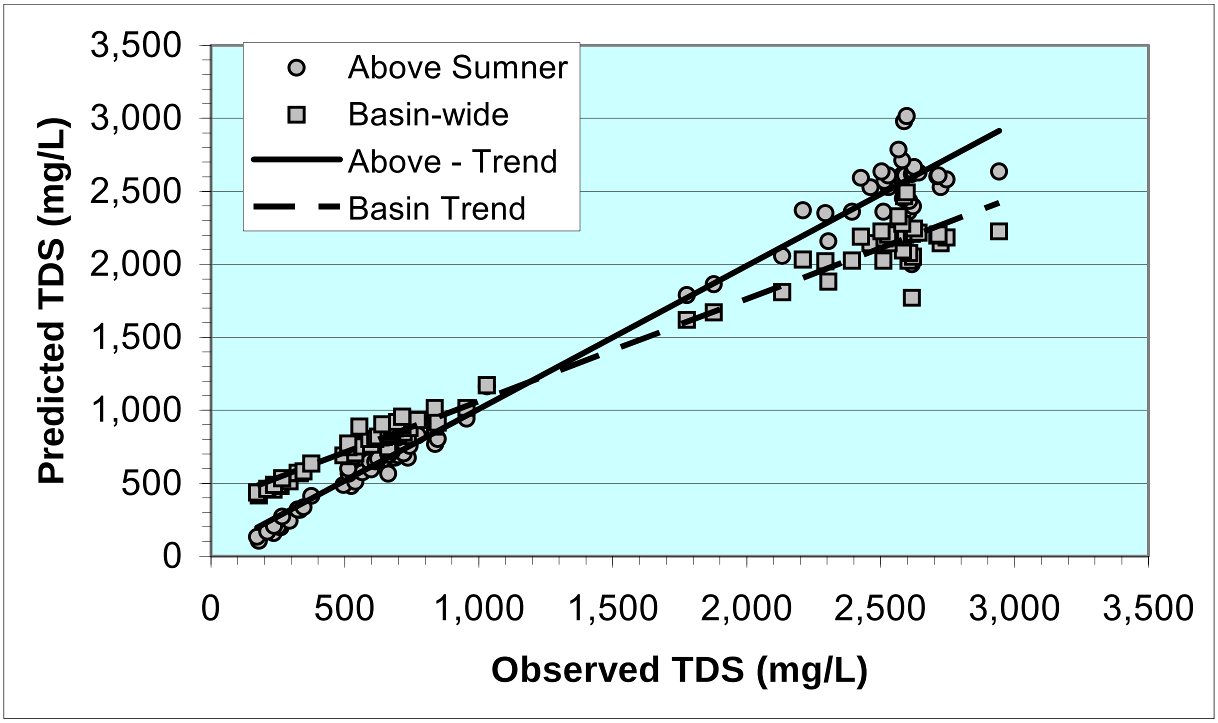


Figure 5: Comparison of the predicted values from the "Above Sumner" TDS regression and those from the "Basin-wide" regression

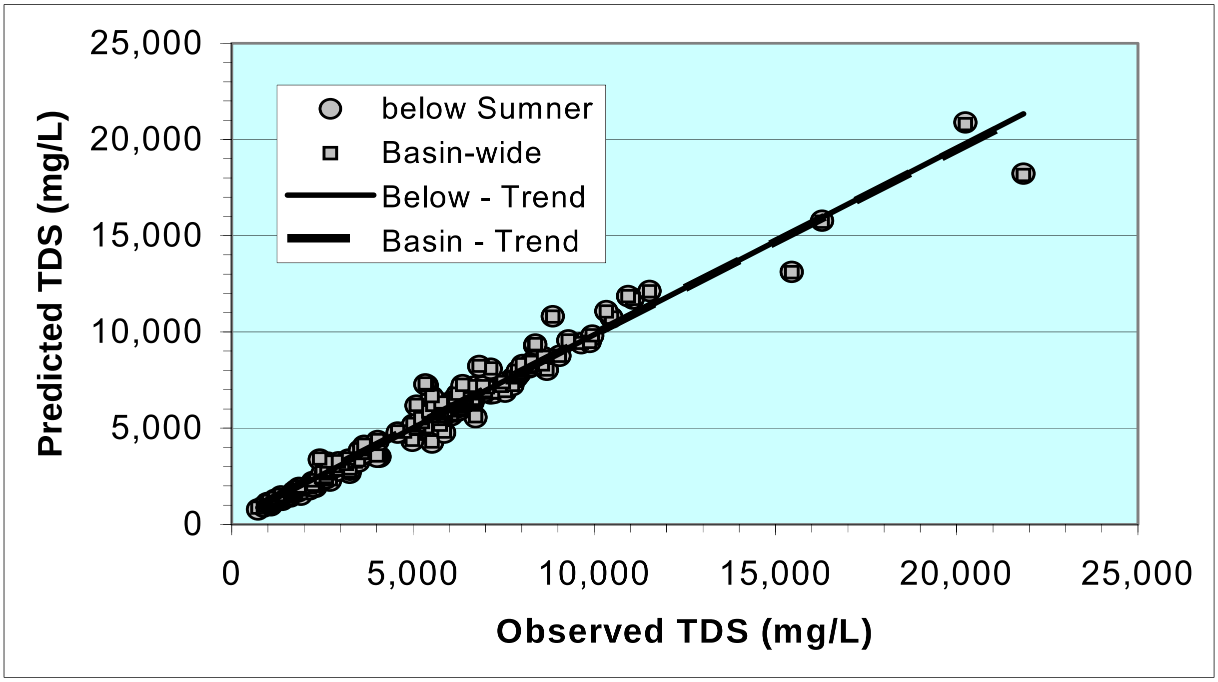


Figure 6: Comparison of the predicted values from the "Below Sumner" TDS regression and those from the "Basin-wide" regression

Comparison to Water Quality Standards

Water quality standards for each reach of the Pecos River are listed in the tables in Attachment 1. The standards for New Mexico are taken from NMWQCC (2002b). The Texas water quality standards were taken from TNRCC (2000). Table 4 summarizes the standards comparison that is shown in detail in the attachment, based only on the standards that were exceeded. Most of the standards included in Table 4 are based on aquatic life criteria. Exceptions to this include the standards for boron and vanadium, which are based on irrigation water criteria. (The cobalt standard in Attachment 1 is also based on an irrigation criterion.) The use of water quality standards is only intended to provide a point of reference for the water quality evaluation. For example, the State of New Mexico evaluation is based on data from the most recent 5 years only (NMWQCC, 2002a).

Table 4. Location, standard, and number of times the standard was exceeded between Sept. 1988 and Aug. 2001 in the Pecos River Basin

Site	Pollutant	Standard	No. of Obs.	No. < D.L.	No. > Std.
above Santa Rosa	Aluminum (μg/L as Al)	87	29	7	5
	Fecal Coliform .7 μm -mf (Col./100 mL)	400	29	23	6
at Santa Rosa	None	—	—	—	0
Puerto de Luna	Mercury (μg/L as Hg)	0.012	13	9	4
	Fecal Coliform .7 μm -mf (Col./100 mL)	400	31	12	3
Acme	Aluminum (μg/L as Al)	87	7	0	2
	Mercury (μg/L as Hg)	0.012	14	10	4
Artesia	Boron (μg/L as B)	750	52	0	1
	Mercury (μg/L as Hg)	0.012	14	9	5
Brantley Dam	None	—	—	—	0
Dark Canyon	None	—	—	—	0
Malaga	Temperature (°C)	32.2	79	N/A	1
	pH, Standard Units	6.6-9	75	N/A	1
	Boron (μg/L as B)	750	68	0	2
Pierce Canyon Crossing	Boron (μg/L as B)	750	68	0	8
Red Bluff	Aluminum (μg/L as Al)	87	23	8	3
	Lead (μg/L as Pb)	H[1]	12	11	1
	Mercury (μg/L as Hg)	0.012	12	3	9
	Vanadium (μg/L as V)	100	25	2	2
Orla	Temperature (°C)	32.2	55	N/A	1

[1] H - indicates a hardness dependent standard that varies from sample to sample

No standards were exceeded at the sites at Santa Rosa, below Brantley Dam, or below Dark Canyon. Although there were very high concentrations of TDS, sulfate, and chloride present in the Pecos River, none of the standards for these constituents were exceeded. The concentrations of all three constituents increase as one proceeds downstream. The standards for TDS, chloride, and sulfate likewise increase enough that their standards are not exceeded even though there are very high concentrations present.

The mercury standard was exceeded more than any other, both in terms of the frequency (22 times) and the number of sites (4) at which it was exceeded. The standard for mercury is well below the detection limit (D.L.) that was available for all of the samples used as a basis of comparison, *i.e.* 0.1 µg/L. Consequently, any time there was measurable mercury in a sample, the standard was exceeded. For the most part, sites at which the mercury standard was not exceeded were those for which there were no mercury data.

Greystone (1997) investigated mercury transport in the Pecos River for the U.S. Army Corps of Engineers. Their results, based on a detection limit less than the water quality standard (*i.e.* 0.005 µg/L), showed that mercury remained below the standard throughout the upper basin. Elevated mercury was only found at a site just north of Acme, indicating a mercury source between there and Sumner Lake, the next upstream site.

Boron exceeded the irrigation standard at 3 of the 11 sites shown in Table 4. The sites include those at Artesia, Malaga, and Pierce Canyon Crossing. The site of most concern to the EIS is the one at Artesia, which is the nearest site located above Brantley Reservoir. However, the boron standard was only exceeded once at Artesia and was not exceeded at the sites below Brantley Dam or the next site below Dark Canyon (Table 4 and Attachment 1: tables 1-6 and 1-7). The reservoir provides dilution by mixing the lower and higher concentration waters throughout the year. This can be illustrated by the median specific conductance at Artesia and below Brantley Dam. The former is 7,100 µS/cm, while the latter is 4,430 µS/cm (see Attachment 1). The equivalent boron concentrations are 355 and 245 µg/L respectively, indicating a more than 100 µg/L reduction in the boron concentration in Brantley Reservoir.

Aluminum also exceeded its standard, which is based on an aquatic life criterion, at 3 sites. The sites included those above Santa Rosa, at Acme, and at Red Bluff (Table 4). These 3 sites are widely dispersed throughout the Pecos Basin. The standard was not exceeded at the intermediate sites.

There were 2 other standards that were exceeded at 2 sites each in the basin. The temperature standard was exceeded at 2 sites in the lower basin, including Malaga and Orla, Texas (Table 4). In each case there was only 1 time that the standard was exceeded. The fecal coliform standard was also exceeded at 2 sites, both of which were in the basin above Sumner Lake (Table 4), including 6 of 29 samples above Santa Rosa and in 3 of 31 samples at Puerto de Luna. The fecal coliform standard is based on a recreation criterion. The only other times that water quality standards were not met were at Malaga (pH) and Red Bluff (lead and vanadium).

Sumner Dam Releases

In 1995 and 1996, water quality measurements were made at 14 cross-sections in the Pecos River between Fort Sumner Irrigation District and Brantley Reservoir at various releases from Sumner Dam (FLO, 1997). The measurements consisted of temperature, D.O., specific conductance, and pH. TDS was estimated from the specific conductance measurements by multiplying by a conversion factor of 0.64. This section of the EIS will evaluate the relationship between Sumner Dam releases and specific conductance at various sites along the Pecos River in the river between Fort Sumner and Brantley Reservoir. This reach of the river is the most likely to be affected by operational changes.

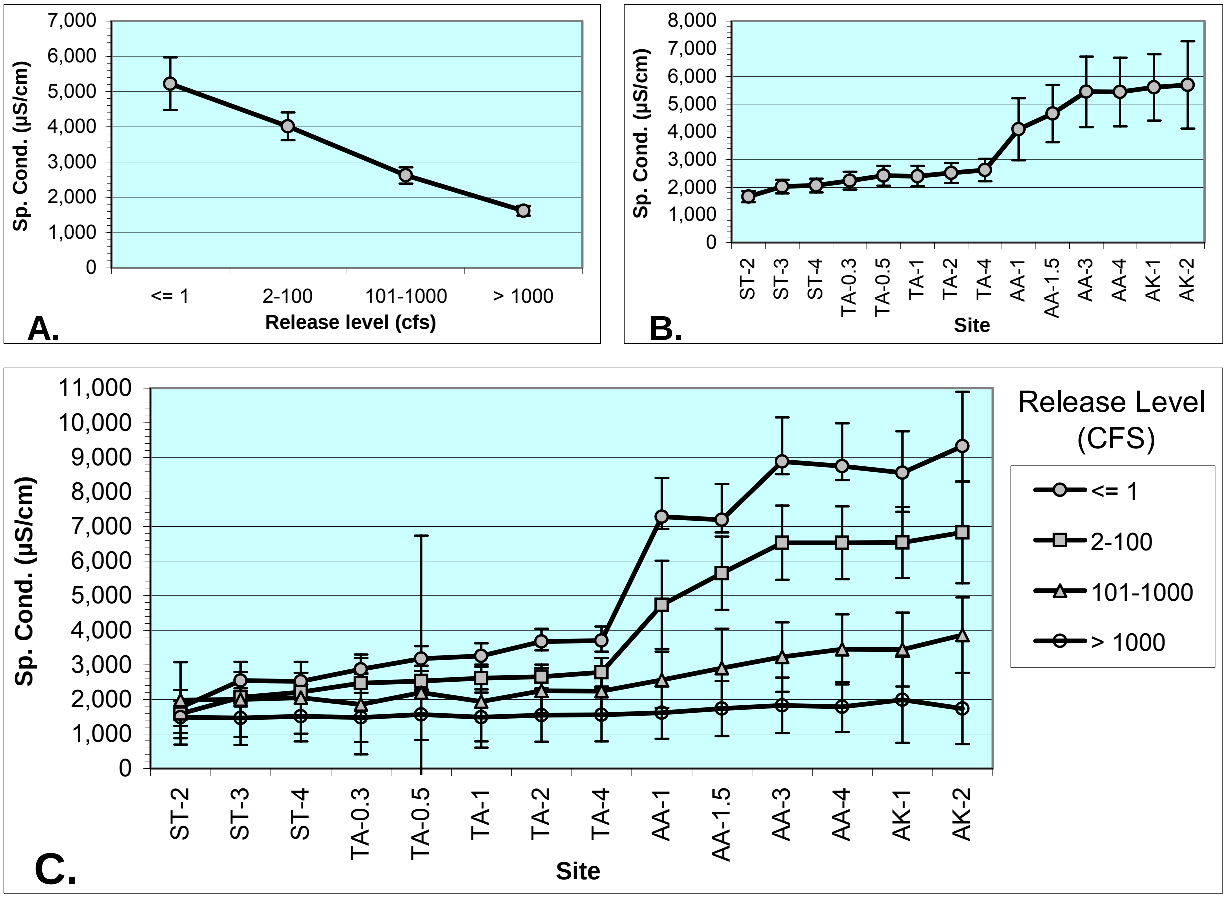
The data collected in 1995-96 were entered into a two-way analysis of variance (ANOVA) to evaluate the significance of the effects of flow, *i.e.* release level, and distance from Sumner Dam as measured by site in relation to the measured specific conductance of the Pecos River. The results are summarized in Table 5. Flow as entered into the ANOVA was based on release levels of #1, 2-100, 101-1000, and >1000 ft^3/s. Although both flow and site are statistically significant, the more significant factor is flow. Of even more interest is the fact the there is also a significant interaction between flow and distance from the release point at Sumner Dam. The various effects and a tabulation of the distance of each site from Sumner Dam for each of the sites appear on Figure 7.

Table 5. Two-way Analysis of Variance of flow (4 levels) and site (14 levels) on specific conductance of the Pecos River between Sumner Dam and Brantley Reservoir

Source	df	Mean Square	F-ratio	Prob. > F
Flow	3	167,886,000	175.865	< 0.000001
Site	13	37,985,300	39.791	< 0.000001
Flow x Site	39	7,397,050	7.749	< 0.000001
Error	242	954,627		

Figure 7A shows an almost linear decrease in specific conductance with increases in releases from Sumner Dam. There is also a decrease in the size of the confidence interval about the mean specific conductance as flow increases. The way the flow intervals are defined makes the scale of the *x*–axis essentially logarithmic.

The plot of specific conductance with distance from Sumner Dam indicates an increase between sites TA-4 and AA-1 (Figure 7B). Recall from Figure 1 that there was an increase in specific conductance between the Acme and Artesia gages. Site TA-2 is the Acme gage. Site TA-4 is located at the Highway 380 Bridge, and site AA-1 is located at the Dexter Bridge. The reach receives inflow from Bitter Creek and Bitter Lakes (FLO, 1997). Farther downstream, the specific conductance continues to increase in the next 2 reaches before leveling off at AA-3, the Artesia gage. The next 2 reaches downstream from AA-1 are each described as receiving inflow from several drainage ditches by FLO (1997). These results indicate that there is more than one source of saline inflows between the Acme and Artesia. The leveling of the specific conductance between AA-3, the Artesia gage, and AK-1 indicates that the specific conductance at the Artesia gage is reasonably representative of that of the Brantley inflow.



Site Designations and Distance (miles) from Sumner Dam

Site	Distance	Site	Distance	Site	Distance	Site	Distance	Site	Distance
ST-2	18.4	TA-0.3	49.1	TA-2	100.7	AA-1.5	148.7	AK-1	206.0
ST-3	27.4	TA-0.5	61.9	TA-4	114.0	AA-3	177.0	AK-2	214.0
ST-4	33.6	TA-1	79.6	AA-1	128.2	AA-4	195.2		

Figure 7: Specific conductance of the Pecos River between Sumner Dam and Brantley Reservoir in relation to flow and distance from the dam as a function of the releases from the dam

Table 5 also indicates that there is a significant interaction effect between the Sumner release and distance from Sumner Dam. This interaction effect is illustrated on Figure 7C. At base flow, which is represented by a release of #1 ft^3/s, there is a small increase in specific conductance between the dam and station TA-4, at which point there is a very large increase in specific conductance. As the releases are increased, the increase in specific conductance becomes less pronounced and is virtually absent at releases of greater than 1,000 ft^3/s from Sumner Dam. In other words, the distance effect on specific conductance of the Pecos River changes with changes in the release from Sumner Dam.

Based on the interaction effect of the specific conductance at the various sites with the release from Sumner Dam, a series of regression relationships were explored. Plots of the data against the release from Sumner Dam and the associated specific conductance at each site appear in Attachment 2. For each site, there are 2 plots. The upper plot shows the actual release from Sumner Dam and the associated specific conductance, while the lower plot shows the similar relationship between the specific conductance and the release as coded in the ANOVA summarized in Table 5. Attachment 2 shows only the best result. The full analysis included a linear bivariate regression, a log-log regression, and 2 semi-log regressions, the latter with the independent and dependent variables being individually log transformed for both the releases and the release codes. Only the best regression for the individual release and the coded release appear in Attachment 2. The best overall regressions are summarized in Table 6.

Table 6. Regressions of specific electrical conductance (EC) on flow at 14 stations on the Pecos River

Site	Dependent Variable (y)	Independent Variable (x)	F	Prob. > F	Equation	r^2
ST-2	Ln EC	Release Code	0.3932	0.538071	none	0.020277
ST-3	Ln EC	Release Code	13.8019	0.001468	$y = e^{(8.016-0.1835x)}$	0.420765
ST-4	EC	Release Code	12.9522	0.002214	$y = 2835-305.8x$	0.432428
TA-0.3	EC	Release Code	22.3919	0.000145	$y = 3366-462x$	0.540973
TA-0.5	EC	Release Code	26.1813	0.000072	$y = 3635-507.8x$	0.592588
TA-1	EC	Release Code	32.8533	0.000016	$y = 3803-575.8x$	0.633581
TA-2	EC	Release Code	44.3475	0.000002	$y = 4131-646.4x$	0.689187
TA-4	EC	Release Code	34.9484	0.000007	$y = 4287-682.6x$	0.624654
AA-1	Ln EC	Release Code	45.1343	0.000002	$y = e^{(9.384-0.5002x)}$	0.692942
AA-1.5	Ln EC	Release	64.1025	< 0.000001	$y = e^{(8.684-0.0010x)}$	0.753239
AA-3	Ln EC	Release Code	89.8660	< 0.000001	$y = e^{(9.760-0.5482x)}$	0.810582
AA-4	Ln EC	Release	106.4391	< 0.000001	$y = e^{(8.868-0.0012x)}$	0.835215
AK-1	Ln EC	Release	75.2456	< 0.000001	$y = e^{(8.856-0.0011x)}$	0.790017
AK-2	Ln EC	Release	106.6965	< 0.000001	$y = e^{(8.948-0.0013x)}$	0.876743

There are several observations that can be made from Table 6 that are not readily evident from Attachment 2. At stations nearer the dam, the coded release is a better measure than the actual release in predicting specific conductance. As can be seen from Attachment 2, the coded release treats each set of releases as a set of replicates. The resulting specific conductance values are then measures of the variability that can be expected within a bracket of release levels. The second observation is that the r^2's of the various regressions increase with distance from the dam. This result is a reflection of the increasing spread between the specific conductance data with distance from the dam that is illustrated on Figure 7C. The regressions proceed from a nonsignificant regression at site ST-2 to one in which about 88 percent of the variation in specific conductance at site AK-2 can be explained by the release (Table 6). The third observation is that most of the best regressions between the release and specific conductance at sites nearest the dam are represented by linear (as used here, arithmetic, rather than exponential) relationships between the specific conductance and the coded release. Beyond station TA-4, log transformed specific conductance data show the better relationship, mostly to the actual release rather than the coded values.

Reservoirs

The New Mexico 303(d) list includes each of the reservoirs (Santa Rosa, Sumner, and Brantley) involved in the Carlsbad EIS (NMWQCC, 2002c). All 3 reservoirs are listed for exceeding mercury fish consumption guidelines. The source of the mercury in each case is listed as atmospheric deposition. However, as was noted above, Greystone (1997) observed a source of mercury between Sumner Dam and Brantley Reservoir that could be the more important source for Brantley Reservoir fish.

Santa Rosa Lake is also listed for having excessive nutrients and siltation. The sources for these pollutants are listed as agriculture (primarily, grazing related) and recreation (road/parking lot runoff). Nutrients (nitrogen and phosphorus) are usually associated with runoff fields containing fertilizer, but can also originate from the breakdown and erosion of livestock manure.

In addition to the nutrients and siltation listed for Santa Rosa Lake, Sumner Lake includes nuisance algae. Nuisance algae are usually a reflection of excessive nutrients. In addition to agriculture and recreation, the sources or causes of the noncompliance with standards include reduction in riparian vegetation, bank destabilization, and additional unknown causes.

Brantley Reservoir is only listed for exceeding mercury fish consumption guidelines. However, there have been 2 fish kills in the reservoir in the last 6 months (Personal communication, January 13, 2003, from Shawn Denny, Southwest Area Fisheries Manager, New Mexico Department of Game and Fish, Roswell, New Mexico, to J. Yahnke, Bureau of Reclamation, Denver, Colorado). The cause of the fish kills were golden algae (*ibid.*). Fish kills in the Pecos Basin at Red Bluff Reservoir in 1988 and in the Pecos River just south of Red Bluff in April 2002 were attributed to the golden alga, *Prymnesium parvum* (NMDGF, 2002). *P. parvum* toxicity has been associated with nutrient stress (Johansson, 2000), in particular, by phosphorus (WADF, 1997).

Brantley Reservoir

Detailed data on reservoirs in the Pecos Basin are confined to Brantley Reservoir. The New Mexico State University's Carlsbad Environmental Monitoring and Research Center (CEMRC) has been monitoring the water quality in Brantley Reservoir under contract with Reclamation since 1997. Depth profiles of temperature, specific conductance, and dissolved oxygen (D.O. - concentration and percent saturation) have been measured weekly since 1997 (CEMRC, 1998; 1999; 2000; 2001; 2002). Profiles from the 1st week of each month have been selected from the weekly data and profiles of temperature-specific conductance and temperature-D.O. are plotted in Attachment 3.

Water quality in reservoirs is greatly affected by density. Density differences within reservoirs can result in layers that differ greatly in water quality. For example, the surface of a reservoir is constantly in contact with the atmosphere, which provides a ready source of oxygen. Alternatively, the deeper layers will be isolated from the atmosphere if there are density layers present. Under these circumstances, the deeper layers may become depleted in dissolved oxygen. This happens frequently in Brantley Reservoir, as will be shown later.

In most cases density is controlled by the temperature of the water in the reservoir, but density can also be controlled by dissolved and suspended solids. In Brantley Reservoir dissolved solids are frequently a factor in controlling the density of water and isolating the deeper layers for prolonged periods during each year. Yahnke (1997) showed that saline winter inflows to Brantley Reservoir follow the inundated river channel and accumulate near the dam. Complete mixing does not occur near the dam until that saline layer is drawn off. In early spring, inflows are less saline than the reservoir and the inflows form a layer on the surface of the reservoir that gradually mixes longitudinally and laterally with the surface layer of the reservoir. Much of the way in which the inflow was distributed in the reservoir was dictated by its difference in salinity from the water already resident in the reservoir.

The data included in Attachment 3, which amount to about ¼ of what are available, illustrate the amount of variation that occurs in the temperature, D.O., and specific conductance regimes in Brantley Reservoir from month to month and year to year. Table 7 provides annual summaries for selected data from the reservoir.

The first thing of note in Table 7 is the fact that there are 30 observations in 1997, but 50 to 52 in the other years. This result is a reflection of the fact that the data collection in 1997 began in June. There are no data available for the first 5 months of the year. Nevertheless, the median inflow EC's are similar in 1997 and 1998. Alternatively, the median D.O. in 1997 is much lower than any of the other years, all of which have a similar median D.O. concentration. The low median appears to be the result of the absence of measurements from the early months of 1997, *i.e.* sampling bias, rather than any real difference between 1997 and the other years.

In addition to the similarity of the median inflow EC's of 1997 and 1998, those of 1999 and 2000 are also similar, both roughly equal to 5,000 µS/cm (Table 7). The median inflow EC for 2001 is roughly ⅓ again as great as the 1999/2000 data. In other words the median inflow EC increased over the 5-year period. Alternatively the minimum and maximum inflow EC fluctuated during the period, although both were somewhat higher in 2001 than in any of the preceding years. The median outflow EC also generally increased throughout the monitoring period. The minimum and maximum outflow followed the pattern of the inflow EC. The outflow EC's were lower than the inflow EC's in most years (Table 7).

The bottom D.O. (dissolved oxygen) data are probably of most interest from a biological perspective. A minimum of 3 mg/L is usually considered necessary for the support of fish. As can be seen by the minimum values, D.O. concentrations in the bottom waters of Brantley Reservoir fell below 1 mg/L in all 5 years and drive fish to more oxygenated layers of the reservoir. Such a deep-water D.O. concentration would also restrict bottom-dwelling invertebrate species to those tolerant of low D.O., such as *Tubifex* sp. worms.

Table 7. Summary statistics – Brantley Reservoir data collected by the CEMRC from June 1997 through December 2001

Year	Statistic	Inflow EC (µS/cm)	Depth (ft.)	Mean EC (µS/cm)	Outflow EC (µS/cm)	Bottom D.O. (mg/L)
1997	Minimum	1,212	32.5	1,971	2,145	0.11
	Median	3,984	37.0	2,917	3,160	0.38
	Maximum	8,308	45.2	5,795	6,444	10.10
	No. of Obs.	30	30	30	30	30
1998	Minimum	921	30.0	1,561	1,580	0.21
	Median	3,935	38.8	3,196	4,057	4.90
	Maximum	9,207	46.0	5,733	6,488	11.94
	No. of Obs.	52	52	52	52	51
1999	Minimum	1,041	30.0	2,622	2,900	0.20
	Median	5,017	40.0	4,264	4,735	4.52
	Maximum	8,108	44.0	6,032	6,830	11.00
	No. of Obs.	52	52	52	52	52
2000	Minimum	1,171	32.5	1,847	1,910	0.00
	Median	4,963	38.0	3,744	4,580	4.14
	Maximum	9,728	44.7	6,059	6,550	11.28
	No. of Obs.	52	52	52	52	52
2001	Minimum	1,456	24.9	3,035	3,134	0.17
	Median	7,622	37.1	4,614	5,324	4.35
	Maximum	11,496	42.6	6,670	7,139	11.71
	No. of Obs.	50	50	50	50	50

The very low bottom D.O. concentrations (< 1 mg/L) are usually present in the summer. This phenomenon is illustrated on Figure 8, which shows plots of weekly surface and bottom D.O. concentrations in Brantley Reservoir. The plot also shows the beginnings of each of the “seasons” as used in this report. The “seasons” were defined based on months as taken by the general conditions shown by the plots in Attachment 3. The splits on this basis are generalized and somewhat imperfect in defining conditions in some years, as illustrated by the fact that D.O. declines during what is defined as the mixed condition is some of the years, particularly prior to the summer of 2001 (Figure 8).

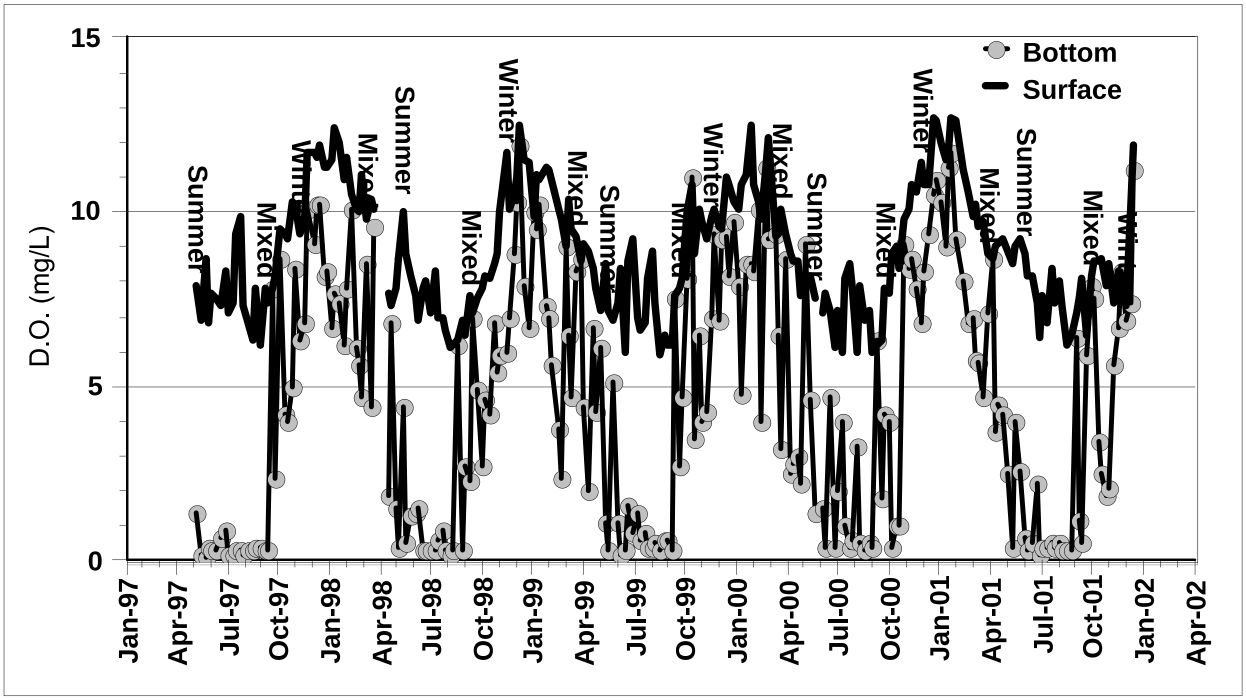


Figure 8: Surface and bottom dissolved oxygen concentrations in Brantley Reservoir from 1997 through 2001

Brantley outflow EC relationships

Reclamation has monitored the EC of the inflow and outflow at Brantley Reservoir since 1993. The complete data set is plotted on Figure 9. Based on data collected during the years 1993-1995, Yahnke (1997b) showed that there was a net loss of salt within Brantley Reservoir. Such a salt loss would cause a decrease in EC. That salt loss in Brantley Reservoir is reflected in the difference in the maximum EC on the *y*–axis of the inflow and outflow plots on Figure 9. The *y*–axis of the inflow plots shows a maximum EC of either 10,000 or 12,000 µS/cm, while all of the outflow plots show a maximum EC of 8,000 µS/cm on the *y*–axis. The data for 1997 through 2001 indicate that the salt loss observed in 1993-1995 was also occurring in the more recent years.

The other difference between the inflow and outflow EC that is evident on Figure 9 is the degree of variability in the two EC data sets. The inflow EC is shows a much higher degree of variation than the outflow EC. The inflow EC shows the much greater degree of variation because of the flow dependent dilution effect described under the Sumner Dam release topic above. The decrease in variability in the outflow EC reflects the mixing of the higher and lower EC water within the reservoir. Because of these different influences, there does not appear to be a good relationship between the inflow and outflow EC in Brantley Reservoir.

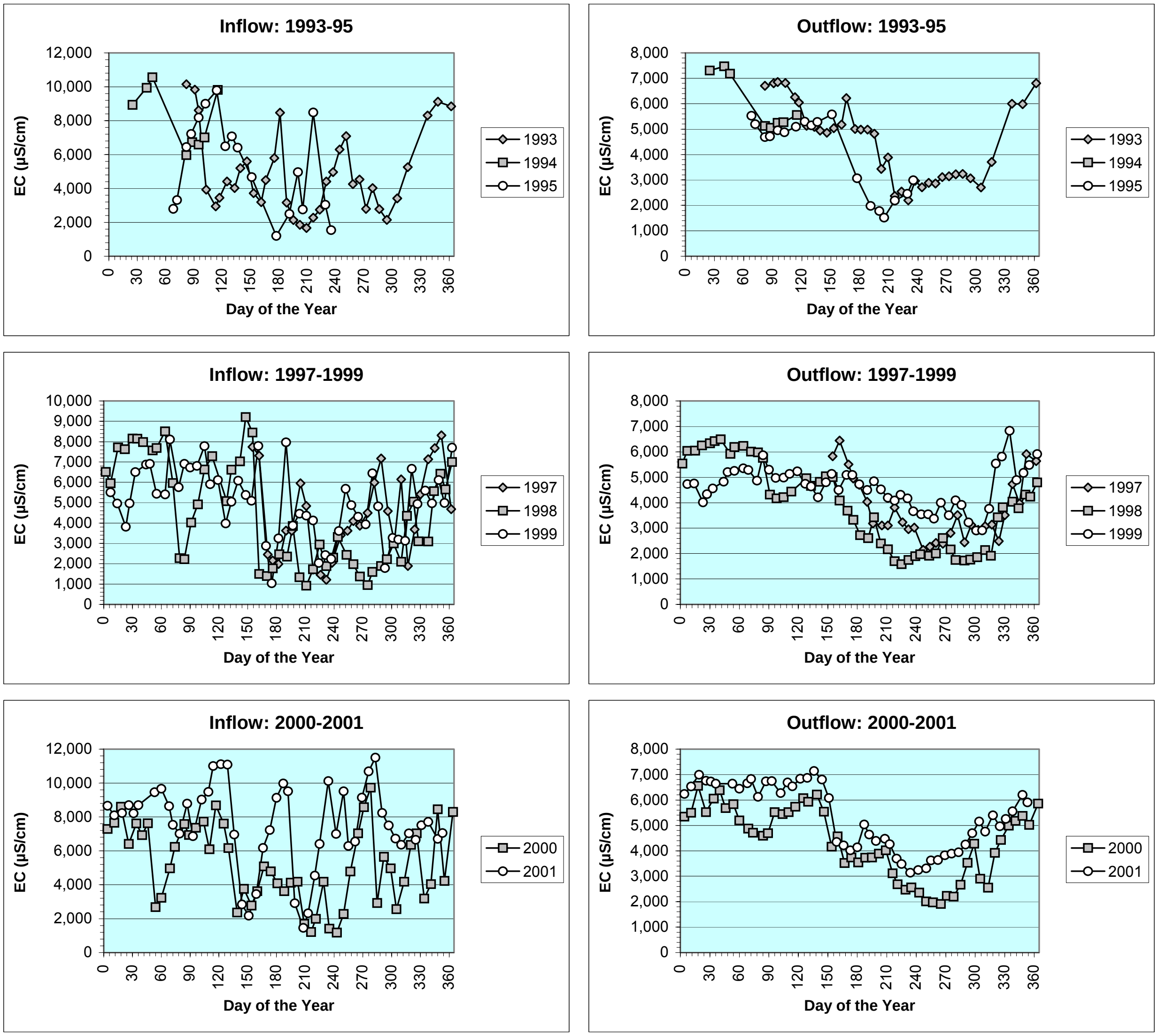


Figure 9: Inflow and outflow specific electrical conductance at Brantley Reservoir since 1993

The first column of Table 8 shows a set of correlations between the outflow and a variety of other variables based primarily on inflow and physical reservoir measurements. Temporal measures, including the date, year, month, and the above described season. The outflow EC shows extremely significant correlations, *i.e.* probability of a greater r occurring by chance alone of < 0.000001 or less than one in a million, with year, month, season, the inflow EC and temperature, the surface and outflow temperature, and the bottom D.O. The best relationship is the inverse correlation with season, which has an r of -0.59. Although the relationship is extremely significant, the amount of variation in the outflow that is explained by the season variable only amounts to about 35 percent. Furthermore, season by itself would not be affected by any of the alternatives, although the relationship between season and the outflow EC could be affected.

Table 8. Correlations between measures of Brantley Reservoir EC and various physical and temporal factors

Factor	Statistic	Outflow EC	Bottom EC	Average EC	EC: O - I	EC Diff.
Date	r	0.2528	0.2640	0.2856	-0.2502	0.0647
	Prob > r	0.000086	0.000040	0.000008	0.000102	0.322624
	n	236	236	236	236	236
Flow	r	-0.0778	-0.0174	-0.0877	0.5971	-0.1170
	Prob > r	0.245954	0.795181	0.191075	< 0.000001	0.080593
	n	224	224	224	224	224
Reservoir Content	r	-0.0689	-0.1374	-0.0539	0.1981	0.1576
	Prob > r	0.304841	0.039971	0.422182	0.002898	0.018293
	n	224	224	224	224	224
Year	r	0.3606	0.3590	0.4024	-0.2409	0.0814
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.000187	0.212948
	n	236	236	236	236	236
Month	r	-0.5203	-0.4607	-0.5621	-0.0373	-0.0821
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.568669	0.208705
	n	236	236	236	236	236
Season	r	-0.5919	-0.4875	-0.4675	0.1140	-0.0453
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.080631	0.488902
	n	236	236	236	236	236
Inflow EC	r	0.5533	0.4674	0.5614	-0.8283	0.1676
	Prob > r	< 0.000001	< 0.000001	< 0.000001	< 0.000001	0.009892
	n	236	236	236	236	236
Inflow Temperature	r	-0.4267	-0.3385	-0.2665	0.1211	0.0214
	Prob > r	< 0.000001	< 0.000001	0.000034	0.063310	0.743973
	n	236	236	236	236	236
Depth	r	-0.0160	-0.0259	0.0085	0.2350	-0.0081
	Prob > r	0.806705	0.692137	0.896454	0.000270	0.901288
	n	236	236	236	236	236
Depth Class	r	0.0066	0.0023	0.0311	0.2511	-0.0290
	Prob > r	0.920170	0.971739	0.634076	0.000096	0.657182
	n	236	236	236	236	236
Stratification	r	-0.0931	0.0890	-0.1507	0.1720	-0.7670
	Prob > r	0.153991	0.172753	0.020583	0.008094	< 0.000001
	n	236	236	236	236	236
Surface Temperature	r	-0.5244	-0.4252	-0.3775	0.1573	-0.0135
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.015602	0.836646
	n	236	236	236	236	236
Outflow Temperature	r	-0.5586	-0.4537	-0.4101	0.1241	-0.0150
	Prob > r	< 0.000001	< 0.000001	< 0.000001	0.056950	0.818481
	n	236	236	236	236	236
Bottom D.O.	r	0.4314	0.2602	0.3286	-0.1962	0.2758
	Prob > r	< 0.000001	0.000054	< 0.000001	0.002524	0.000018
	n	235	235	235	235	235
Temperature Difference	r	-0.1775	-0.1706	-0.2827	-0.0461	-0.1117
	Prob > r	0.006256	0.008619	0.000010	0.480797	0.086731
	n	236	236	236	236	236

There is also an extremely significant relationship between the inflow and outflow EC. The correlation alone, like the one for season, does not show a high degree of explanation of the outflow EC, only about 31 percent. Although the individual variables may not do a good job of explaining the variation in the outflow EC, a combination of variables included in Table 8 may work better. This was investigated by entering temporal variables along with variables that could be extracted from and operations model of the alternatives into a stepwise multiple regression analysis. The resulting best model predictions are plotted against the observed data on Figure 10. Based on the R^2, the model explains about 62 percent of the variation in the outflow EC. The equation is also shown on Figure 10 and includes the season and month, the inflow (Q_i), the inflow EC (EC_i), and a variable that was not mentioned earlier, the reservoir content (cont on Figure 10). There was no significant individual correlation between the outflow EC and the reservoir content (Table 8), but the reservoir content becomes significant relative to the other variables included in the multiple regression.

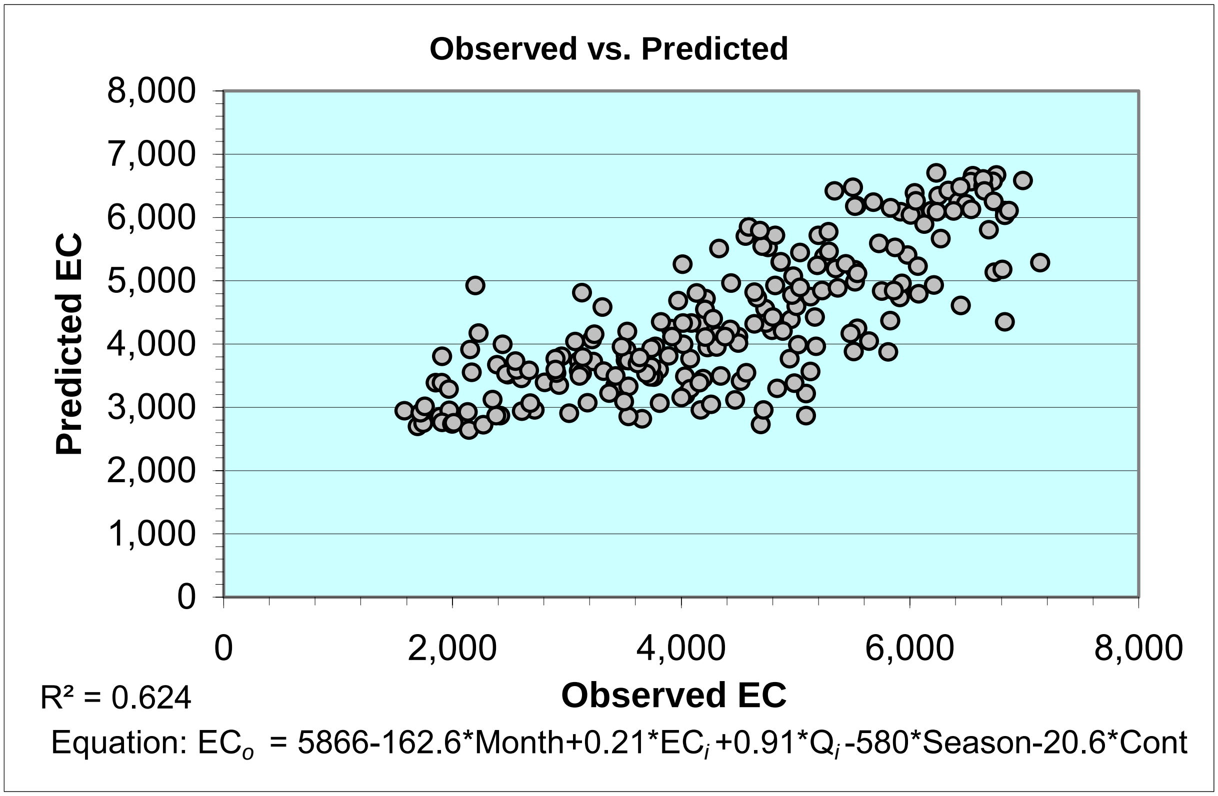


Figure 10: Observed vs. predicted EC in the Brantley Reservoir outflow based on the “best fit” model developed by stepwise multiple regression analysis

The other variables shown on the first line of Table 8 include the bottom EC, the average EC, EC: O-I, which is the difference between the inflow and outflow EC, and the EC difference through the water column, *i.e.* difference between the surface and the bottom EC. The bottom EC and the EC difference are dependent on the physical distribution of salt within the water column. These variables could be evaluated with a mathematical model, but such a model is beyond the scope of the analysis contemplated for this EIS. The average EC is based on averaging the EC over the length of the water column. This average could be estimated by calculating a flow-weighted average EC for the reservoir. However, such a flow-weighted average would represent a fully mixed condition for the reservoir. As is amply illustrated in Attachment 3, the EC of Brantley Reservoir is anything but evenly distributed through the water column on most occasions.

The final variable to be discussed of those in Table 8 is EC: O-I, the change in EC in Brantley Reservoir, which would be the difference between the data plotted on the left and right plots on Figure 9. Although most of the correlations in Table 8 are no better than those for the outflow EC, the correlation with the inflow EC is the best in the table, with an r of 0.8283. Based on that r, the inflow EC can explain 69 percent of the variation in the change in EC in the reservoir. The resulting regression relationship is shown on Figure 11. The change in EC can be used to back-calculate the outflow EC in accordance with the following equation:

$$EC_o = EC_i + (2757 - 0.67*EC_i).$$

The inflow EC (EC_i) can be calculated as was described in the section on the Sumner Dam releases. That value can then be used to evaluate the changes in the EC in Brantley Reservoir using the above relationship to estimate the outflow EC.

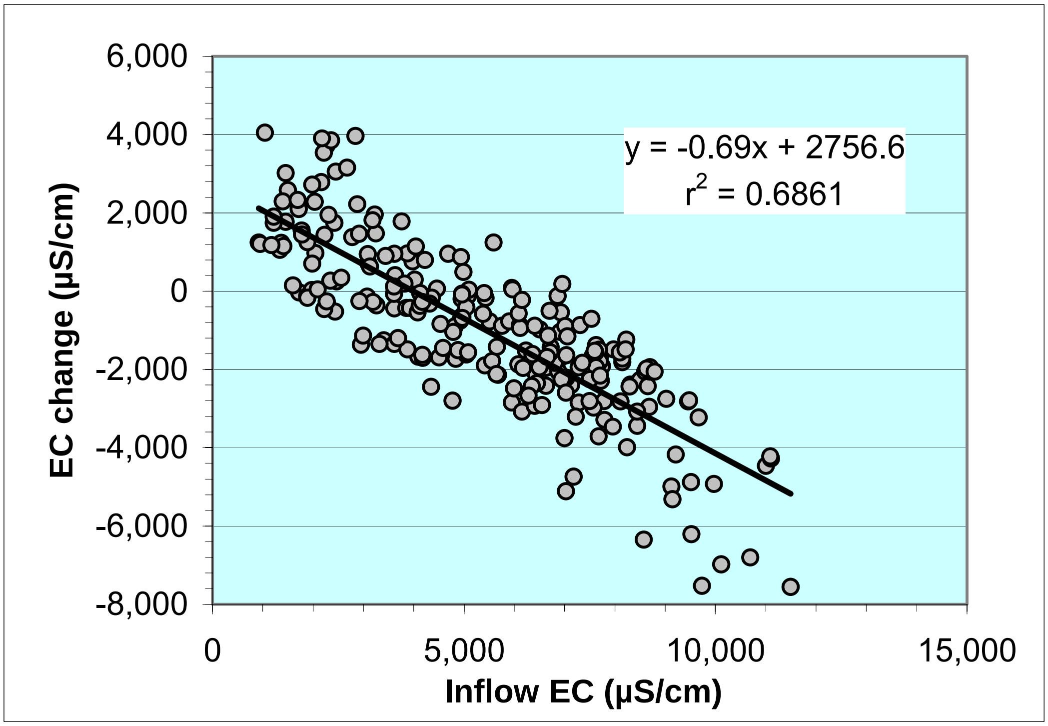


Figure 11: Regression of the change in EC in Brantley Reservoir on the inflow EC

Sumner Lake

Water quality data for Sumner Lake are rather sparse in comparison to Brantley Reservoir. The USGS operated a gage below Sumner Dam from September 1959 through August 1988. The specific conductance data from that record are plotted on Figure 12. There is a gap in the record from September 1966 until March 1972. For most of the period, the data consist of monthly readings, but the data are daily through much of the 1980's. The main purpose of Figure 12 is to illustrate the amount of variation in specific conductance that there is within and between years. In most of the years shown on Figure 12, the specific conductance of the Sumner Dam releases has a minimum between 500 and 1000 µmho/cm (=µS/cm) and a maximum between 2500 and 3000 µmho/cm.

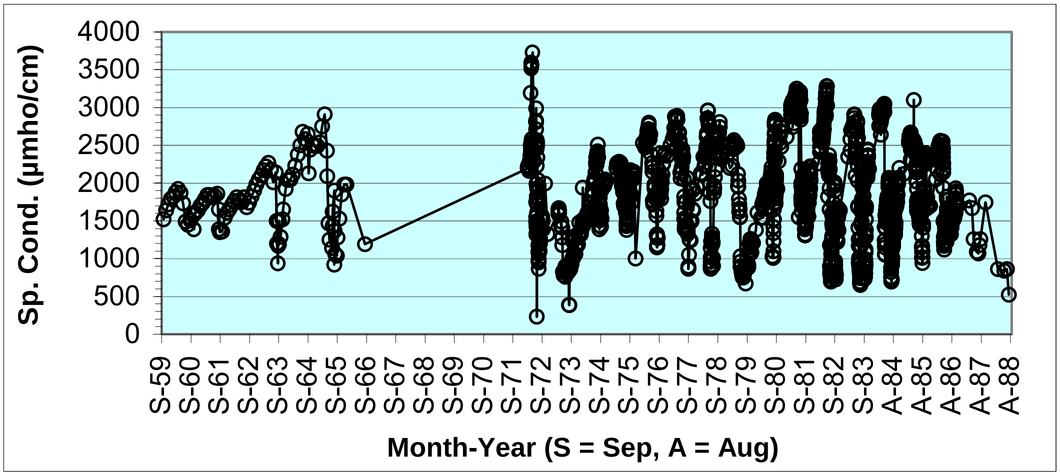


Figure 12: Specific conductance of the Pecos River downstream from Sumner Dam from 1959 through 1988

The New Mexico Department of Game and Fish measured surface temperature, specific conductance, D.O., and turbidity from May 2001 through May 2002 in conjunction with a study of reservoir fish. The data were provided by Shawn Denny (fisheries manager, Southeast Area, New Mexico Department of Game and Fish, Roswell, New Mexico; personal communication of January 30, 2003). The specific conductance data are summarized by month in Table 9. There were between 10 and 40 measurements in each set of data. The data in the early part of the study were collected at as many as 8 sites with 5 replicate measurements made distributed around each site. In the later part of the study, the goal was to get as much coverage of the lake as possible.

Based on the median EC data in Table 9, the lowest EC occurred in August, followed closely by the EC in April of the following year. The peak median EC occurred in May 2002, although the median EC in May 2001 ranked in the middle of the data set. The general pattern of the median EC data was to increase from May 2001 through July

2001, followed by a decrease through March 2001, with anther increase to the end of the data set in May 2002. This pattern is compared with the long-term average and confidence interval of the EC release data on Figure 13. The long-term average release EC shows a maximum in April and a minimum in August (Figure 13). There is not a great deal of difference in the months of occurrence of the extremes of the 2 data sets. There is only a 1 month difference in the time that the maximum occurred in the 2 data sets; the minimum EC in the 2 data sets occurred in the same month.

Table 9. Summary of New Mexico Department of Game and Fish data for Sumner Lake during 2001 and 2002

Date	No. of Obs.	Minimum	Median	Maximum
May 2001	40	880	1865	2100
Jun. 2001	40	2037	2110	2154
Jul. 2001	35	1670	2290	2630
Aug. 2001	25	1220	1250	2210
Oct. 2001	15	2090	2130	2290
Nov. 2001	30	1826	1856	2600
Dec. 2001	17	1826	1873	1879
Feb. 2002	20	1802	1851	1867
Mar. 2002	15	1260	1300	1870
Apr. 2002	10	2386	2450	2470
May 2002	10	2521	2714	2760

The above comparison is an attempt to evaluate whether there is a difference between the 2 data sets. Seven of the 11 median monthly EC's from the recent data are within the confidence intervals of the long-term monthly release data. This result would seem to indicate that there is not a great difference between the 2 data sets. However, a Mann-Whitney test comparing the 2 data sets did show a statistically significant difference, *i.e.* Mann-Whitney U of 2,665 and a probability of 0.0358.

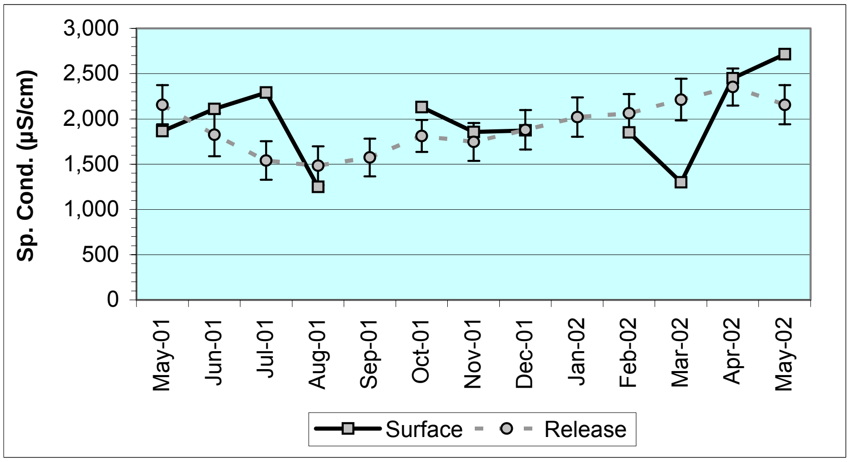


Figure 13: Median surface specific conductance of Sumner Lake during 2001 and 2002 along with the long-term confidence

Santa Rosa Lake

The Albuquerque District of the U.S. Army Corps of Engineers (CoE) monitors water quality in Santa Rosa Lake. Temperature and D.O. profiles are measured periodically at up to 3 sites in the reservoir. The flow from the outlet is also monitored. Data for Santa Rosa Lake were provided by the CoE covering the period 1980 through 2002. The data set also includes EC in mho/cm, pH and Secchi depth, all of which have only 1 reading per site. All of the EC readings were 0.3 mmho/cm, which is equivalent to 300 µmho/cm. All of the Secchi depths were 1 meter. The pH ranged from 7 to 8 and was measured to the nearest pH unit. Because there was little or no variation in these constituents, the description of Santa Rosa Lake will focus on the temperature and D.O. profiles.

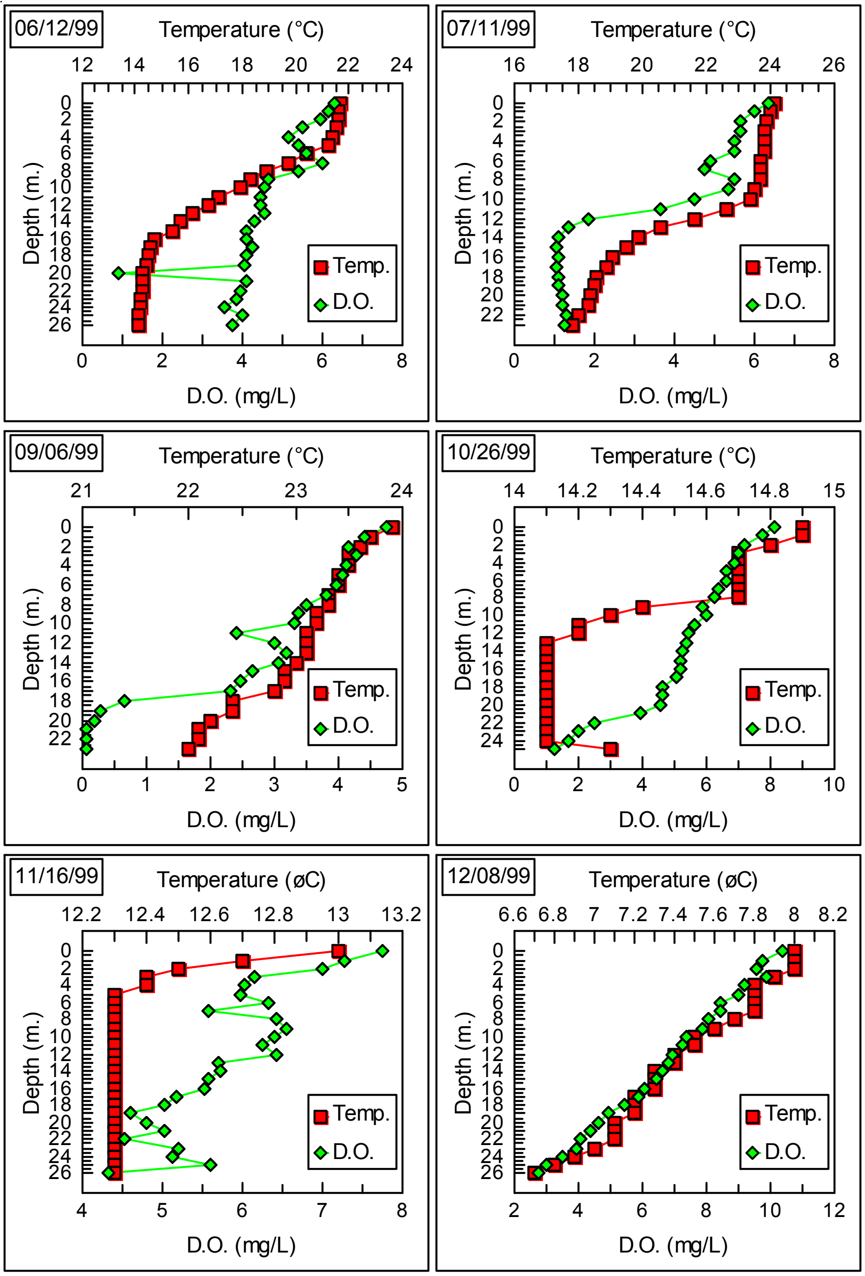


Figure 14: 1999 temperature and DO profiles from Santa Rosa Lake

Figure 14 shows monthly temperature and D.O. profiles from Santa Rosa Lake measured between June and December 1999. In June, there was weak thermal stratification between 5 and 7 meters, although there was a continuing significant drop in temperature to a depth of 15 meters. At the same time, the D.O. dropped off rapidly just below the depth of maximum temperature difference (Figure 14). In July, there was an even more distinctive thermocline present; this thermocline was located at a depth between 10 and 13 meters. There was a dramatic decline in D.O. at the depth of the thermocline (Figure 14). The September 1999 profile on Figure 14 also appears to show deep thermal stratification accompanied by a dramatic drop in D.O. However, the change in temperature is less than 0.5°C and is exaggerated by the scale of the *y*–axis, which total only 3°C. Alternatively, the decrease in D.O. between 17 and 18 in September is large and amounts to about 1.5 mg/L. The D.O. declined further to less than 0.1 mg/L near the reservoir sediments. In October 1999, there also appears to be a large decrease in temperature between 8 and 9 meters, but this decline appears more dramatic than it actually is because of the scale of the *y*-axis, which totals only 1°C. The D.O. shows a gradual decline throughout the water column in October with the greatest decrease near the sediments. In November 1999, the reservoir was essentially isothermal with a small amount of surface warming. At the same time, the D.O. profile shows an erratic pattern of increases and decreases through the length of the water column, but the general pattern is one of decreasing D.O. from surface to bottom. The last set of profiles on Figure 14 is for December 1999. There is an almost linear decrease in both temperature and D.O. throughout the length of their respective profiles. The decrease in temperature amounts to less than 1.5°C, while the D.O. decrease is from over 10 mg/L to less than 2 mg/L. There was an increase in the surface D.O. in December in comparison to November, but the bottom D.O. decreased in the intervening month (compare the D.O. axes in November and December). As a generality and on the basis of the 1999 profiles, the sediments appear to generate a large effect on the D.O. regime of Santa Rosa Lake, and any restriction of mixing due to thermal stratification drops the bottom D.O. to near 0.

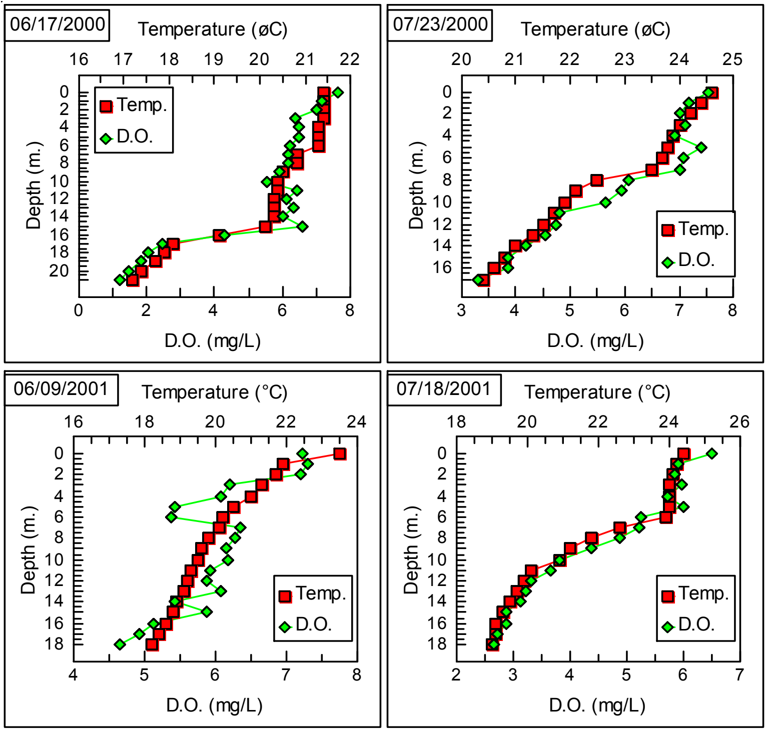


Figure 15: Temperature and DO profiles from June and July of 2000 and 2001 in Santa Rosa Lake

Figure 15 shows a similar set of June and July 2000 and 2001 temperature and D.O. profiles to those of Figure 14. Maximum thermal stratification develops in June and July and the remainder of this characterization will focus on those months.

In June 2000, there was a thermocline deep in the profile. There is a dramatic decline in D.O. right along the thermocline. There is a similar set of temperature and D.O. profiles in July. However, the July profiles are something of an anomaly in that the usually expected progression of thermal stratification is one of deepening; the July thermocline is shallower than that in June (Figure 15). The decline in D.O. in its profile still coincides with the depth of the thermocline. Consequently the 2000 profiles in Figure 15 support the conclusions based on the 1999 data in the previous figure.

The June 2001 temperature profile does not show a distinctive thermocline. There is surface warming that effects the greatest temperature change in the profile, but that change is restricted to the surface. Below the surface there is a gradual decrease in temperature throughout the profile. The temperature changes through the profile amount to only a tenth to a few tenths of a degree Celsius. The D.O. profile is somewhat erratic with both increases and decreases through the profile. The rather large increase in D.O. at the depth of around 7 meters probably reflects the influence of a higher D.O. interflow or a layer of actively photosynthesizing algae. The depth of the D.O. change does coincide with one of the larger temperature changes (0.3°C) in the profile.

The July 2001 temperature and D.O. profiles are nearly overlain on Figure 15. There is a distinctive thermocline in July located between 6 and 9 meters. The maximum decrease in temperature is 1.3°C between 6 and 7 meters. At the temperature of the water in this layer, the density change between the 2 layers of water is rather large and would represent very strong stratification. The D.O. concentration follows the plot of the temperature profile exactly with the mechanism of the oxygen decline almost certainly being decomposition of organic matter in the reservoir sediments that consumes the isolated hypolimnetic oxygen reserve. The July 2001 temperature and D.O. profiles are similar to those of 1999, but the D.O. decrease in July 2001 is somewhat less dramatic than in 1999.

There is one EC reading at each of the reservoir sites and the outflow from Santa Rosa Lake for each date in the database. As was noted above, all of the readings for all of the dates and all of the sites are the same, 0.3 mho/cm (or 300 µS/cm). This does not seem realistic. As is shown in Attachment 1, the inflow EC has ranged from 192 to 4,350 µS/cm, while the EC in the town of Santa Rosa about 9 miles downstream from the dam has ranged from 340 to 3710 µS/cm. The range in the outflow EC at Santa Rosa should approximate that of the outflow, but has never been that low. Consequently, the data do not seem usable for alternatives analysis. However, the operations of Santa Rosa Lake are not expected to change due to the water offset program. The above data are presented to simply characterize the historic water quality of the reservoir.

Ground Water Quality

Aquifers in the study area were described above. The ground water system in the Pecos River Valley is also described in Barroll and Shomaker (2003) and Robson and Banta (1995). Robson and Banta (1995) also includes a discussion of ground water quality in the basin. That discussion is reproduced below:

> Ground water in the western part of the carbonate aquifer in the Roswell Basin generally contains a preponderance of dissolved calcium, magnesium, and sulfate and is classified as either a calcium sulfate or a calcium magnesium sulfate type water. Calcium concentrations generally range from 100 to 500 milligrams per liter, magnesium concentrations generally range from 50 to 130 milligrams per liter, and sulfate concentrations generally range from 300 to 1,400 milligrams per liter. The water is of similar chemical composition to that in other carbonate-rock aquifers where active dissolution of limestone, dolomite, and gypsum is occurring. The water is classified as very hard. Dissolved-solids concentrations generally range from 700 to 2,600 milligrams per liter.
>
> Along the northeastern margin of the carbonate-rock aquifer, dissolved sodium and chloride concentrations in the water can be large; consequently, the water is classified as a sodium chloride type. Sodium concentrations in this area generally range from 1,500 to 3,000 milligrams per liter, and chloride concentrations range from 2,000 to 5,000 milligrams per liter (fig. 16). The water in this area is classified as very hard. Dissolved-solids concentrations range from 7,000 to 12,000 milligrams per liter.
>
> Water of large sodium chloride (salt) content is of particular concern in the Roswell Basin because most water is used for irrigation, and many crops can be damaged by excessive salt in the water and soil. The source of the large chloride concentrations in the carbonate-rock aquifer is uncertain but might be brine that moved across the relatively impermeable eastern boundary of the aquifer. Seasonal water-level declines in the carbonate-rock aquifer might temporarily reverse the direction of ground-water movement across the eastern boundary and enable brines in the deeper parts of the San Andres Limestone to move westward into the carbonate-rock aquifer. Chloride concentrations in water in the eastern part of the aquifer generally are larger near the end of the pumping season when water-level declines are large; concentrations decrease in the winter and early spring when water levels have returned to nonpumping levels. Large chloride concentrations in water samples from the bottom of some wells indicate that these concentrations are larger at greater depth in water in the eastern part of the carbonate-rock aquifer (fig. 17).
>
> When water with large chloride concentration is deep in the carbonate-rock aquifer (fig. 17A), it has little effect on the water quality in shallow parts of the aquifer, and water pumped from wells is of relatively uniform quality. However, if the water with large chloride concentration is drawn farther into the aquifer (fig. 17B), then wells close to the eastern boundary can be severely affected (well C), and more westerly wells might be unaffected or only moderately affected

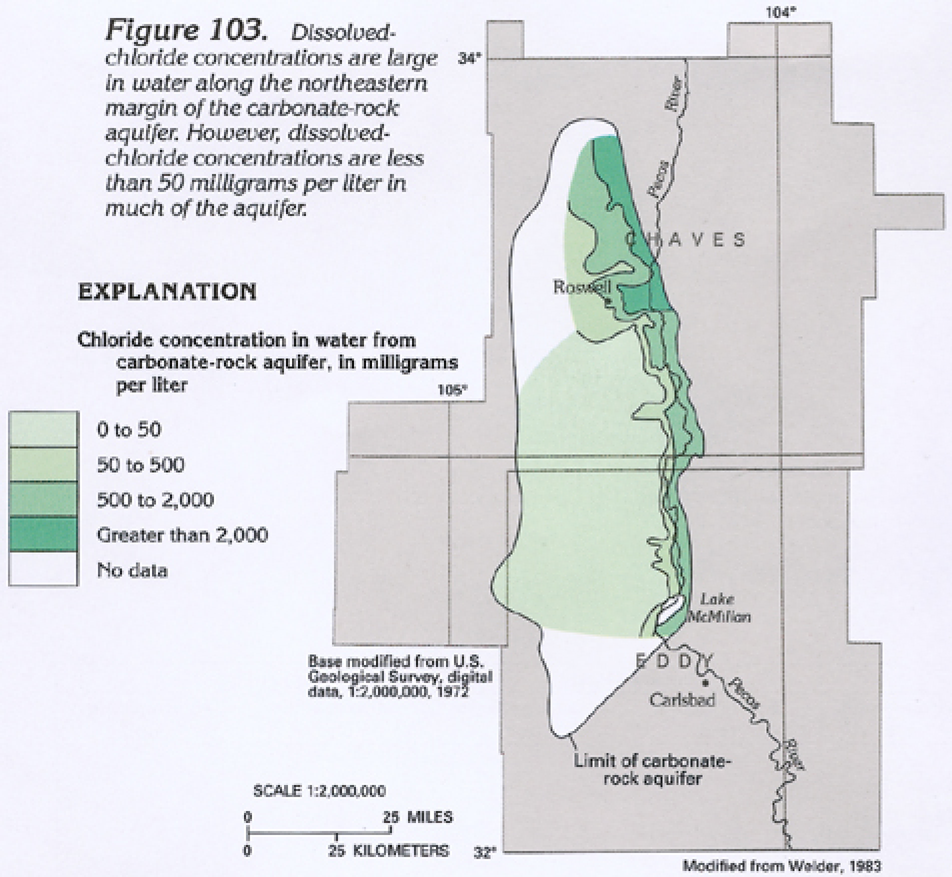


Figure 16: Reproduction of Figure 103 of Robson and Banta (1995)

(wells A and B), depending on well location and depth. Water in the carbonate-rock aquifer to the east of Roswell has undergone a marked increase in chloride concentration. Between 1959 and 1978, chloride concentrations increased by 1,000 to 2,000 milligrams per liter in water from some wells in this area. Increases in 1959-78 chloride concentrations generally have been less than 100 milligrams per liter along the southern one-half of the eastern margin of the aquifer.

Water in the southern one-half of the alluvial aquifer generally is a calcium sulfate type. In the northern one-half of the aquifer, and at a few points along the southeastern margin of the aquifer, the water generally is a mixed calcium sodium sulfate chloride type. The water is very hard throughout the aquifer; dissolved-solids concentrations range from about 500 to 5,000 milligrams per liter. Chloride concentrations range from about 50 milligrams per liter along the western margin of the aquifer to about 2,000 milligrams per liter in a few areas along the eastern margin of the aquifer (fig. 18).

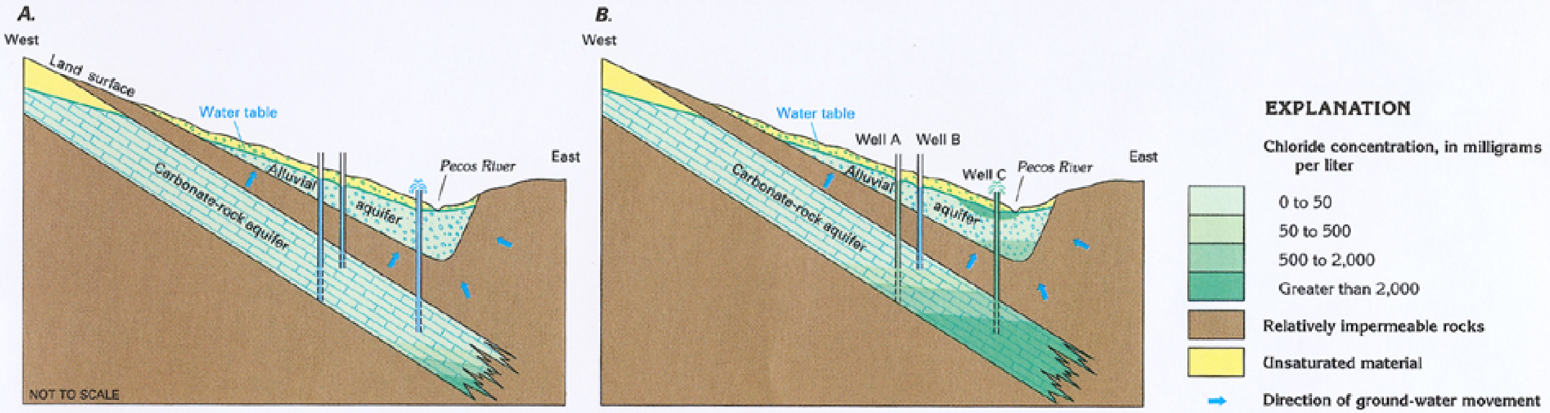


Figure 104. *A, During winter months when water levels in the aquifer are high, water with large chloride concentration can be present in the deep parts of the carbonate-rock aquifer. B, As water levels decline during the growing season, water with large chloride concentration can move upward and degrade the quality of water in some wells and in the alluvium.*

Figure 17: Reproduction of Figure 104 of Robson and Banta (1995)

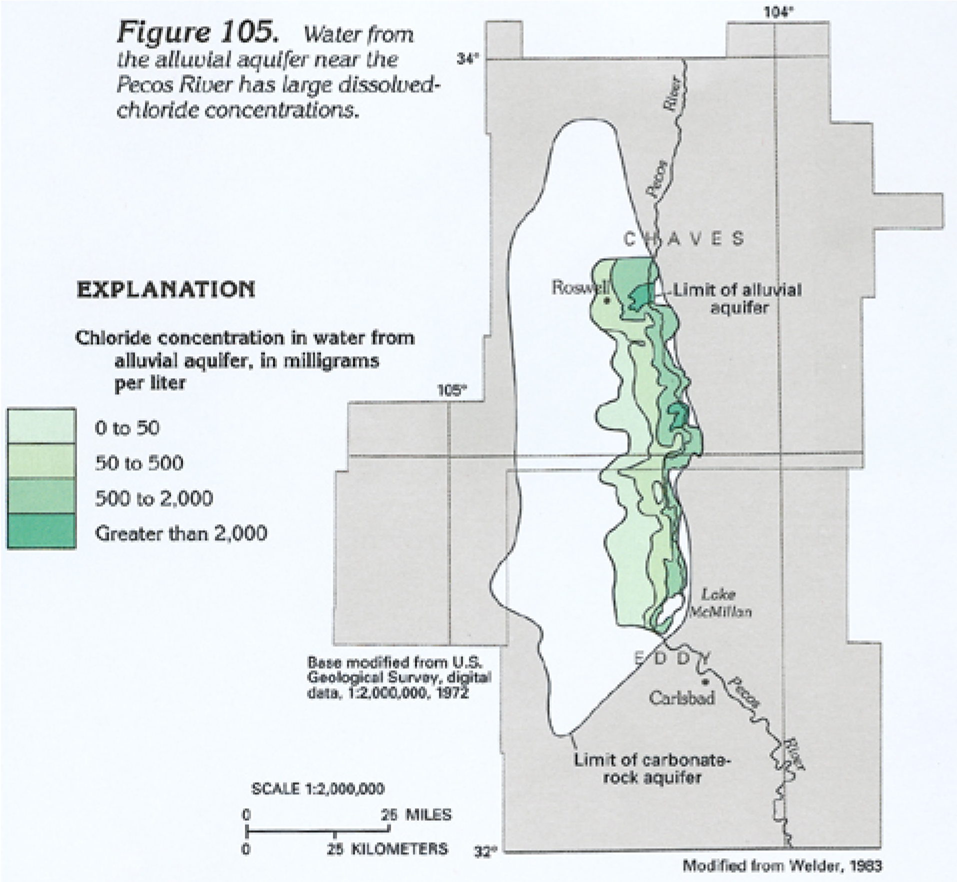


Figure 18: Reproduction of Figure 105 of Robson and Banta (1995)

> In the eastern part of the alluvial aquifer, chloride concentrations can be large in ground water near the upper or lower parts of the aquifer. Large concentrations in the upper part of the aquifer probably are caused by infiltration of water with large chloride concentration from local canals or from wells completed in more saline zones in the carbonate-rock aquifer (fig. 17B). Evapotranspiration by phreatophytes also concentrates dissolved minerals in the soil and shallow water table near the Pecos River. Water with large chloride concentration in the lower part of the alluvial aquifer likely is caused by upward movement of more saline water through the upper confining layer of the carbonate-rock aquifer. Both processes have caused water-quality degradation in the alluvial aquifer. Between about 1957 and 1978, chloride concentrations increased from 30 to 1,000 milligrams per liter in water from some wells.

The above described increase in chloride in the ground water was previously noted in the surface water description for the Pecos River. There is an increase in the percent chloride in the Pecos River beginning near Acme. The change to a high percentage is very evident at the Artesia gage on the Pecos River (see Figure 2 in the Basin-wide Water Quality section).

Ground water quality data from the 3 counties were inventoried and retrieved from the USGS NWIS database. The retrieval included a total of 42 observations from 20 sites. The data encompassed the period 1938 through 1972. Based on the assumption that these and other data were used by Robson and Banta (1995) and the fact that there were no recent data, they were not used further in this description.

Measured and Estimated Drain Quality

At the time that the data on Sumner Dam releases (see surface water quality section) were collected by Flo (1997), EC measurements were made at several drains adjacent to the Pecos River. The data for drains from Ft. Sumner Irrigation District (FSID) lands are shown on Figure 19. In the winter and spring of 1995, the EC of the 2 drains paralleled each other, but the EC of the lower drain is about 1,000 µS/cm higher. The EC of the drains remained fairly stable in the winter, but decreased in the spring. In June, the EC of the Fort Park drain increased, while that of the lower drain decreased. The net result was that the EC of the Fort Park Drain exceeded that of the Lower Drain by several hundred µS/cm. By August, the EC of the drains returned to the levels that had been present the preceding May. The EC of the drains appears to be unchanged most of the year, but decreases after the onset of the irrigation season. This type of response would be a reflection of dilution of the ground water feeding the drains by the applied irrigation water.

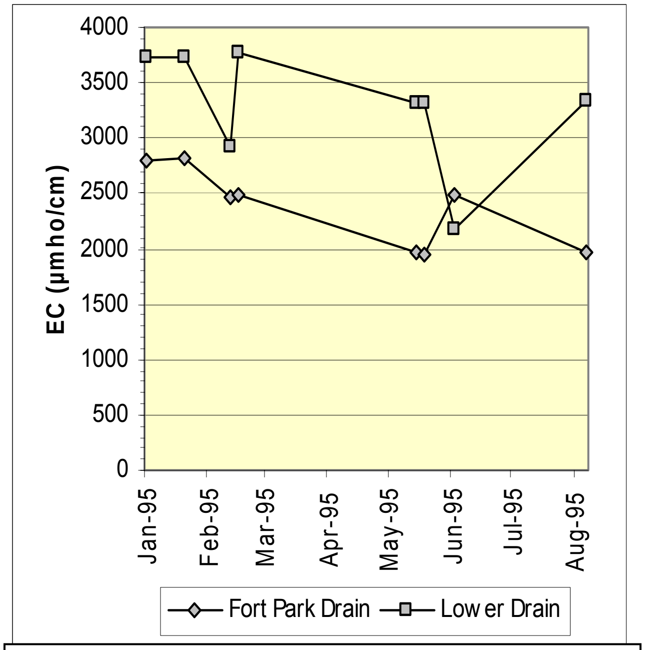


Figure 19: EC of the Fort Park and Lower drains

In general, the EC of the Fort Park Drain (Figure 19) are within the confidence interval of the Pecos River during low flow (see Figure 7 in the Sumner Dam Releases section under surface water). The EC of the Lower Drain was somewhat higher than that of the Fort Park Drain. However, although there is an increase in the EC of the Pecos River between stations ST-3 and TA-0.3 (see above referenced Figure 7), the upper limit of the EC confidence interval for the river at low flow remains below the EC of the Lower Drain. The lack of a change in the upper confidence interval between the above referenced sites indicates that the Lower Drain does not have a great effect on the EC of the river, even at low flow.

The drains discharge directly to the river. The Fort Park Drain is located about 25 miles downstream from Sumner Dam, while the Lower Drain is located about 35 miles downstream from the dam near Taiban. When there is no release from the dam, the gains in the river would be due to ground water accretions to the river. Based on this assumption, the alluvial ground water quality data were supplemented by calculating the EC of the unmeasured gains between sites when the river EC measurements were made in 1995-96. The EC's were calculated when the flow at the railroad bridge site, which is located about 18 miles downstream from the dam was less than 2 ft^3/s. The resulting EC data are shown on Figure 5. The EC's were calculated as the change between sites ST-2, the railroad bridge site, and ST-3, the Old Fort Park site, and between ST-3 and ST-4, the Taiban site. The drain data from Figure 19 are also plotted on Figure 20 as a basis for comparison to evaluate agreement between the calculated ungaged gains and measured drain data. The assumption is that the measured drain data are representative of all of the ground water from the area that enters the river. However, the drain data may be representative of only part of the ungaged gains, if ground water under the FSID is variable in quality.

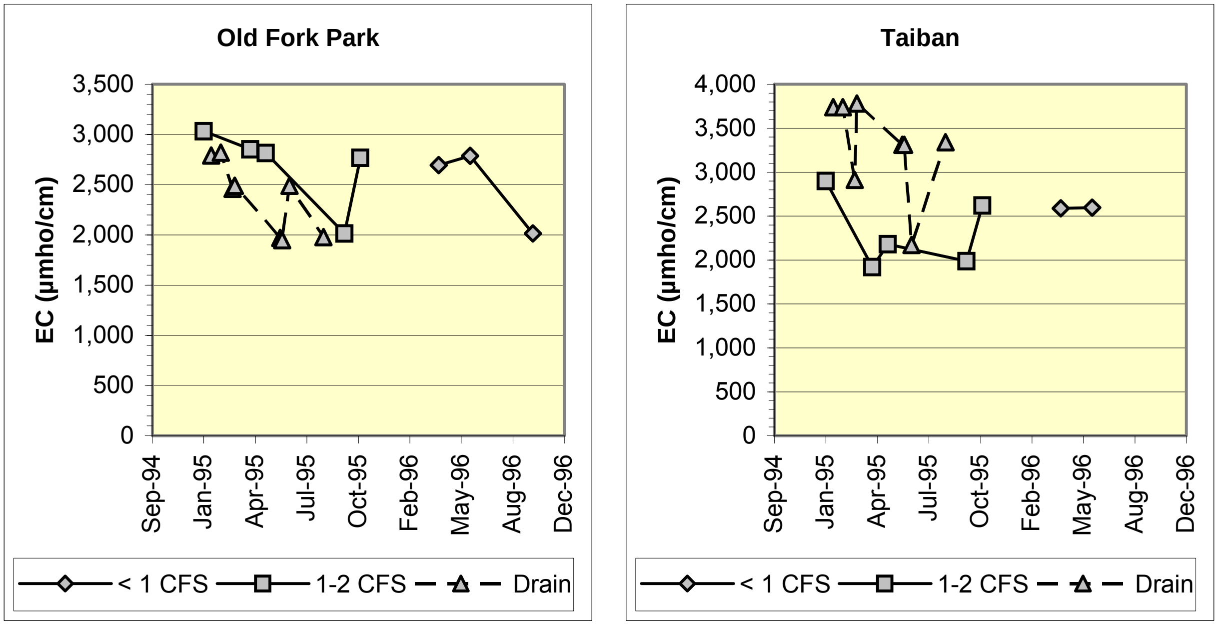


Figure 20: Comparison of the calculated EC of ungaged gains and measured drain EC

The flows shown on Figure 20 represent the flow of the Pecos River at site ST-2, which is located about 18 miles downstream from Sumner Dam. Since there was no release from Sumner Dam at the time when the measurements were made, the flows represent seepage gains between the dam and ST-2. As can be seen from Figure 20, all of the measured drain EC's are from 1995 and all of the calculated EC's from 1995 coincide with seepage of between 1 and 2 ft^3/s. Alternatively, all of the calculated data and the lowest seepage gains, *i.e.* < 1 ft^3/s, were from 1996, when there are no measured drain data.

The 2 sets of calculated EC's show a dichotomy in the comparisons with measured drain EC's. In the case of the data from the area of the Old Fort Park Drain, all of the calculated EC's are greater than the measured drain data, while in the case of the Lower Drain area, all of the calculated values except 1 are less than the measured drain data (Figure 20). The differences between the measured and calculated EC's in the area of the Old Fort Park Drain are smaller than those from the Lower Drain area. The calculated EC of the ungaged gains in the 2 river reaches show little difference, while the drains show a relatively large difference in EC. The calculated EC data indicate that the EC of the ground water in the area is much more uniform than the drain data show. In addition, the calculated EC data indicate that the ground water EC is much more like the river and the Old Fort Park drain on the average, than it is like the EC of the Lower Drain. It should be noted that, according to Flo (1997), both of the drains and Taiban Creek, along with diffuse irrigation return flows, enter the Pecos River between sites ST-3 and ST-4. Consequently, the calculated EC shown on the Lower Drain plot on Figure 5 represent a mix of all of these sources.

Bureau of Reclamation Samples

Additional drain and ground water EC measurements in the EIS study area were made during March and April 2003 (Brummer, 2003a & b). The March data included additional measurements of the EC of the FSID drains (Table 10). The March 2003 measurements are similar to those shown on Figure 4 from January 1995. In both 1995 and 2003, the EC of the Lower Drain is much higher than that of the main drain, but more so in 1995. The differences should reflect interannual variation.

Most of the data in Table 10 come from 3 general areas. The general areas include ones near Dexter, the McMillan Delta, and the CID salt cedar control demonstration area. The data from these areas can be used to demonstrate areal differences in EC in the shallow aquifers.

The EC of the ground water in the Dexter area is about twice that of the FSID area (Table 10). The 2 well samples have an EC of 6-7,000 µS/cm. However, the drain reading at over 16,000 µS/cm is over twice as high as the well readings. Unless there was an extreme amount of evaporative concentration of the drain water, the wells and the drain represent much different sources of water, but, if so, they do indicate that ground water EC in the area can vary greatly.

The only other area where there were gains such that an inflow EC could be calculated from the Flo (1997) flow and EC data were at sites in the Pecos Basin near Dexter. The EC of ungaged gains was calculated for the reaches between TA-4, located at the Acme gage, and AA-1, located at the Highway 380 crossing, and between AA-1 and AA-1.5, located near Dexter. Those data are plotted on Figure 21.

The calculated EC of the ungaged gains in the Highway 380 reach show a much larger degree of variation than those of the Dexter reach (Figure 21). In the Highway 380

Table 10. EC from wells and springs along the Pecos River in 2003

Site	Date	Location	Specific Conductance (µS/cm)	Depth to water	Remarks
FSID main drain	March 2003	weir	2,720	—	5-10 ft^3/s flow
FSID lower drain	March 2003	Ditch	3,480	—	1-2 ft^3/s flow
Roswell municipal	March 2003	—	1,092	—	—
Well water	4/4/2003	Dexter - near river	7,100	—	Ag well
Well water	4/4/2003	Dexter	6,300	—	Ag well
Ag drain	4/4/2003	Dexter	16,100	—	Ag drain to Pecos river
m-37	4/5/2003	McMillan delta	4,110	35.5 feet bgs[1]	CID obs well
m-38	4/5/2003	McMillan delta	—	Dry at 28 feet	CID well
M35	4/5/2003	McMillan delta	11,400	28.0’ bgs	CID well
m-33	4/5/2003	McMillan delta	4,500	15.5’ bgs	CID well
M-32	4/5/2003	McMillan delta	8,200	32.7’ bgs	CID well
m-30	4/5/2003	McMillan delta	9,100	28’ bgs	CID well
m-29	4/5/2003	McMillan delta	6,600	29.0’ bgs	CID well
m-28	4/5/2003	McMillan delta	2,300	30.5’ bgs	CID well
m-25	4/5/2003	McMillan delta	1,100	23.0’ bgs	CID well
m-26	4/5/2003	McMillan delta	4,550	28.5’ bgs	CID well
m-24	4/5/2003	McMillan delta	2,550	25.0’ bgs	CID well
m-36	4/5/2003	McMillan delta	4,960	30.0’ bgs	CID well
Well 1 demo	4/7/2003	Demonstration area - SC control[2]	10,100	21.5’ bgs	Obs well
Mc17	4/7/2003	Demo area	10,870	7.5’ bgs	Old usbr obs well
Well 8	4/7/2003	Demo area	4,200	9.7’ bgs	Obs well
Well 3	4/7/2003	Demo area	4,400	16.8’ bgs	Obs well
Well 5	4/7/2003	Demo area	2,920	7.5’ bgs	Obs well near river
Carlsbad springs	3/19/2003	Near flume	5,200	—	—
Carlsbad tap	3/19/2003	Municipal wells	770	—	—
Carlsbad tap	4/8/2003	Municipal wells	708	—	—
Supplemental well	4/8/2003	Irrigation well u986 north	1,429	—	—
Supplemental well	4/8/2003	Irrigation well u896 south	1,557	—	—

[1] bgs – below ground surface

[2] SC control – CID salt cedar (tamarisk) control demonstration area

reach, the EC of the gains range from about 10,000 µS/cm to over 28,000 µS/cm. However, 5 of the 6 calculated values are in the range of 10,000 to 20,000 µS/cm. On the other hand the EC values of the Dexter reach are much lower than those in the Highway 380 reach. All of the calculated EC’s of the gains in the Dexter reach are between 6,000 and 8,000 µS/cm. In other words the maximum EC of the Dexter reach is lower than the minimum EC in the Highway 380 reach. This would mean that there would be a decrease in the river EC if it were lower than the gain EC. As is indicated

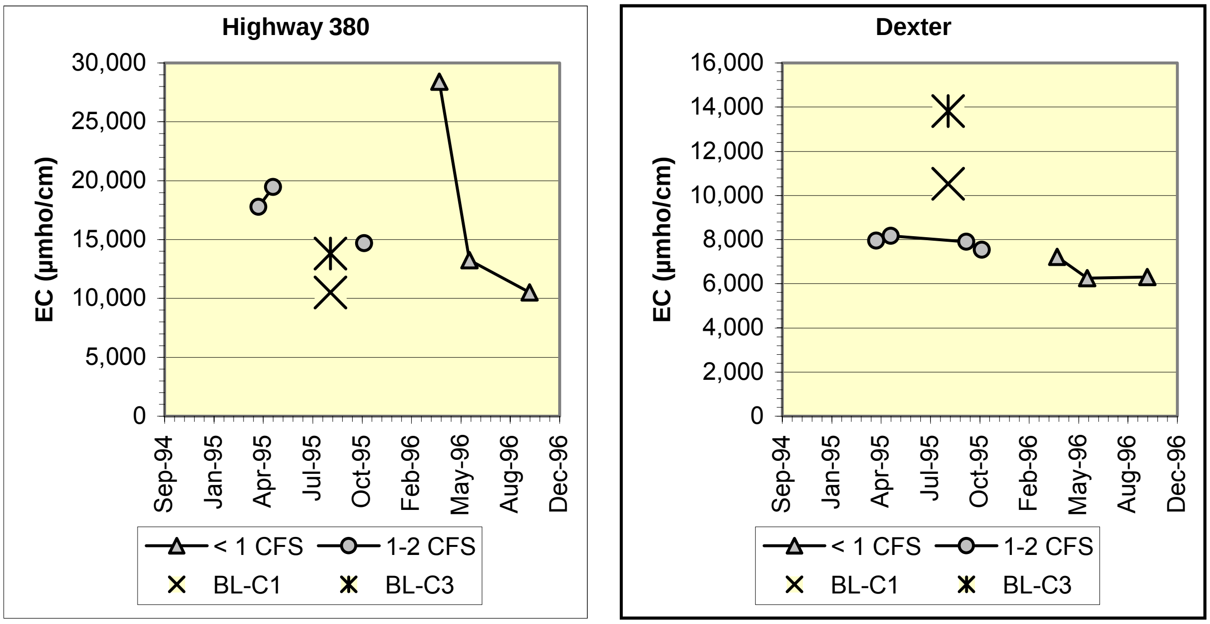


Figure 21: Calculated EC of gains in the Highway 380 and Dexter reaches of the Pecos River and measured EC of the Bitter Lakes drains

on the above reference Figure 7, there is a small decrease in EC between stations AA-1 and AA-1.5 at very low flow, but not at Sumner releases > 2 ft^3/s.

Figure 21 also shows an EC measurement of the Bitter Lakes drains. Those EC measurements were made in August and plot slightly below the EC of the gains at Highway 380, although the EC of BL-C3 is only slightly lower. Alternatively, the Bitter Lakes Drain EC measurements plot similar to the calculated EC of the drains from 1996 measurements. The drain EC measurements plot well above the calculated EC of the gains in the Dexter reach of the Pecos River (Figure 21). This result would indicate that the drain measurements are not particularly representative of the ground water quality in Dexter reach of the Pecos River.

The largest body of data in Table 10 is from the McMillan delta area at the upstream end of Brantley Reservoir. The EC's in that data set range from 1,100 to 11,400 µS/cm, indicating an extremely high degree of variation in the shallow (< 36 feet) ground water. The second largest EC data set in Table 10 is from the CID salt cedar demonstration control area. That data set also shows a high degree of variation in EC with a range from 2,920 to 10,870 µS/cm. Because of the high degree of variation within those data sets, there is no statistically significant difference between the 2 data sets, *i.e.* t = 0.66, probability of a greater t occurring by chance alone = 0.52, based on normalized (log-transformed) data. This leads to the somewhat ambiguous conclusion that the ground water in the lower Pecos Valley is uniformly variable.

All of the towns in the Pecos Basin below Sumner Dam obtain their municipal water from wells. Table 10 includes EC measurements of the treated water in Roswell and Carlsbad. While most of the other data in table 10 reflect the water quality of the Pecos alluvial aquifer, the City of Carlsbad obtains its water from the Capitan aquifer. There are 2 EC measurements of the Carlsbad municipal water in Table 10. Both of the EC measurements are between 700 and 800 µS/cm.

Barroll and Shomaker (2003) describe the Capitan aquifer and its relationship to the Carlsbad water supply. The following is summarized or quoted from that description.

As stated in Barroll and Shomaker (2003), the Capitan aquifer is an ancient reef which includes cavernous limestone from which high capacity wells can produce good quality water. The Capitan reef is a thick accumulation of Permian age massive limestone beds in which Carlsbad Caverns also formed. At Carlsbad, the Capitan aquifer is about 1,600 feet thick and immediately underlies the alluvium (*ibid*.).

An idealized stratigraphic column (aquifers) adapted from Land (2003) is shown in Table 11. Table 11 shows the variation in geologic formations from northwest to southeast and the relative position of the Capitan aquifer. The formations shown above the Capitan Reef are those that may be present, but are not present in all locations. As noted above, none of the formations shown in Table 11 overlie the Capitan Reef near Carlsbad.

Table 11. Stratigraphy of southeast New Mexico (adapted from Land, 2003)

<table>
<tr><th rowspan="2">Era</th><th rowspan="2">Period</th><th colspan="4">NW ◄——————► SE</th></tr>
<tr><th colspan="2">Northwest Shelf</th><th colspan="2">Delaware Basin</th></tr>
<tr><td rowspan="4">Cenozoic</td><td rowspan="2">Quaternary</td><td colspan="4">Pecos Valley alluvial fill</td></tr>
<tr><td colspan="4">Gatuna Formation</td></tr>
<tr><td rowspan="2">Tertiary</td><td colspan="4">Ogallala Formation</td></tr>
<tr><td colspan="4">Sierra Blanca Formation</td></tr>
<tr><td rowspan="3">Mesozoic</td><td>Cretaceous</td><td colspan="4"></td></tr>
<tr><td>Jurassic</td><td colspan="4"></td></tr>
<tr><td>Triassic</td><td colspan="4">Santa Rosa Fm./Dockum Group</td></tr>
<tr><td rowspan="11">Paleozoic</td><td rowspan="11">Permian</td><td colspan="2">Rustler Fm.</td><td colspan="2">Rustler Fm.</td></tr>
<tr><td colspan="2">Salado Fm.</td><td colspan="2">Salado Fm.</td></tr>
<tr><td colspan="2"></td><td colspan="2">Castille Fm.</td></tr>
<tr><td rowspan="5">Artesia Group</td><td>Tansil</td><td rowspan="5">Capitan Reef</td><td rowspan="5">Delaware Mountain Group</td></tr>
<tr><td>Yates</td></tr>
<tr><td>Seven Rivers</td></tr>
<tr><td>Queen</td></tr>
<tr><td>Grayburg</td></tr>
<tr><td colspan="2">San Andres/Glorieta</td><td colspan="2" rowspan="2">Bone Springs Formation</td></tr>
<tr><td colspan="2">Yeso/Victoria Peak</td></tr>
<tr><td colspan="2">Abo Fm.</td><td colspan="2">Hueco Group</td></tr>
</table>

There is an extremely transmissive segment of the Capitan aquifer extending from the Guadalupe Mountains to just east of the Pecos River. Water levels in all wells completed in this segment of the reef are at the same elevation and rise and fall in unison in response to recharge events (such as floods in Dark Canyon) and ground water withdrawals. Water quality in the Capitan aquifer is generally excellent southwest of Carlsbad with concentrations of total dissolved solid less than 700 mg/L (EC ~1075 µS/cm). West and north of Carlsbad, ground water mixes with poorer quality water from the bedrock aquifers in the Pecos Valley and lower quality river water seeping in from Lake

Avalon. Originally Carlsbad diverted from the Capitan aquifer using a well field near the Pecos River. Degradation of water quality caused the city to drill a new well field closer to the Guadalupe Mountains, and thus closer to the source of natural recharge. Any increase in pumping from the Capitan aquifer may lead to farther decrease in water quality.

Table 10 also shows an EC reading from Carlsbad Springs. As can be seen, the EC of Carlsbad Springs is much greater than that of Carlsbad city water. The original discharge of the Capitan aquifer was Carlsbad Springs (Barroll and Shomaker, 2003). As noted in Barroll and Shomaker (2003), ground water pumping now intercepts much of that natural recharge. That pumping is reflected in depletions of spring flow and flow of the Pecos River. Artificial recharge associated with leakage from Lake Avalon enters the Capitan aquifer near the city of Carlsbad and is now a large component of the present flow of Carlsbad Springs (*ibid.*). Consequently the EC of Carlsbad Springs is more like that of the Pecos River than of the good quality water in the more westerly segment of the Capitan aquifer.

New Mexico State Engineer Ground Water Data

The Roswell District of the New Mexico Office of the State Engineer (OSE) periodically measures chloride (Cl) and specific electrical conductance (EC) from wells throughout the District. The complete data set was provided to Reclamation (Elisa Sims, OSE, personal communication to Jim Yahnke, Reclamation; letter of July 29, 2004). The Cl and EC data, along with the location, water temperature, and water-bearing formation (aquifer) for wells located within township-range locations along the mainstem of the Pecos River between Sumner Dam and the lower end of the CID were entered into a spreadsheet. The township-range combinations entered are shown in Table 12, which also includes a break down by county and irrigation district, if any. The data encompass measurements made from 1927 through 1999.

The main focus of the ground water analysis will be on the alluvial aquifer in the CID, which is located in Eddy County. However, data from De Baca and Chaves counties were also included in the database for the EIS because replacement water for the CID would likely originate from those areas. In addition, the data would provide a basis for comparison for the water quality estimates above, particular in the lower reach between Acme and Artesia, where the water quality is extremely poor on the basis of the estimates from the Bitter Lakes area.

Table 12. Alluvial areas between Fort Sumner Dam and the Southern end of the CID

De Baca County		**Chaves County**		**Eddy County**	
FSID		South of FSID		CID	
Township	Range	Township	Range	Township	Range
T3N	R26E	T4S	R25E	T21S	R27E
T2N	R26E	T5S	R25E	T21S	R28E
		T6S	R25E	T22S	R27E
South of FSID		PVACD		T22S	R28E
Township	Range	Township	Range	T23S	R27E
T1N	R26E	T7S	R25E	T23S	R28E
T1S	R25E	T8S	R24E	T24S	R27E
T2S	R25E	T9S	R24E	T24S	R28E
T3S	R25E	T10S	R25E		
		T11S	R26E		
		T12S	R26E		
		T13S	R26E		
		T14S	R26E		
		T15S	R26E		
		T16S	R26E		
		T17S	R27E		

Carlsbad Irrigation District (CID)

Data from wells located in the CID are summarized by water-bearing formation in Table 13A. The alluvial aquifer shows the greatest range in EC of any of the aquifers, primarily because of the maximum value that is shown, *i.e.* over 200,000 µS/cm, which would be considered a brine. That measurement, which is nearly 10 times as high as the next highest EC value, was made in 1967 and was the only measurement made from that particular well; as noted in Table 13, the result is considered a statistical outlier and has been discarded from any of the other analyses.

More EC measurements were made in the CID in wells in the alluvial aquifer (212 - Table 13A) than in all of the other aquifers combined (157). The greatest median EC is also in the alluvial aquifer. As is noted in the footnote to Table 13, by far the highest maximum EC was also measured in a well from one of the unrecorded aquifers; the use noted for the well was that it was associated with the mining of ore, which may account for its extremely high EC. The median EC in wells from 4 of the aquifers, including the Capitan Reef and the Rustler, Castille, and Tansil formations, are similar and only differ by a little over 400 µS/cm, with a range between 3,223 and 3,660 µS/cm (Table 13A). By far the lowest median EC of any of the formations shown in Table 13 is in the Yates Formation. The next lowest EC is from wells where the aquifer is not recorded and, not surprisingly, appears to represent a mix of sources.

Table 13. Summary of ground water EC data in various aquifers in the CID

A. Summary statistics by aquifer

Aquifer	Samples	Minimum	Median	Maximum
Alluvium	212	1,036	5,000	22,300
Rustler	32	460	3,223	9,720
Castille	3	3,490	3,591	3,830
Capitan Reef	78	520	3,305	28,800
Tansil	20	1,320	3,660	16,520
Yates	12	420	653	5,000
Not noted	12	720	2,315	203,120

B. Kruskal-Wallis test of EC in ground water in different aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Alluvium	Capitan Reef	38.48	< 0.000001	Yes
Alluvium	Rustler	17.39	0.000030	Yes
Alluvium	Castille	2.55	0.109985	No
Alluvium	Tansil	2.11	0.146118	No
Alluvium	Yates	23.98	0.000001	Yes
Alluvium	Not noted	4.91	0.026681	Yes
Capitan Reef	Rustler	0.35	0.551411	No
Capitan Reef	Castille	0.02	0.864612	No
Capitan Reef	Tansil	1.25	0.262909	No
Capitan Reef	Yates	13.11	0.000294	Yes
Rustler	Tansil	0.01	0.925072	No
Yates	Rustler	11.38	0.000743	Yes
Yates	Tansil	14.26	0.000159	Yes

Table 13B presents a statistical comparison of the EC of wells in the various aquifers. Although the median EC of the alluvial wells is much higher than that of any of the other aquifers, the EC of the alluvial wells is not significantly different from that of wells in the Castille or Tansil formations, the wells of which are the 2nd and 3rd highest (Table 13A). In the case of wells in the Castille Formation, there are too few samples (3) to make a valid comparison. Although not shown in Table 13B, the results of the statistical comparison of the EC of wells from the Castille Formation show no significant differences from that of measurements from any of the other aquifers, including that from the Yates Formation. The EC of the wells in the Yates Formation is significantly lower than that of wells from any of the other aquifers.

As was noted above, the Capitan Reef (or Capitan Limestone) is an important aquifer in the Carlsbad area. The EC of wells in the Capitan Reef is similar to that of wells in the Rustler, Castille, and Tansil Formations. Ignoring the Castille Formation for reasons noted above, the comparisons of the EC in the Capitan with that of wells in the Rustler and Tansil formations show somewhat odd results. The median EC of the Capitan and Rustler wells show a difference of less than 100 µS/cm, but there is a significant difference between the 2 sets of EC data (Table 13B). Alternatively, there is a difference of over 350 µS/cm between the median EC of wells in the Capitan and Tansil Formations, yet there is no significant difference in those data sets (Table 13B). The median is only 1 point within the distribution of the data. The statistical test that is being used ranks the combined data sets and compares the resulting sum of the ranks of each against the proportion of each of the data sets that should be in each based on their number of observations. Because the medians are so similar, it is probably of little consequence whether the differences are significant or not. The important conclusions seem to be that ground water in the Carlsbad area from the Yates Formation is significantly lower in salt than other water, while water from the alluvium is generally higher in EC than other water.

Fort Sumner Irrigation District (FSID)

The FSID may also be affected by the Program in that water rights could be obtained for use farther downstream. However, the main consideration in the FSID is the returns from irrigation. The water quality of drains in the FSID was discussed above. The assumption there was that the drainage represented the ground water under the FSID. The OSE data set also includes data from wells within the FSID. A breakdown of the EC data by formation is included in Table 14A and a nonparametric comparison of the EC by aquifer is shown in Table 14B.

The FSID is primarily underlain by strata of Triassic age, while the CID was primarily underlain by Permian age strata, although in both cases Quaternary alluvium constitutes an important aquifer. The majority of EC measurements from the FSID are from alluvial wells (Table 14A). The total number of observations from wells in deeper strata combined is much less than the number from the alluvial wells alone.

Table 14. Comparison of EC in ground water under the FSID

A. Summary statistics for EC by FSID aquifer (µS/cm)

Formation	Samples	Minimum	Median	Maximum
Alluvium	63	570	2286	7430
Chinle	8	990	1237	6920
Santa Rosa	25	650	1988	5177
Artesia Group	1	—	2290	—

B. Kruskal-Wallis test of EC in FSID aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Alluvium	Santa Rosa	0.345	0.556835	No
Alluvium	Chinle	4.527	0.033359	Yes
Chinle	Santa Rosa	2.824	0.092892	No

Table 14 shows data from wells in the Chinle Formation. The Chinle Formation was not shown among the strata presented earlier in Table 11. According to Bachman (1981), the Chinle Formation constitutes the beds that overlie the Santa Rosa Formation in eastern New Mexico; both of those formations are included in the Triassic Dockum Group in eastern New Mexico. However, Bachman (1981) indicates that there is little justification for extending the formational names into southeastern New Mexico and prefers to call the Triassic rocks just that or call them the Dockum Group, undivided, as is shown in Table 11. In addition, Ken Fresquez, OSE, Roswell, New Mexico, who provided the data, indicates that the formational codes are preliminary and have not been verified and, in essence, are not to be trusted. The problem is that there are apparent differences in the EC of the ground water in the different formations, a factor that could be meaningful when offset water is obtained.

There is a statistically significant difference between the EC of the Quaternary alluvium and the Triassic Chinle Formation (Table 14B). There is no significant difference between the EC of the alluvium and the Santa Rosa Formation nor between that of the Santa Rosa and Chinle formations (Table 14B). The median EC of the Chinle Formation water is lower than the median EC of either the alluvium or the Santa Rosa Formation. Alternatively, the minimum EC of the Chinle Formation water is greater than the minima of either of the other formations, while its maximum EC is intermediate between the maxima of the other 2 formations. Another potential factor in the differences is that there are far fewer EC data points from the Chinle Formation than from either of the other formations. It may be that the Chinle Formation EC data are not truly representative of the EC of water in the formation, but there is no way to determine if that is the case based on the current data set.

Ground Water EC south of the FSID

The alluvial ground water in the river reach between the FSID and the PVACD may or may not be affected by the Carlsbad Water Supply Program. In the event that make up water is obtained from the area, the quality of water will be described. The wells from which there are EC measurements in the OSE data set are in the same water-bearing formations as was the case of the FSID. The majority of the measurements in both the FSID and the area to its south are from the alluvium, but the second greatest number are in wells from the Permian Artesia Group, undivided, while in the FSID the second most common aquifer from which measurements were made was the Triassic Santa Rosa Formation. Very few measurements were made in either area from other aquifers.

The EC data from the area south of the FSID, but north of the PVACD, are summarized in Table 15A. In this area of the Pecos Valley, the 3 most frequent data set for aquifers includes the data includes the data where the aquifer from which the water is drawn was not identified. There are also 2 sets of samples from surface springs; the aquifer from which the springs issue is similarly not identified. With the exception of the springs and water from the Santa Rosa Formation, where the median EC is approximately 1,500 and 11,000 µS/cm, the median EC of the ground water in the remaining aquifers is about 3,000 µS/cm (Table 15A). This is a bit higher than the EC of the FSID, which looks to be about 2,000 µS/cm based on the data in Table 14A.

Table 15. Summary of ground water EC data from the area between the FSID and the PVACD

A. Summary statistics of EC of ground water (µS/cm)

Formation	Samples	Minimum	Median	Maximum
Alluvium	40	956	2888	8200
Santa Rosa	4	1212	1454	1686
Chinle	5	2620	2872	3498
Artesia Group	37	813	3202	16580
Spring	2	3110	11030	18950
Not noted	6	2340	3186	4520

B. Kruskal-Wallis test of EC of ground water in different aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Artesia Group	Alluvium	0.019	0.890520	No
Alluvium	Not noted	0.345	0.557115	No
Alluvium	Santa Rosa	6.001	0.014299	Yes
Alluvium	Chinle	0.033	0.856689	No

Table 15B shows a statistical comparison between the EC of water in the alluvial aquifer with that in each of the other 4 sets of ground water data, including data from the 3 other aquifers and the data from identified aquifers. The only significant difference in EC from the alluvial aquifer is with the water from the Santa Rosa Formation. As with the Kruskal-Wallis tests on the EC of the FSID ground water, the statistical significance of the difference is not that great – both show probabilities between 0.01 and 0.05. In both instances, the amount of data from the data set that shows the difference from the alluvial aquifer is relatively small. There are 8 observations from the Chinle Formation in the FSID (Table 14A) and only 4 from the Santa Rosa Formation in the area to its south (Table 15A). Nevertheless, the median EC of the water from the wells in the Santa Rosa Formation is about ½ that of wells in the alluvium.

The inequity of the number of samples among aquifers was noted in the preceding discussion. There is also a large variation in sampling effort among areas along the river. Table 16 shows a summary of EC data by township in the FSID (T3N and T2N) and the area to the south (T1N through T6S). The townships selected for inclusion in the data set for the area between Sumner Dam and Brantley Reservoir, unlike that for the CID, are only those that encompass the river. The first 2 townships in Table 16 comprise the FSID and have the greatest number of measurements. The third township is immediately adjacent and probably receives some subsurface flow from the district. South of township 1N, the number of alluvial ground water EC measurements drops off dramatically from 22 to just 1 in township 1S. Each of the townships south of 1N and north of the PVACD has less than 10 EC measurements from the alluvial ground water (Table 16).

Table 16. Summary of alluvial ground water EC data by Township for wells in the FSID and to the south

Township	Samples	Minimum	Median	Maximum
03N	26	570	1661	2965
02N	37	910	2310	7430
01N	22	956	2160	8200
01S	1	—	2100	—
02S	3	3881	3945	4109
03S	7	3270	4170	5548
04S	2	1272	1991	2710
05S	5	3065	4429	6370
06S	0	—	—	—

The EC of the Pecos River shows an increase between Sumner Dam and Brantley Reservoir. Based on the median EC data in Table 16, the alluvial ground water appears to also show an increase in the same area. However, the small number of data points in the data set for the townships south of the FSID make any conclusions in that regard somewhat tentative, but such a conclusion is consistent with the fact that the increase is much more evident at the lower releases from Sumner Dam. The river in such a case consists mostly of base flow, *i.e.*, gains from ground water inflows.

Pecos Valley Artesian Conservancy District

The PVACD is a potential source of the water to offset the reduction in the CID supply due to the Carlsbad Project operational changes for the bluntnose shiner. In addition, land owners within the PVACD have offered to sell about 18,900 acres of land and associated water rights to the State of New Mexico for use in compliance with the settlement agreement with the State of Texas over the Pecos River Compact (OSE-ISC, 2003). Any such acquisition would be addressed in a separate EIS (*ibid.*), but would add water to the river. Water acquired from the PVACD for either of the above purposes would be expected to originate from the artesian aquifer. No matter what the purpose, the water quality of the river could be affected.

EC data for the various aquifers in the PVACD are summarized in Table 17A. Sampled wells in the PVACD represent a larger number and a somewhat different set of aquifers than the previous areas of the Pecos River upstream. The largest number of samples in the area north of the PVACD were from wells in the alluvium and the Artesia Group. Much of the increase in the number of aquifers is due to the samples from the Seven Rivers and Grayburg formations, both of which are members of the Artesia Group. The separation of the Artesia Group and 2 of its members adds names to the list.

Table 17. Comparison of EC in ground water in various aquifers in the PVACD

A. Summary statistics of EC (µS/cm) of ground water by aquifer

Formation	Samples	Minimum	Median	Maximum
Alluvium	872	890	5459	94400
Artesia Grp.	633	1750	5550	72400
Seven Rivers	11	4060	5849	6730
Grayburg	23	1291	1405	2383
San Andres	1923	561	3920	189900
Not noted	27	2832	6340	33000
Spring, seep	11	3310	4250	6820

B. Kruskal-Wallis test of EC of ground water in different aquifers

Aquifer 1	Aquifer 2	X^2	Prob. > X^2	Significant
Alluvium	San Andres	192.162	< 0.000001	Yes
Alluvium	Artesia Grp.	17.231	0.000033	Yes
Alluvium	Seven Rivers	0.238	0.625308	No
Alluvium	Grayburg	58.360	< 0.000001	Yes
Alluvium	Spring, seep	1.137	0.286197	No
Alluvium	Not noted	5.698	0.016984	Yes
Artesia Grp.	Seven Rivers	0.001	0.975223	No
Artesia Grp.	Grayburg	66.117	< 0.000001	Yes
Artesia Grp.	San Andres	221.970	< 0.000001	Yes

In the PVACD, the most commonly sampled aquifer was the San Andres Formation, which underlies the Artesia Group of aquifers (see Table 11). The alluvium and Artesia Group were the next most frequently sampled aquifers in that order in the PVACD (Table 17A).

Although the median EC of the Artesia Group and the alluvium in the PVACD are not greatly different (approximately 100 µS/cm - Table 17A), the 2 data sets show a statistically significant difference (Table 17B). In point of fact, the EC of the alluvium shows a significant difference from all of the other aquifers except the Seven Rivers Formation, which has the fewest EC measurements of any of the aquifers (Table 17).

There is also no significant difference between the EC of the alluvial wells and the surface seeps and springs (Table 17B). The springs and seeps, along with the Seven Rivers Formation, have the fewest observations of any of the water sources in Table 17. The surface seeps and springs do not represent a distinctive aquifer, but rather a surface discharge of ground water. The seeps and/or springs could be discharging alluvial ground water, as indicated by the lack of a significant difference in EC from the alluvial ground water, or water from any other formation that outcrops in the area, particularly from the San Andres which also has a similar EC (Table 17).

Valley-wide EC

It was shown above that the EC varies within the Pecos Valley. A breakdown of the EC in the areas encompassed by the various irrigation districts in the Pecos Valley is shown on Figure 22. The aquifers included on Figure 22 are the ones most often sampled in the OSE data base. The alluvial aquifer is present in all of the areas and sampled with the overall greatest frequency, although other aquifers may be sampled more frequently in individual areas (Figure 22B). The purpose of the inclusion of the category of "other" aquifers is to show the variation from north to south. The Artesia Group of aquifers is generally the second most commonly sampled, but there is only 1 measurement from that group in the FSID, while the Capitan Reef was the 2nd most commonly sampled aquifer in the CID (Figure 22B). The alluvial aquifer was the most commonly sampled in 3 of the 4 areas shown on Figure 20B, but the San Andres Formation was by far the most often sampled aquifer in the PVACD.

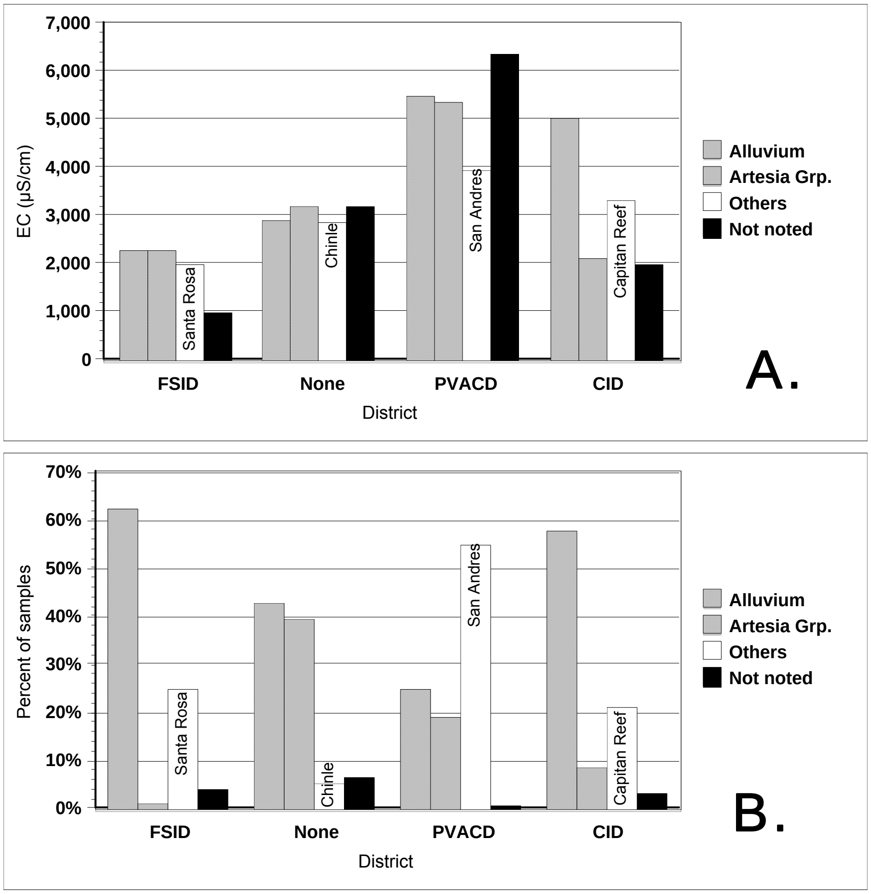


Figure 5: EC of ground water and breakdown of measurements by aquifer in the irrigation district areas on the Pecos Valley

In 3 of the 4 aquifers, the EC of the alluvium and that of the Artesia Group is not greatly different (Figure 22A). However, there is a large difference in the EC of the 2 aquifers in the CID, *i.e.* the EC of the Artesia Group is about 3,000 µS/cm lower. The main point of Figure 22 is to show that the quality of offset water for CID from ground water sources may be rather different from water currently in the District. In general ground water from the northern part of the valley nearer Sumner Dam has a lower EC than that nearer Brantley Reservoir, based on a breakdown by irrigation district and adjacent areas, but this is only generally true. There is actually much more variation in EC of the ground water than is shown by Figure 22.

There is also a large amount of variation in the median ground-water EC between townships in the river reach between Sumner Dam and Brantley Reservoir. Figure 23 shows a plot of the median ground-water EC in each of the townships along the river in that reach. Figure 23 also shows a plot of the estimated mileage of the center of each township from Sumner Dam. Sumner Dam is located on the approximate line between townships 5N and 4N. The estimated distance plotted on Figure 23 would be the equivalent of air miles, rather than river miles. In the equations for the trend lines

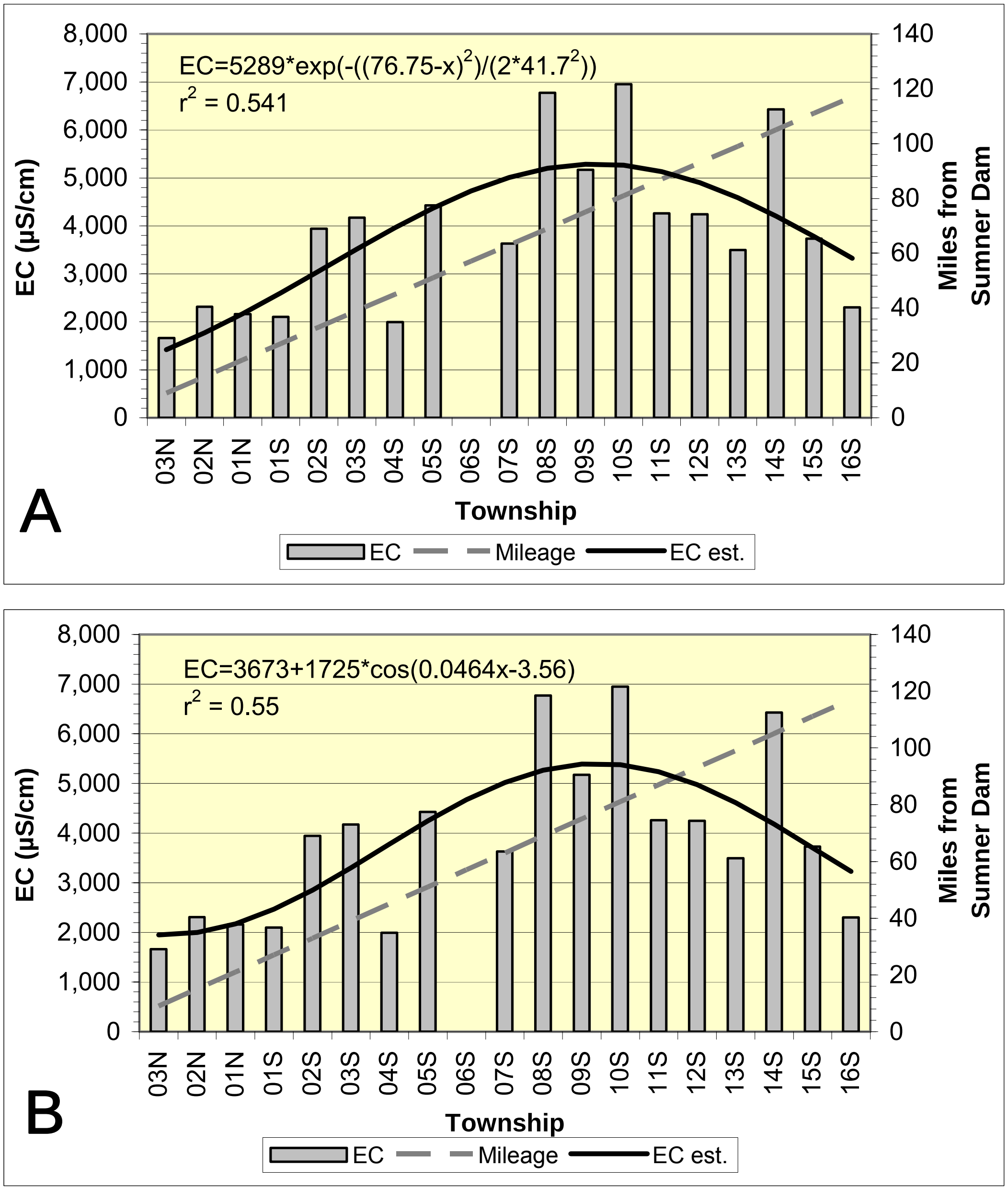


Figure 6: Median ground-water EC of the alluvial aquifer between Sumner Dam and Brantley Reservoir and two methods of showing trends

shown on Figure 23, the “x” is actually the mileage plotted against the 2nd *y*-axis, rather than the townships that are shown on the *x*-axis. The r^2-values for the trend lines are rather poor, but that is primarily a reflection of the variation in the median EC for the townships.

A possible reason for the high degree of variation is related to the large disparity in sampling effort in the townships. This is illustrated by Table 18, which shows the number of samples and the EC of wells in the 3 most heavily sampled aquifers in each of the townships between Sumner Dam and Brantley Reservoir.

Table 18. EC (µS/cm) and number of measurements in the ground water in the most heavily sampled aquifers in each township between Sumner Dam and Brantley Reservoir

Township	Estimated Mileage	Alluvium		Artesia Group		San Andres Fm.	
		Samples	EC	Samples	EC	Samples	EC
03N	9	26	1,661	0	—	0	—
02N	15	37	2,310	1	2,290	0	—
01N	21	22	2,160	0	—	0	—
01S	27	1	2,100	10	3,067	0	—
02S	33	3	3,945	2	1,310	0	—
03S	39	7	4,170	4	14,088	0	—
04S	45	2	1,991	6	2,480	0	—
05S	51	5	4,429	4	3,300	0	—
06S	57	0	—	11	3,202	0	—
07S	63	1	3,627	50	3,160	0	—
08S	69	66	6,773	98	5,057	632	5,475
09S	75	145	5,170	86	4,190	257	3,929
10S	81	219	6,950	320	10,500	79	9,840
11S	87	1	4,260	25	3,960	1	3,530
12S	93	30	4,246	18	3,070	147	3,767
13S	99	131	3,495	22	2,900	420	1,710
14S	105	150	6,425	0	—	63	1,457
15S	111	59	3,730	1	4,710	169	2,229
16S	117	66	2,300	6	2,915	154	1,659
17S	123	4	11,595	7	3,290	1	189,900

There are samples from the alluvium from each of the townships except 6S. However, the number of EC measurements between T1S and T7S is much smaller than form most of the townships to the north or the south, with the exception of T11S where there was only 1 measurement.

There are only 4 EC measurements in the alluvial aquifer of T17S. The combination of the large increase in EC in comparison with other wells in the alluvium and the small number of samples raises the question of the representativeness of the data. The township and range combination in which the wells are located is the same as the location of the USGS Artesia gage. As was noted above in the surface water section, the EC in the reach of the river upstream and at the Artesia gage shows a continual increase. Such an increase in the surface water is consistent with gains of saline inflows from ground water. On this basis, the high EC of the ground water in T17S is consistent with other data and should be considered to be a reflection of actual conditions.

There is only 1 EC measurement from the Artesia Group in T1N through T3N. The majority of EC measurements from wells in these townships were either from the alluvium or aquifers composed of the Triassic Santa Rosa and Chinle formations. The Artesia Group is of Permian age (Table 11). There are 10 or fewer EC measurements from the Artesia Group from T1S south through T5S, at which point the number of measurements increases considerably to a maximum of 320 in T10S. As was noted in Table 11, the geology of the valley changes from northeast to southwest. The increase in the number of wells in the Artesia Group from north to south is probably a reflection of that change in the aquifers as illustrated in Table 11.

The majority of EC measurements in the PVACD is from wells in the San Andres Formation. The artesian aquifer for which the PVACD was formed is located within the sequence of east-dipping carbonate rocks of the San Andres Formation (Barroll and Shomaker, 2003). Consequently, the PVACD should reflect the extent of San Andres outcrops near the Pecos River and the predominance of wells in the San Andres Formation in the PVACD should be expected. The EC in the San Andres shows a general decrease from north to south, although there is a dramatic increase shown in T17S (Table 18). However, the very high median EC, indicative of a brine, in the San Andres Formation reflects only 1 measurement; the well is an oil well and would not be representative of the general water quality of the aquifer. Most of the wells sampled in T17S were in the overlying Grayburg Formation of the Artesia Group, which has a much lower EC than that of the San Andres Formation (Table 17).

Water Quality Impacts

As discussed previously, the following indicators were selected to evaluate agricultural soil and land resources:

- Electrical conductivity (EC)
- Total dissolved solids (TDS, which in most cases needs to be computed from EC due to limited TDS data)

Summary of Impacts

Differences between the various action alternatives and the No Action Alternative are not at all straightforward. Depending on conditions, the action alternatives may show increases or decreases in the water quality indicator, specific electrical conductance. Consequently, this overview of the differences between the action alternatives and the No Action alternative will be based on a comparison of the overall average EC for the 60 years of hydrology from the RiverWare model.

Table 19 shows the average EC at the USGS gauge near Artesia and downstream from Brantley Dam for the pre-1991 baseline, No Action Alternative, No Action Alternative with a 6-week restriction on block releases, and the five action alternatives, the last of which includes three target levels of summer flows at the Taiban gauge. Table 19 also shows the rank of the mean EC from each of these alternatives. The last column of table 19 shows the difference between the mean EC for the No Action Alternative or the difference in EC between the two No Action Alternative formulations, or the difference in the mean EC between the No Action Alternative and each action alternative.

The greatest difference in EC is between the pre-1991 baseline and the No Action Alternative, which represents the existing condition. If the analysis is representative of conditions in the field, the greatest effects on water quality have already occurred. However, it should also be noted that the analysis summarized in table 19 does not include any attempt to offset depletions to the CID water supply.

Table 19 indicates that the overall average EC would be lower under the No Action Alternative with the 6-week restriction and the Acme Constant and Acme Variable Alternatives than the under No Action Alternative. Consequently, the average EC of the No Action Alternative ranks fifth overall among the alternatives. The overall average EC would be higher under the Critical Habitat Alternative and the four different formulations of the alternatives with target flows at the Taiban gauge than under the No Action Alternative. The addition of water offset options equally to the various alternatives would change the average EC, but may or may not change the rankings of the various alternatives. Changes in the rankings of the average EC due to the application of the water offset options would be primarily due to the need of more or less offset water by the various alternatives. The need for more or less offset water

Table 19. Water quality comparison of alternatives

Artesia EC (µS/cm)			
Alternative	Mean	Rank	Change
Pre-1991 baseline	5,217	1	—
No Action	5,710	5	493[1]
No Action w/6week	5,670	3	-40
Taiban Constant	5,760	7	50[2]
Taiban Variable (40 cfs)	5,756	6	46
Taiban Variable (45 cfs)	5,763	9	52
Taiban Variable (55 cfs)	5,765	10	55
Acme Constant	5,618	2	-92
Acme Variable	5,672	4	-38
Critical Habitat	5,762	8	52
EC downstream from Brantley Dam			
Alternative	Mean	Rank	Change
Pre-1991 baseline	4,432	1	—
No Action	4,619	5	187
No Action w/6week	4,605	3	-14
Taiban Constant	4,639	7	20
Taiban Variable (40 cfs)	4,635	6	16
Taiban Variable (45 cfs)	4,640	9	21
Taiban Variable (55 cfs)	4,640	10	21
Acme Constant	4,580	2	-39
Acme Variable	4,605	4	-15
Critical Habitat	4,640	8	21

[1] difference from the baseline

[2] difference from the No Action alternative

would make it impossible to apple offsets equally to all of the alternatives and the No Action Alternative.

Scope and Methods

The focus of the water quality impact analysis is on the Pecos River near Brantley Reservoir. The specific electrical conductance of water is related to total dissolved solids. Specifically, we compare the alternatives based on EC at two gages near Brantley: Artesia and Pecos River below Brantley. The EC at the Artesia gauge reflects the EC of the inflow to Brantley Reservoir. The inflow (Artesia) EC also was used to estimate the EC of the outflow from Brantley Reservoir, which is considered to represent the EC of the CID water supply. The estimated EC of the Brantley Reservoir releases was evaluated against the spring EC goal of CID for each of the alternatives.

Dry, Wet, and Average Conditions for Surface Water

Because surface water quality is intimately related to the amount of water in the system, the water quality impact analysis relies on the results of the RiverWare model. The reservoir contents from the RiverWare model were used to calculate the Effective Brantley Storage (EBS). The EBS was calculated for each by extracting the storage data for April 1 of each year and calculating the EBS using the following formula:

Avalon Storage + Brantley Storage + 0.75 x Sumner Storage + 0.65 x Santa Rosa Storage.

The EBS values were then used to determine whether April 1 of each year should be classified as being wet, normal, or dry. The breakdown of years in each of the groups is shown in table 20.

Table 20. Breakdown of dry, normal, and wet years by alternative based on EBS

Alternative	Dry Years	Normal Years	Wet Years
Pre-1991 baseline	19	21	20
No Action	22	24	14
No Action w/6week	23	23	14
Taiban Constant	24	19	17
Taiban Variable (40 cfs)	25	18	17
Taiban Variable (45 cfs)	25	17	18
Taiban Variable (55 cfs)	23	19	18
Acme Constant	25	24	11
Acme Variable	23	25	12
Critical Habitat	24	19	17

As shown in table 20, the number of years in each classification varies with alternative, and for most of the alternatives, there are more dry years than either normal or wet years. In other words, the number of dry years is greater among the action alternatives than under the No Action Alternative.

The low, median, and high flow years for each of the groupings in table 20 are shown in table 21. As might be expected from the variation in the number of years in each of the groupings, the median year also varies among the various alternatives with one notable exception. The driest year for all of the alternatives is the same, 1965 (Table 21). The driest year is likely to be the most critical and its use will put the alternatives on the

Table 21. Year between 1940 and 1999 that is representative of various water supply year types based on EBS

Alternative	Extreme Driest year	Representative year by alternative		
		Dry Year	Normal Year	Wet Year
Pre-1991 baseline	1965	1952	1967	1943
No Action	1965	1952	1962	1943
No Action w/6week	1965	1978	1941	1956
Taiban Constant	1965	1981	1967	1985
Taiban Variable (40 cfs)	1965	1954	1967	1985
Taiban Variable (45 cfs)	1965	1954	1947	1959
Taiban Variable (55 cfs)	1965	1975	1997	1985
Acme Constant	1965	1990	1960	1951
Acme Variable	1965	1949	1960	1943
Critical Habitat	1965	1975	1967	1950

same basis for comparison. In other words, 1965 should represent something of a “worst case” scenario.

Each action alternative was compared to the No Action Alternative by plotting the daily estimated EC for each selected year for the gauge at Artesia, which represents the inflow to Brantley Reservoir, and the estimated EC of the Brantley Reservoir releases, which represents the EC of the water supply to CID. The plots, which appear in Attachment 4, show EC at the two sites for a wet year, a normal year, a dry year, and 1965, the driest year in the record. The impact assessment in this appendix shows tabular comparisons of the mean annual EC for each of the alternatives at Artesia and downstream from Brantley Dam for each of the above years.

Groundwater Quality Impact Assessment

The ground-water quality analysis focuses on changes in the quality of the recharge water in the CID. Most of the recharge to the CID ground water would not be affected by any of the alternatives. Any change in the quality (EC) of the recharge due to an alternative is compared to the quality of the No Action Alternative. The most affected sources of recharge would be the seepage from the Main Canal and the Southern Main Canal.

The effects of the water offset options vary greatly in their effects on water quality. The greatest differences depend more on the source of the offset water than the actual amount of water acquired. As was shown in chapter 3, there is a large difference in quality from north to south in both the river and the ground water between Fort Sumner Dam and Brantley Reservoir. The effects were evaluated based on various scenarios and mixes of source water for the offset supply. These sources were superimposed on the quality of water at the Artesia gauge that was estimated as described above.

No Action Alternative

The projected mean annual EC at Artesia for the No Action Alternative, which is equivalent to the present or current condition in terms of Carlsbad Project operations, is compared to an historic or pre-1991 operation in table 22. The table shows the projected average (geometric mean) EC for each site in each of the four years. The table also shows annual the difference between the two data sets with the different operations.

Table 22. Comparison of present condition with pre-1991 baseline

Site	Condition	Year	Year type	EC (µS/cm)	
				Average[1]	Difference
Artesia	Pre-1991 baseline	1943	Wet	4,707	—
		1967	Normal	5,861	—
		1952	Dry	5,592	—
		1965	Driest	6,213	—
	No Action (present)	1943	Wet	5,018	285
		1962	Normal	6,280	390
		1952	Dry	6,166	584
		1965	Driest	7,081	937
Brantley Dam	Pre-1991 baseline				
		1943	Wet	4,253	—
		1967	Normal	4,643	—
		1952	Dry	4,527	—
		1965	Driest	4,735	—
	No Action (present)	1943	Wet	4,361	106
		1962	Normal	4,772	125
		1952	Dry	4,750	204
		1965	Driest	5,043	323

[1] All of the averages presented here and in later tables are based on log-transformed data.

As should be expected, the highest average EC for each of the sites occurs in the driest year. However, the second highest EC does not occur in the dry year, but rather in the normal year (table 22). The dry year EC ranks third. More importantly, all of the comparisons show an increase in EC over the pre-1991 baseline operation; i.e. all of the differences are positive and illustrative of increases. This result indicates that the experimental operations over the last decade would increase the EC of Carlsbad Project water somewhat, although that increase is not as great as the one shown at the Artesia gauge.

To put the changes in EC into perspective, figure 24 shows the effect of increase in EC on the yield of alfalfa. The data to construct figure 24 were taken from Ayers and Westcot (1985). As shown on figure 22, there is a linear decrease in the percent yield of alfalfa in the EC range between 1,300 and 10,000 µS/cm. The decrease amounts to about a 10-percent decrease with each increase in EC of 900 µS/cm. On this basis, the effects of the greater EC at Brantley Dam would be less than 5 percent. However, the range in annual average EC for the pre-1991 baseline is between about 4,250 and 4,700µS/cm. With this range of EC, some yield reduction should already be occurring. On the basis of information presented in figure 24, the reduction would be on the order of 30 to 40 percent. However, it should be noted that the values plotted on figure 24 are considered a guide relative tolerances; absolute tolerances vary depending on climate, soil conditions, and climate (Ayers and Westcot, 1985). In the Pecos River area at the higher EC values, the presence of gypsum often reduces the actual yield reduction.

The EC data in table 22 are annual averages. Within the year, a range in EC would occur. The projected range in EC for the pre-1991 baseline and the No Action Alternative in a normal year are shown on figure 25. The remaining year-types are shown in the attachment, but the normal year is presented here as an example. As can be seen, while there is a net annual increase in EC under the current condition, the increase only occurs for part of the year.

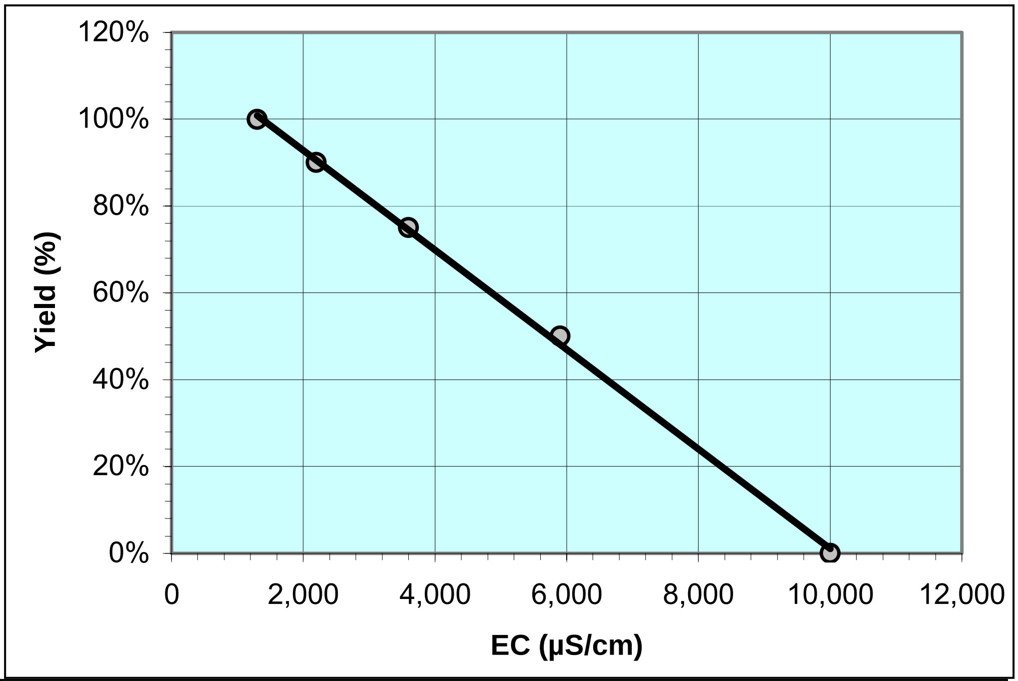


Figure 24: Effect of increased EC on alfalfa yields.

- In the winter, there is little difference in EC, although the EC of the pre-1991 baseline is slightly higher.
- During April, the pre-1991 baseline EC is considerably higher
- Through most of May and June, the No Action Alternative EC is quite a bit higher than that of the pre-1991 baseline.
- During most of the summer, the pre-1991 baseline EC is generally higher.

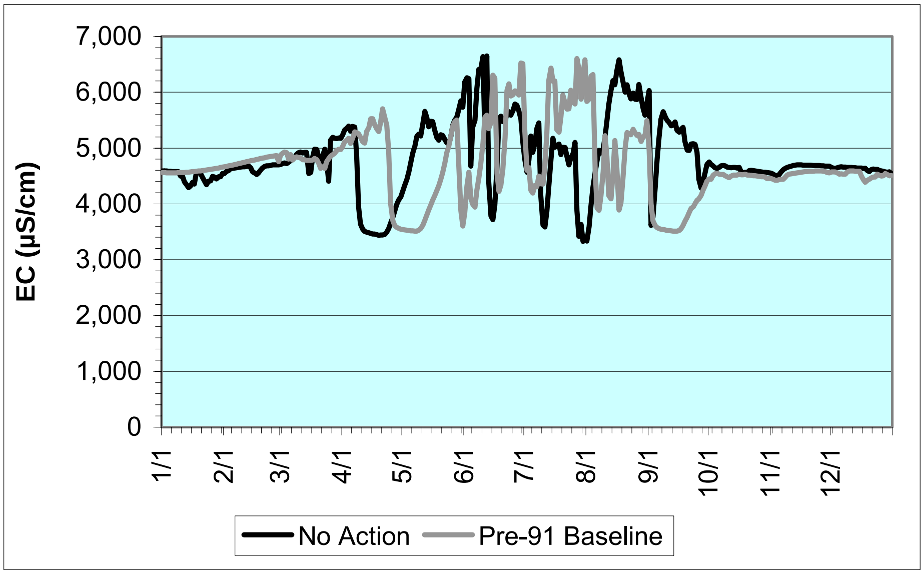


Figure 25: Daily EC at the Artesia gage in a normal year for the pre-1991 baseline and the No Action (present condition) Alternative

On figure 25, the range in EC for both conditions is from about 3,500 to about 6,500 µS/cm. From this perspective, there is probably little difference in the effects of changing from one operation to the other. Depending on the duration of the high EC, the yield reduction would be more a factor of the greatest EC, rather than the average.

Another important point is that the sensitivity of alfalfa to salt varies during the growing season. Alfalfa has been shown to be very sensitive to salinity during emergence Bauder et al. (1992). For example, the results of an experiment by Bauder et al. (1992) indicate that the loss of seedlings increased at TDS concentrations somewhere between 1,150 and 1,650 milligrams per liter (approximate EC of 1,770 and 2,540 µS/cm, respectively). The 100-percent yield level of alfalfa shown on figure 24 is at an EC of 1,300 µS/cm, with a 10-percent reduction in yield at 2,200 µS/cm. However, there is a large difference between seeding survival and a reduction in productivity in that the latter only involves growth, not survival.

The modification of the No Action Alternative that incorporates a 6-week restriction on block releases results in change in EC from that projected for the No Action alternative without the restriction, which is used as the No Action Alternative for purposes of the alternatives comparison. Table 23 presents a comparison of the projected EC for each of the two formulations of the No Action. The differences in EC in the various year-types among the alternatives are somewhat odd and unexpected. EC increases in three of the four year-types, but the increases are the reverse of what would be expected. The smallest increase at both the Artesia gauge and Brantley Dam is projected to occur during the driest year in the record, while the largest increase is projected to occur in the wet year. To further complicate matters, there is a large projected decrease in the normal year. The differences in EC are a reflection of the different operations necessitated by the block release restriction. The increases in EC that are shown in table 23 are a net annual change and are presented for alternatives comparison. For the timing of the differences, see Attachment D. Many of the resulting differences shown in table 23 can be attributed to differences in spills that are brought about when the operating criteria for the reservoirs in the system are dictated by factors that do not relate strictly to an optimal reservoir operation.

Table 23. Comparison of the No Action Alternative (present) with the No Action with the 6-week block release restriction alternative

Site	Condition	Year	Year type	EC (µS/cm)	
				Average	Difference
Artesia	No Action (present)	1943	Wet	5,018	—
		1962	Normal	6,280	—
		1952	Dry	6,166	—
		1965	Driest	7,081	—
	No Action w/6 week	1956	Wet	6,098	1,161
		1941	Normal	2,930	-3,095
		1978	Dry	6,858	850
		1965	Driest	7,119	32
Brantley Dam	No Action (present)	1943	Wet	4,361	—
		1962	Normal	4,772	—
		1952	Dry	4,750	—
		1965	Driest	5,043	—
	No Action w/6 week	1956	Wet	4,730	376
		1941	Normal	3,792	-957
		1978	Dry	4,978	270
		1965	Driest	5,052	9

Another factor affecting differences is that the same years are not necessarily compared. Only the driest year, 1965, is the same for all alternatives. The representative or median dry, normal and wet years often are different for the different alternatives. In the pre-1991 baseline comparison with the No Action Alternative, only the normal years differ (table 22). In the case of the two formulations of the No Action Alternative, the dry, normal, and wet year types are each represented by different years (table 23).

Another point to consider is that the relationship that generates the Brantley Dam EC is predicated on a certain degree of mixing or lack of mixing due to saline inflows that are denser than water in the reservoir. The relationship predicts a large decrease in EC when the EC is large because of mixing, but the resulting EC of the outflow is still relatively high. Alternatively, at lower EC, the relationship predicts an increase in EC because of mixing with the reservoir, but the outflow is still low because the EC of the reservoir should be low. The relationship is based on the way the reservoir reacted during the last decade. The future with the different operations may be different from the projections using the historic relationships. For example, the increase in releases from Fort Sumner Reservoir will dilute the inflows to Brantley Reservoir during what would otherwise be base inflow periods. This will dilute the Brantley Reservoir inflows. This may affect the degree of mixing that occurs during those lower flow periods. Consequently, the projected EC of the outflows from Brantley Dam may be based on a relationship that will change in the future. This is further explored in Attachment 5.

Another point to consider is that the simulated operation of Brantley Reservoir does not completely mimic the historic operation by CID. The higher EC underflow described above causes a buildup of high EC water in the bottom of the reservoir in front of the outlet. This buildup is most severe in winters where there is little inflow from local rainfall or snowmelt. The accumulation results because the normal saline winter inflows are around 60 ft^3/s, while the releases amount to about 20 ft^3/s. The excess is stored. Large inflows of lower EC water from rainfall or snowmelt can mix the saline bottom layer and dilute it. The saline water would be harmful if used to irrigate sensitive emergent alfalfa (or other crops as well). When there has not been enough winter inflow to mix the saline bottom water, CID has delivered a block release from Sumner Reservoir to effect the mixing prior to the initial delivery of irrigation water in the spring. These spring block releases for water quality improvement are not simulated in RiverWare. Consequently, the dilution that would be expected prior to the initial delivery of irrigation water (usually around April 1) is shown occurring in May in the pre-1991 baseline and in mid-April for the No Action alternative on figure 25. Because RiverWare does not simulate water quality, some other trigger would be needed for the early spring block release for water quality control. For purposes of the impact assessment, it was assumed that some means of water quality improvement will be made in the spring irrigation water deliveries even though the hydrologic model results do not necessarily show that happening.

Taiban Constant Alternative

The Taiban Constant alternative has a year-round target flow of 35 ft^3/s. Table 24 shows the projected average annual EC of the Taiban Constant alternative at the Artesia gauge and downstream from Brantley Dam for each of the 3 years types and the driest year in the record. The last column of the table shows the difference in EC from that of the No Action alternative. The EC of the No Action alternative for each of the year types were previously presented in tables 22 and 23 and are not repeated for the remaining alternatives.

The Taiban Constant Alternative is projected to show higher EC at the Artesia gauge in three of the four year types than under the No Action Alternative (table 24). In this case, the results are somewhat more in line with expectation, although the average increase in EC in the normal year is larger than that in either the dry year or the driest year in the record. The two dry-year average increases are essentially the same, at around 250 µS/cm, while the average increase in the normal year is much greater at over 600 µS/cm, or more than twice as large as the dry year increase. The wet year shows the only decrease relative to the No Action Alternative.

Table 24. Comparison of the No Action Alternative (present) and the Taiban Constant Alternative

Site	Year	Year type	EC (µS/cm)	
			Average	Difference
Artesia	1985	Wet	4,545	-352
	1967	Normal	6,771	660
	1981	Dry	6,349	245
	1965	Driest	7,250	261
Brantley Dam	1985	Wet	4,225	-123
	1967	Normal	4,976	227
	1981	Dry	4,820	95
	1965	Driest	5,107	77

Because the projected EC downstream from Brantley Dam is related to the inflow EC, the pattern of EC changes will be the same as the one shown for the Artesia gauge. Because of the buffering in the reservoir, the average EC will be lower than that at the gauge. It follows from the lower EC that the differences between an alternative and the No Action Alternative will generally be smaller as well. These latter two generalizations are shown in table 24, but the first is not exactly followed. At the Artesia gauge, the increase in the projected EC during the dry year is not as great as that in the driest year, but it is somewhat larger than that of the driest year downstream from Brantley Dam (table 24). However, the difference in the two increases is small and likely does not represent any real difference between the two.

Taiban Variable Alternative

The Taiban Variable alternative has the same winter target as the Taiban Constant alternative, but the Taiban Variable has three different formulations, each with a different summer target. Table 25 presents a comparison of the Taiban Variable Alternative at each of the three summer target levels.

Table 25. Comparison of the No Action Alternative (present) and the Taiban Variable Alternative at three summer target flow levels

Site	Year type	EC (µS/cm) – 55 cfs			EC (µS/cm) – 45 cfs			EC (µS/cm) – 40 cfs		
Artesia		Year	Average	Difference	Year	Average	Difference	Year	Average	Difference
	Wet	1985	4,621	-285	1959	5,342	444	1985	4,571	-300
	Normal	1997	5,126	-1,194	1947	5,861	-385	1967	6,770	659
	Dry	1975	7,004	923	1954	6,363	563	1954	6,376	571
	Driest	1965	7,197	190	1965	7,208	134	1965	7,178	114
Brantley Dam	Wet	1985	4,249	-100	1959	4,480	133	1985	4,235	-111
	Normal	1997	4,406	-371	1947	4,640	-132	1967	4,976	227
	Dry	1975	4,995	273	1954	4,862	173	1954	4,866	176
	Driest	1965	5,087	53	1965	5,083	40	1965	5,076	34

Table 25 illustrates the way in which the representative years can change just with the way in which an alternative is formulated. In table 4.36, the wet year is represented by 1985 for two of the alternative target levels, while the third alternative target level is represented by 1959. The dry year is similarly represented by 1954 for two of the alternative target levels, while the dry year is represented by 1975 for the third. The normal year is represented by a different year for each of the three alternative target levels. The years were previously shown in table 20, but the reason behind the difference is shown in table 25. Recall that the representative year is the one with the median EBS in each category. Because the number of years in each category changes among the alternatives (and target levels for alternatives with multiple formulations), as shown in table 20**,** the medians in the categories also change, which may further cause a change in average EC between the representative years even though the rankings of the years may not change. In other words, a possible factor in the differences is the number of years in the data base used to calculate the individual average EC.

The comparison of the EC of the various formulations of the Taiban Variable Alternative in table 25 also shows differences among the three that are more likely an actual factor in the operations than any artifact of the analysis, as described in the preceding paragraph. In the normal year, the average EC increases as the target flow decreases. This is the expected result, because the EC is inversely related to the flow at the Artesia gage. As the target flow and, thus, the flow itself increases, there is increasingly greater dilution of saline inflows in the lower reach of the river between Sumner Dam and Brantley Reservoir. However, the interrelationship among the EC of the three alternative target levels changes from the normal year when the dry and wet year are considered. In the dry year, the highest average EC is shown in the wet year. This is likely due to the fact that the target is so high that the available water is exhausted and no flow can be provided at which time there would be no dilution of the saline inflows for part of the year. The supply would be more adequate to meet the lower target flows than would be the case with the highest target flow. In the wet year, the highest average EC at about 5,300 µS/cm is shown for the intermediate target flow, while the EC of highest and lowest target flows are if around 4,600 µS/cm. The difference may be because of the difference in representative years, a difference in spills, or a combination of the 2 factors. The driest year in table 25 eliminates the effect of changing years, but also shows the EC of the intermediate flow target to be slightly greater than that of either the highest or lowest flow targets. However, the average EC for all three flow targets is within differences due to rounding, i.e. 7,200 µS/cm, and should be considered essentially equal.

Within each of the target flow levels, the projected average EC is lowest in the wet year (table 25). The EC in the normal, dry, and driest year is progressively higher within each set of target flow results.

The greatest difference in EC at the Artesia gauge between any of the three target flow levels of the Taiban Variable Alternative and that of the No Action Alternative is a decrease during the normal year at the highest flow target level (table 25). During the same year-type (normal) at Artesia, there is a somewhat smaller decrease in EC at the intermediate target flow level, but an increase in EC at the lowest target level. In all of the other year-types, there is projected to be an increase in EC at all of the target flow levels with the exception of a projected decrease in the wet year at the highest target flow (table 25). Interestingly, the largest average annual increase also involves the highest target flow; that increase occurs during the dry year. For all of the target flow levels, the increase in EC over that of the No Action alternative is larger in the dry year than the one for the driest year. This result may reflect a condition in the driest year when little can be done differently no matter what the intended operation may be – there is just no water available to provide any flexibility.

The results of the EC comparison downstream from Brantley Dam show the same pattern in the changes relative to the No Action Alternative as were shown at the Artesia gauge. This reflects the fact that the basis for the estimated EC at the site downstream from Brantley Dam is the EC at the Artesia gauge. The only thing to note is that the average EC downstream from Brantley Dam is lower than the one at the Artesia gauge. The overall differences in the EC at the two sites are larger during the dryer years than in the wetter years. In the wet year, the difference in the average EC between the Artesia gauge and Brantley Dam is about 600 µS/cm, but the same difference is over 2,000 µS/cm under dryer conditions.

Acme Constant Alternative

Table 26 presents the projected average EC for the Acme Constant Alternative at the two sites for each of the year-types. In the case of the Acme Constant Alternative, the lowest average EC (5,200 µS/cm at the Artesia gauge) occurs in the normal year. The EC in the wet and dry years is approximately the same (5,700 µS/cm) and about

500µS/cm higher than in the normal year. In the driest year, the projected average EC would be about 1,000 µS/cm higher yet. The EC downstream from Brantley Dam is much lower, and the differences among the EC of the different year-types are damped (table 26).

Table 26. Comparison of the No Action Alternative (present) and the Acme Constant Alternative

Site	Year	Year type	EC (µS/cm)	
			Average	Difference
Artesia	1951	Wet	5,657	713
	1960	Normal	5,199	-933
	1990	Dry	5,703	-526
	1965	Driest	6,659	-397
Brantley Dam	1951	Wet	4,577	222
	1960	Normal	4,464	-294
	1990	Dry	4,555	-183
	1965	Driest	4,901	-143

In three of the four year types, the EC of the Acme Constant Alternative is less than the respective EC of the No Action alternative. The lone increase in EC in comparison to the No Action Alternative is projected to occur in the wet year. Decreases in EC relative to the No Action Alternative are projected in the normal, dry, and driest years, with the largest decrease in the normal year and the smallest in the driest year (table 26).

Acme Variable Alternative

Table 27 presents the average EC of the Acme Variable Alternative for each of the four year types. The highest average EC of the four year types is shown in the driest year, which is no surprise. However, the lowest average annual EC of the four years is shown for the dry year. The average EC in the dry year is nearly 1,000 µS/cm lower than that of the normal year. The average EC of the wet and normal years are intermediate between those of the preceding year types, but despite the 1,000 µS/cm noted above, each is nearer the low average EC of the dry year rather than the high EC of the driest year.

All of the annual average ECs under the Acme Variable Alternative are negative (table 27), indicating a decrease in EC relative to the No Action Alternative. The greatest difference is shown for the dry year, and the smallest difference is for the driest year. To reinforce how inordinately low the dry year EC is, the difference from the No Action Alternative dry EC is by far the largest of the three year types at 1,606 µS/cm, which is more than twice as large a decrease as the next largest, which is shown in the normal

Table 27. Comparison of the No Action Alternative (present) and the Acme Variable Alternative

Site	Year	Year type	EC (µS/cm)	
			Average	Difference
Artesia	1943	Wet	4,900	-92
	1960	Normal	5,445	-782
	1949	Dry	4,591	-1,606
	1965	Driest	7,021	-83
Brantley Dam	1943	Wet	4,320	-39
	1960	Normal	4,531	-237
	1949	Dry	4,250	-486
	1965	Driest	5,020	-27

year. The differences from the EC of the No Action Alternative in the wet year and the driest year are comparatively small, both are less than 100 µS/cm.

The average annual ECs downstream from Brantley Dam are all in the range of EC that would show a reduction relative to that at the Artesia gage. The rankings of the annual average EC and the differences for the year-types are the same as those at the Artesia gage.

Critical Habitat Alternative

Table 28 presents the annual average EC of the four year types as projected for the Critical Habitat Alternative. The average annual EC rank inversely to the way the year types rank in terms of water supply, i.e. the lowest EC is in the wet year, while the average annual EC increases as water supply decreases. The lowest average annual EC is much lower than any of the other three in table 28.

The differences in EC from those of the No Action Alternative do not quite follow the pattern of the average EC. The smallest EC difference from that of the No Action Alternative occurs in the driest year. The sequence of increasing differences with decreasing water supply follows for the other three years, i.e. wet through dry (table 28). The differences from the No Action alternative show the same pattern as those at the Artesia gage.

Table 28. Comparison of the No Action Alternative (present) and the Critical Habitat Alternative

Site	Year	Year type	EC (µS/cm)	
			Average	Difference
Artesia	1950	Wet	5,096	241
	1967	Normal	6,723	617
	1975	Dry	7,060	985
	1965	Driest	7,209	134
Brantley Dam	1950	Wet	4,408	64
	1967	Normal	4,958	210
	1975	Dry	5,015	294
	1965	Driest	5,083	40

Actions Common to All Alternatives

Two sets of actions are common to all alternatives: (1) water offset options to address depletions and (2) additional water acquisition options to augment river flows. The impacts for the offset options are summarized in table 29. The augmentation options are essentially a subset of the offset options that are restricted to a location upstream from the critical habitat.

The analysis of the various offset options includes those that would be most effective and easy to implement in a timely manner. The first set of offset options relates to water acquisition, either by purchase or lease. From a practical perspective, the only difference between purchase and lease is that one is permanent and one is temporary. In terms of the effect on water quality, there is no other difference between the two activities.

The relationship between EC and flow is inverse. In other words, greater flow in the river provides greater dilution of diffuse saline inflows resulting in lower EC. The water acquisition offset options would leave water in the river rather than it being diverted for irrigation. The EC values presented in the preceding tables in can be adjusted to illustrate the EC if a set of offset such options are superimposed on the depleted flows evaluated previously. In the years that represent the year-types shown in those impact tables, the total offset can be supplied by the set of water acquisition options if the total amount of water that can be purchased or leased were available. On the possibly unwarranted assumption that this is true, resulting adjusted EC computed based on the correlation between flow rate and EC at the Artesia gage is presented in table 30. The problem is that in dry years, water may be short everywhere and acquired water rights

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
A	Onfarm conservation	Depends on the source of the water: FSID or CID – negligible, PVACD – moderate benefit	Sumner Dam to Roswell, negligible; with PVACD, moderate between Roswell and Brantley Res.	For the duration of the practices	Water from FSID would be essentially the same quality as water from Sumner Dam. In general, savings on CID would be used on CID and not enter the river. Water from PVACD, assumed from the artesian aquifer, would be slightly lower in EC (~4000 µS/cm) than the river near Artesia (~7000 µS/cm) and would have a moderate benefit to the river.
B	Drain construction/ renovation	Negligible	Sumner Dam to Brantley Res.	Indefinitely (as long as the drains remain)	Most of the time, the Pecos River consists of ground-water accretions. The EC of the river and its alluvial ground water in any given reach are essentially the same. Adding more to a reach would change nothing.
C	Hernandez Idea/Plan	Negligible	The water quality throughout the reach does not change greatly.	N/A	As long as the pump site remains north of Highway 380, there would be no effect on water quality if water from the lower end of the reach is returned.
D	Water right purchases	The effects are essentially the same as option A.	Depends on the location of the purchases	Long-term	See option A.
E	Water right leases	The effects are essentially the same as option A.	Depends on the location of the leases	Duration of the lease	See option A.
F	Riparian vegetation control	Minor to moderate improvement in ground- water quality	Localized	Short-term	Because of the salt concentrating nature of salt cedar, its removal could improve water quality. Removal of other high water-use vegetation could yield a minor decrease in the concentrating effects of evapotranspiration.
G	Acequia improvements	Negligible	From Puerto de Luna to Sumner Reservoir	Long-term	This is another form of water conservation. The water quality between Puerto de Luna and Sumner Lake does not change. Adding similar quality water would have no effect.
H	Pump supplemental wells	Negligible	Localized	Short-term	This would be an expansion of an existing use within the CID. Any effects would be those of the depletions themselves.
I	Import Canadian River water	Major	General	For the duration of the diversion	The EC of the water in the vicinity of Puerto de Luna is about 2,500 µS/cm. The median EC of the Canadian

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
					River downstream from Conchas Dam has been 7700 µS/cm during the last decade (1992-2003).
J	Reservoir entitlement storage	Negligible	General	Short-term	There could be a slight reduction in EC due to the reduction in the concentrating effect of evaporation.
K	Desalination	Negligible to minor	Localized	For the duration of any discharge	If the treated water is discharged to surface waters for delivery, the EC of the receiving stream could be raised or lowered depending on the volume and EC of the discharge relative to the EC and flow. The goal is to meet the irrigation standard, but there is none for EC (or TDS) in New Mexico.
L	Change cropping patterns	Negligible	Localized	Short-term	The analysis focused on CID. There may be no change or there may be reduced deliveries to Brantley Reservoir. In either case, there should be no measurable change in EC in the Pecos River.
M	Lower ground-water levels	Moderate	Localized	Long-term	Some of the seepage from the McMillan delta is highly saline. Lowering the water table would reduce seepage. If this seepage were reduced, under the assumption that areas with shallow ground water have higher EC, EC could be lowered in the vicinity of the seeps.
N	Range and watershed management	Negligible	Localized	For the duration of the activity	Additional base inflow would contribute additional ground water to the river. As noted before, the EC of the various river reaches generally reflects the EC of the adjacent ground water. This should not change.
O	Cloud seeding	Minor	Localized	Short-term	Effects would be confined to storm events. The increase in frequency or duration of storms could cause brief dilution of EC. The main effects would be increased erosion and TSS.
P	Ground-water recharge/ conjunctive use	See Q	Localized	For the duration of the activity	The WOOG team couldn't envision the option costing any less pumping water back into the ground (as opposed to just retiring pumpers and leaving it in the ground); so it became

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
					equivalent to Option Q.
Q	Well field development	Minor to moderate	Localized	For the duration of the activity	Seven Rivers: moderate decrease in EC when pumped water discharged to river. Buffalo Valley: minor decrease to moderate increase depending on source of water
R	Rio Hondo flood control	Minor	Localized	Short-term	Not an offset option; being built by the Corps.
S	Additional metering	Moderate	Localized	Long-term	Another form of water conservation that would focus on the area around Roswell. Should improve water quality somewhat.
T	Evaporation suppression	Negligible to major	Localized	Short-term	Evaporation-suppression would reduce EC slightly in the reservoirs. Toxicity of suppressants is unknown; could possibly have severe effects on biota.
U	Fort Sumner area gravel pit pumping	Negligible	Localized	Short-term	Ground water, which feeds the gravel pit, in the vicinity of the FSID is similar in EC to the river; adding ground water to the river in the area of the pit would have no noticeable effect.
V	Kaiser Channel lining	Minor	Localized	Short-term	Most of the recharge occurs from block releases and is apparently of good quality. The elimination of the better quality recharge could allow for poorer quality of ground water in the delta, but would probably have little effect on the river.
W	Import Salt Basin or Capitan Reef water	Minor	Localized	Short-term	According to the New Mexico Oil & Gas Commission's 2004 report, the water in the Salt Basin in of high quality. Importation of Salt Basin water would improve water quality to an undefined degree.
X	Flash distillation (desalination) cogeneration power plant	Minor	Localized	Long-term	Similar to Option K from a water quality perspective. Total volume of water is relatively small and could not greatly affect the quality of the Pecos River.
Y	Treat oil field waste water	Minor	Localized	For the duration of the activity	The option envisions treating oil field production waste to either of 2 levels of TDS: 5,000 mg/L – would degrade the river slightly

Table 29. Water offset options impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized, or general)	Impact duration (short-term, long-term)	Impact summary
					500 mg/L – would improve the river slightly
Z	Renegotiate compact-forbearance	Negligible	General	Long-term	Similar in effect to option A, although the lands to be retired are downstream from the CID.

mg/L = milligrams per liter

may not yield the amount of offset water needed. The data presented in table 30 ignore that possibility and assume that the water needed up to the limit will be available.

Table 30. Difference in EC from that at the near Artesia gage from addition of offset water to the bypass flows shown in tables 23-28 for each of the individual alternatives

Alternative	Wet Year	Normal Year	Dry Year	Driest Year - 1965
No Action	-57	-420	-301	0
No Action w/6week	-44	-1	-365	0
Taiban Constant	-42	-840	-88	-29
Taiban Variable (40 cfs)	-42	-840	-1235	-441
Taiban Variable (45 cfs)	0	-81	-1113	-447
Taiban Variable (55 cfs)	-54	-31	-1257	-631
Acme Constant	-335	-136	-372	-230
Acme Variable	-40	-165	-452	-29
Critical Habitat	0	-23	-1290	0

The only time a value in table 30 is not negative is when no offset is needed. The condition is projected to occur in the wet year with the Critical Habitat and the Taiban Variable at the intermediate target flow alternatives. Interestingly, there is also no projected offset needed in the driest year for the No Action, its modification with the block release restriction, and, once again, the Critical Habitat alternative. In these cases, there would be no change relative to what was earlier shown for the individual alternatives in previous tables.

In general the largest projected decreases in EC in table 30 occur during the dry year. The No Action Alternative, for which the largest decrease is in the normal year, is the lone exception to this generalization. The decrease at the Artesia gauge shown in table

30 for the No Action Alternative is slightly larger than the increase that was shown in table 22, i.e. 390 μS/cm. The net effect would be essentially no change in EC in the representative normal year. Alternatively, in the wet and dry years, EC would be greater under the No Action Alternative than under the pre-1991 baseline; the offset option decreases would not be enough to completely offset the previously shown increases.

As another example, EC under the No Action Alternative with the block-release restriction is much lower than under No Action Alternative. Table 31 indicates that the offset options would cause a further decease of 1 μS/cm or essentially no additional change. It should be noted that the EC data on which the relationships are based were rounded to the nearest 10 μS/cm. Furthermore the regressions on which the EC projections are based have an even greater error. Consequently, changes of less than100μS/cm (or in some cases more than that) should be considered no change at all.

Table 31. Comparison of adjusted and unadjusted (previously shown in tables 23-28) for the EC (μS/cm) at the near Artesia gage

Alternative	Adjusted		Unadjusted	
	Normal year	Dry year	Normal year	Dry year
No Action	6,101	6,032	6,280	6,160
No Action with 6-week	2,930	6,702	2,930	6,858
Taiban Constant	6,479	6,345	6,771	6,349
Taiban Variable (40 cfs)	6,479	5,823	6,770	6,376
Taiban Variable (45 cfs)	5,823	5,865	5,861	6,363
Taiban Variable (55 cfs)	5,112	6,404	5,126	7,004
Acme Constant	5,135	5,499	5,199	5,703
Acme Variable	5,368	4,383	5,445	4,591
Critical Habitat	6,708	6,445	6,723	7,060

To put EC after application of the offset options into better perspective, the EC for the normal and dry years for each of the alternatives are shown in table 31 along with those after the offset options are included. The apparent inconsistencies related to the selection of years in comparison with the No Action Alternative that were discussed earlier are still shown in the adjusted EC data, but the decreases relative to the bypass flows alone are apparent. In all cases, the EC of the alternatives after adjusting for the additional flow due to the offset options is lower than that without the adjustment. This result indicates that the offsets, in addition to ameliorating the effects of depletions, ameliorate the effects on EC as well.

In addition to the offset options, there are additional water acquisition (AWA) options. The distinction between the two sets of options is that the purpose of the AWA options is to augment the flow to meet targets through the critical habitat. As a consequence, the AWA options must have a means of delivering water well upstream from the CID. In many cases, the AWA options are similar in their effects to the offset options shown above in table 29. For comparison, the effects of the AWA options are summarized in Table 32.

Table 32 Additional water acquisition option impacts on water quality

Option	Option category	Impact intensity (negligible, minor, moderate, or major)	Impact location (localized or general)	Impact duration (short-term, long-term)	Impact summary
A	Water right purchase	Depends on the source of the water: FSID or CID – negligible, PVACD – moderate benefit	Localized - Sumner Dam to Roswell, negligible; with PVACD, moderate between Roswell and Brantley Reservoir.	Long-term	See option D of preceding table.
B	Water right lease	Same as A	Same as A	Short-term – for the duration of the lease	See option E of preceding table
C	On-farm conservation	Same as A	Same as A	Short-term – for the duration of the practices	See option A of preceding table
D	Cropping pattern changes	Same as A	Same as A	Short-term – for the duration of the practices	See option L of preceding table – another form of conservation
E	Riparian vegetation control (upstream of Upper Critical Habitat)	Minor to moderate improvement in ground-water quality	Localized	Short-term – periodic with return of vegetation	See option F of preceding table
F	Import Canadian River water	Major	General	For the duration of the diversion	See option I of preceding table
G	Range and watershed management	Negligible	Localized	For the duration of the activity	See option N of preceding table
H	Evaporation suppression	Negligible to major	Localized	Short-term	See option T of preceding table
I	Fort Sumner area gravel pit pumping	Negligible	Localized	Short-term	See option U of preceding table
J	Fort Sumner well field	Negligible	Localized	Short-term	Ground water in the vicinity of Ft. Sumner is similar in quality to the river; adding the ground water to the river would have no effect on EC

Effects on Ground-Water EC

The differences in EC as forecast for the ground-water recharge are shown on figure 26. The figure shows the minimum, median, and maximum EC for each for the alternatives as a stacked bar graph. The median EC is the focus of the impacts analysis. For the most part, the median EC of the alternatives appear to rest on the 9,000 µS/cm gridline (figure 26). The EC pre-1991 baseline is well below that grid line at 8,700 µS/cm. The increase in EC of all of the alternatives relative to the baseline is consistent with the results of the river analysis presented previously.

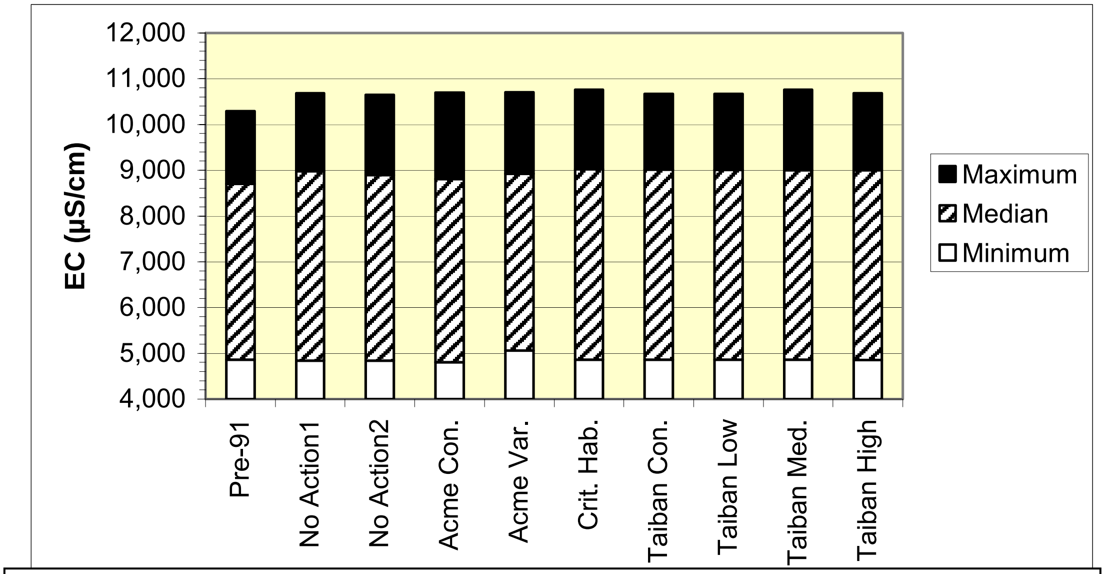


Figure 26: Minimum, median, and maximum EC (µS/cm) of the pre-1991 baseline, the No Action Alternative, and each of the action alternatives

Of the two formulations of the No Action Alternative, the No Action Alternative with the 6-week restriction on block releases (No Action 2 on figure 26) would each result in a slightly smaller increase in the recharge to ground water within the CID in comparison to the pre-1991 baseline than the No Action Alternative without the restriction. The only other alternatives that have a somewhat lower projected median EC than the No Action Alternative are the Acme Constant and the Acme Variable Alternative. The Acme Constant Alternative would have the lesser increase of the two Acme alternatives. The actual increases in the EC of the ground water relative to that of the recharge are assumed to be proportional to what has occurred historically.

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ATTACHMENT 1

SUMMARY WATER QUALITY DATA TABLES FOR STATIONS ON THE MAINSTEM OF THE PECOS RIVER

Table 1–1. USGS 08382650 Pecos River above Santa Rosa Lake, NM (1988-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	3	11.5	15	19.5	28.7	55	N/A	0
Spec. Cond. (µS/cm)	None	192	390	791	895	4,350	53	N/A	N/A
Diss. Oxygen (mg/L)	None	6.0	8.0	8.8	9.8	12.8	52	N/A	N/A
pH, Standard Units	6.6-9	7.4	7.9	8.1	8.2	8.6	55	N/A	0
Calcium (mg/L as Ca)	None	34	66	140	158.5	200	50	N/A	N/A
Magnesium (mg/L as Mg)	None	3.8	8.3	17.4	19.1	25.9	50	N/A	N/A
Sodium (mg/L as Na)	None	4.7	8.8	11.0	11.0	20.5	50	N/A	N/A
Potassium (mg/L as K)	None	0.8	1.2	1.3	1.5	3.6	50	N/A	N/A
Chloride (mg/L as Cl)	400	0.9	4.7	6	7	12	49	N/A	0
Sulfate (mg/L as SO_4)	2,000	31	100	290	340	470	49	N/A	0
Aluminum (µg/L as Al)	87	2	< 10	10	30	7,400	29	7	5
Arsenic (µg/L as As)	150	< 1.0	< 1.0	1.00	< 2.0	2.00	23	17	0
Beryllium (µg/L as Be)	5.3	0.03	< 0.50	< 0.50	< 0.50	< 1.00	21	20	0
Boron (µg/L as B)	750	11	20	33	40	60	21	0	0
Cadmium (µg/L as Cd)	H[2]	< 0.04	< 1.00	< 1.00	< 1.00	< 1.00	23	23	0
Chromium (µg/L as Cr)	H	< 0.8	< 0.8	< 1.0	< 1.0	2.0	23	19	0
Cobalt (µg/L as Co)	50	0.1	< 1.00	< 3.00	< 3.00	< 3.00	29	25	0
Copper (µg/L as Cu)	H	< 1.0	1.0	1.5	2.0	6.0	23	2	0
Lead (µg/L as Pb)	H	< 0.08	< 1.00	< 1.00	1.0	2.0	23	16	0
Nickel (µg/L as Ni)	H	< 0.06	< 1.00	< 1.00	1.03	5.00	29	14	0
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	1.0	< 2.4	31	23	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 1.0	< 1.0	8.0	29	28	0
Vanadium (µg/L as V)	100	< 6.0	< 6.0	< 6.0	< 6.0	8.0	20	19	0
Zinc (µg/L as Zn)	H	< 1	2	4	9	19	23	4	0
Fecal Coliform .7 µm -mf (Col./100 mL)	400	0	< 1	8	110	> 6000	29	23	6
TDS (mg/L)	3,000	140	304	580	637	782	28	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.

[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–2. USGS 08383000 Pecos River at Santa Rosa, NM (downstream from the lake: 1988-98)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	4	9.5	15	19	31	45	N/A	0
Spec. Cond. (FµS/cm)	None	340	1855	2470	2635	3710	43	N/A	N/A
Diss. Oxygen (mg/L)	None	5.7	7.9	8.7	9.8	12	42	N/A	N/A
pH, Standard Units	6.6-9	7	7.7	7.8	8.1	8.4	44	N/A	0
Calcium (mg/L as Ca)	None	52	440	535	550	610	28	N/A	N/A
Magnesium (mg/L as Mg)	None	6.2	53	66	69	82	28	N/A	N/A
Sodium (mg/L as Na)	None	6.8	42.5	50	54	58	28	N/A	N/A
Potassium (mg/L as K)	None	1.6	2.0	2.2	2.3	3.1	28	N/A	N/A
Chloride (mg/L as Cl)	400	4.8	53	60	65	73	28	N/A	0
Sulfate (mg/L as SO_4)	2,000	67	1,200	1,450	1,500	1,800	28	N/A	0
Aluminum (µg/L as Al)	750	8	8	10	12	18	6	0	0
Arsenic (µg/L as As)	150	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	6	6	0
Beryllium (µg/L as Be)	5.3	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Boron (µg/L as B)	750	30	88	100	110	120	28	0	0
Cadmium (µg/L as Cd)	H[2]	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Chromium (µg/L as Cr)	H	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Cobalt (µg/L as Co)	50	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Copper (µg/L as Cu)	H	1.4	3.1	5.3	5.9	6.0	6	0	N/A[3]
Lead (µg/L as Pb)	H	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Mercury (µg/L as Hg)	0.012	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	6	6	0
Nickel (µg/L as Ni)	H	1.22	4.43	5.25	6.62	16.00	6	0	N/A[3]
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	6	6	0
Silver (µg/L as Ag)	H	< 1.00	< 2.00	< 2.00	< 2.00	< 2.00	6	6	0
Zinc (µg/L as Zn)	H	2	5	6	8	10	6	0	N/A[3]

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.

[2] H - indicates that the standard is based on water hardness and varies from sample to sample.

[3] N/A - Not available - hardness data do not coincide with trace element data; comparison not possible.

Table 1–3. USGS 08383500 Pecos River near Puerto De Luna, NM (1988-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	0.5	9.5	16.5	24.0	29.0	51	N/A	0
Spec. Cond. (µS/cm)	None	297	1,680	2,740	2,910	3,350	51	N/A	N/A
Diss. Oxygen (mg/L)	None	6.4	7.9	9.4	10.7	15.1	50	N/A	N/A
pH, Standard Units	6.6-9	7.3	8.0	8.1	8.2	8.8	49	N/A	0
Calcium (mg/L as Ca)	None	69	393	545	560	610	50	N/A	N/A
Magnesium (mg/L as Mg)	None	8	50	68	71	90	51	N/A	N/A
Sodium (mg/L as Na)	None	11	69	99	100	120	51	N/A	N/A
Potassium (mg/L as K)	None	1.4	2.0	2.2	2.4	3.6	51	N/A	N/A
Chloride (mg/L as Cl)	400	6	99	140	146	180	51	N/A	0
Sulfate (mg/L as SO_4)	2,000	110	1,050	1,500	1,600	1,800	51	N/A	0
Aluminum (µg/L as Al)	87	< 1	2	6	7	19	18	5	0
Arsenic (µg/L as As)	150	< 1.0	< 1.0	< 1.0	< 2.0	3	33	27	0
Beryllium (µg/L as Be)	150	< 0.06	< 1.00	< 1.50	< 2.00	< 2.00	18	18	0
Boron (µg/L as B)	750	30	85	110	120	150	51	0	0
Cadmium (µg/L as Cd)	H[2]	< 0.04	< 1.00	< 1.00	< 2.00	6.00	33	28	0
Chromium (µg/L as Cr)	H	< 0.8	< 1.0	1.1	2.0	5.0	33	22	0
Cobalt (µg/L as Co)	50	0.11	1.06	< 1.50	< 2.00	< 2.00	18	14	0
Copper (µg/L as Cu)	H	< 1.0	1.0	3.0	5.2	14.0	33	5	0
Lead (µg/L as Pb)	H	0.05	< 1.00	< 1.00	< 2.00	1.00	33	30	0
Mercury (µg/L as Hg)	5	< 0.1	< 0.1	< 0.1	0.1	0.9	13	9	4
Nickel (µg/L as Ni)	H	< 0.10	1.65	3.82	5.89	15.00	18	4	0
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	< 2.0	4.9	33	32	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 2.0	< 2.0	< 2.0	18	18	0
Zinc (µg/L as Zn)	H	< 1	4	6	< 10	36	33	9	0
Fecal Coliform .7 µm -mf (Col./100 mL)	5	< 1	< 3	< 10	185	5,800	31	12	3
TDS (mg/L)	3,000	271	967	2,442	2,542	2,574	50	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.

[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–4. USGS 08386000 Pecos River near Acme, NM (1988-98)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	3.0	6.3	15.5	20.6	29.0	41	N/A	0
Spec. Cond. (µS/cm)	N/A	875	1,880	2,680	3,748	5,500	41	N/A	N/A
Diss. Oxygen (mg/L)	N/A	5.3	8.6	9.5	11.2	13.0	38	N/A	N/A
pH, Standard Units	6.6-9	7.3	8.0	8.1	8.2	8.3	38	N/A	0
Calcium (mg/L as Ca)	None	140	280	370	453	580	41	N/A	N/A
Magnesium (mg/L as Mg)	None	22	50	76	93	140	41	N/A	N/A
Sodium (mg/L as Na)	None	30	92	160	320	560	41	N/A	N/A
Potassium (mg/L as K)	None	2.3	3.0	3.6	4.2	5.6	40	N/A	N/A
Chloride (mg/L as Cl)	4,000	27	115	200	425	860	41	N/A	0
Sulfate (mg/L as SO_4)	2,500	370	885	1,200	1,393	1,900	41	N/A	0
Aluminum (µg/L as Al)	87	5	6	8	107	293	7	0	2
Arsenic (µg/L as As)	150	< 1.0	< 1.0	< 1.0	1	2	22	13	0
Beryllium (µg/L as Be)	150	< 1.00	< 1.00	< 2.00	< 2.00	< 2.00	7	7	0
Cadmium (µg/L as Cd)	H[2]	< 1.00	< 1.00	< 1.00	< 1.00	4.00	22	21	0
Chromium (µg/L as Cr)	H	< 1.0	< 1.0	1.0	2.0	3.0	22	14	0
Cobalt (µg/L as Co)	50	< 1.00	< 1.00	< 2.00	< 2.00	< 2.00	7	6	0
Copper (µg/L as Cu)	H	< 1.0	1.0	1.0	3.3	14.0	22	5	0
Lead (µg/L as Pb)	H	< 1.00	< 1.00	< 1.00	< 2.00	< 5.00	22	21	0
Mercury (µg/L as Hg)	0.012	< 0.1	< 0.1	< 0.1	0.1	0.4	14	10	4
Nickel (µg/L as Ni)	H	2.1	3.5	4.0	10.0	12.0	7	0	0
Selenium (µg/L as Se)	5	< 1.0	< 1.0	< 1.0	< 1.0	1.0	22	19	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 2.0	< 2.0	< 2.0	7	7	0
Zinc (µg/L as Zn)	H	2	4	< 10	10	11	22	8	0
Fecal Coliform .7 µm -mf (Col./100 mL)	400	< 1	< 1	< 3	< 10	> 600	11	8	0
TDS (mg/L)	8,000	656	1,336	2,091	2,589	4,014	37	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.

[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–5. USGS 08396500 Pecos River near Artesia, NM (1988-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	0.5	10.6	17.5	22.0	29.0	54	N/A	0
Spec. Cond. (μS/cm)	None	1,390	3,863	7,100	8,335	13,900	52	N/A	N/A
Diss. Oxygen (mg/L)	None	6.2	8.0	10.1	11.0	14.8	50	N/A	N/A
pH, Standard Units	6.6-9	7.1	8.0	8.1	8.3	8.6	49	N/A	0
Calcium (mg/L as Ca)	None	200	380	510	560	700	52	N/A	N/A
Magnesium (mg/L as Mg)	None	32	99	170	190	290	52	N/A	N/A
Sodium (mg/L as Na)	None	55	415	910	1,100	2,000	51	N/A	N/A
Potassium (mg/L as K)	None	1.7	4.7	6.4	8.5	19.0	52	N/A	N/A
Chloride (mg/L as Cl)	6,000	82	680	1,600	1,890	4,000	51	N/A	0
Sulfate (mg/L as SO_4)	3,000	73	1,100	1,625	1,800	2,500	52	N/A	0
Aluminum (μg/L as Al)	87	< 1	< 4	12	0	0	19	9	0
Arsenic (μg/L as As)	150	< 1.0	< 1.0	1.4	2.0	3.0	34	14	0
Beryllium (μg/L as Be)	150	< 0.06	< 1.00	< 3.00	< 4.00	< 4.00	19	19	0
Boron (μg/L as B)	750	76	225	355	435	900	52	0	1
Cadmium (μg/L as Cd)	H[2]	< 0.10	< 1.00	< 1.00	< 4.00	6.0	34	30	0
Chromium (μg/L as Cr)	H	< 0.8	< 1.0	2.0	< 4.0	< 10.0	33	21	0
Cobalt (μg/L as Co)	50	0.75	< 1.00	< 3.00	< 4.00	4.58	19	14	0
Copper (μg/L as Cu)	H	< 1.0	1.0	< 4.0	6.8	28.0	34	2	0
Lead (μg/L as Pb)	H	0.11	< 1.00	< 1.00	< 4.00	8.0	34	29	0
Mercury (μg/L as Hg)	5	< 0.1	< 0.1	< 0.1	0.1	0.5	14	9	5
Nickel (μg/L as Ni)	H	< 0.2	3.3	5.0	7.4	21.0	19	3	0
Selenium (μg/L as Se)	5	< 1.0	1.7	1.4	< 2.4	3.7	34	11	0
Silver (μg/L as Ag)	H	< 1.0	< 1.0	< 3.0	< 4.0	< 4.0	19	19	0
Zinc (μg/L as Zn)	H	< 4	6	< 10	12	27	34	7	0
TDS (mg/L)	14,000	762	2,440	4,478	5,080	8,874	49	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.

[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–6. USGS 08401500 Pecos River below Brantley Dam near Carlsbad, NM (1988-1997)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	3.5	10.5	16.0	23.0	28.5	45	0
Spec. Cond. (µS/cm)	None	1,490	3,020	4,430	6,405	8,100	42	N/A
Diss. Oxygen (mg/L)	None	6.6	8.6	9.9	11.2	13.5	43	N/A
pH, Standard Units	6.6-9	7.1	7.8	8.0	8.2	8.7	43	0
Calcium (mg/L as Ca)	None	200	345	425	470	560	36	N/A
Magnesium (mg/L as Mg)	None	38	81	110	153	200	36	N/A
Sodium (mg/L as Na)	None	93	318	475	745	1,000	36	N/A
Potassium (mg/L as K)	None	3.0	5.0	6.1	6.8	11.0	36	N/A
Chloride (mg/L as Cl)	None	130	520	750	1,250	1,900	35	N/A
Sulfate (mg/L as SO_4)	None	580	1,100	1,200	1,500	2,100	35	N/A
Boron (µg/L as B)	750	90	189	245	313	440	36	0

Table 1–7 USGS 08405200 Pecos River below Dark Canyon at Carlsbad, NM (1988-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	34	3.0	14.0	21.0	26.5	32.0	79	0
Spec. Cond. (µS/cm)	None	1,870	3,133	3,735	4,270	5,500	76	N/A
Diss. Oxygen (mg/L)	None	5.2	7.8	9.0	10.3	13.9	76	N/A
pH, Standard Units	6.6-9	7.0	7.7	7.8	8.0	8.9	76	0
Calcium (mg/L as Ca)	None	200	300	330	370	441	79	N/A
Magnesium (mg/L as Mg)	None	42	93	110	128	162	79	N/A
Sodium (mg/L as Na)	None	120	300	350	408	601	79	N/A
Potassium (mg/L as K)	None	2.24	4.34	4.90	5.44	27.90	79	N/A
Chloride (mg/L as Cl)	3,500	180	484	590	686	991	79	0
Sulfate (mg/L as SO_4)	2,500	650	940	1,060	1,200	1,400	79	0
Boron (µg/L as B)	750	110	198	226	263	591	68	0

Table 1–8. USGS 08406500 Pecos River near Malaga, NM (1988-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	5.5	13.3	19.5	26.3	37.0	79	1
Spec. Cond. (µS/cm)	None	3,160	5,900	6,400	7,000	12,000	78	N/A
Diss. Oxygen (mg/L)	None	5	8	9	11	16	74	N/A
pH, Standard Units	6.6-9	7.0	7.8	8.0	8.1	9.3	75	1
Calcium (mg/L as Ca)	None	270	460	492	525	650	79	N/A
Magnesium (mg/L as Mg)	None	86	170	190	212	280	79	N/A
Sodium (mg/L as Na)	None	290	670	740	838	1,900	79	N/A
Potassium (mg/L as K)	None	4.2	9.2	10.8	12.0	51.0	79	N/A
Chloride (mg/L as Cl)	10,000	440	1,100	1,290	1,453	3,300	78	0
Sulfate (mg/L as SO_4)	3,000	630	1,500	1,670	1,800	2,700	78	0
Boron (µg/L as B)	750	200	358	395	450	1,000	68	2

Table 1–9. USGS 08407000 Pecos River at Pierce Canyon Crossing, NM (1988-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	5.5	14.5	21.0	26.0	31.0	79	0
Spec. Cond. (µS/cm)	None	2,910	7,940	9,030	10,200	32,500	78	N/A
Diss. Oxygen (mg/L)	None	5	8	10	11	17	74	N/A
pH, Standard Units	6.6-9	7.0	7.9	8.0	8.2	8.7	75	0
Calcium (mg/L as Ca)	None	260	462	500	541	700	78	N/A
Magnesium (mg/L as Mg)	None	86	180	210	230	360	78	N/A
Sodium (mg/L as Na)	None	300	1,100	1,305	1,573	6,600	78	N/A
Potassium (mg/L as K)	None	7	30	37	47	250	78	N/A
Chloride (mg/L as Cl)	10,000	500	1,853	2,205	2,675	11,000	78	0
Sulfate (mg/L as SO_4)	3,000	670	1,543	1,705	1,970	2,800	78	0
Boron (µg/L as B)	750	71	428	505	597	1,640	68	8

Table 1–10. USGS 08407500 Pecos River at Red Bluff, NM (1988-1994)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. < D.L.[1]	No. > Std.
Temperature (°C)	32.2	5.0	11.3	16.3	25.4	30.0	36	N/A	0
Spec. Cond. (µS/cm)	None	3,820	9,000	10,500	12,200	31,200	35	N/A	N/A
Diss. Oxygen (mg/L)	None	5.3	8.1	9.3	10.6	14.7	34	N/A	N/A
pH, Standard Units	6.6-9	7.9	8.1	8.1	8.2	8.8	36	N/A	0
Calcium (mg/L as Ca)	None	300	450	475	572.5	860	34	N/A	N/A
Magnesium (mg/L as Mg)	None	98	190	205	255	440	34	N/A	N/A
Sodium (mg/L as Na)	None	410	1,200	1,600	2,000	6,300	34	N/A	N/A
Potassium (mg/L as K)	None	3.3	30	44	57	230	33	N/A	N/A
Chloride (mg/L as Cl)	10,000	620	2,100	2,700	3,350	11,000	33	N/A	0
Sulfate (mg/L as SO_4)	3,000	990	1,650	2,000	2,200	3,200	33	N/A	0
Aluminum (µg/L as Al)	87	< 10	< 10	20	30	750	23	8	3
Arsenic (µg/L as As)	150	< 1.0	1.0	1.0	2.0	3.0	12	2	0
Beryllium (µg/L as Be)	5.3	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	12	12	0
Cadmium (µg/L as Cd)	H[2]	< 1	< 1	< 2	< 2	11	12	9	0
Chromium (µg/L as Cr)	H	< 1	< 2	< 2	3	7	12	5	0
Cobalt (µg/L as Co)	50	< 1	< 1	< 1	1	4	24	19	0
Copper (µg/L as Cu)	H	< 1	1	2	3	8	12	2	0
Lead (µg/L as Pb)	H	< 1	< 2	< 2	< 3	31	12	11	1
Mercury (µg/L as Hg)	0.012	< 0.1	0.1	0.1	0.3	0.7	12	3	9
Nickel (µg/L as Ni)	H	< 1	< 1	< 1	2	11	24	18	0
Selenium (µg/L as Se)	5	< 1	1	1	2	< 4	25	8	0
Silver (µg/L as Ag)	H	< 1.0	< 1.0	< 1.0	< 1.0	< 4.0	24	24	0
Vanadium (µg/L as V)	100	14	< 25	45	59	170	25	2	2
Zinc (µg/L as Zn)	H	< 10	10	20	30	40	12	3	0
TDS (mg/L)	20,000	2,560	5,801	6,736	8,275	21,775	36	N/A	0

[1] D.L. - Detection Limit for trace elements (limit indicated by < in table). N/A - not applicable.

[2] H - indicates that the standard is based on water hardness and varies from sample to sample

Table 1–11. USGS 08412500 Pecos River near Orla, TX (1992-2001)

Pollutant	Standard	Minimum	25th Pctile	Median	75th Pctile	Maximum	No. of Obs.	No. > Std.
Temperature (°C)	32.2	3.0	16.6	23.0	25.0	38.0	55	1
Spec. Cond. (µS/cm)	None	6,120	8,933	9,415	10,475	19,500	54	N/A
Diss. Oxygen (mg/L)	5	5.3	7.2	8.4	10.0	13.4	44	0
pH, Standard Units	6.5-9	7.1	7.7	7.8	7.9	8.1	50	0
Bicarbonate (mg/L) as HCO_3)	None	54	91	101	125	172	46	N/A
Calcium (mg/L as Ca)	None	472	544	586	650	940	55	N/A
Magnesium (mg/L as Mg)	None	179	204	223	238	340	55	N/A
Sodium (mg/L as Na)	None	938	1,203	1,300	1,473	4,600	55	N/A
Potassium (mg/L as K)	None	2	28	31	33	43	55	N/A
Chloride (mg/L as Cl)	7,000	1,580	2,035	2,155	2,535	6,400	55	0
Sulfate (mg/L as SO_4)	3,500	1,680	1,985	2,035	2,238	3,000	55	0
TDS (mg/L)	15,000	4,938	6,130	6,302	7,296	15,385	46	1

ATTACHMENT 2

PLOTS OF SPECIFIC CONDUCTANCE AT VARIOUS SUMNER DAM RELEASE LEVELS AT STATIONS ON THE MAINSTEM OF THE PECOS RIVER

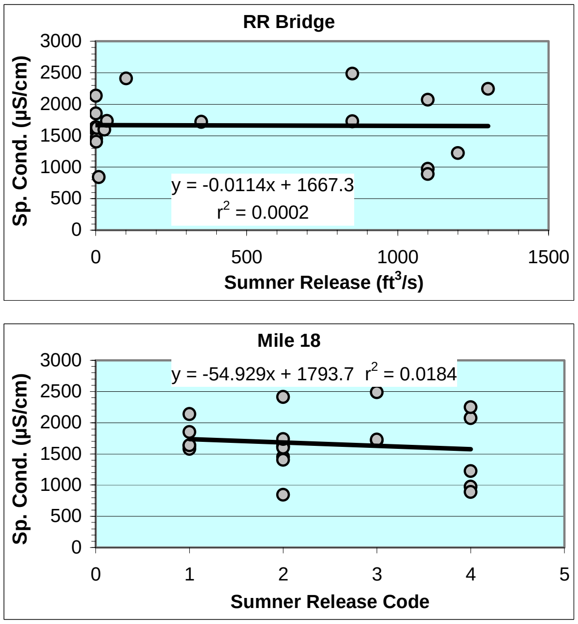


Figure 1: Relationship between the Sumner release and the specific conductance at site ST-2

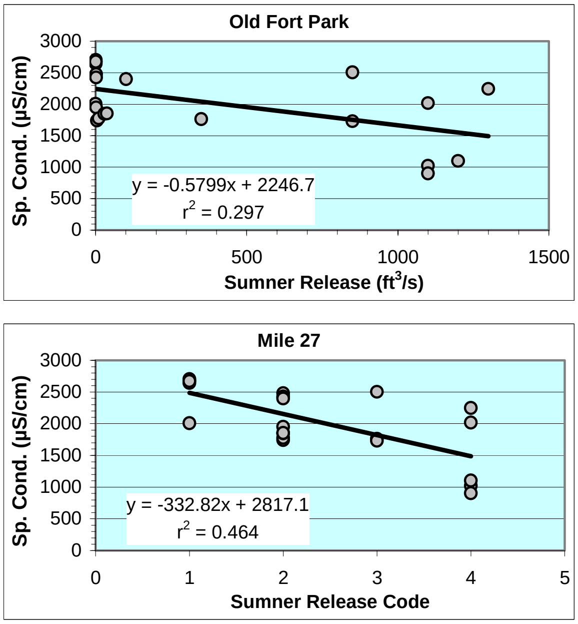


Figure 2: Relationship between the Sumner release and the specific conductance at site ST-3

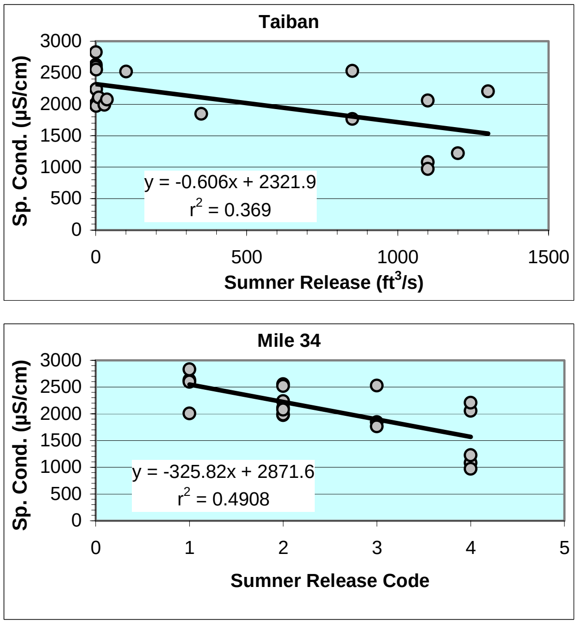


Figure 3: Relationship between the Sumner release and the specific conductance at site ST-4

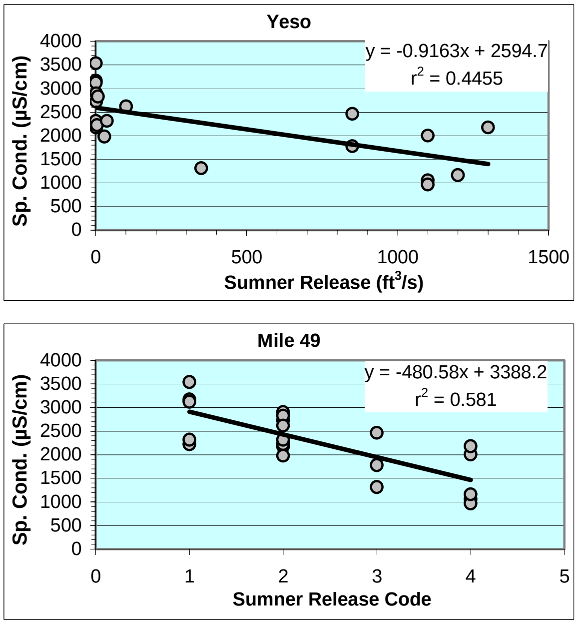


Figure 4: Relationship between the Sumner release and the specific conductance at site TA-0.3

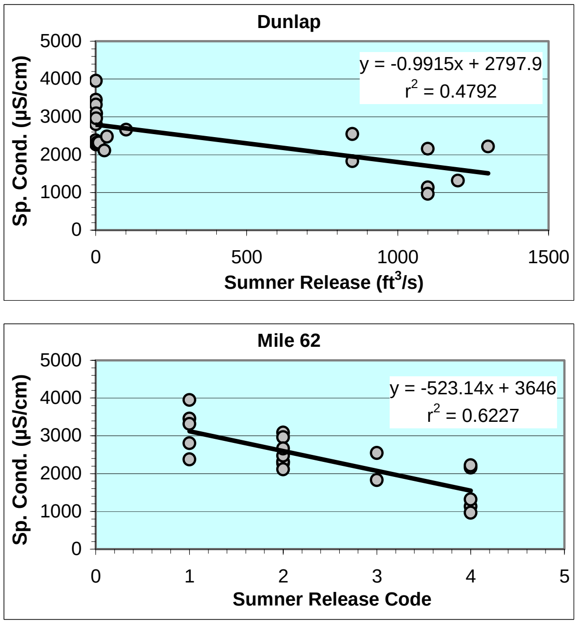


Figure 5: Relationship between the Sumner release and the specific conductance at site TA-0.5

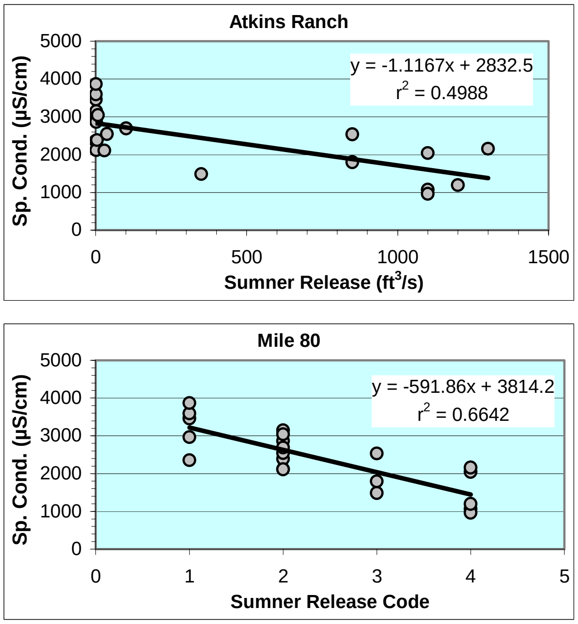


Figure 6: Relationship between the Sumner release and the specific conductance at site TA-1

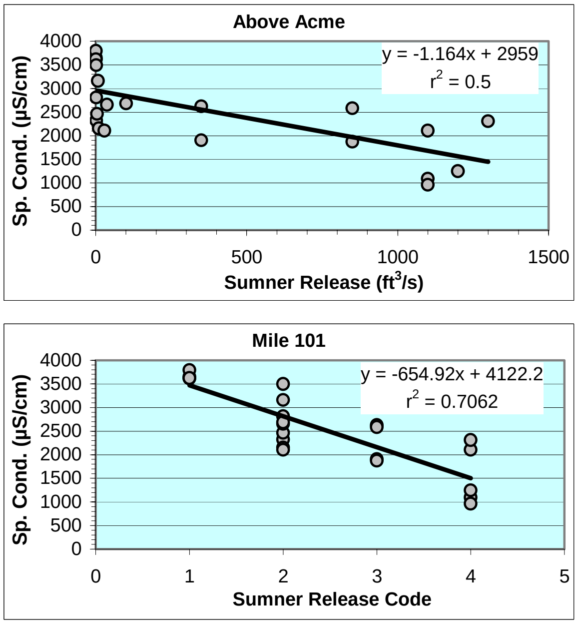


Figure 7: Relationship between the Sumner release and the specific conductance at site TA-2

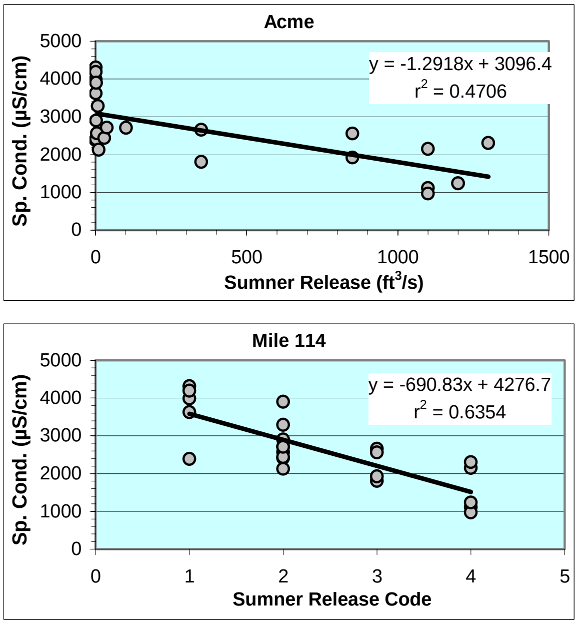


Figure 8: Relationship between the Sumner release and the specific conductance at site TA-4

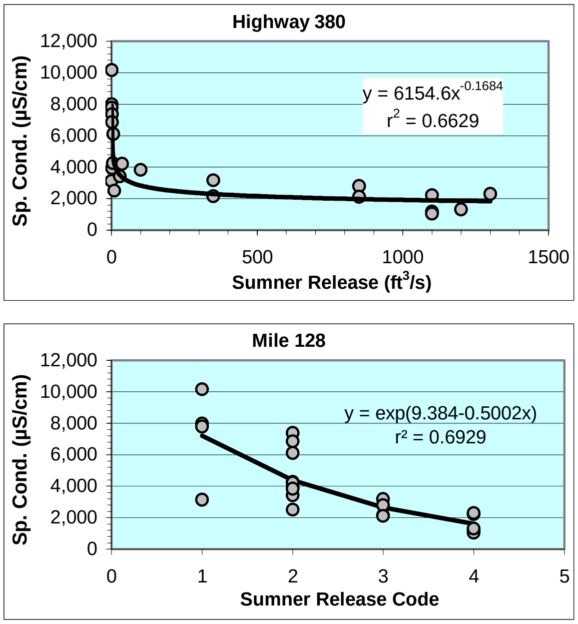


Figure 9: Relationship between the Sumner release and the specific conductance at site AA-1

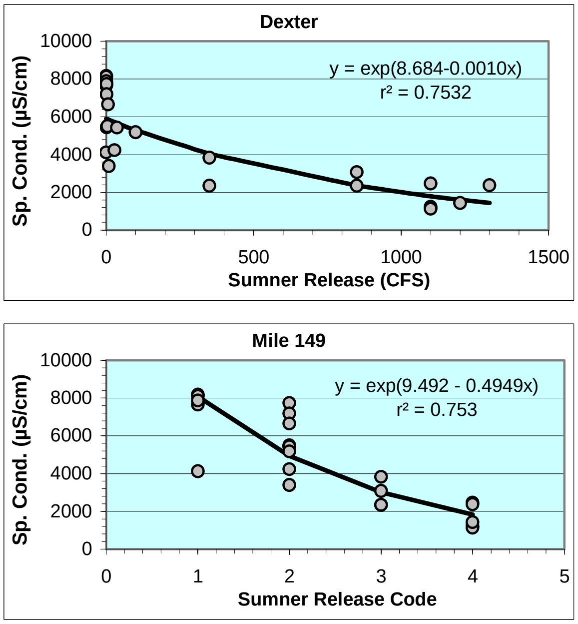


Figure 10: Relationship between the Sumner release and the specific conductance at site AA-1.5

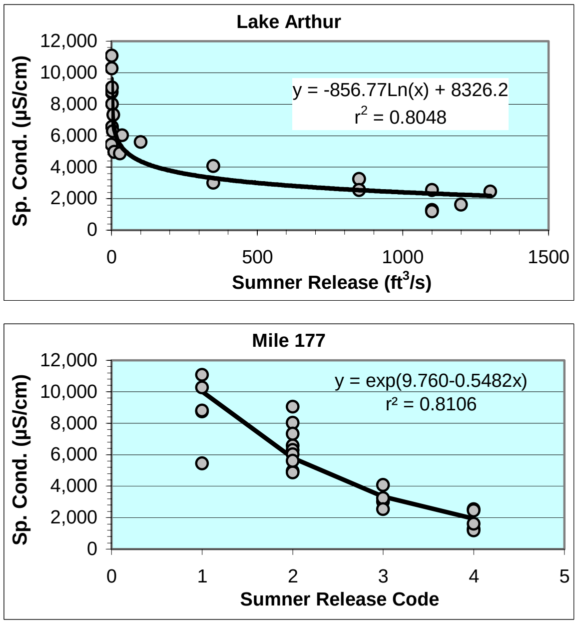


Figure 11: Relationship between the Sumner release and the specific conductance at site AA-3

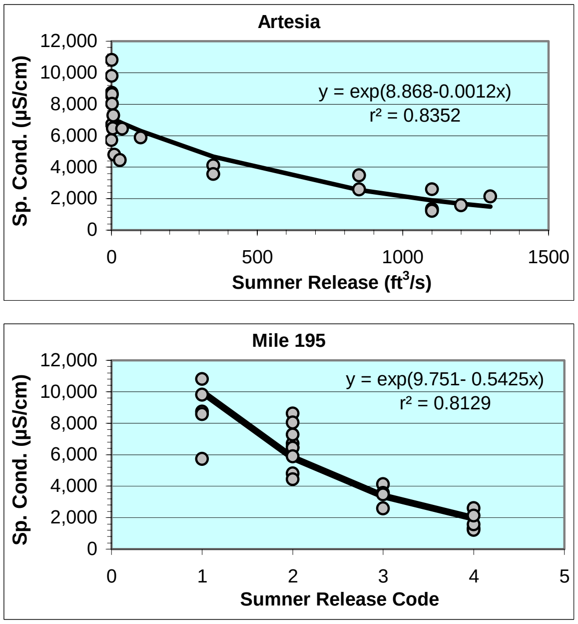


Figure 12: Relationship between the Sumner release and the specific conductance at site AA-4

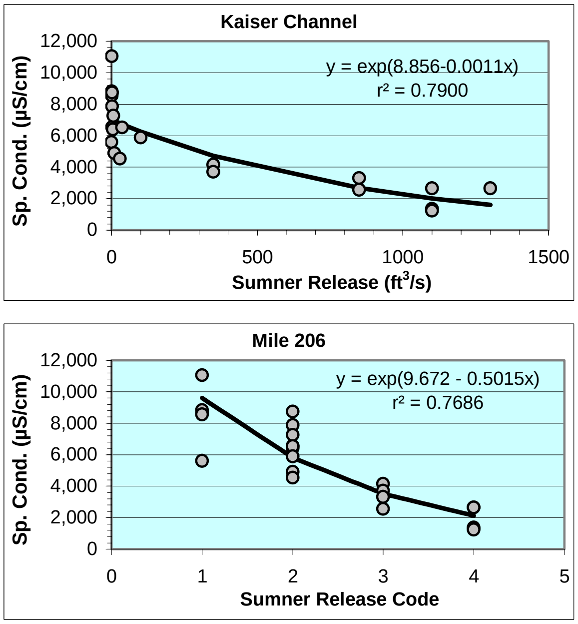


Figure 11: Relationship between the Sumner release and the specific conductance at site AK-1

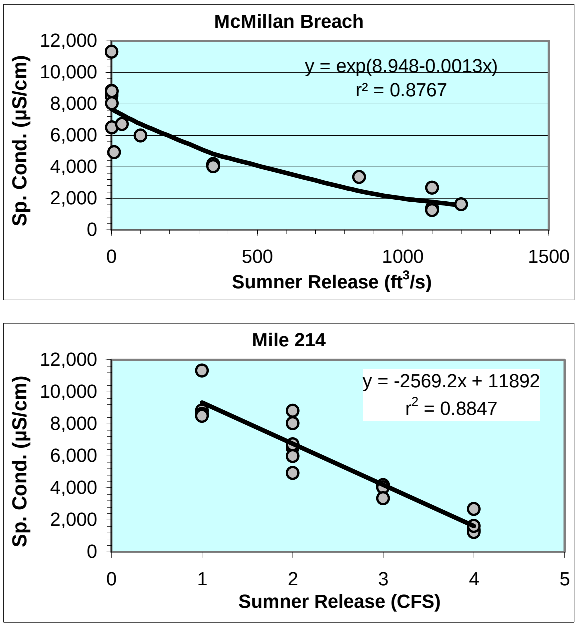
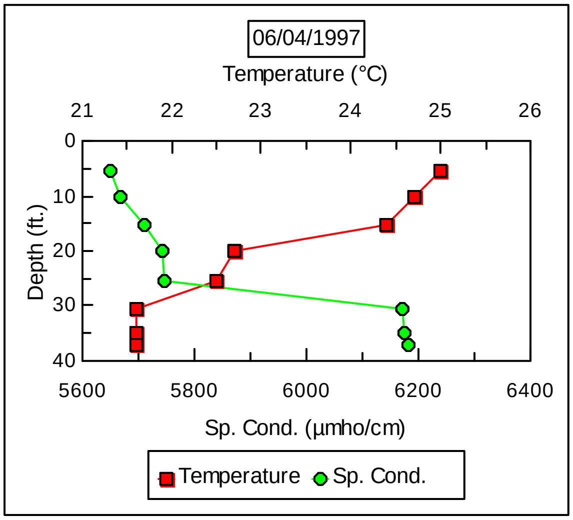
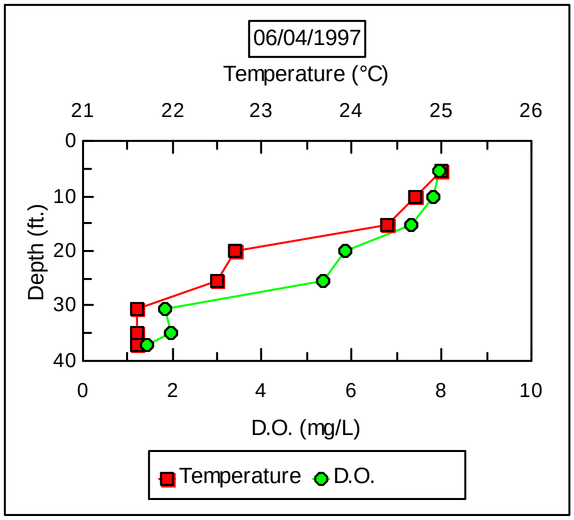


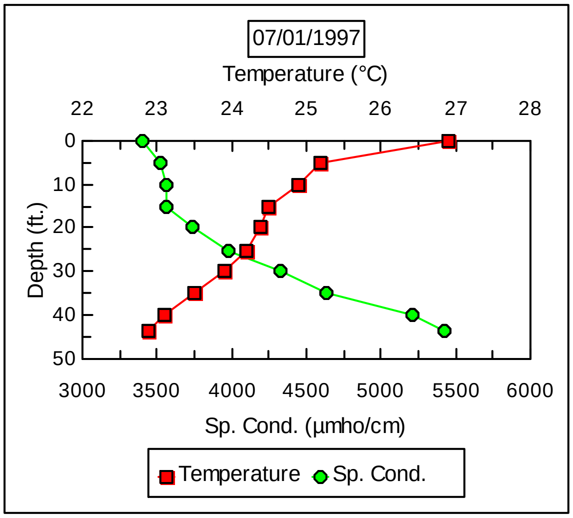
Figure 12: Relationship between the Sumner release and the specific conductance at site AK-2

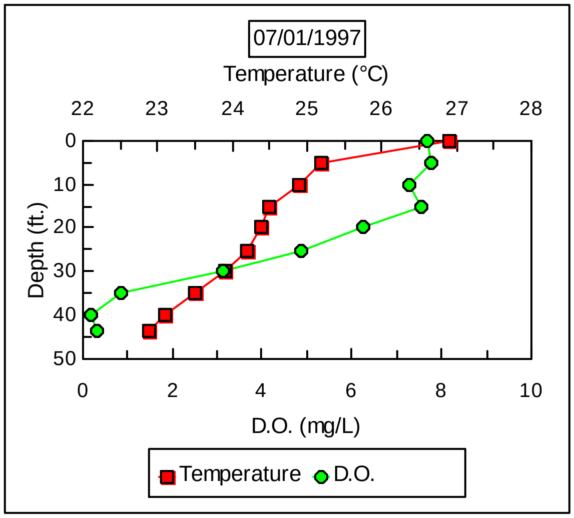
ATTACHMENT 3

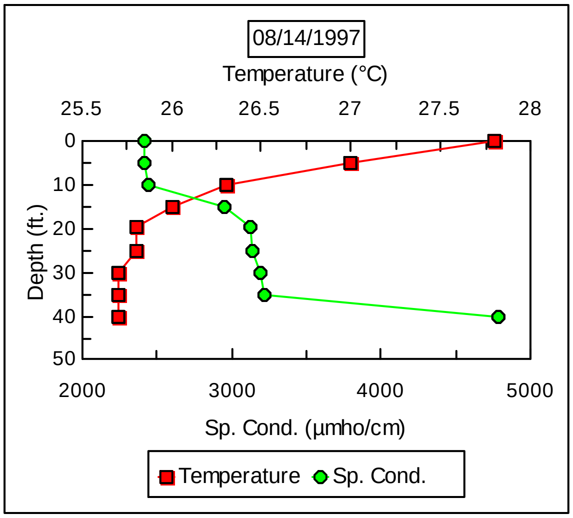
TEMPERATURE AND DISSOLVED OXYGEN PROFILES IN BRANTLEY RESERVOIR 1997 – 2001

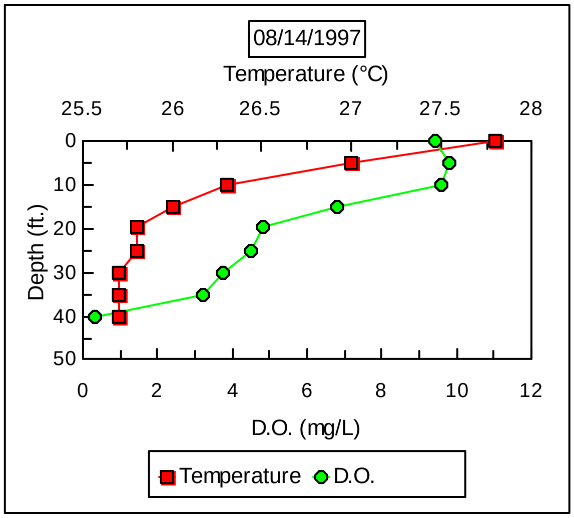

06/04/1997
Temperature (°C)
21
22
23
24
25
26
Depth (ft.)
0
10
20
30
40
5600
5800
6000
6200
6400
Sp. Cond. (µmho/cm)
🟥 Temperature
● Sp. Cond.

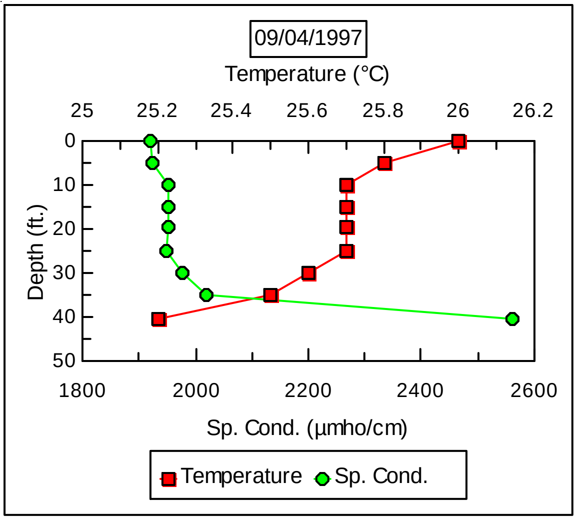

06/04/1997
Temperature (°C)
21
22
23
24
25
26
Depth (ft.)
0
10
20
30
40
0
2
4
6
8
10
D.O. (mg/L)
🟥 Temperature
● D.O.

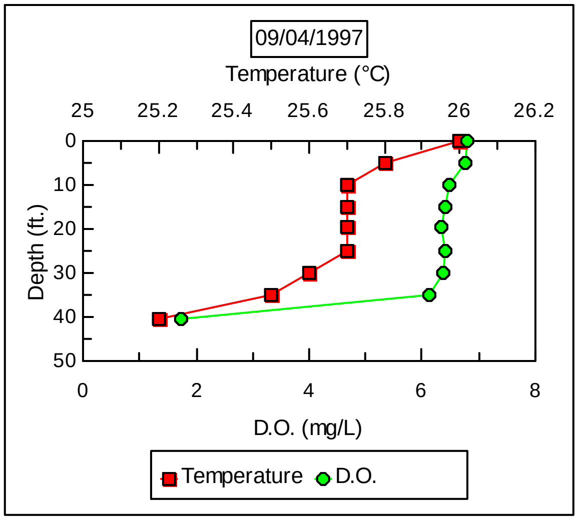

07/01/1997
Temperature (°C)
22
23
24
25
26
27
28
Depth (ft.)
0
10
20
30
40
50
3000
3500
4000
4500
5000
5500
6000
Sp. Cond. (µmho/cm)
🟥 Temperature
● Sp. Cond.

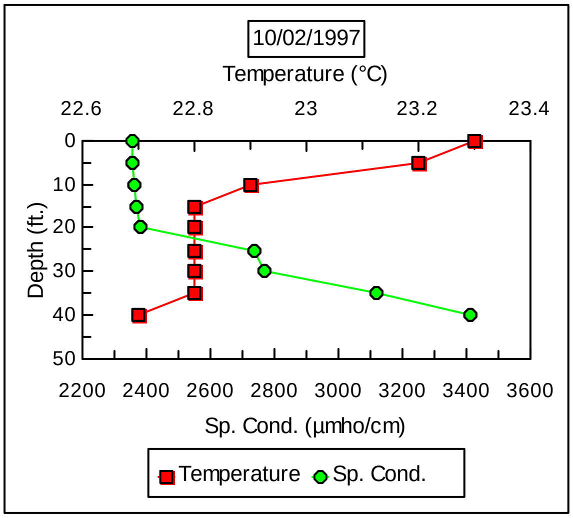

07/01/1997
Temperature (°C)
22
23
24
25
26
27
28
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
10
D.O. (mg/L)
🟥 Temperature
● D.O.

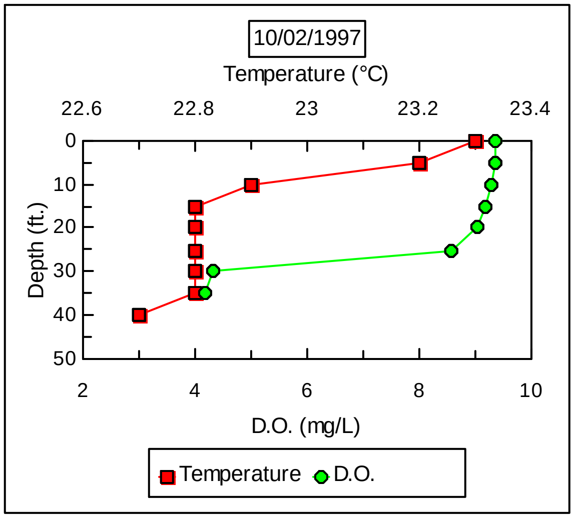

08/14/1997
Temperature (°C)
25.5
26
26.5
27
27.5
28
Depth (ft.)
0
10
20
30
40
50
2000
3000
4000
5000
Sp. Cond. (µmho/cm)
🟥 Temperature
● Sp. Cond.

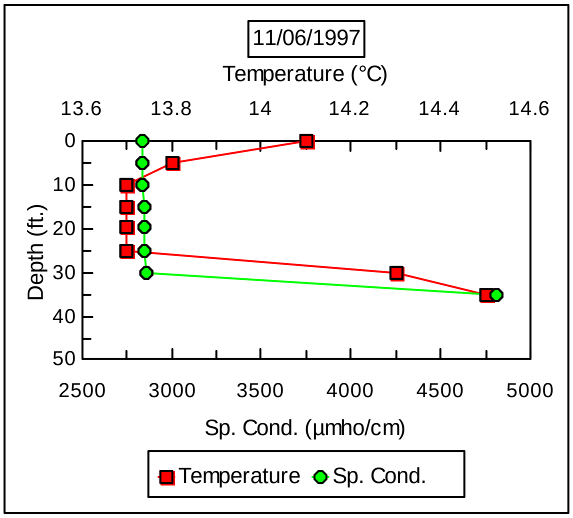

08/14/1997
Temperature (°C)
25.5
26
26.5
27
27.5
28
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
10
12
D.O. (mg/L)
🟥 Temperature
● D.O.

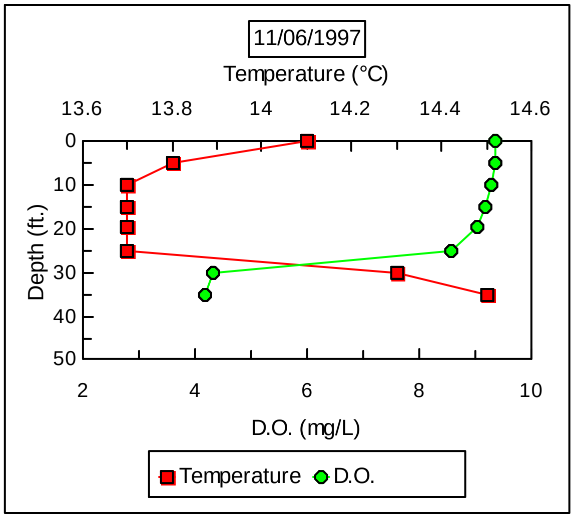

09/04/1997
Temperature (°C)
25
25.2
25.4
25.6
25.8
26
26.2
Depth (ft.)
0
10
20
30
40
50
1800
2000
2200
2400
2600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

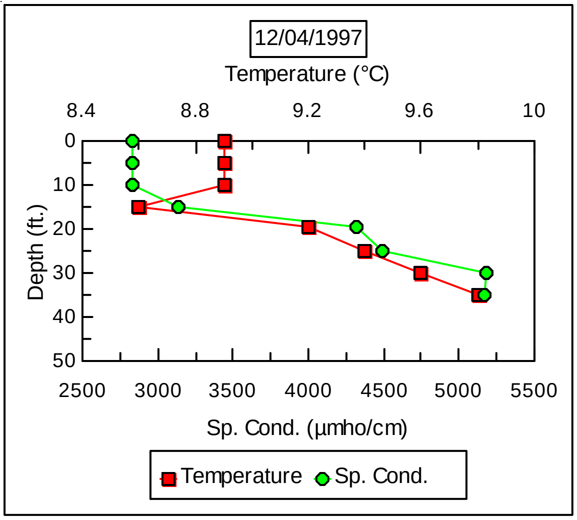

09/04/1997
Temperature (°C)
25
25.2
25.4
25.6
25.8
26
26.2
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

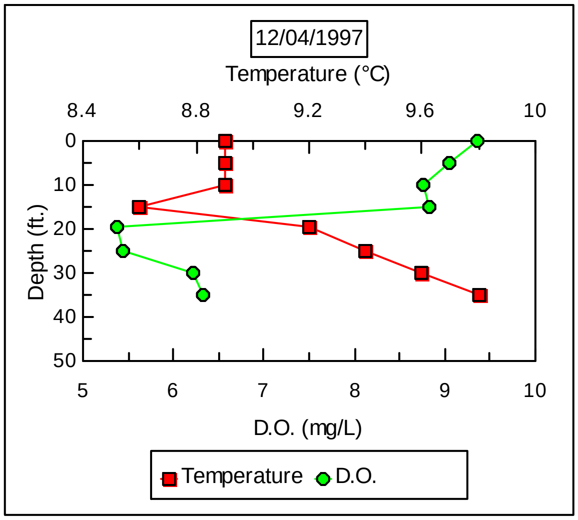

10/02/1997
Temperature (°C)
22.6
22.8
23
23.2
23.4
Depth (ft.)
0
10
20
30
40
50
2200
2400
2600
2800
3000
3200
3400
3600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

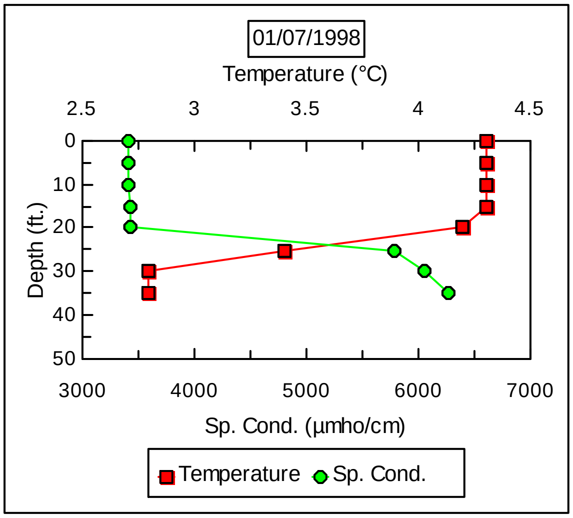

10/02/1997
Temperature (°C)
22.6
22.8
23
23.2
23.4
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

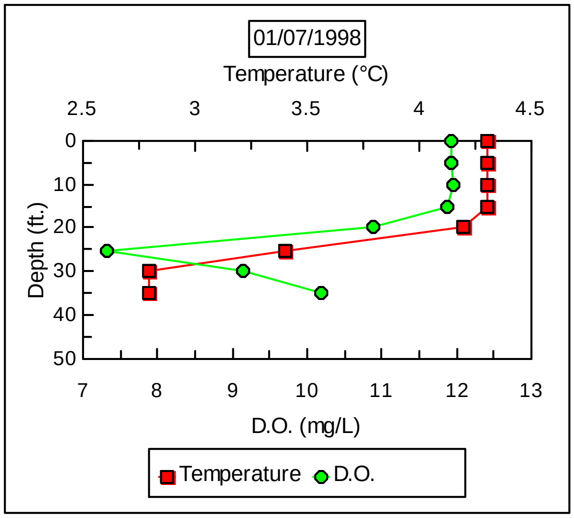

11/06/1997
Temperature (°C)
13.6
13.8
14
14.2
14.4
14.6
Depth (ft.)
0
10
20
30
40
50
2500
3000
3500
4000
4500
5000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

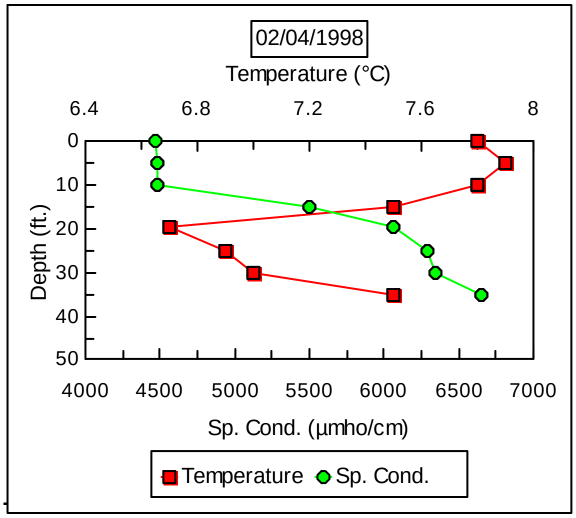

11/06/1997
Temperature (°C)
13.6
13.8
14
14.2
14.4
14.6
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

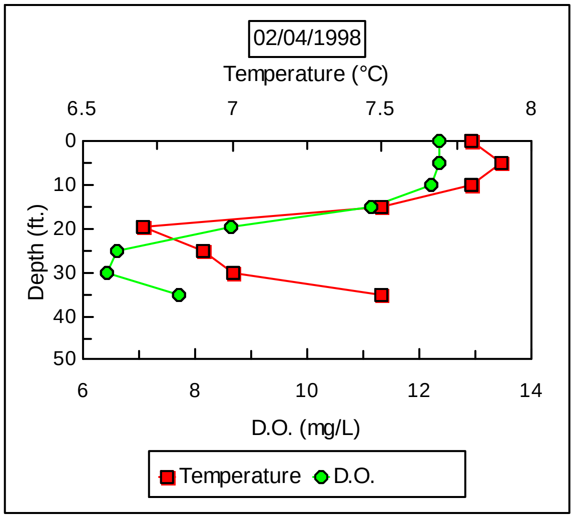

12/04/1997
Temperature (°C)
8.4
8.8
9.2
9.6
10
Depth (ft.)
0
10
20
30
40
50
2500
3000
3500
4000
4500
5000
5500
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

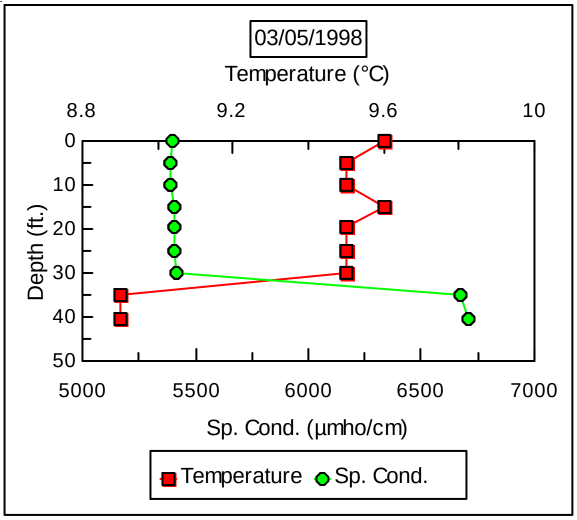

12/04/1997
Temperature (°C)
8.4
8.8
9.2
9.6
10
Depth (ft.)
0
10
20
30
40
50
5
6
7
8
9
10
D.O. (mg/L)
🟥 Temperature ● D.O.

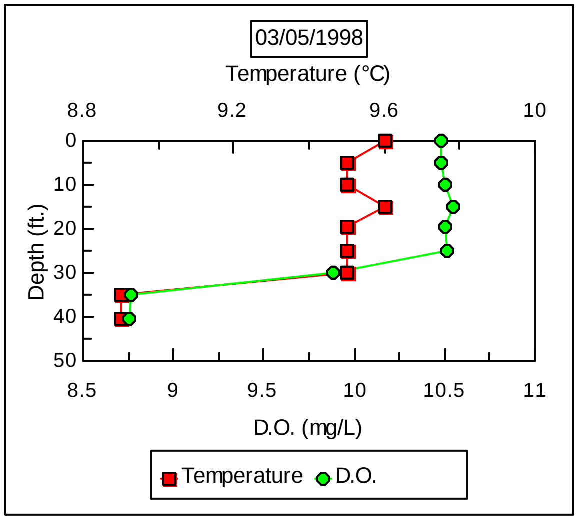

01/07/1998
Temperature (°C)
2.5
3
3.5
4
4.5
Depth (ft.)
0
10
20
30
40
50
3000
4000
5000
6000
7000
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

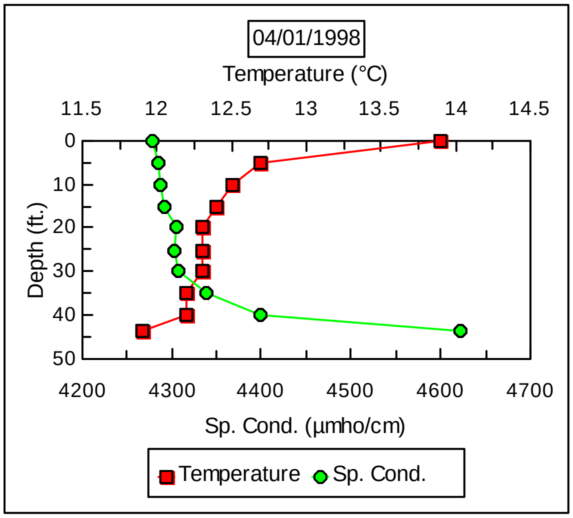

01/07/1998
Temperature (°C)
2.5
3
3.5
4
4.5
Depth (ft.)
0
10
20
30
40
50
7
8
9
10
11
12
13
D.O. (mg/L)
🟥 Temperature ● D.O.

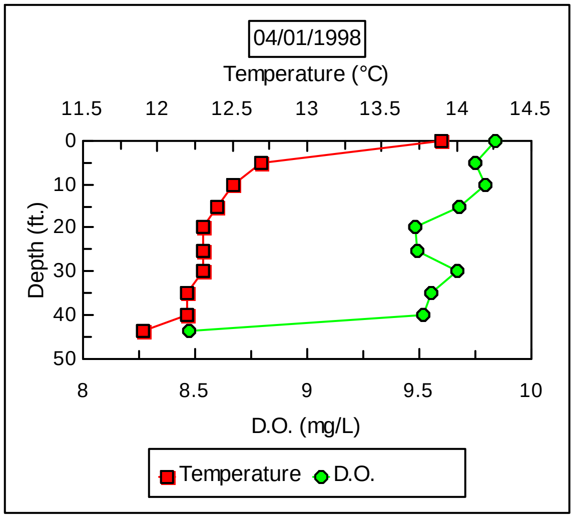

02/04/1998
Temperature (°C)
6.4
6.8
7.2
7.6
8
Depth (ft.)
0
10
20
30
40
50
4000
4500
5000
5500
6000
6500
7000
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

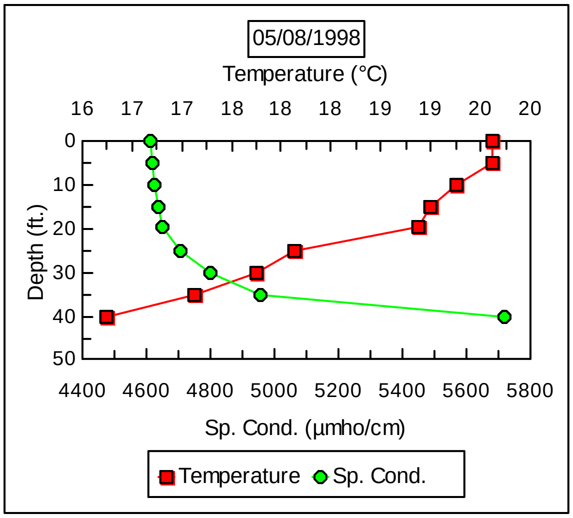

02/04/1998
Temperature (°C)
6.5
7
7.5
8
Depth (ft.)
0
10
20
30
40
50
6
8
10
12
14
D.O. (mg/L)
🟥 Temperature ● D.O.

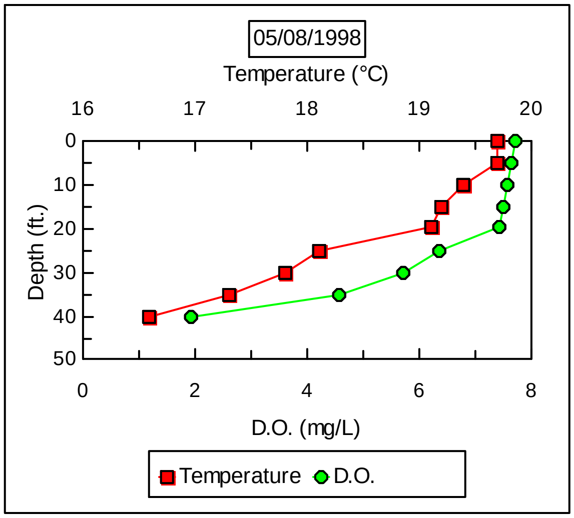

03/05/1998
Temperature (°C)
8.8
9.2
9.6
10
Depth (ft.)
0
10
20
30
40
50
5000
5500
6000
6500
7000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

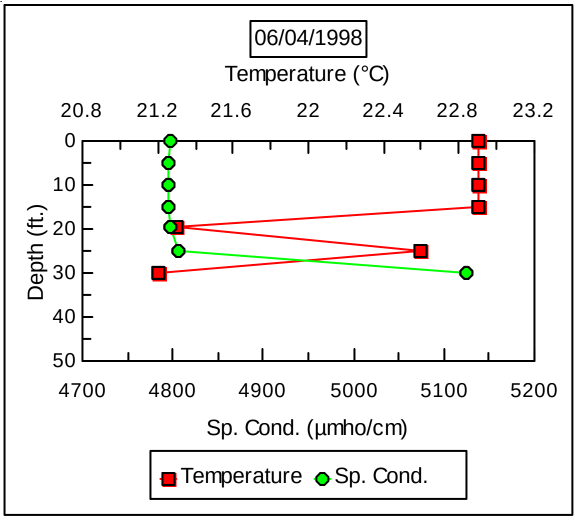

03/05/1998
Temperature (°C)
8.8
9.2
9.6
10
Depth (ft.)
0
10
20
30
40
50
8.5
9
9.5
10
10.5
11
D.O. (mg/L)
Temperature
D.O.

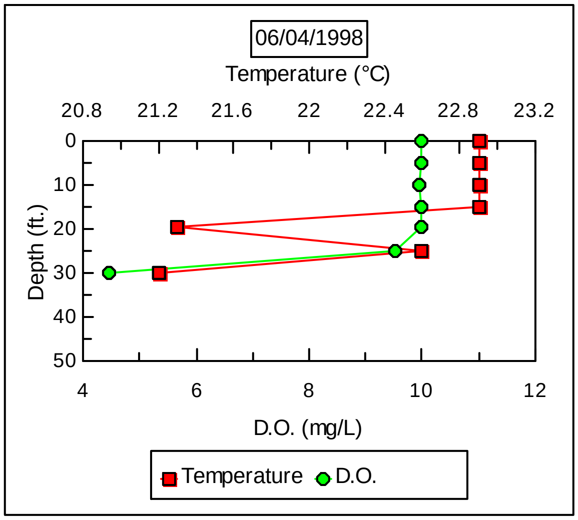

04/01/1998
Temperature (°C)
11.5
12
12.5
13
13.5
14
14.5
Depth (ft.)
0
10
20
30
40
50
4200
4300
4400
4500
4600
4700
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

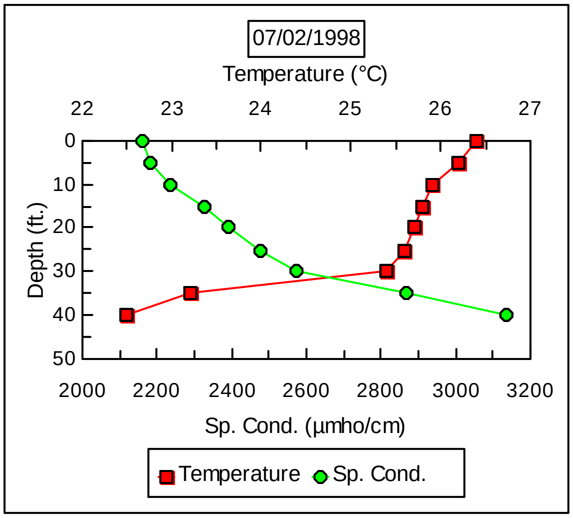

04/01/1998
Temperature (°C)
11.5
12
12.5
13
13.5
14
14.5
Depth (ft.)
0
10
20
30
40
50
8
8.5
9
9.5
10
D.O. (mg/L)
Temperature
D.O.

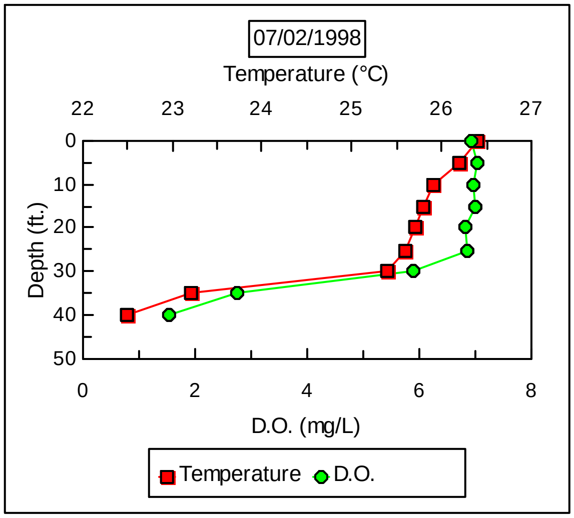

05/08/1998
Temperature (°C)
16
17
17
18
18
18
19
19
20
20
Depth (ft.)
0
10
20
30
40
50
4400
4600
4800
5000
5200
5400
5600
5800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

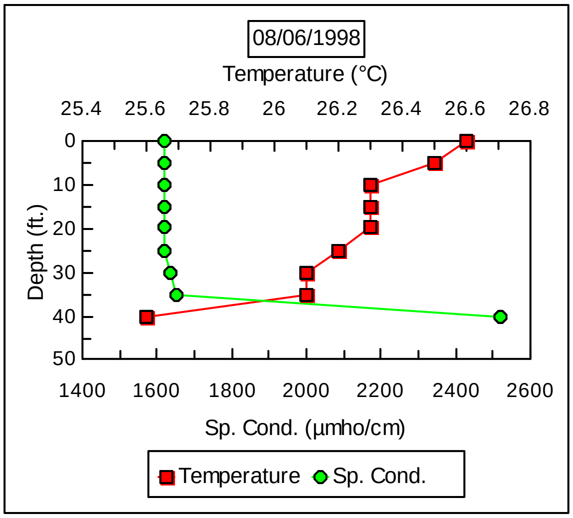

05/08/1998
Temperature (°C)
16
17
18
19
20
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

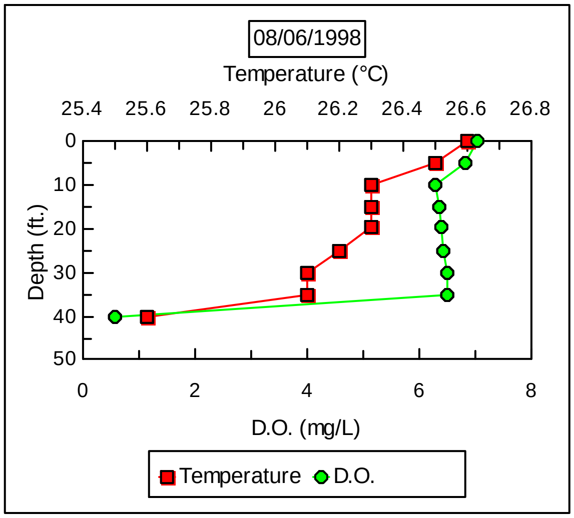

06/04/1998
Temperature (°C)
20.8 21.2 21.6 22 22.4 22.8 23.2
Depth (ft.)
0 10 20 30 40 50
4700 4800 4900 5000 5100 5200
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

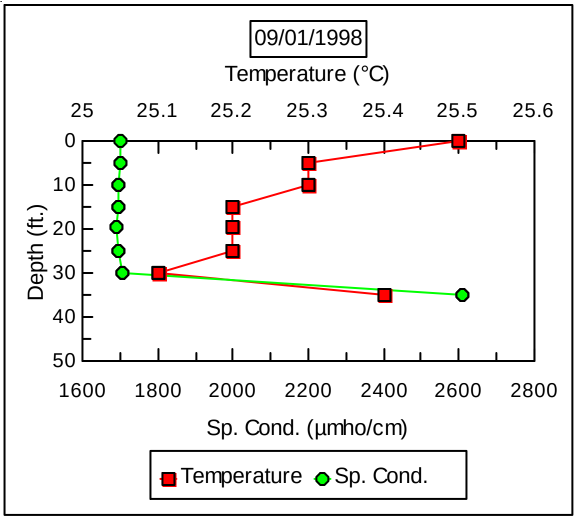

06/04/1998
Temperature (°C)
20.8 21.2 21.6 22 22.4 22.8 23.2
Depth (ft.)
0 10 20 30 40 50
4 6 8 10 12
D.O. (mg/L)
Temperature
D.O.

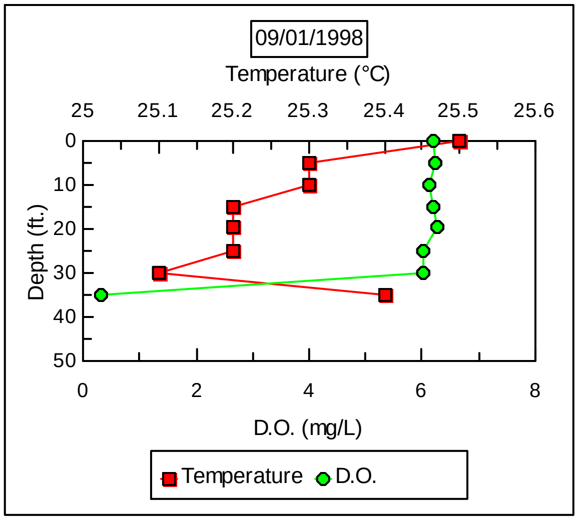

07/02/1998
Temperature (°C)
22 23 24 25 26 27
Depth (ft.)
0 10 20 30 40 50
2000 2200 2400 2600 2800 3000 3200
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

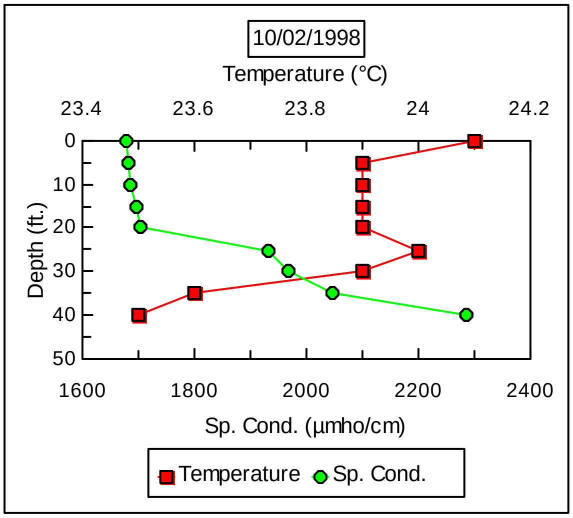

07/02/1998
Temperature (°C)
22 23 24 25 26 27
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature
D.O.

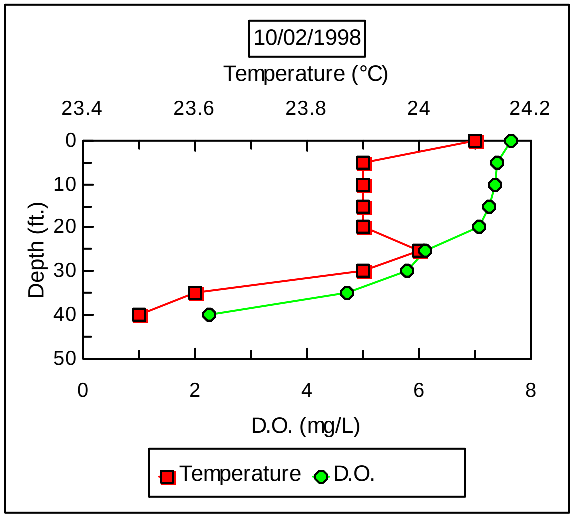

08/06/1998
Temperature (°C)
25.4 25.6 25.8 26 26.2 26.4 26.6 26.8
Depth (ft.)
0 10 20 30 40 50
1400 1600 1800 2000 2200 2400 2600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

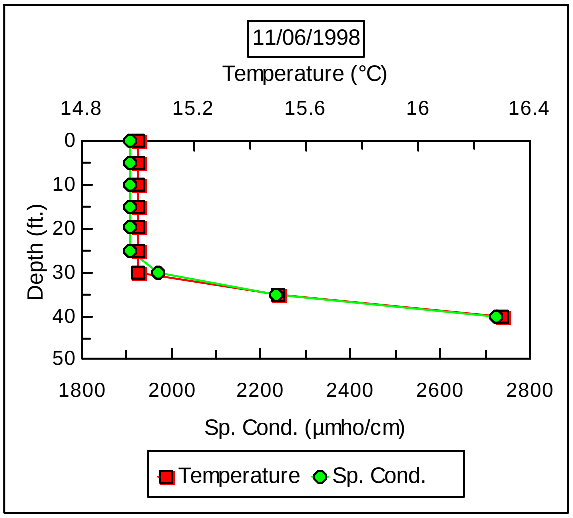

08/06/1998
Temperature (°C)
25.4 25.6 25.8 26 26.2 26.4 26.6 26.8
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature
D.O.

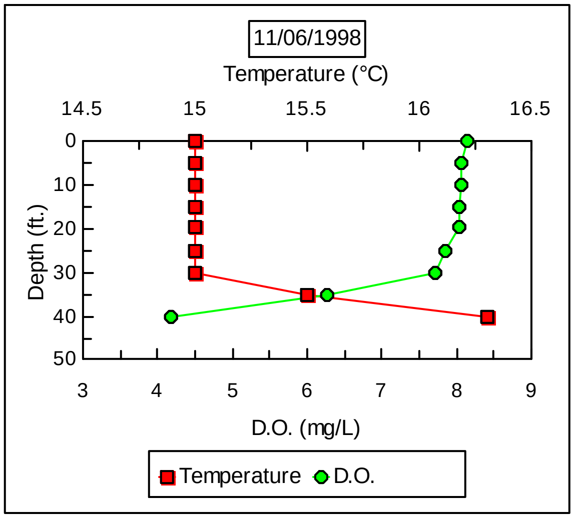

09/01/1998
Temperature (°C)
25 25.1 25.2 25.3 25.4 25.5 25.6
Depth (ft.)
0 10 20 30 40 50
1600 1800 2000 2200 2400 2600 2800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

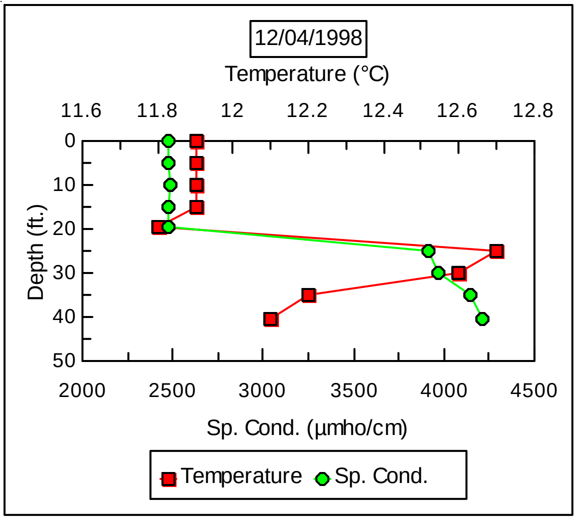

09/01/1998
Temperature (°C)
25 25.1 25.2 25.3 25.4 25.5 25.6
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature
D.O.

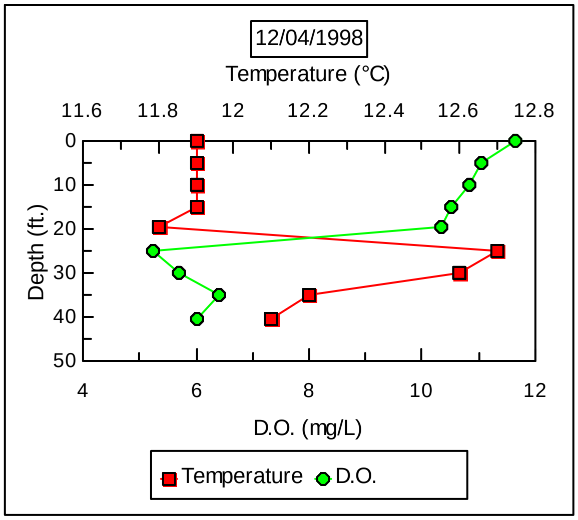

10/02/1998
Temperature (°C)
23.4 23.6 23.8 24 24.2
Depth (ft.)
0 10 20 30 40 50
1600 1800 2000 2200 2400
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

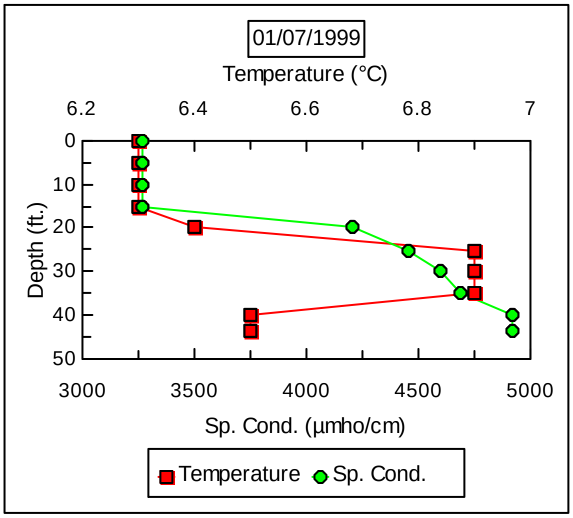

10/02/1998
Temperature (°C)
23.4 23.6 23.8 24 24.2
Depth (ft.)
0 10 20 30 40 50
0 2 4 6 8
D.O. (mg/L)
Temperature
D.O.

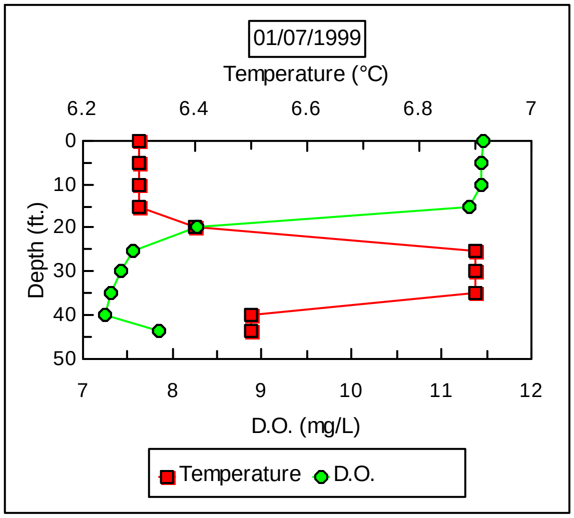

11/06/1998
Temperature (°C)
14.8 15.2 15.6 16 16.4
Depth (ft.)
0 10 20 30 40 50
1800 2000 2200 2400 2600 2800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

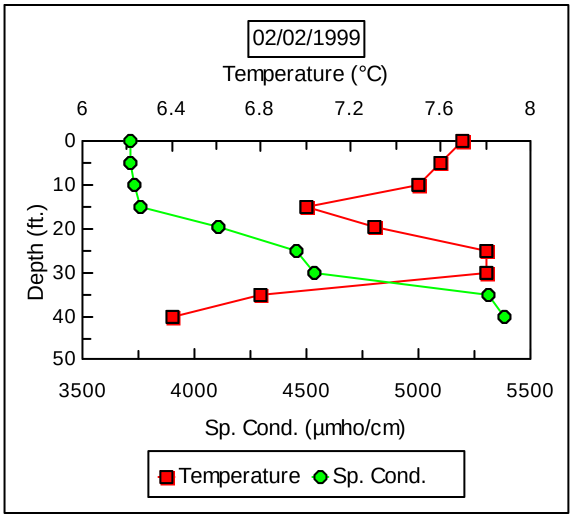

11/06/1998
Temperature (°C)
14.5 15 15.5 16 16.5
Depth (ft.)
0 10 20 30 40 50
3 4 5 6 7 8 9
D.O. (mg/L)
Temperature
D.O.

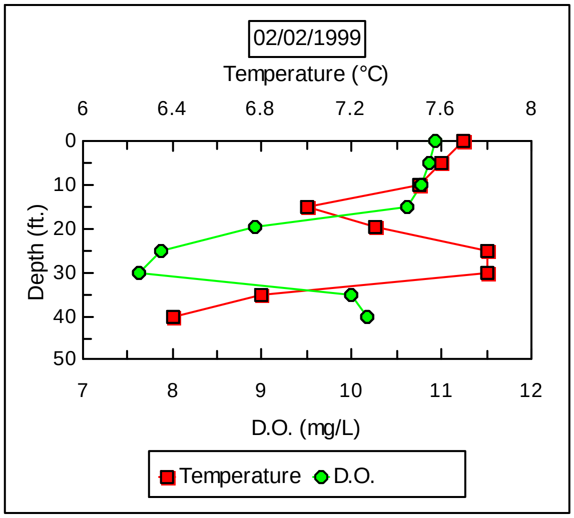

12/04/1998
Temperature (°C)
11.6
11.8
12
12.2
12.4
12.6
12.8
Depth (ft.)
0
10
20
30
40
50
2000
2500
3000
3500
4000
4500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

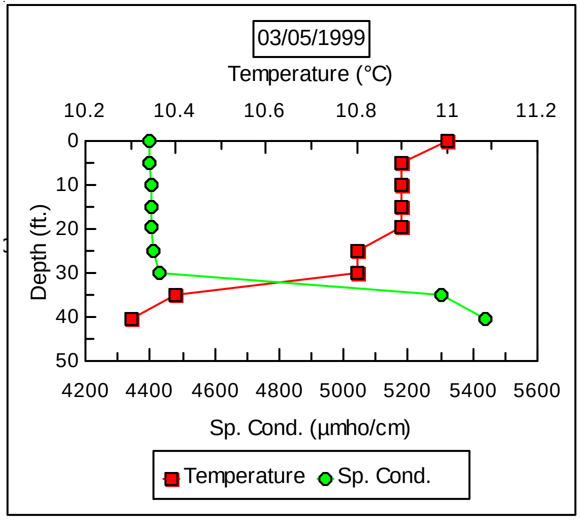

12/04/1998
Temperature (°C)
11.6
11.8
12
12.2
12.4
12.6
12.8
Depth (ft.)
0
10
20
30
40
50
4
6
8
10
12
D.O. (mg/L)
Temperature
D.O.

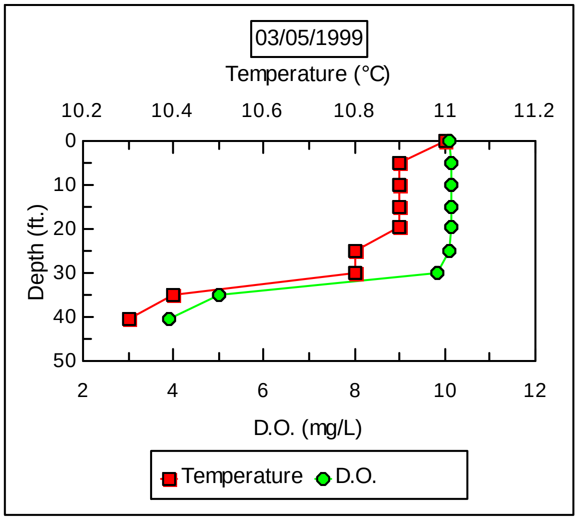

01/07/1999
Temperature (°C)
6.2
6.4
6.6
6.8
7
Depth (ft.)
0
10
20
30
40
50
3000
3500
4000
4500
5000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

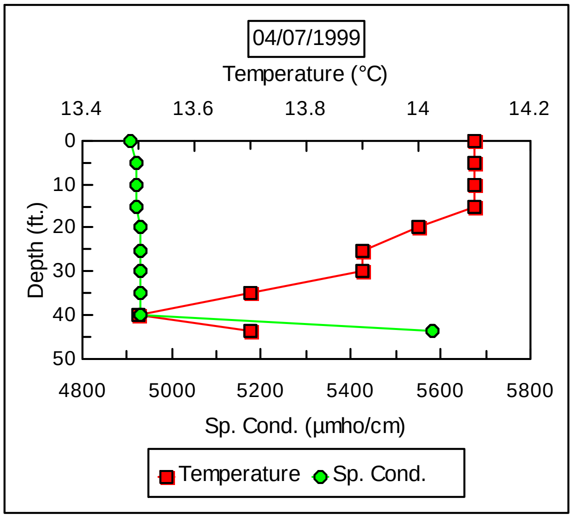

01/07/1999
Temperature (°C)
6.2
6.4
6.6
6.8
7
Depth (ft.)
0
10
20
30
40
50
7
8
9
10
11
12
D.O. (mg/L)
Temperature
D.O.

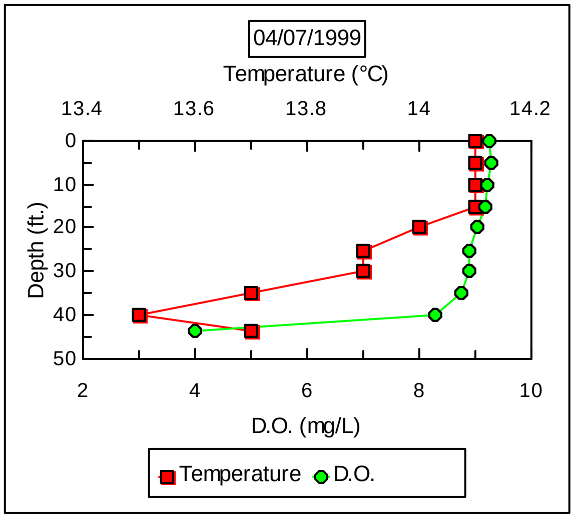

02/02/1999
Temperature (°C)
6
6.4
6.8
7.2
7.6
8
Depth (ft.)
0
10
20
30
40
50
3500
4000
4500
5000
5500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

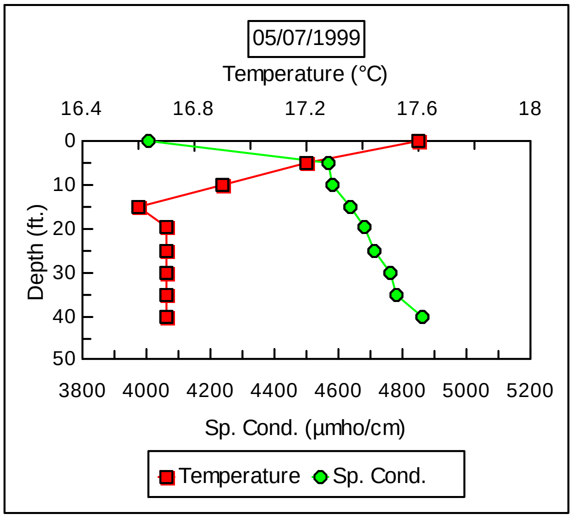

02/02/1999
Temperature (°C)
6
6.4
6.8
7.2
7.6
8
Depth (ft.)
0
10
20
30
40
50
7
8
9
10
11
12
D.O. (mg/L)
Temperature
D.O.

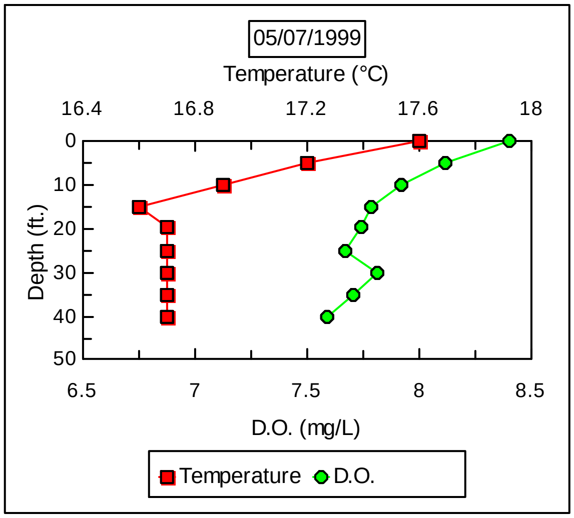

03/05/1999
Temperature (°C)
10.2
10.4
10.6
10.8
11
11.2
Depth (ft.)
0
10
20
30
40
50
4200
4400
4600
4800
5000
5200
5400
5600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

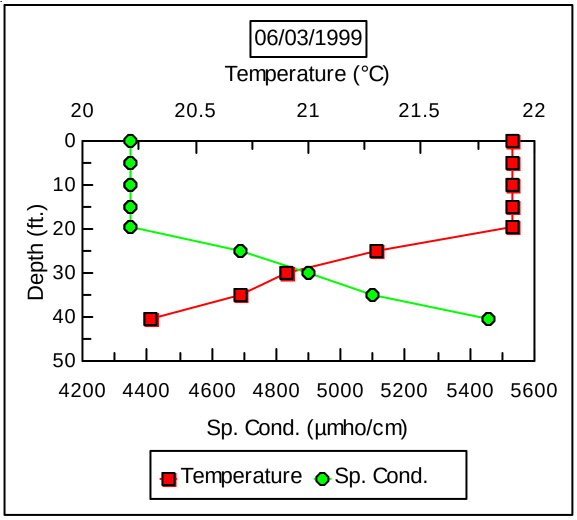

03/05/1999
Temperature (°C)
10.2
10.4
10.6
10.8
11
11.2
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
12
D.O. (mg/L)
Temperature
D.O.

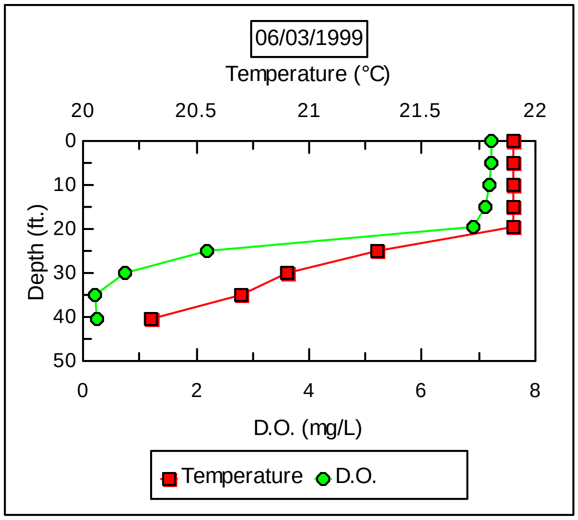

04/07/1999
Temperature (°C)
13.4
13.6
13.8
14
14.2
Depth (ft.)
0
10
20
30
40
50
4800
5000
5200
5400
5600
5800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

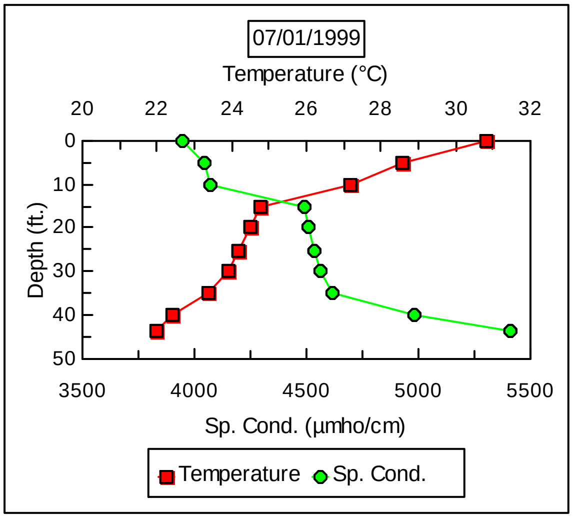

04/07/1999
Temperature (°C)
13.4
13.6
13.8
14
14.2
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

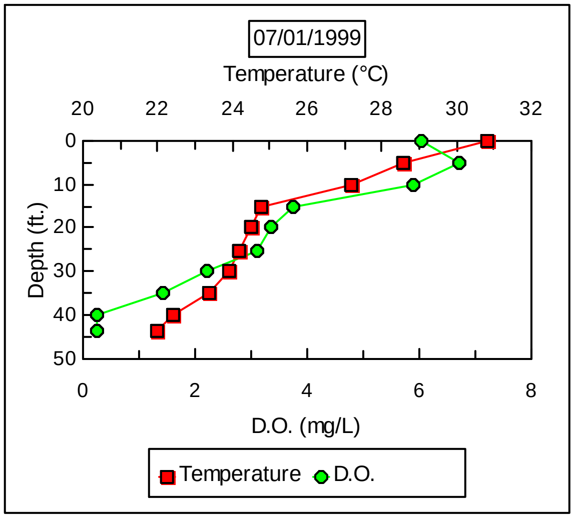

05/07/1999
Temperature (°C)
16.4
16.8
17.2
17.6
18
Depth (ft.)
0
10
20
30
40
50
3800
4000
4200
4400
4600
4800
5000
5200
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

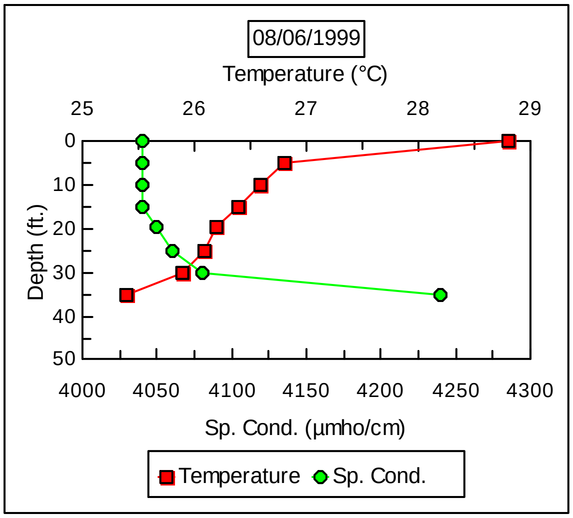

05/07/1999
Temperature (°C)
16.4
16.8
17.2
17.6
18
Depth (ft.)
0
10
20
30
40
50
6.5
7
7.5
8
8.5
D.O. (mg/L)
Temperature
D.O.

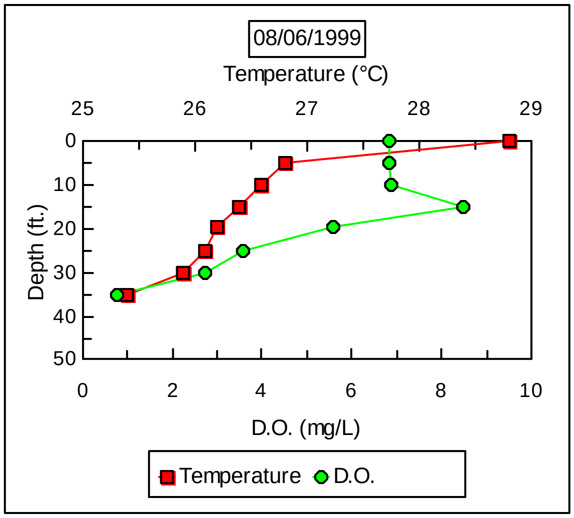

06/03/1999
Temperature (°C)
20
20.5
21
21.5
22
Depth (ft.)
0
10
20
30
40
50
4200
4400
4600
4800
5000
5200
5400
5600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

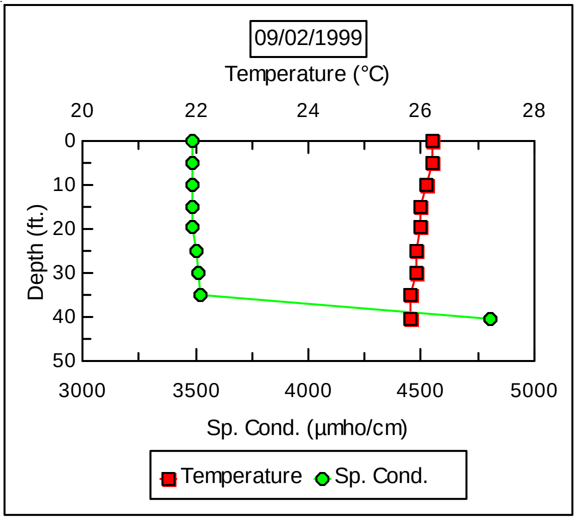

06/03/1999
Temperature (°C)
20
20.5
21
21.5
22
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

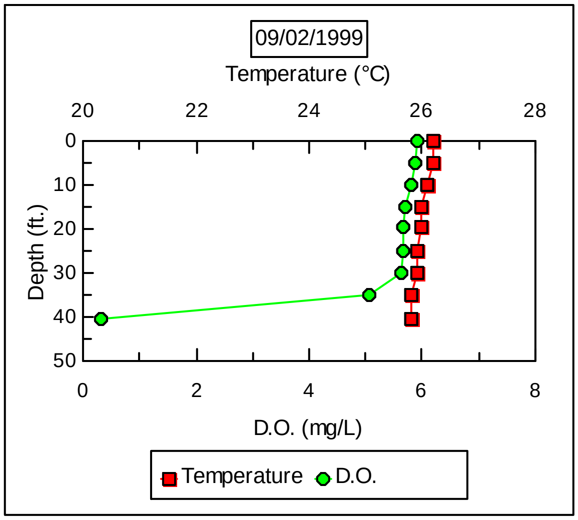

07/01/1999
Temperature (°C)
20
22
24
26
28
30
32
Depth (ft.)
0
10
20
30
40
50
3500
4000
4500
5000
5500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

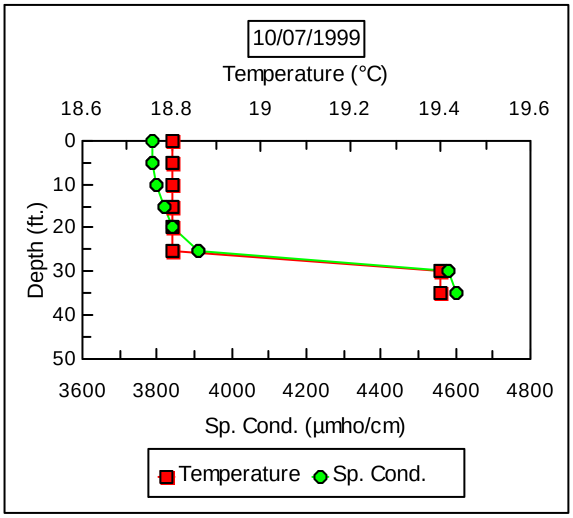

07/01/1999
Temperature (°C)
20
22
24
26
28
30
32
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

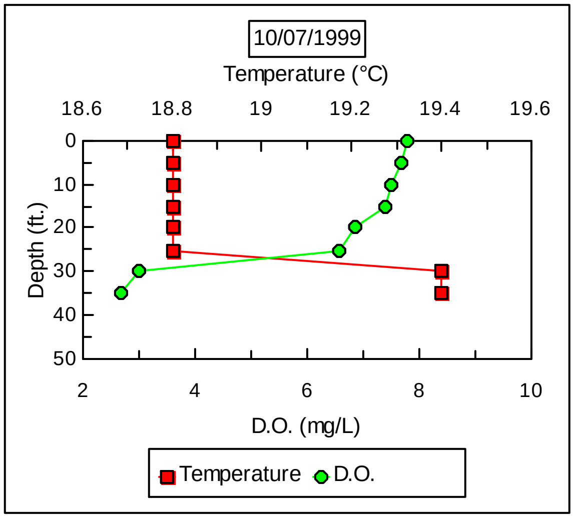

08/06/1999
Temperature (°C)
25
26
27
28
29
Depth (ft.)
0
10
20
30
40
50
4000
4050
4100
4150
4200
4250
4300
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

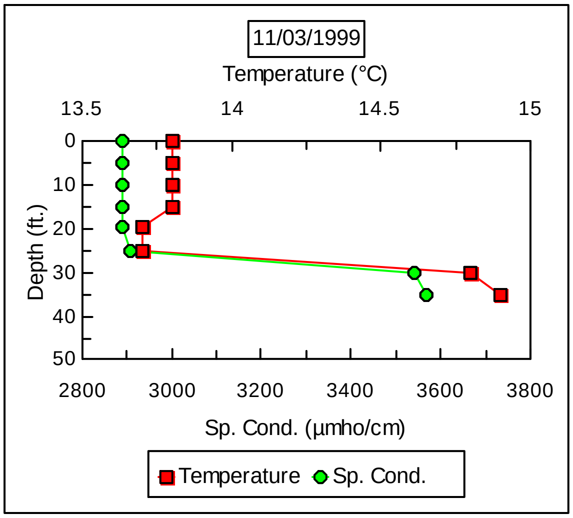

08/06/1999
Temperature (°C)
25
26
27
28
29
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

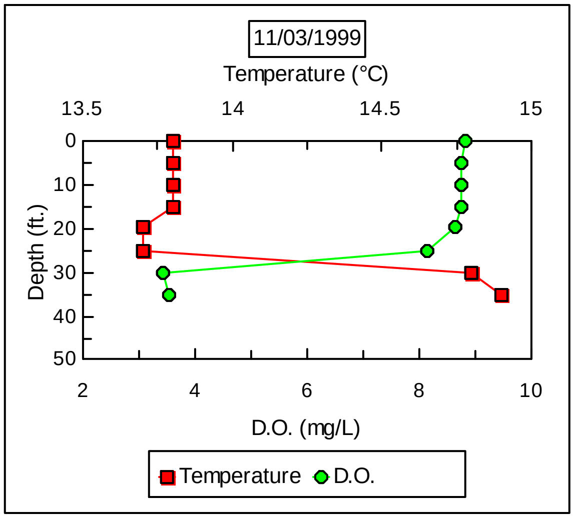

09/02/1999
Temperature (°C)
20
22
24
26
28
Depth (ft.)
0
10
20
30
40
50
3000
3500
4000
4500
5000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

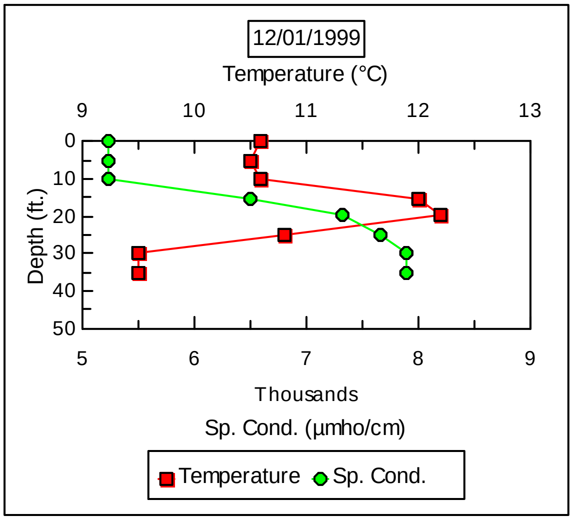

09/02/1999
Temperature (°C)
20
22
24
26
28
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

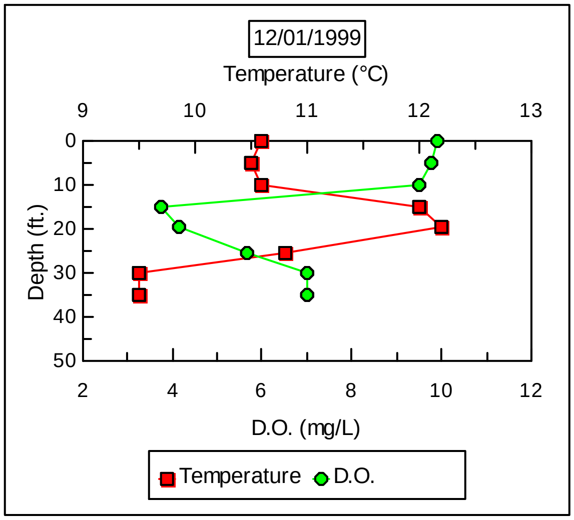

10/07/1999
Temperature (°C)
18.6
18.8
19
19.2
19.4
19.6
Depth (ft.)
0
10
20
30
40
50
3600
3800
4000
4200
4400
4600
4800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

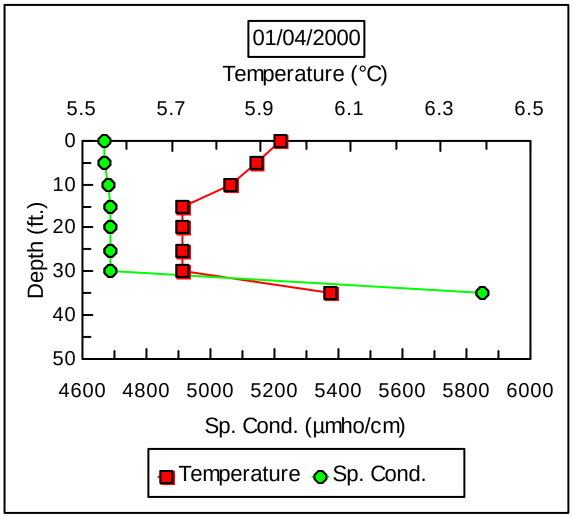

10/07/1999
Temperature (°C)
18.6
18.8
19
19.2
19.4
19.6
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

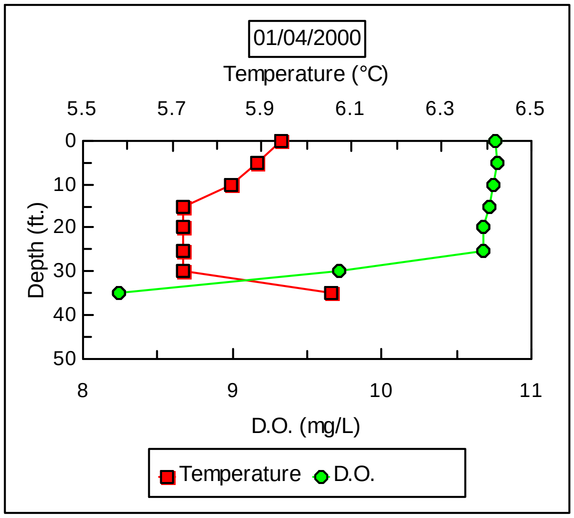

11/03/1999
Temperature (°C)
13.5
14
14.5
15
Depth (ft.)
0
10
20
30
40
50
2800
3000
3200
3400
3600
3800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

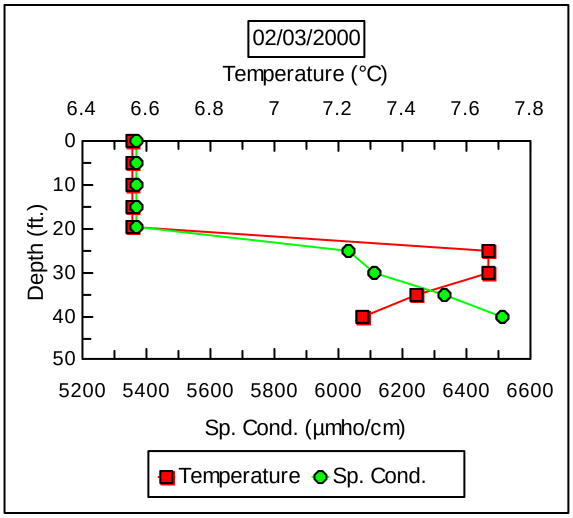

11/03/1999
Temperature (°C)
13.5
14
14.5
15
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

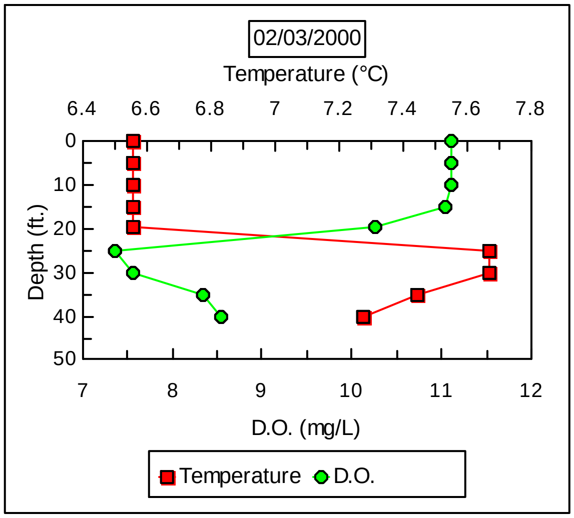

12/01/1999
Temperature (°C)
9
10
11
12
13
0
10
20
30
40
50
Depth (ft.)
5
6
7
8
9
Thousands
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

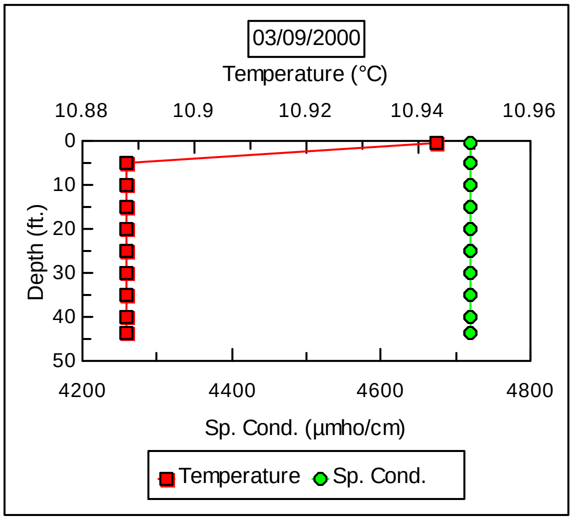

12/01/1999
Temperature (°C)
9
10
11
12
13
0
10
20
30
40
50
Depth (ft.)
2
4
6
8
10
12
D.O. (mg/L)
Temperature
D.O.

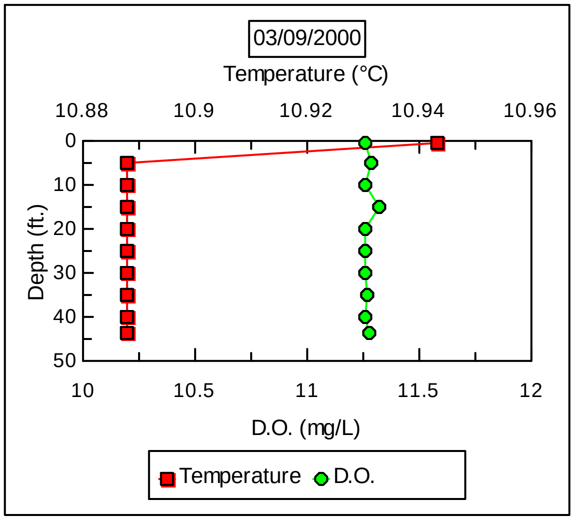

01/04/2000
Temperature (°C)
5.5
5.7
5.9
6.1
6.3
6.5
0
10
20
30
40
50
Depth (ft.)
4600
4800
5000
5200
5400
5600
5800
6000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

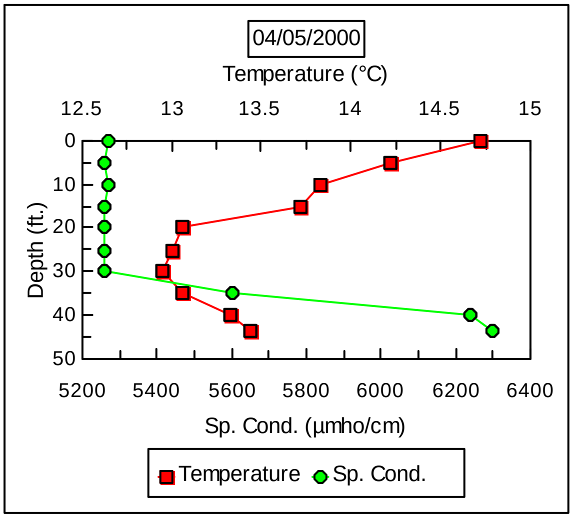

01/04/2000
Temperature (°C)
5.5
5.7
5.9
6.1
6.3
6.5
0
10
20
30
40
50
Depth (ft.)
8
9
10
11
D.O. (mg/L)
Temperature
D.O.

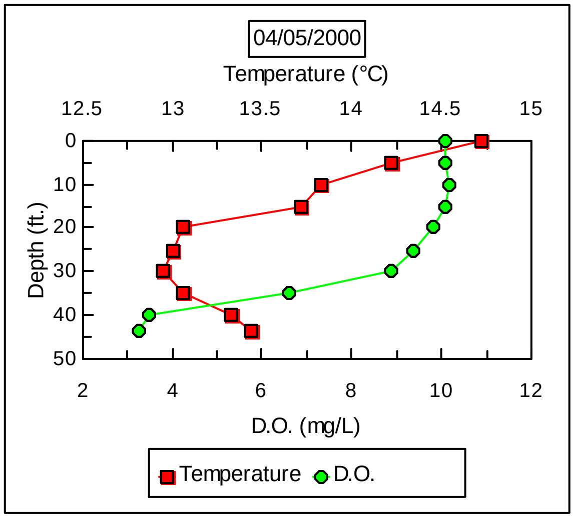

02/03/2000
Temperature (°C)
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
0
10
20
30
40
50
Depth (ft.)
5200
5400
5600
5800
6000
6200
6400
6600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

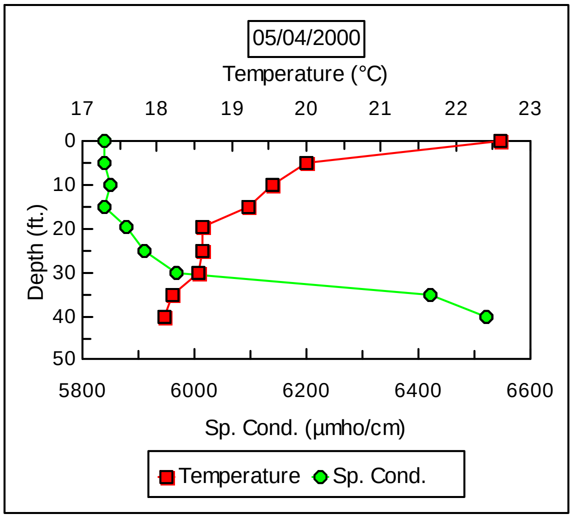

02/03/2000
Temperature (°C)
6.4
6.6
6.8
7
7.2
7.4
7.6
7.8
0
10
20
30
40
50
Depth (ft.)
7
8
9
10
11
12
D.O. (mg/L)
Temperature
D.O.

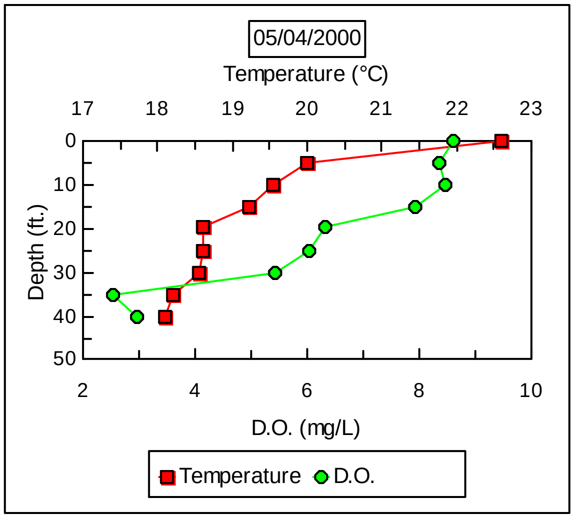

03/09/2000
Temperature (°C)
10.88
10.9
10.92
10.94
10.96
Depth (ft.)
0
10
20
30
40
50
4200
4400
4600
4800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

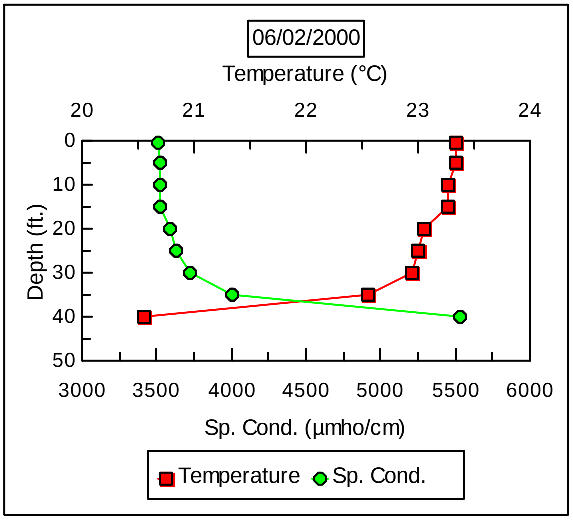

03/09/2000
Temperature (°C)
10.88
10.9
10.92
10.94
10.96
Depth (ft.)
0
10
20
30
40
50
10
10.5
11
11.5
12
D.O. (mg/L)
Temperature
D.O.

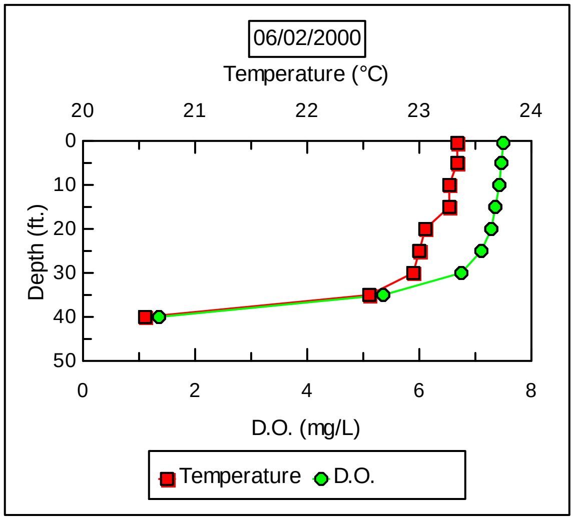

04/05/2000
Temperature (°C)
12.5
13
13.5
14
14.5
15
Depth (ft.)
0
10
20
30
40
50
5200
5400
5600
5800
6000
6200
6400
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

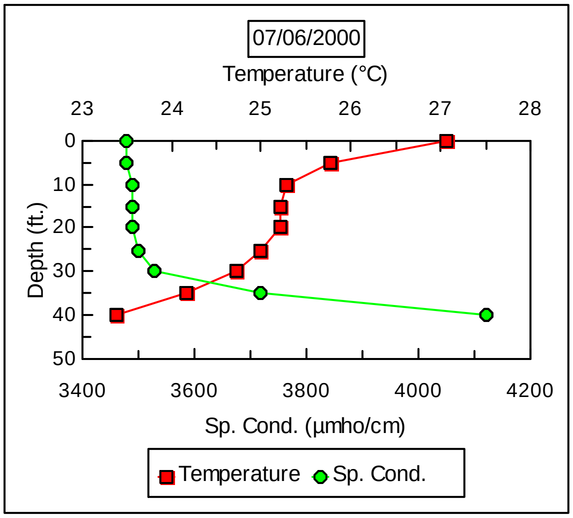

04/05/2000
Temperature (°C)
12.5
13
13.5
14
14.5
15
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
12
D.O. (mg/L)
Temperature
D.O.

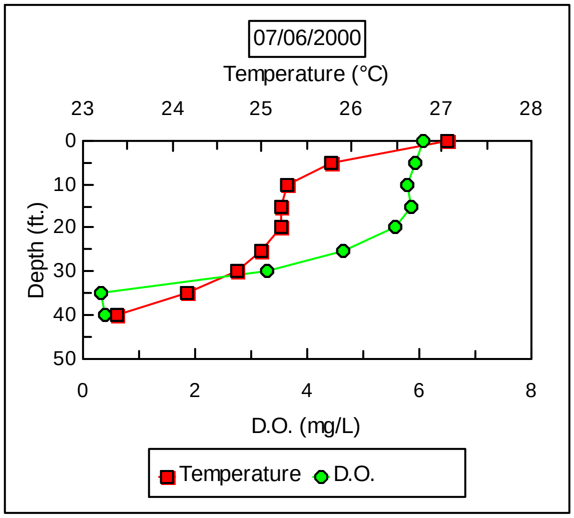

05/04/2000
Temperature (°C)
17
18
19
20
21
22
23
Depth (ft.)
0
10
20
30
40
50
5800
6000
6200
6400
6600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

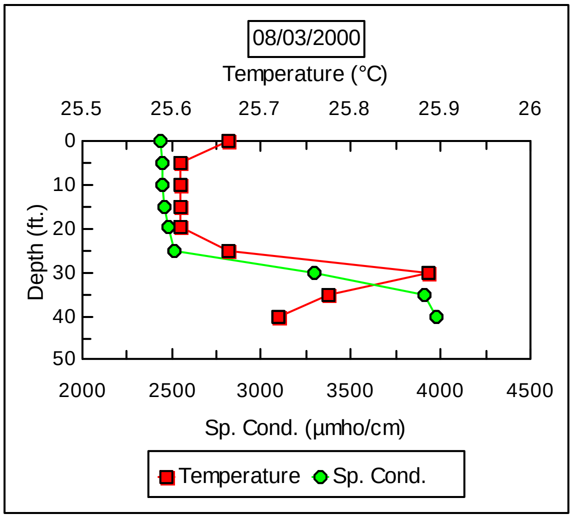

05/04/2000
Temperature (°C)
17
18
19
20
21
22
23
Depth (ft.)
0
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

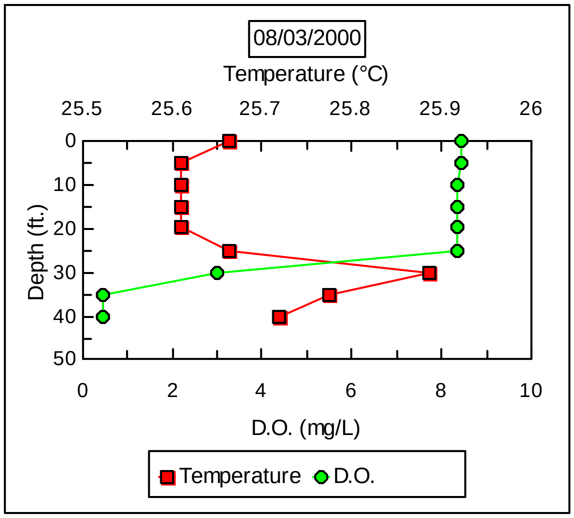

06/02/2000
Temperature (°C)
20
21
22
23
24
Depth (ft.)
0
10
20
30
40
50
3000
3500
4000
4500
5000
5500
6000
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

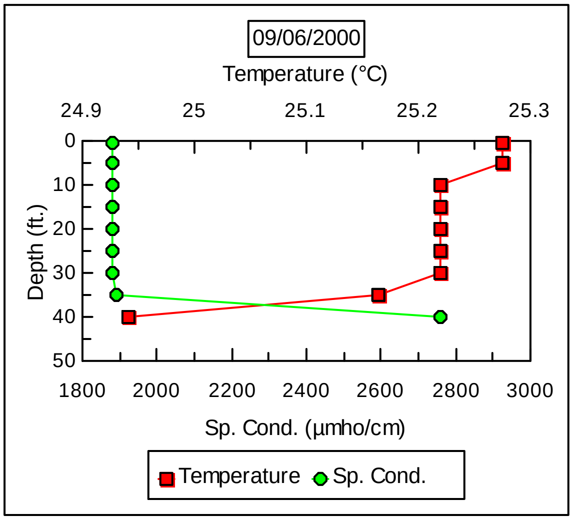

06/02/2000
Temperature (°C)
20
21
22
23
24
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

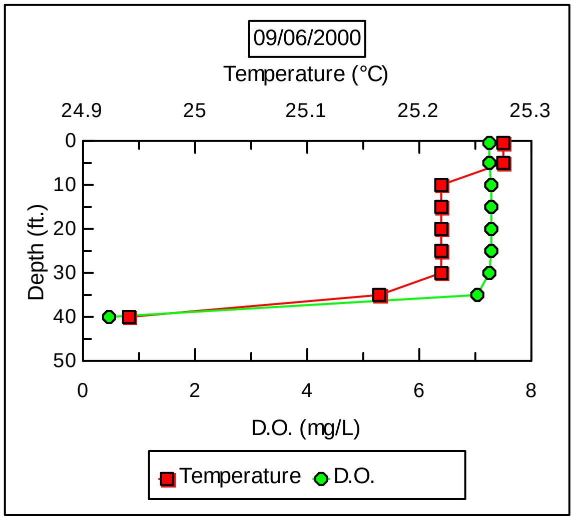

07/06/2000
Temperature (°C)
23
24
25
26
27
28
Depth (ft.)
0
10
20
30
40
50
3400
3600
3800
4000
4200
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

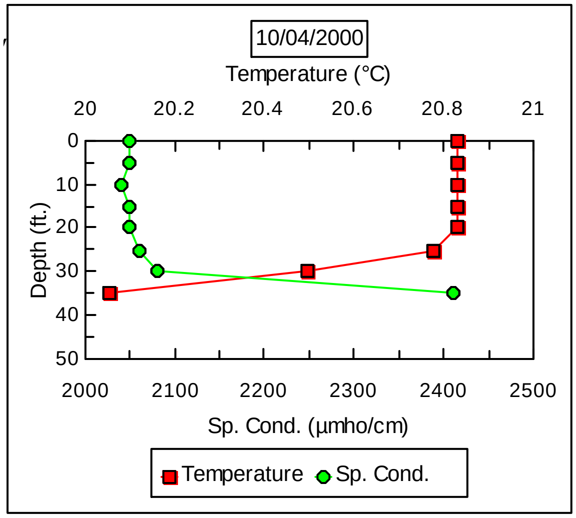

07/06/2000
Temperature (°C)
23
24
25
26
27
28
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.

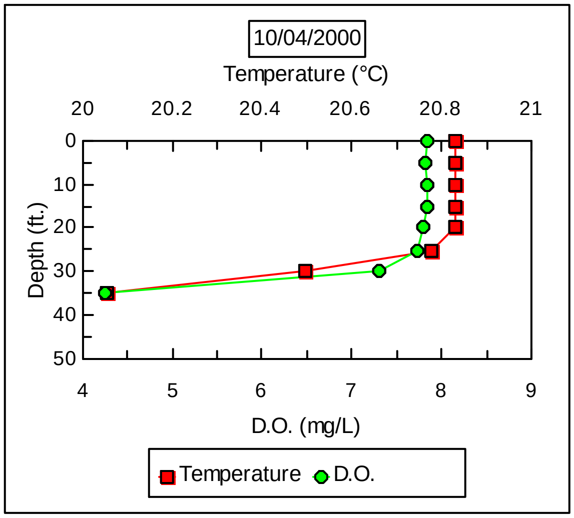

08/03/2000
Temperature (°C)
25.5
25.6
25.7
25.8
25.9
26
Depth (ft.)
0
10
20
30
40
50
2000
2500
3000
3500
4000
4500
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.

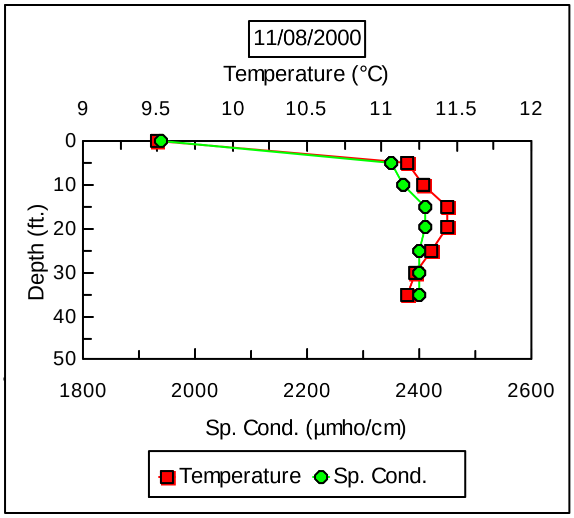

08/03/2000
Temperature (°C)
25.5
25.6
25.7
25.8
25.9
26
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.

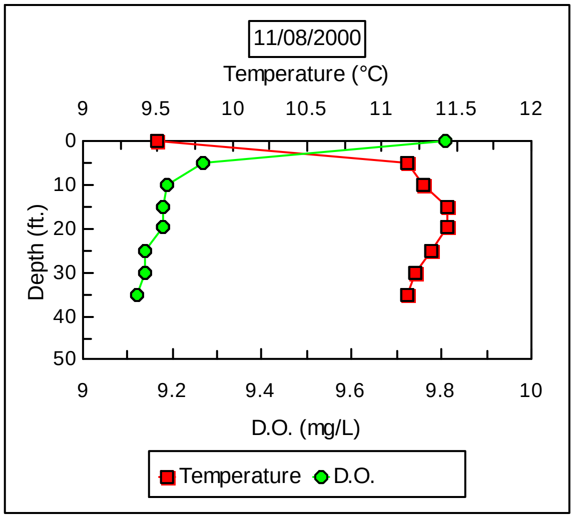

09/06/2000
Temperature (°C)
24.9
25
25.1
25.2
25.3
Depth (ft.)
0
10
20
30
40
50
1800
2000
2200
2400
2600
2800
3000
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

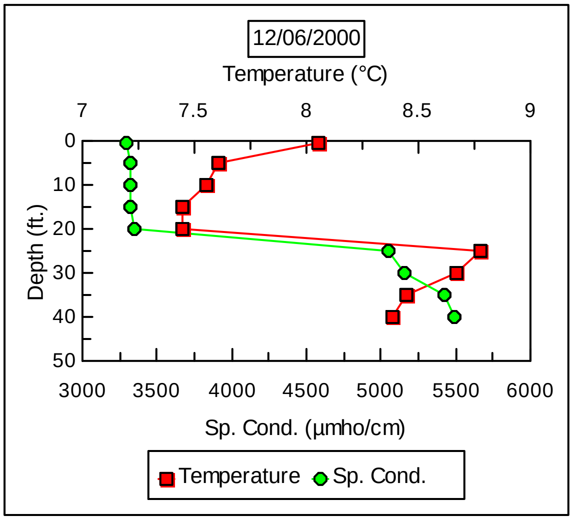

09/06/2000
Temperature (°C)
24.9
25
25.1
25.2
25.3
Depth (ft.)
0
10
20
30
40
50
0
2
4
6
8
D.O. (mg/L)
🟥 Temperature ● D.O.

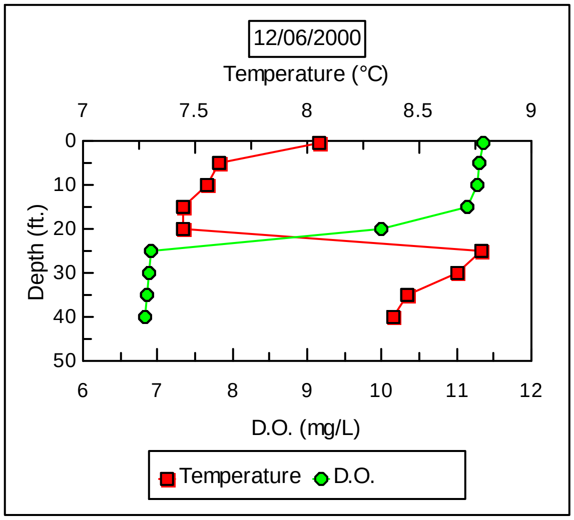

10/04/2000
Temperature (°C)
20
20.2
20.4
20.6
20.8
21
Depth (ft.)
0
10
20
30
40
50
2000
2100
2200
2300
2400
2500
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

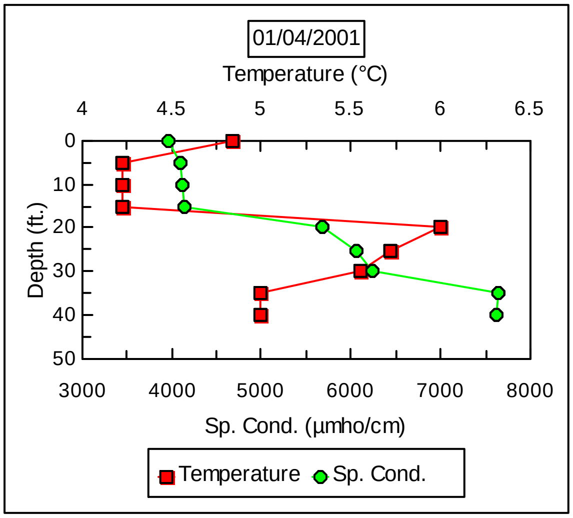

10/04/2000
Temperature (°C)
20
20.2
20.4
20.6
20.8
21
Depth (ft.)
0
10
20
30
40
50
4
5
6
7
8
9
D.O. (mg/L)
🟥 Temperature ● D.O.

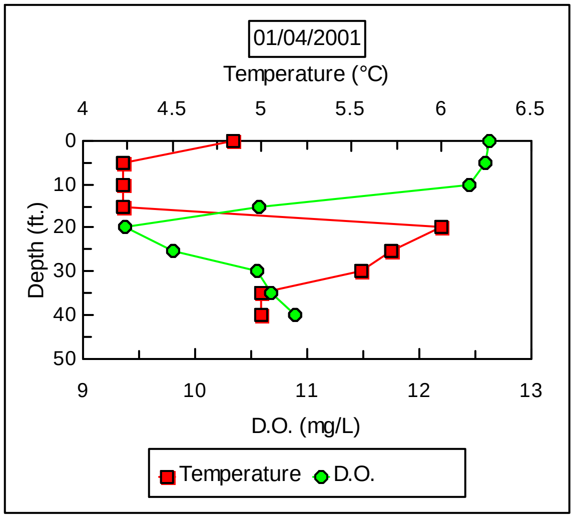

11/08/2000
Temperature (°C)
9
9.5
10
10.5
11
11.5
12
Depth (ft.)
0
10
20
30
40
50
1800
2000
2200
2400
2600
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

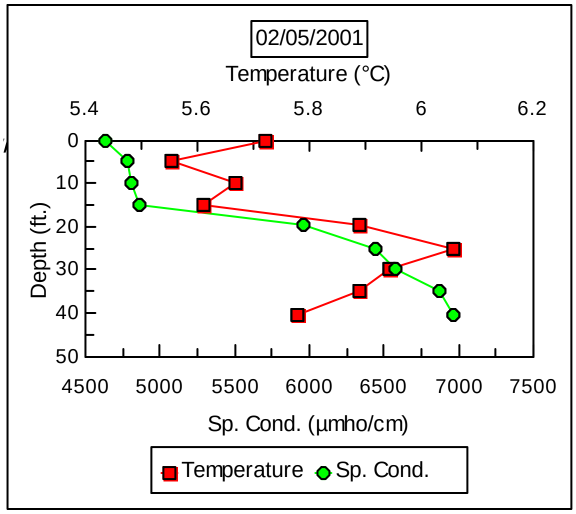

11/08/2000
Temperature (°C)
9
9.5
10
10.5
11
11.5
12
Depth (ft.)
0
10
20
30
40
50
9
9.2
9.4
9.6
9.8
10
D.O. (mg/L)
🟥 Temperature ● D.O.

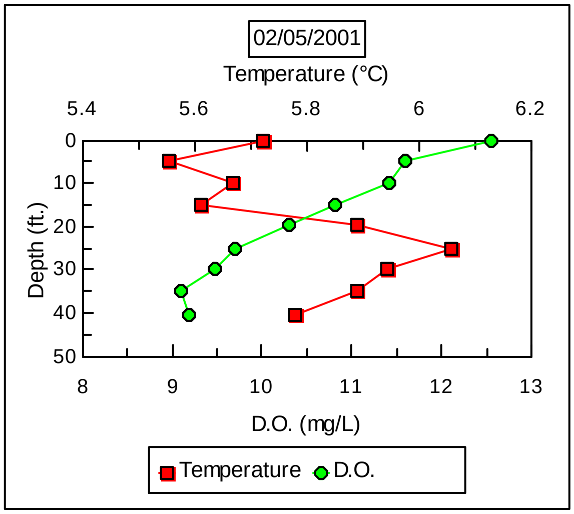

12/06/2000
Temperature (°C)
7
7.5
8
8.5
9
Depth (ft.)
0
10
20
30
40
50
3000
3500
4000
4500
5000
5500
6000
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

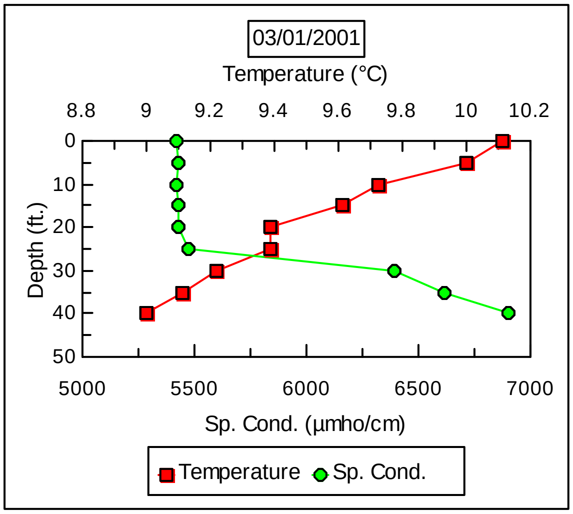

12/06/2000
Temperature (°C)
7
7.5
8
8.5
9
Depth (ft.)
0
10
20
30
40
50
6
7
8
9
10
11
12
D.O. (mg/L)
🟥 Temperature ● D.O.

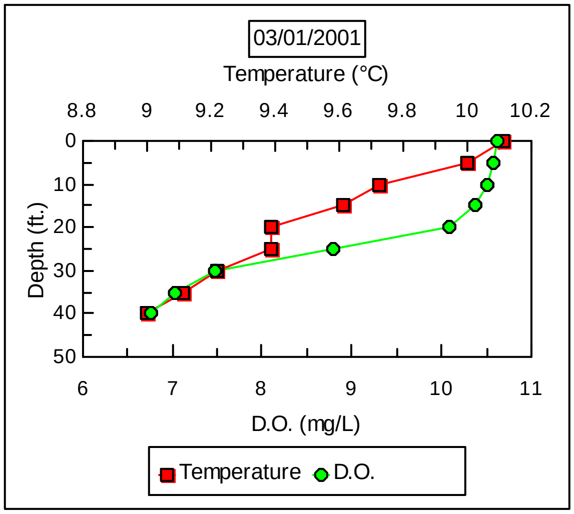

01/04/2001
Temperature (°C)
4
4.5
5
5.5
6
6.5
Depth (ft.)
0
10
20
30
40
50
3000
4000
5000
6000
7000
8000
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

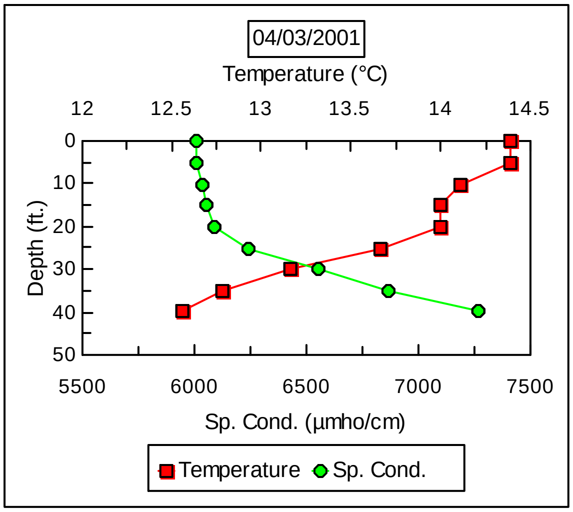

01/04/2001
Temperature (°C)
4
4.5
5
5.5
6
6.5
Depth (ft.)
0
10
20
30
40
50
9
10
11
12
13
D.O. (mg/L)
🟥 Temperature ● D.O.

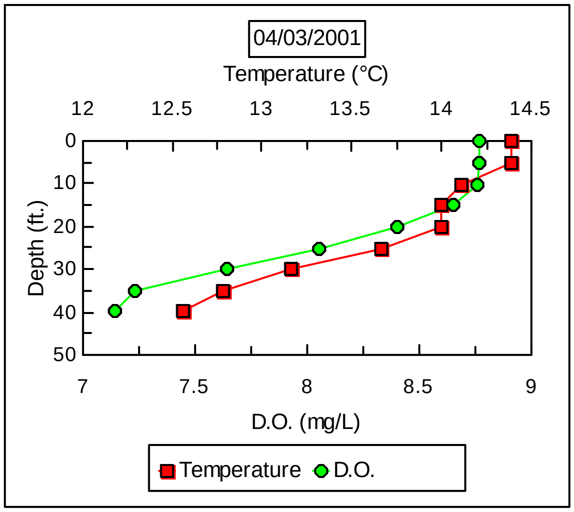

02/05/2001
Temperature (°C)
5.4
5.6
5.8
6
6.2
Depth (ft.)
0
10
20
30
40
50
4500
5000
5500
6000
6500
7000
7500
Sp. Cond. (µmho/cm)
🟥 Temperature ● Sp. Cond.

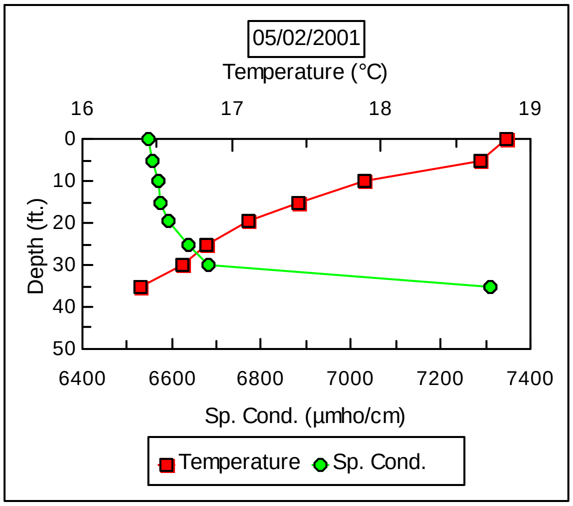

02/05/2001
Temperature (°C)
5.4
5.6
5.8
6
6.2
Depth (ft.)
0
10
20
30
40
50
8
9
10
11
12
13
D.O. (mg/L)
🟥 Temperature ● D.O.

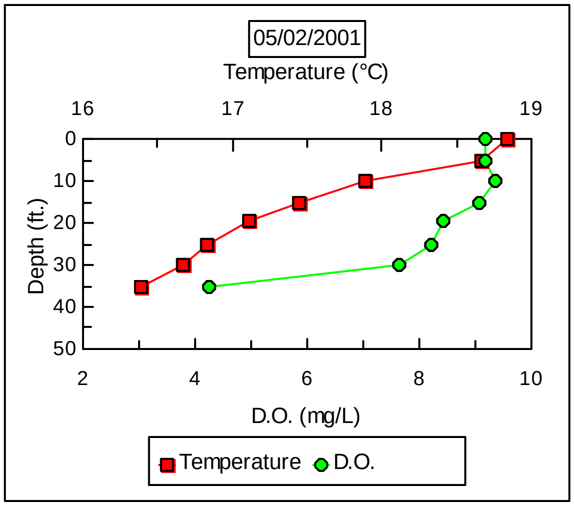

03/01/2001
Temperature (°C)
8.8
9
9.2
9.4
9.6
9.8
10
10.2
Depth (ft.)
0
10
20
30
40
50
5000
5500
6000
6500
7000
Sp. Cond. (µmho/cm)
🟥 Temperature
● Sp. Cond.


03/01/2001
Temperature (°C)
8.8
9
9.2
9.4
9.6
9.8
10
10.2
Depth (ft.)
0
10
20
30
40
50
6
7
8
9
10
11
D.O. (mg/L)
🟥 Temperature
● D.O.


04/03/2001
Temperature (°C)
12
12.5
13
13.5
14
14.5
Depth (ft.)
0
10
20
30
40
50
5500
6000
6500
7000
7500
Sp. Cond. (µmho/cm)
🟥 Temperature
● Sp. Cond.


04/03/2001
Temperature (°C)
12
12.5
13
13.5
14
14.5
Depth (ft.)
0
10
20
30
40
50
7
7.5
8
8.5
9
D.O. (mg/L)
🟥 Temperature
● D.O.


05/02/2001
Temperature (°C)
16
17
18
19
Depth (ft.)
0
10
20
30
40
50
6400
6600
6800
7000
7200
7400
Sp. Cond. (µmho/cm)
🟥 Temperature
● Sp. Cond.


05/02/2001
Temperature (°C)
16
17
18
19
Depth (ft.)
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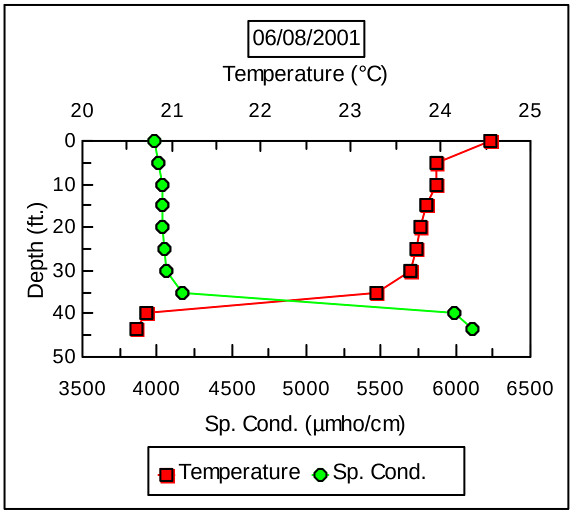
10
20
30
40
50
2
4
6
8
10
D.O. (mg/L)
🟥 Temperature
● D.O.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23
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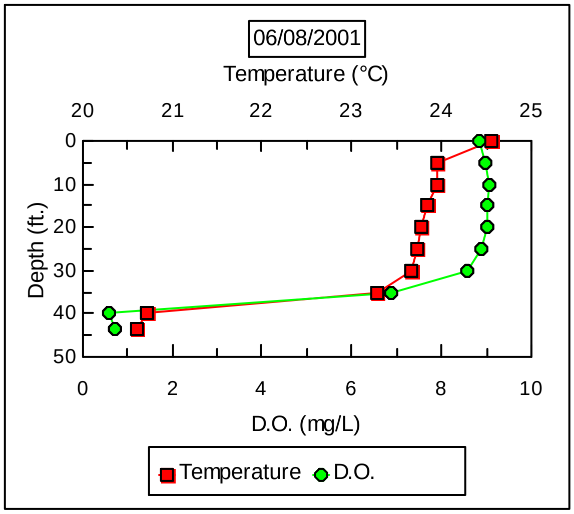
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.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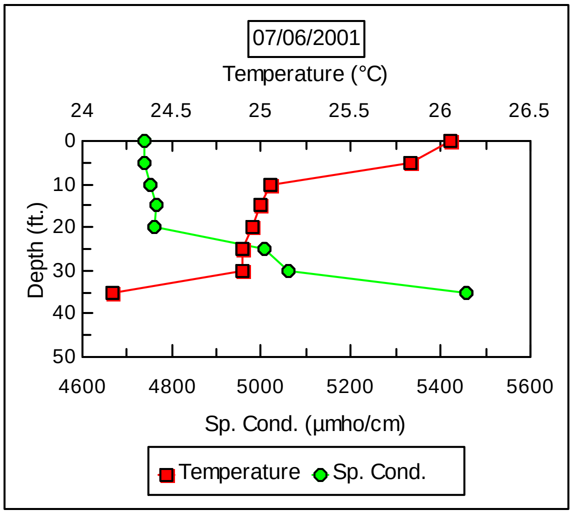
Temperature
D.O.


07/06/2001
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25
25.5
26
26.5
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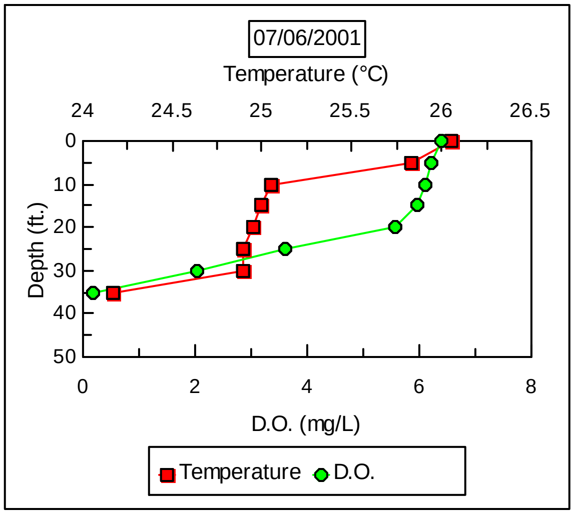
4600
4800
5000
5200
5400
5600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


07/06/2001
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25.5
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26.5
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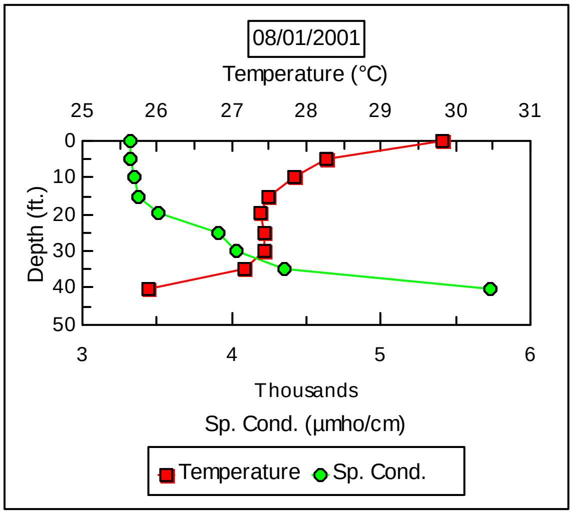
40
50
0
2
4
6
8
D.O. (mg/L)
Temperature
D.O.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27
28
29
30
31
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30
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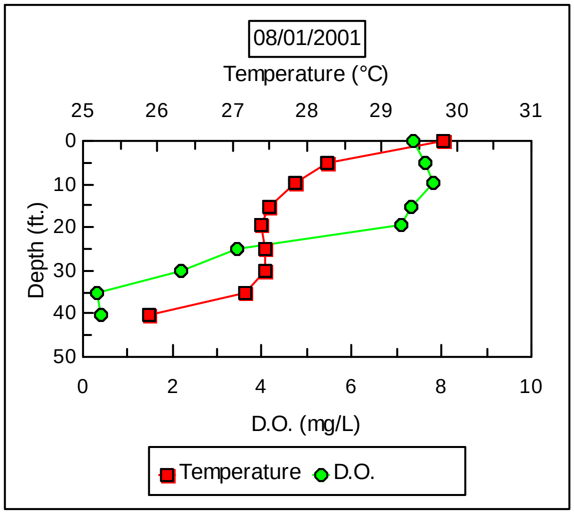
3
4
5
6
Thousands
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.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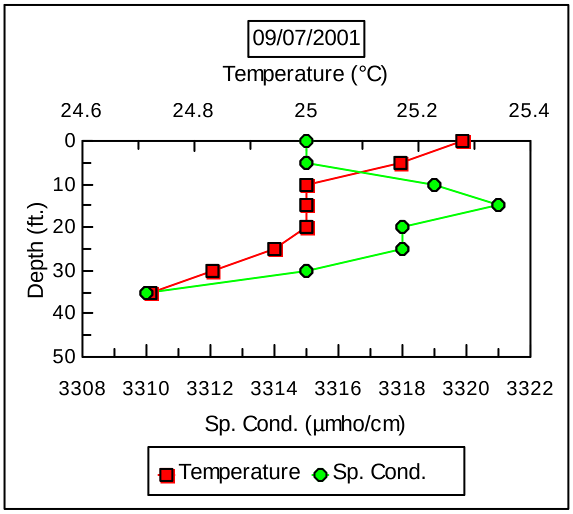
4
6
8
10
D.O. (mg/L)
Temperature
D.O.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25
25.2
25.4
Depth (ft.)
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10
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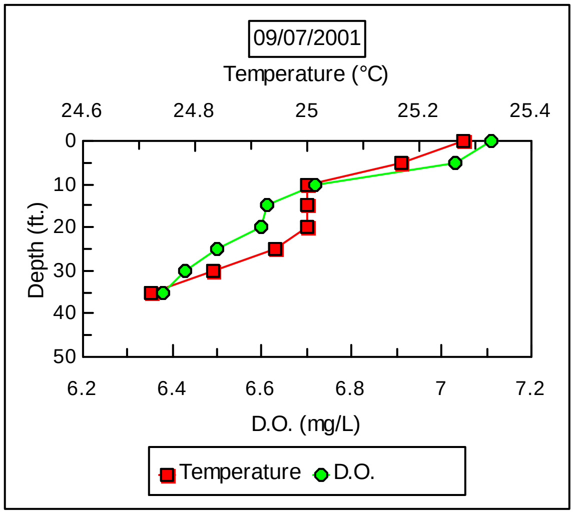
3312
3314
3316
3318
3320
3322
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


09/07/2001
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Depth (ft.)
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10
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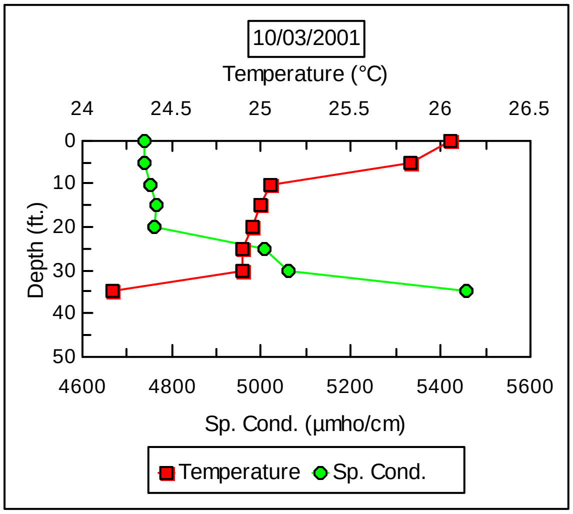
6.6
6.8
7
7.2
D.O. (mg/L)
Temperature
D.O.


10/03/2001
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26.5
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20
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50
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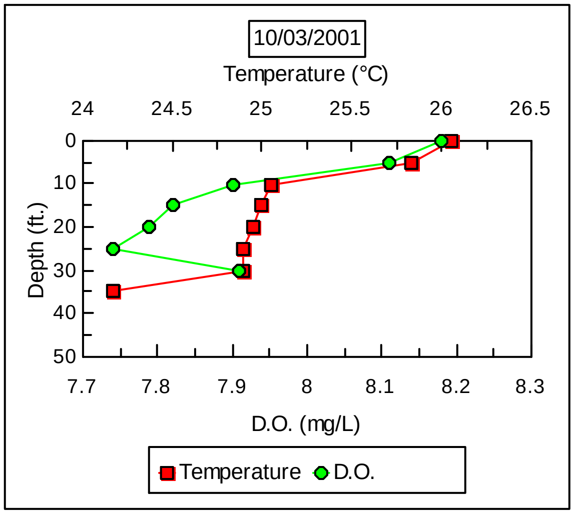
5000
5200
5400
5600
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.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26.5
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7.9
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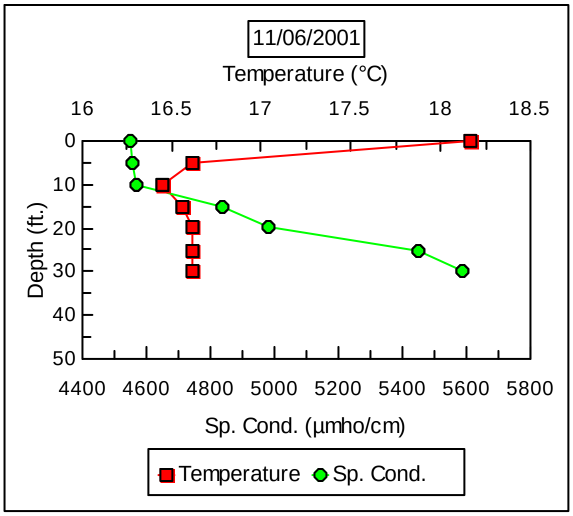
8.1
8.2
8.3
D.O. (mg/L)
Temperature
D.O.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17
17.5
18
18.5
Depth (ft.)
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10
20
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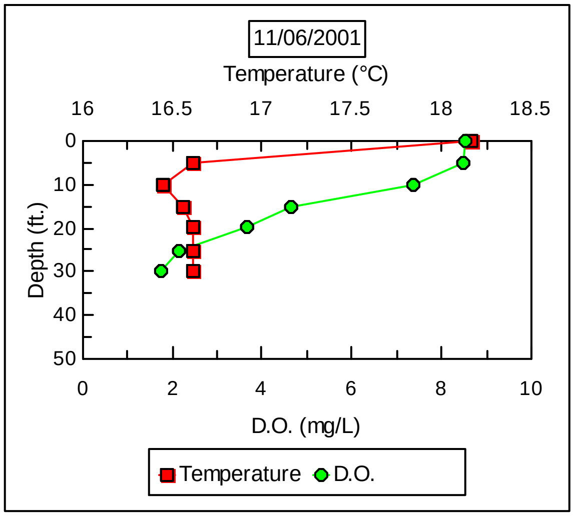
40
50
4400
4600
4800
5000
5200
5400
5600
5800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


11/06/2001
Temperature (°C)
16
16.5
17
17.5
18
18.5
Depth (ft.)
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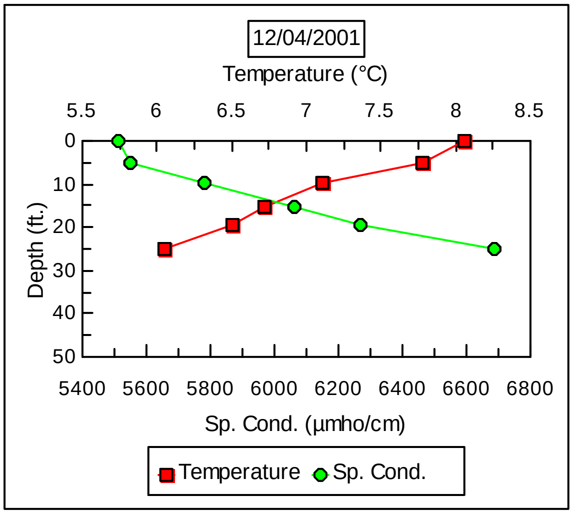
30
40
50
0
2
4
6
8
10
D.O. (mg/L)
Temperature
D.O.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6.5
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7.5
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8.5
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5800
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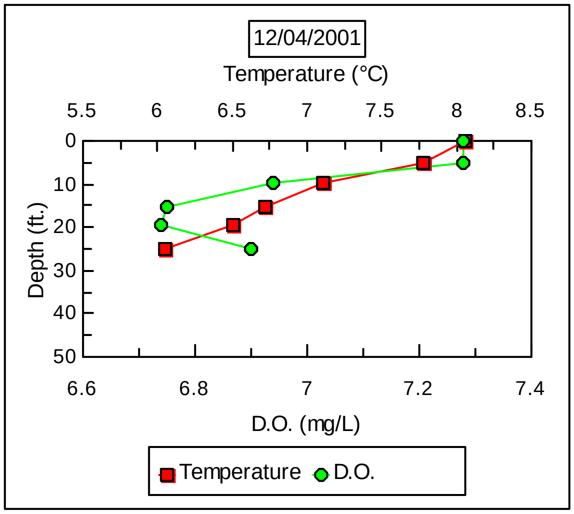
6800
Sp. Cond. (µmho/cm)
Temperature
Sp. Cond.


12/04/2001
Temperature (°C)
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6
6.5
7
7.5
8
8.5
Depth (ft.)
0
10
20
30
40
50
6.6
6.8
7
7.2
7.4
D.O. (mg/L)
Temperature
D.O.

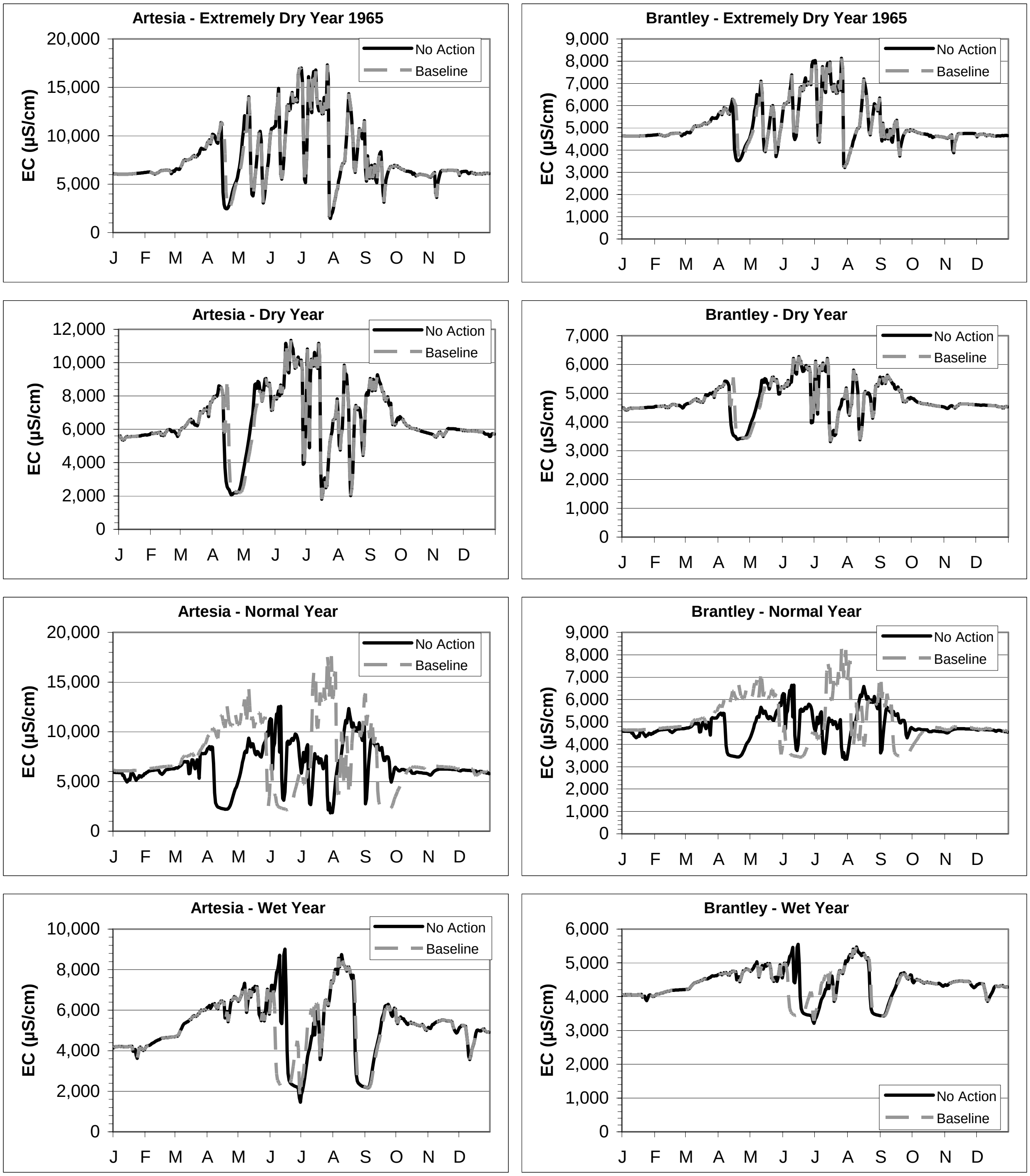
ATTACHMENT 4

DRY, NORMAL, AND WET YEAR EC PLOTS

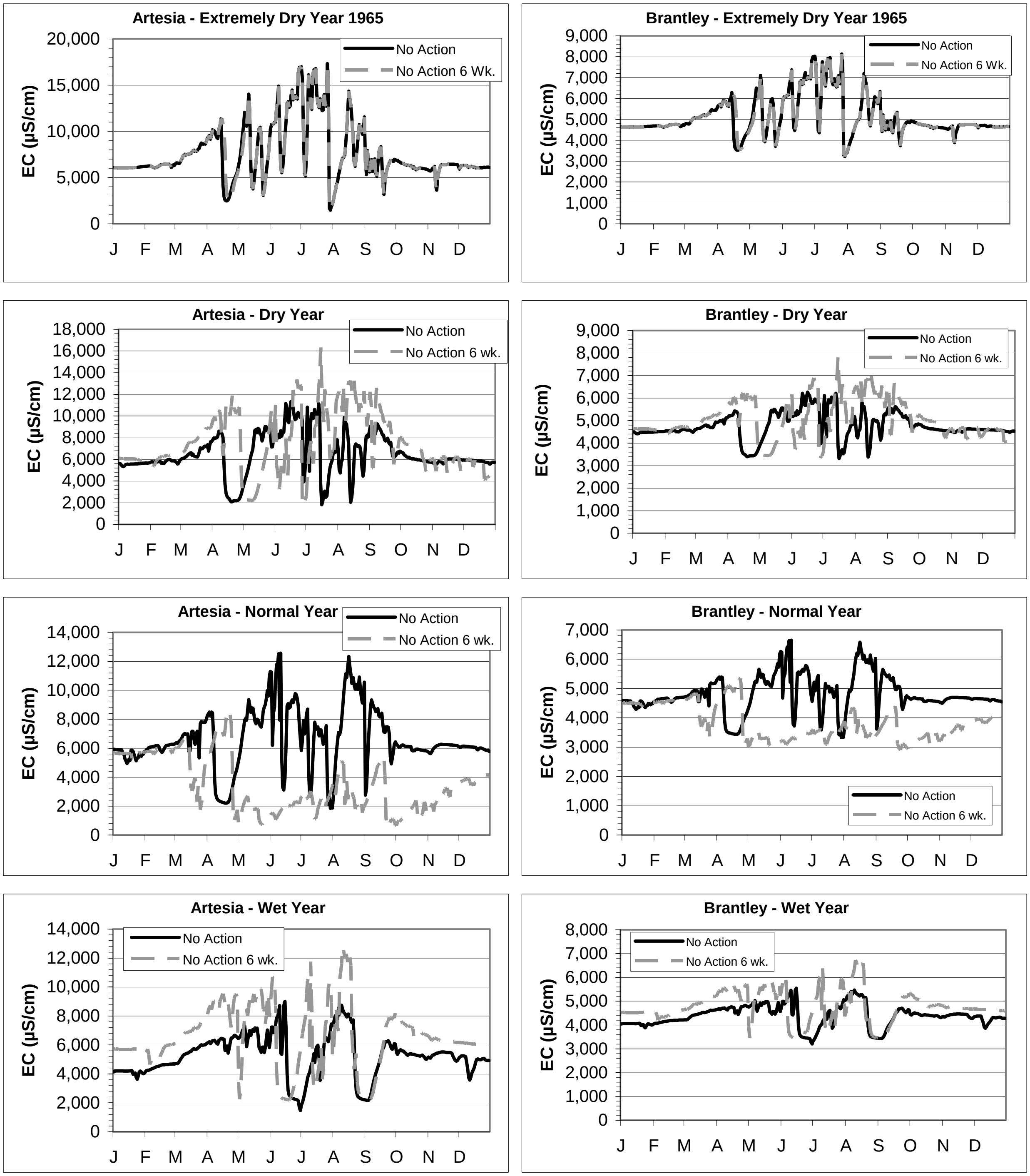
Breakdown of dry, normal, and wet years by alternative based on Effective Brantley Storage (EBS)			
Alternative	Dry Years	Normal Years	Wet Years
Pre-1991 baseline	19	21	20
No Action	22	24	14
No Action w/6week	23	23	14
Taiban Constant	24	19	17
Taiban Variable (40 cfs)	25	18	17
Taiban Variable (45 cfs)	25	17	18
Taiban Variable (55 cfs)	23	19	18
Acme Constant	25	24	11
Acme Variable	23	25	12
Critical Habitat	24	19	17

EBS = Avalon storage + Brantley storage + (0.75 x Sumner storage) + (0.65 x Santa Rosa storage)

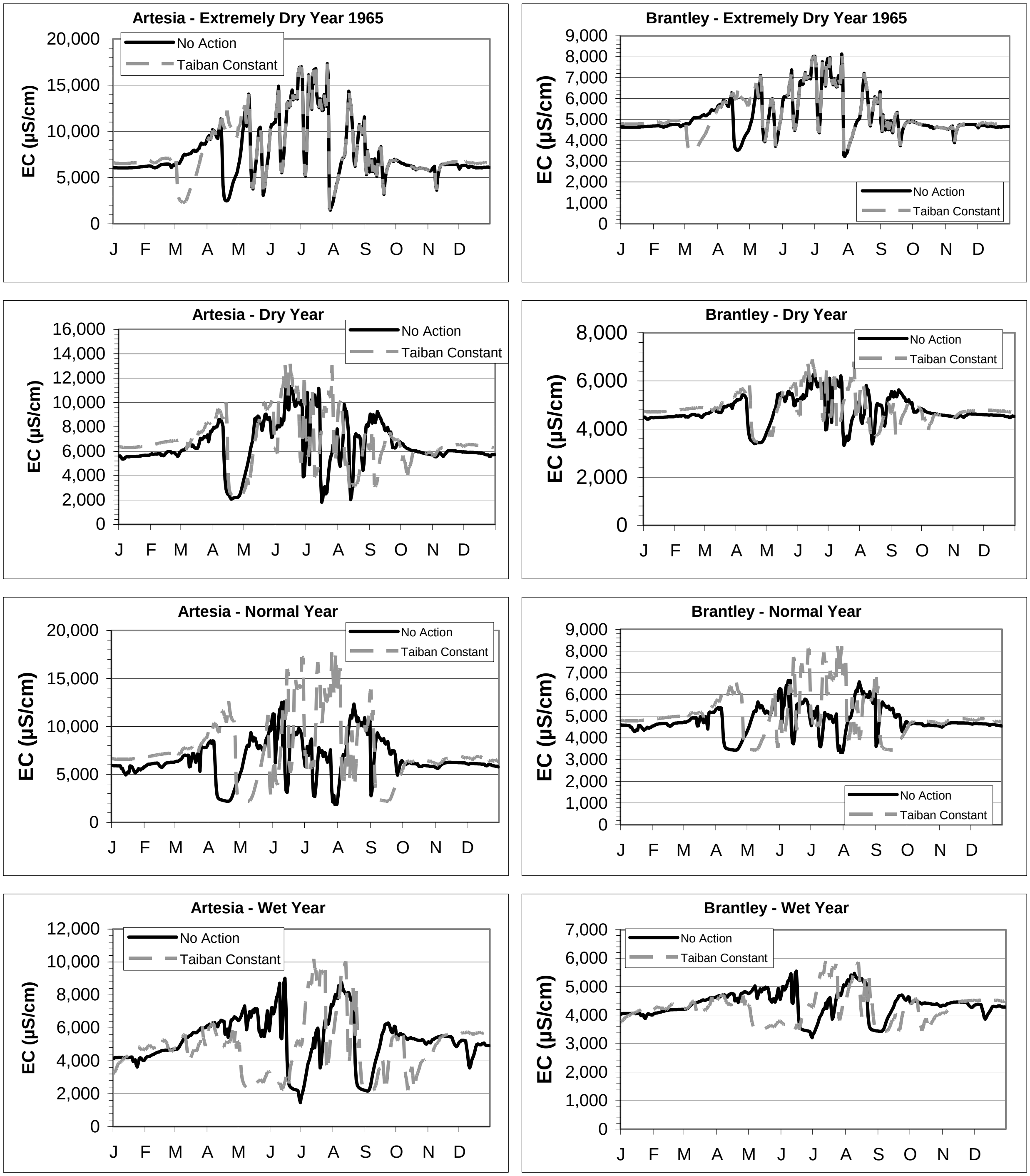
Classification:
Dry Hydrologic Condition – EBS < 75,000 acre-feet
Average (Normal) Hydrologic Condition – EBS > 75,000 & < 110,000 acre-feet
Wet Hydrologic Condition – EBS > 110,000 acre-feet



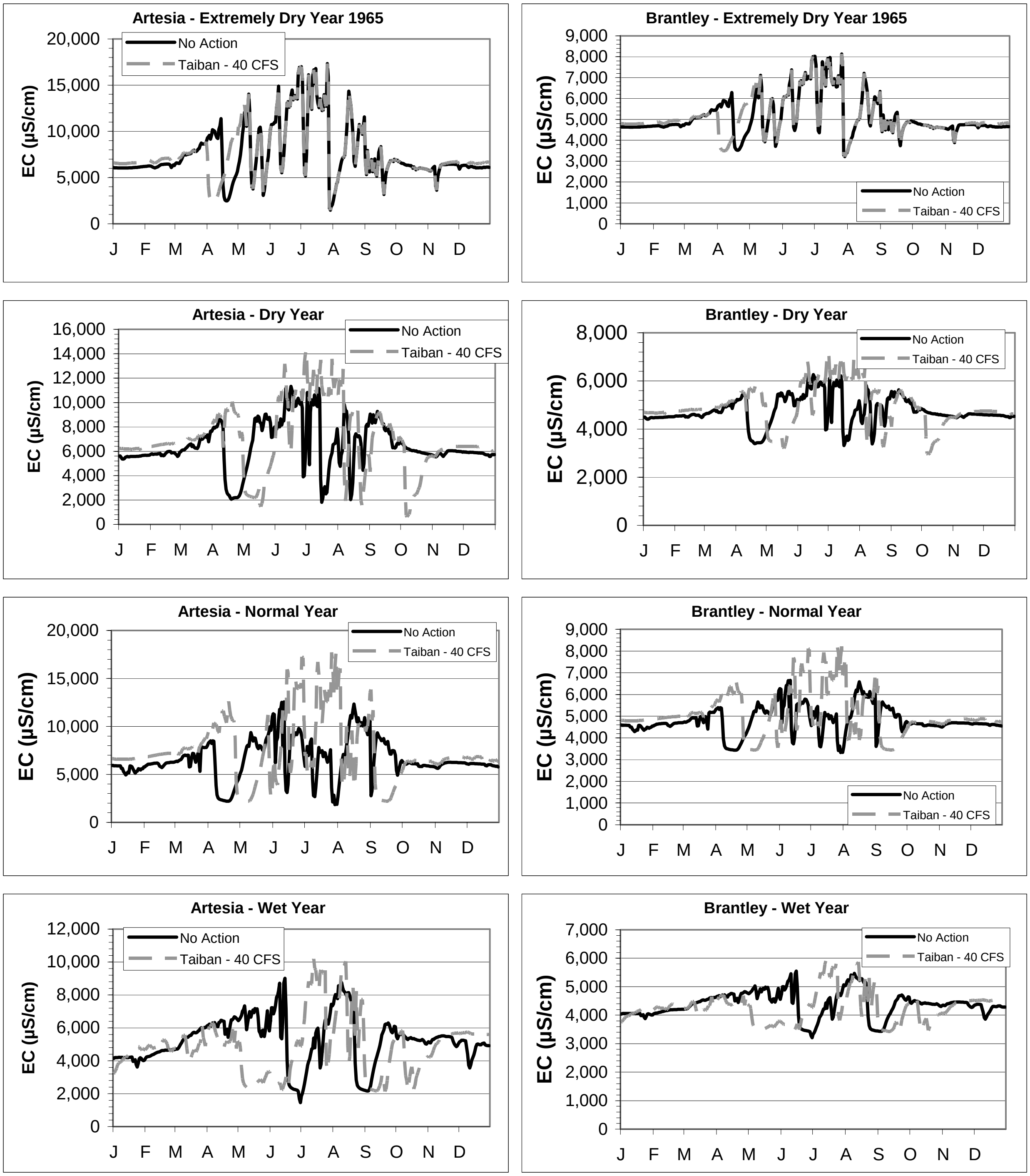
Comparison of the projected daily EC for the pre-1991 Baseline and the No Action Alternative (present condition) at the near Artesia and below Brantley gages in each of 4 EBS year-types



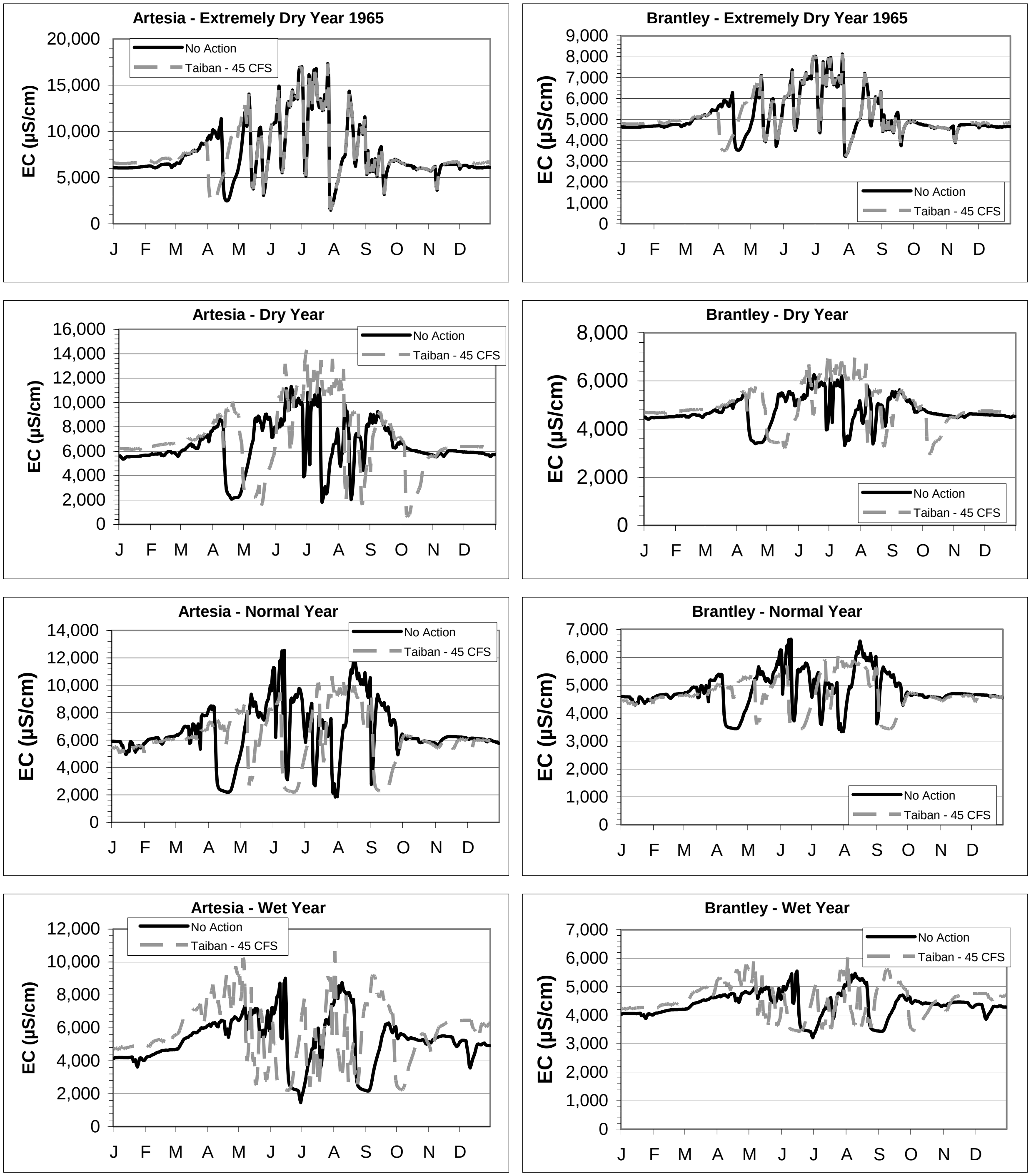
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the No Action with the 6-week limitation on block releases at the near Artesia and below Brantley gages in each of 4 EBS year-types



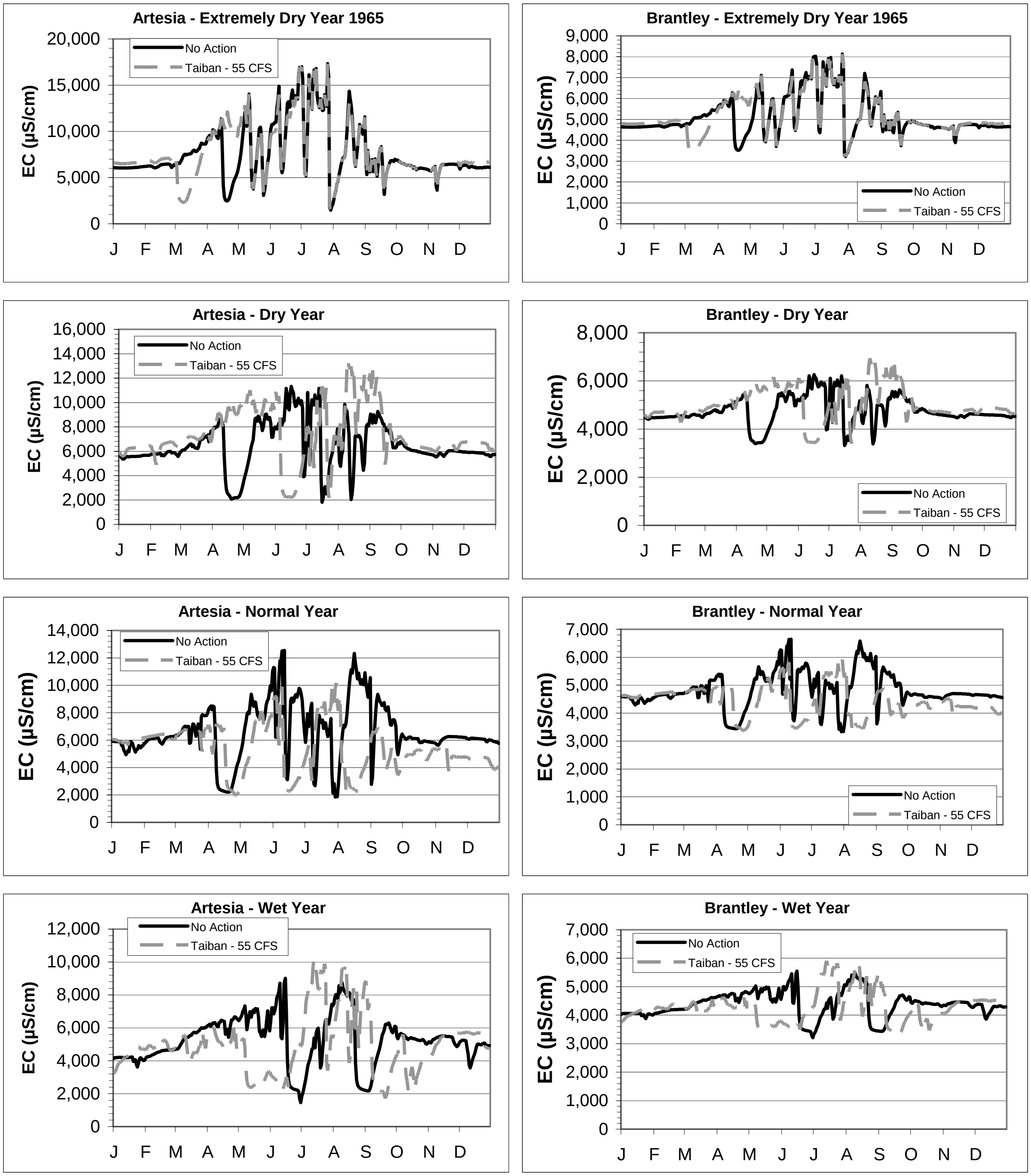
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Constant Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



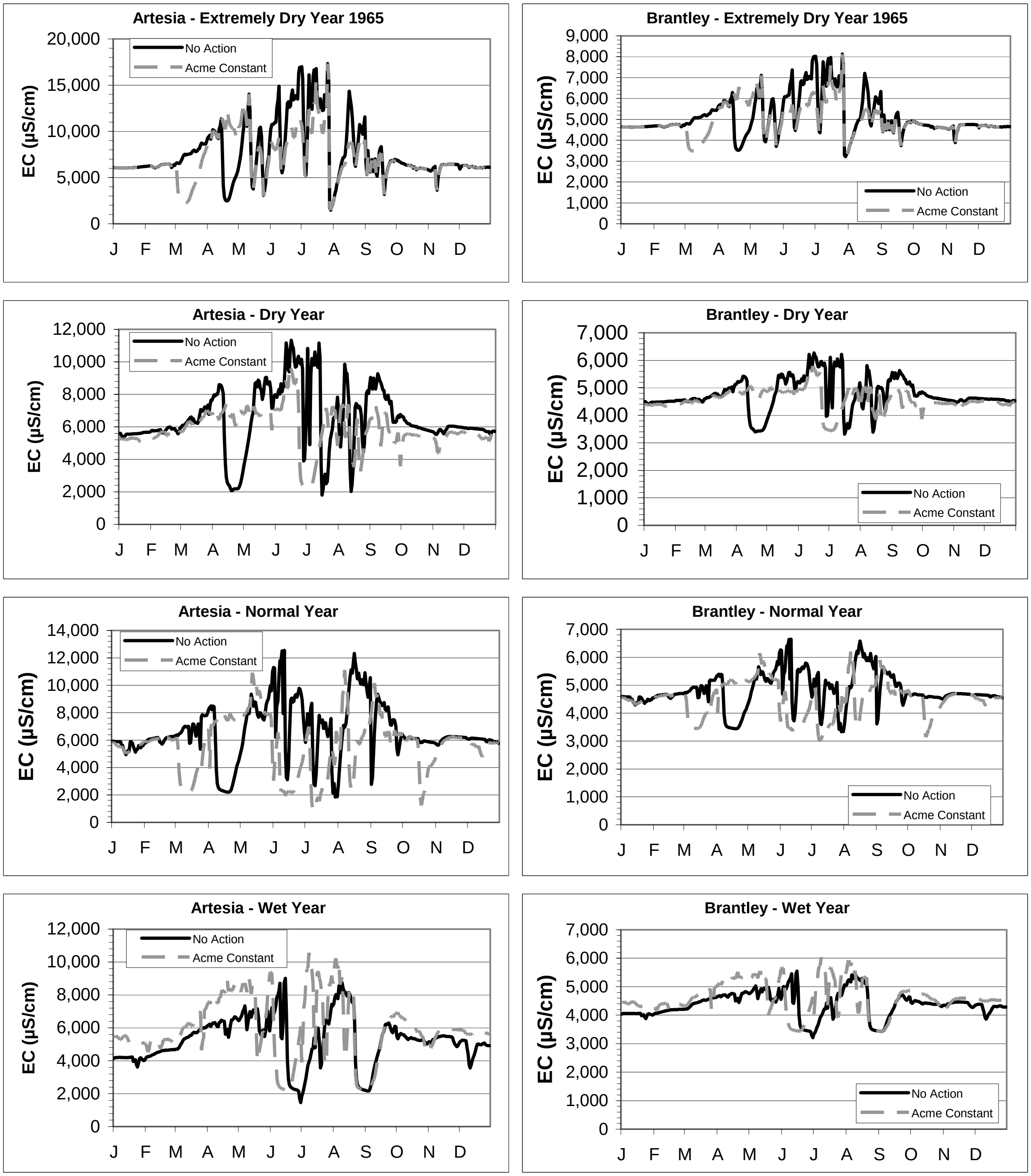
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Variable Low Target Flow (40 ft^3/s) Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



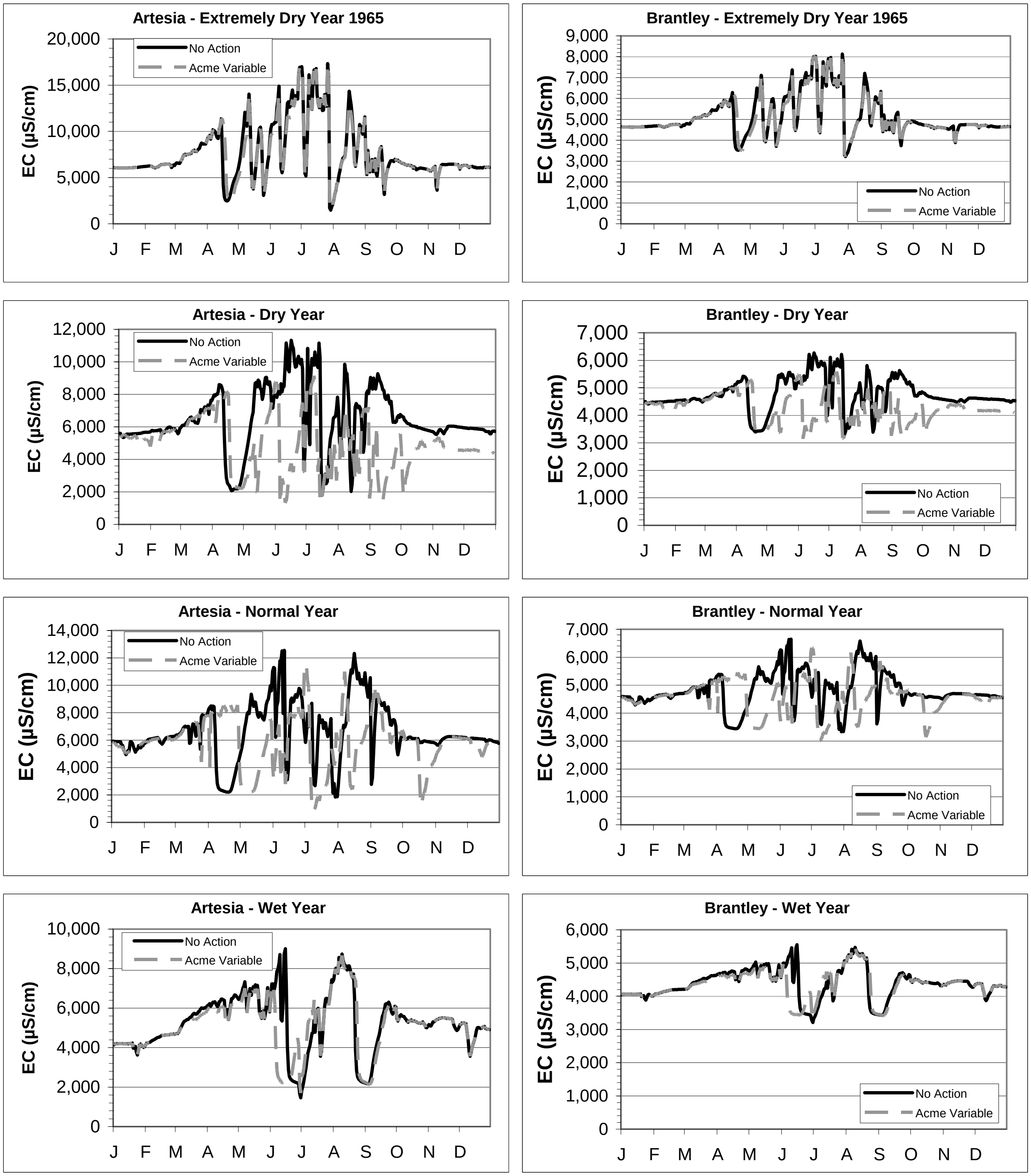
Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Variable Medium Target Flow (45 ft^3/s) Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Taiban Variable High Target Flow (55 ft^3/s) Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types



Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Acme Constant Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types


Artesia - Extremely Dry Year 1965

Brantley - Extremely Dry Year 1965

Artesia - Dry Year

Brantley - Dry Year

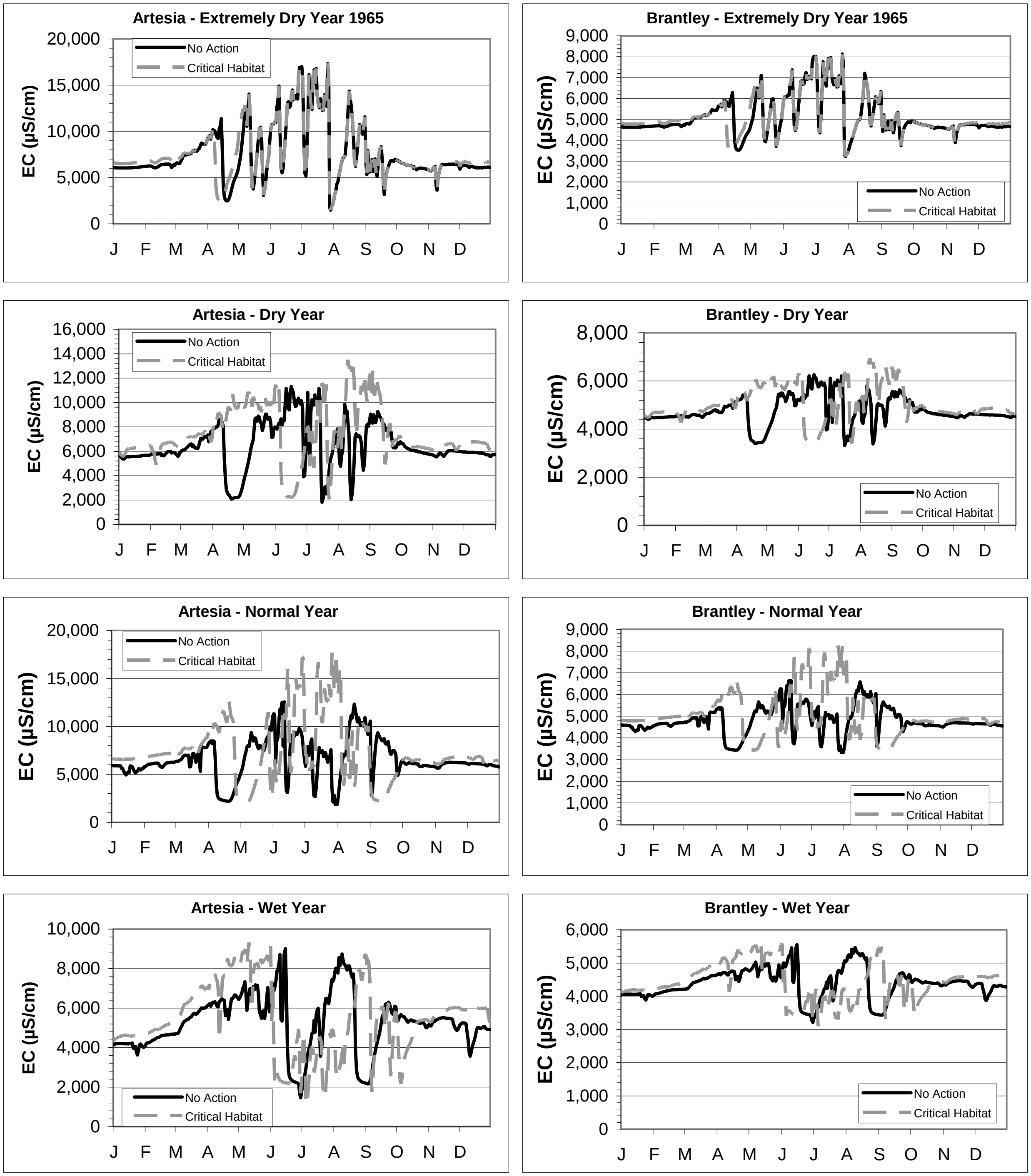
Artesia - Normal Year

Brantley - Normal Year

Artesia - Wet Year

Brantley - Wet Year

Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Acme Variable Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types


Artesia - Extremely Dry Year 1965

Brantley - Extremely Dry Year 1965

Artesia - Dry Year

Brantley - Dry Year

Artesia - Normal Year

Brantley - Normal Year

Artesia - Wet Year

Brantley - Wet Year

Comparison of the projected daily EC for No Action Alternative (present condition) with that of the Critical Habitat Alternative at the near Artesia and below Brantley gages in each of 4 EBS year-types

ATTACHMENT 5

BRANTLEY SALINITY ISSUE PAPER

HYDROSPHERE
Resource Consultants

Date: 03 December 2004

To: Jim Yahnke, Miguel Rocha, US Bureau of Reclamation
Tomas Stockton, Tetra Tech
John Carron, Hydrosphere

Cc: Sara Rhoton, Peter Burck, Elisa Sims, NMISC
Marsha Carra, US Bureau of Reclamation
David Batts, Kevin Doyle, Tetra Tech

From: Jim McCord, Ph.D., P.E., Jodi Clark

Subject: Brantley Salinity Issues: Investigation of Winter Season Salinity Stratification from Impact Analysis Results

Introduction

The purpose for doing the analyses presented in this memo was to evaluate late-winter salinity stratification from impact analysis results in an attempt to answer the following question:

> Will winter bypasses lead to development of an excessively thick “fresh water” upper layer that will adversely affect CID’s ability to mechanically mix a deep “saline” layer, thus forcing CID to “waste” saline water prior to the beginning of the irrigation season?

The motivation for looking into this issue stems from the observation by Jim Yahnke (WQ Workgroup) that impact analysis model results showed fewer early Spring block releases than the historical data. Historically, Tom Davis (CID) called for an early block release to “freshen up” poor water quality in Brantley. Figures 1 and 2 show typical profiles of total dissolved solids (TDS) in Brantley in Summer and late Winter respectively.

Lake Salinity Stratification

We began by performing a mass balance on Brantley. We focused on the November 1 to March 1 time period for each water year and calculated the cumulative daily change in volume for 11/01/n – 03/01/n+1 from Brantley daily storage values for each scenario. We also calculated the volume from components.

$$V_{iw} = \int_{11/1/n}^{3/1/n+1} Q_{\inf low} dt \cong \int_{11/1/n}^{3/1/n+1} (Q_{Kaiser} + BrantleyUL - Q_{PRbelowBrantley} - Evaporation) dt$$

where

V_{iw} = Winter volume inflow to Brantley (11/01/n and 03/01/n+1)

$Q_{\inf low}$ = Daily inflows to Brantley

Q_{Kaiser} = Daily flows Pecos River at Kaiser

$BrantleyUL$ = Brantley Unidentified Losses

$Q_{PRbelowBrantley}$ = Daily flows Pecos River below Brantley

$Evaporation$ = Daily Brantley Evaporation

The daily value for each component was directly calculated from model results for each scenario including Brantley elevation used in the Brantley UL calculations. The Brantley UL was based on correlation to change in Brantley elevation (Fig. 3). Figure 4 shows a check of component volume calculations against modeled Brantley volume for each alternative. The component data was then used to evaluate the salinity stratification. The saline layer top elevation was calculated first using the elevation storage correlation shown in Fig 5. The storage used was the minimum of the initial November 1 storage or 3,500 AF plus the Brantley UL value. Total Brantley volume was calculated next as the initial November 1 Volume + Kaiser – Pecos River below Brantley + Brantley UL. The fresher layer (also reservoir) top elevation was then calculated using this volume and the elevation-storage rating curve (Fig. 5). The thickness of the fresher layer was then calculated by subtracting the top elevation of the more saline layer from the top of the fresher layer. A plot showing the exceedance curve of fresh layer thickness for each scenario is shown in Figure 6.

Outflow Salinity

We also looked at the correlation of specific electrical conductance (EC) inflow and change in EC Outflow-Inflow (O-I) from data that was representative of times when there was an early spring block release (Fig. 7). This yielded a higher correlation than the model developed by Jim Yahnke using year round data (Fig. 8). We also developed a correlation between Brantley storage at the beginning of the early spring block release and the average outflow EC during the block release (Fig. 9). Using this correlation, we developed an exceedance curve for Brantley outflow EC based on March 1 storage as shown in Figure 10. Table 1 shows the ranking of the scenarios based on mean Brantley outflow EC derived from March 1 Brantley Storage. This ranking is quite different from the average annual Brantley outflow EC ranking reported by Jim Yahnke in magnitude, ordering, and range of variability (Table 1). The narrow range for the predicted average annual EC indicates that it is not strongly impacted by the variation in operations among the alternatives. The predicted early spring EC results, on the other hand, suggest a greater impact by the variation in operations among the alternatives.

Ayers and Westcott (1985) provided data that shows a linear decrease in percent yield of alfalfa in the EC range between 1,300 and 10,000 µS/cm (Fig. 11). This relationship was used in conjunction with our computed early spring EC to develop an exceedance curve of alfalfa yield reduction for each scenario (Fig. 12).

Summary

These results show that

- The alternatives with higher winter bypass flows are more likely to develop a thicker fresh layer (Figure 6).
- There is a higher correlation between inflow EC and change in EC (O-I) for data during early spring block releases that for year round data (Figures 7 and 8).
- There may be a relationship between average outflow EC during an early spring block release and Brantley volume at the beginning of the block release (Figure 9).
- Seasonal variations in operations affect outflow EC (Table 1).
- The more alternatives with higher winter bypass flows result in a higher mean early spring outflow EC (Figure 10) and thus have a higher likelihood of adverse impacts to crops (Figure 12).

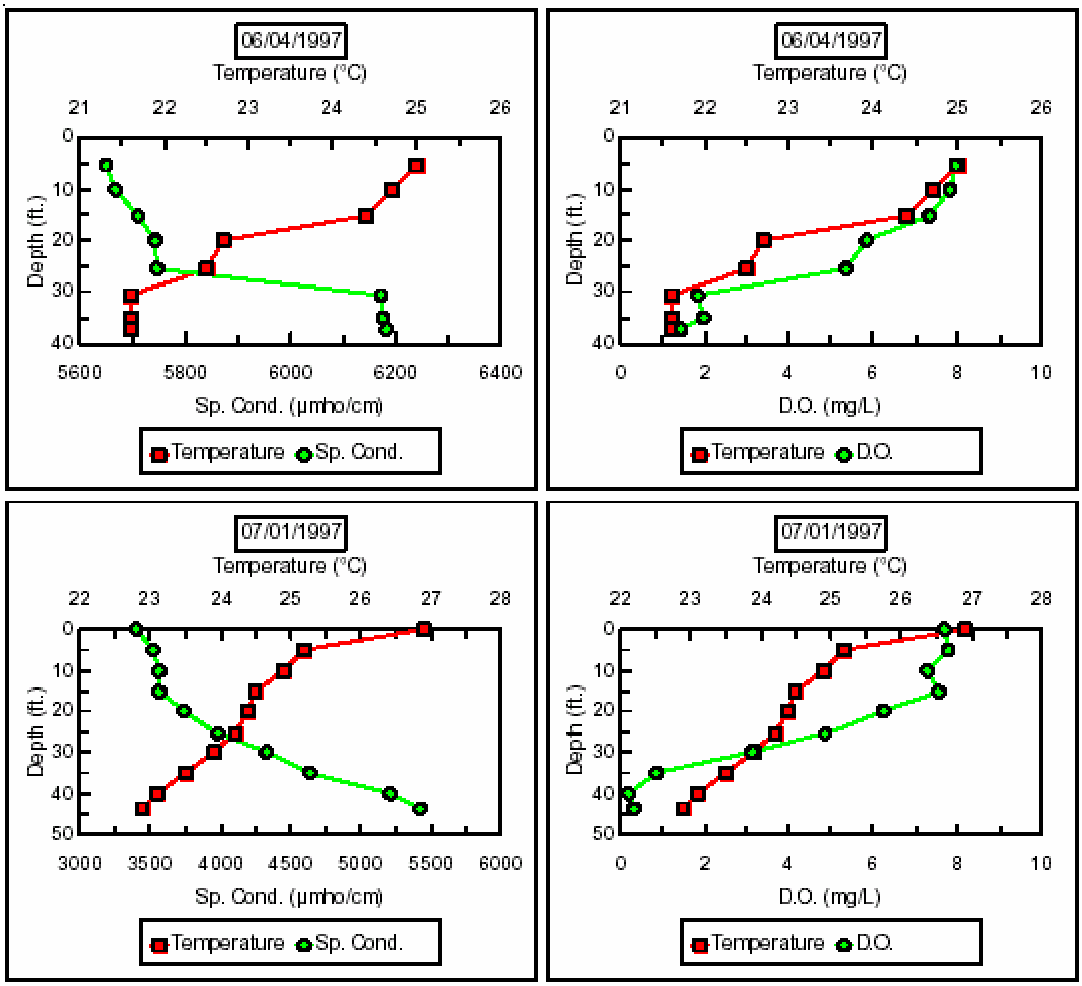


Figure 1. Summertime TDS (Sp. Cond.) profiles in Brantley Reservoir.

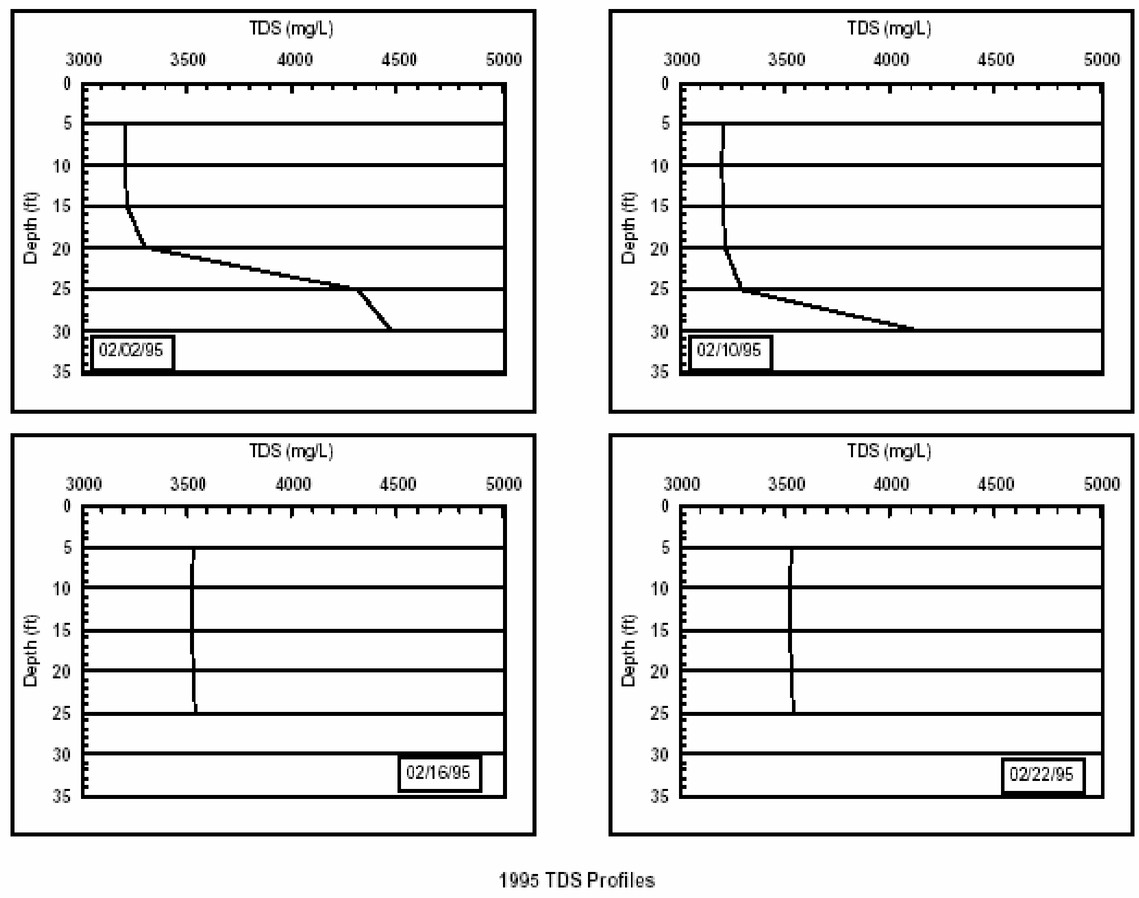


Figure 2. Late Winter TDS profiles for Brantley Reservoir.

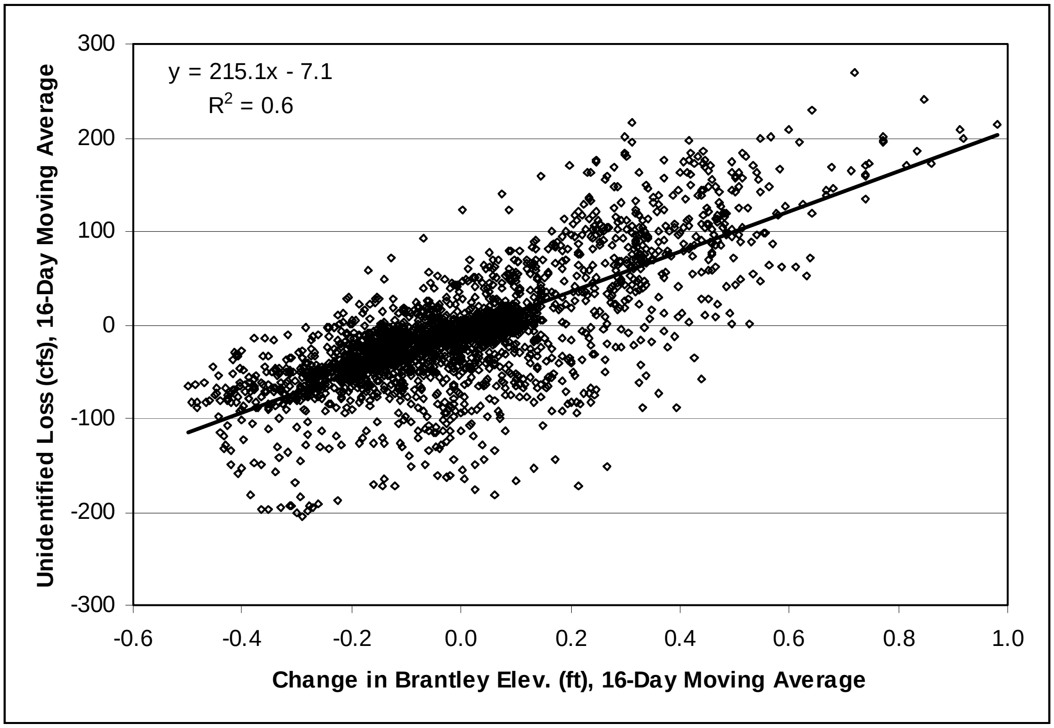


Figure 3. Scatter plot and best fit linear model for ULs versus change in reservoir elevation. 16-day moving average of equation components.

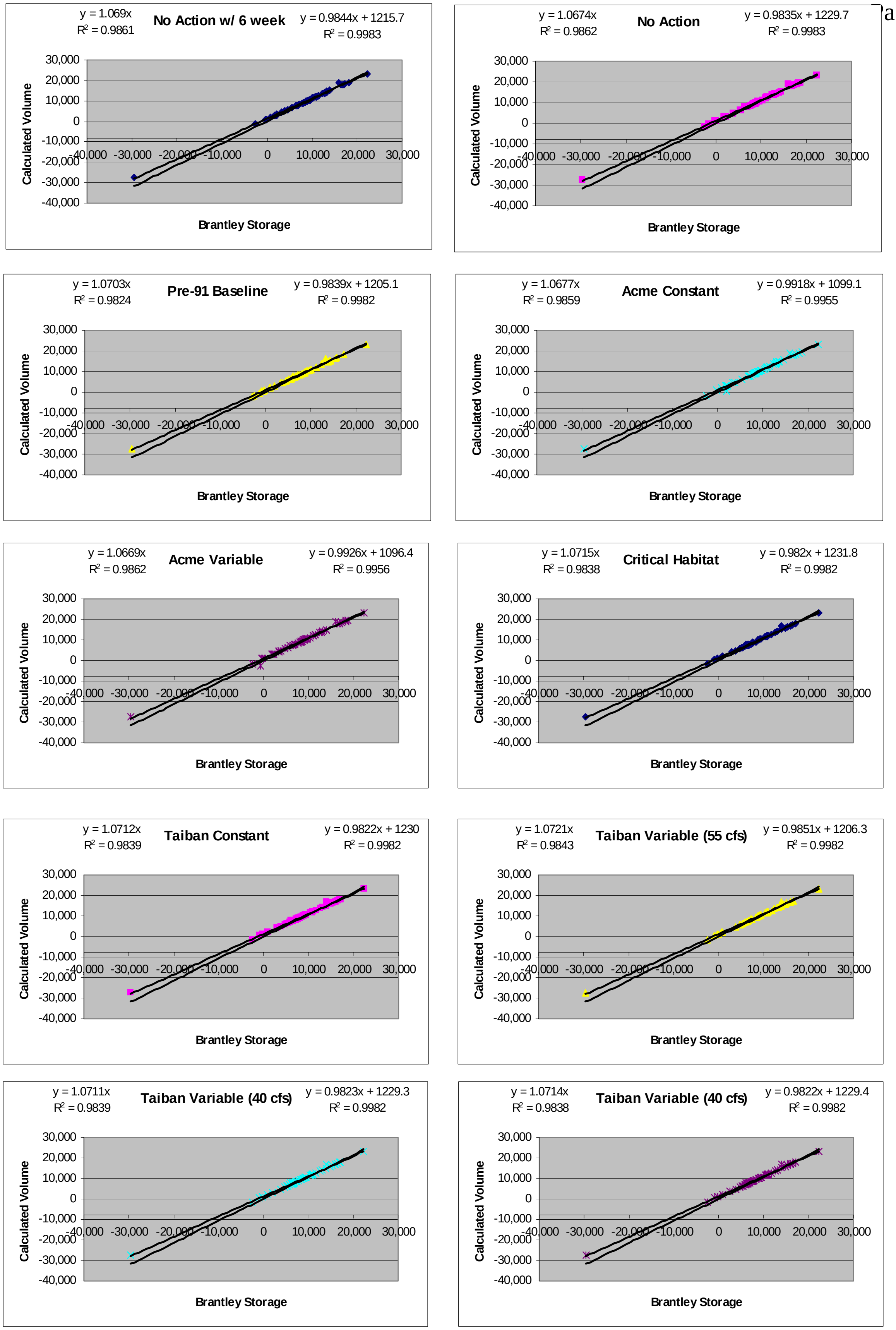


Figure 4. Mass Balance check of modeled Brantley Storage and calculated Volume from model components.

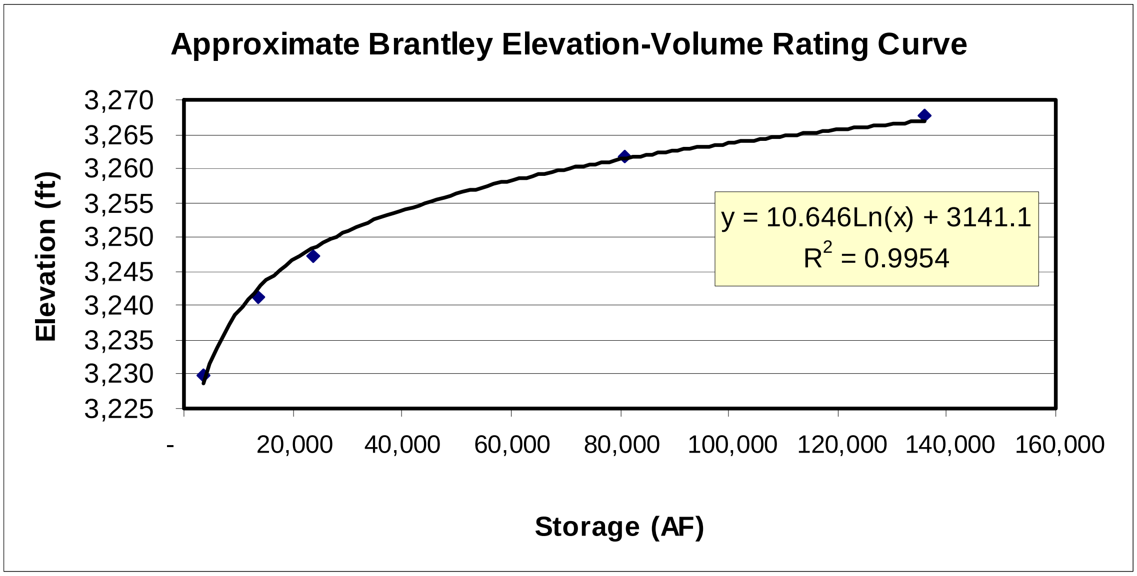


Figure 5. Approximate Brantley elevation – volume rating curve.

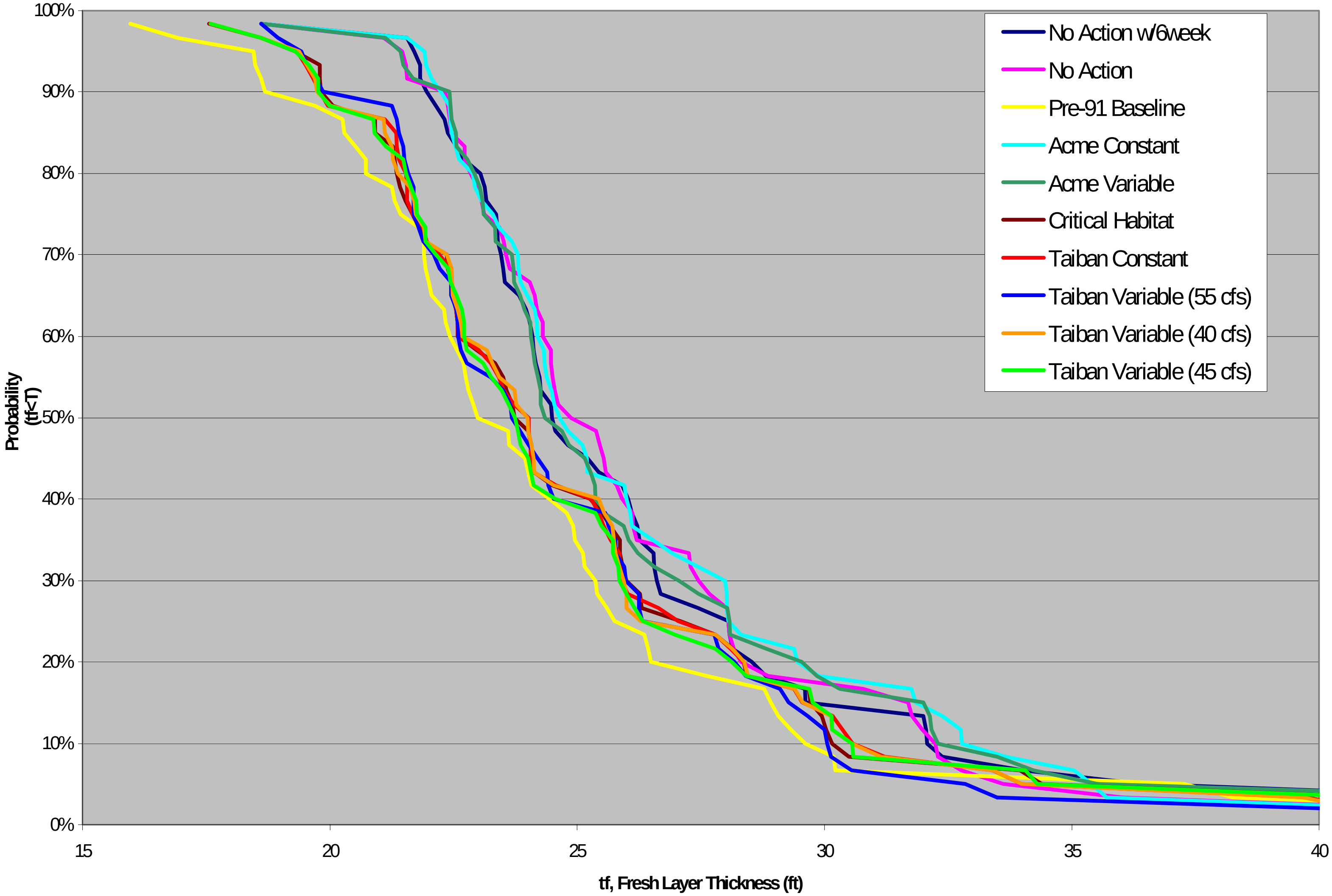


Figure 6. Exceedance curve of fresh layer thickness for each scenario.

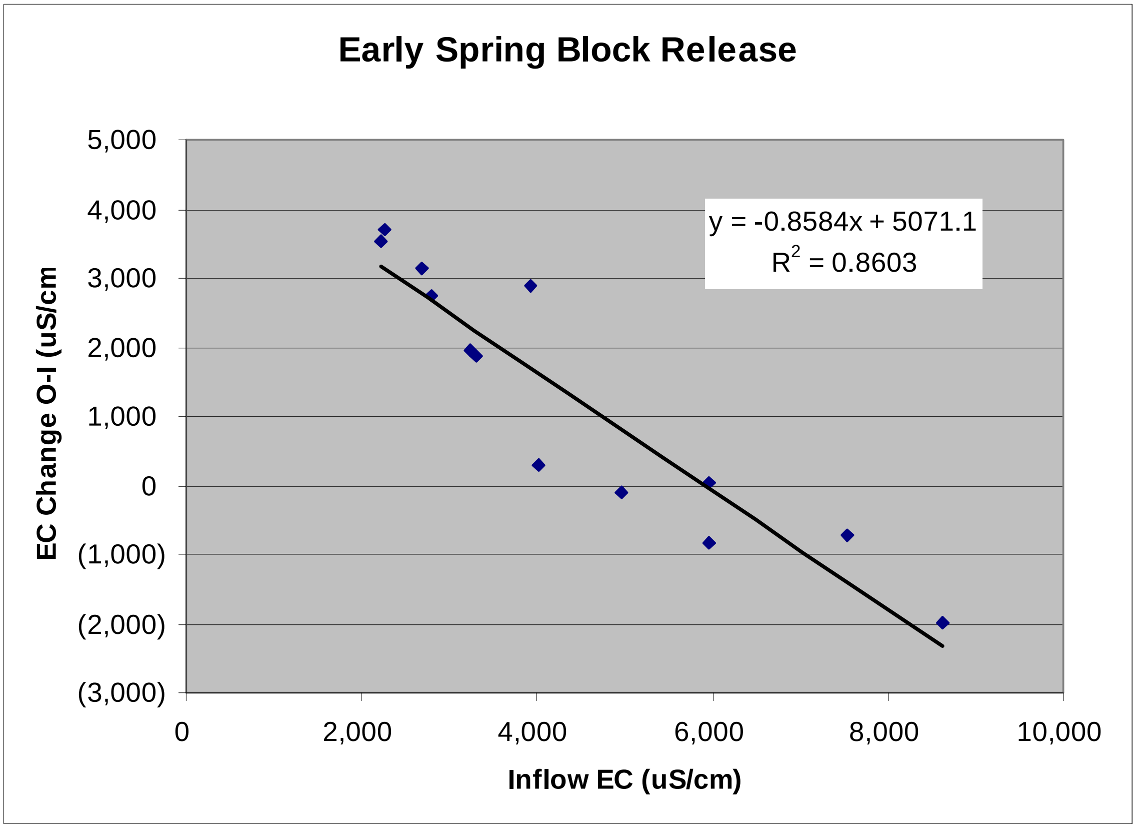


Figure 7. Plot of inflow EC versus change in EC (Outflow – Inflow) for dates when there were early spring block releases between February 1 and April 15.

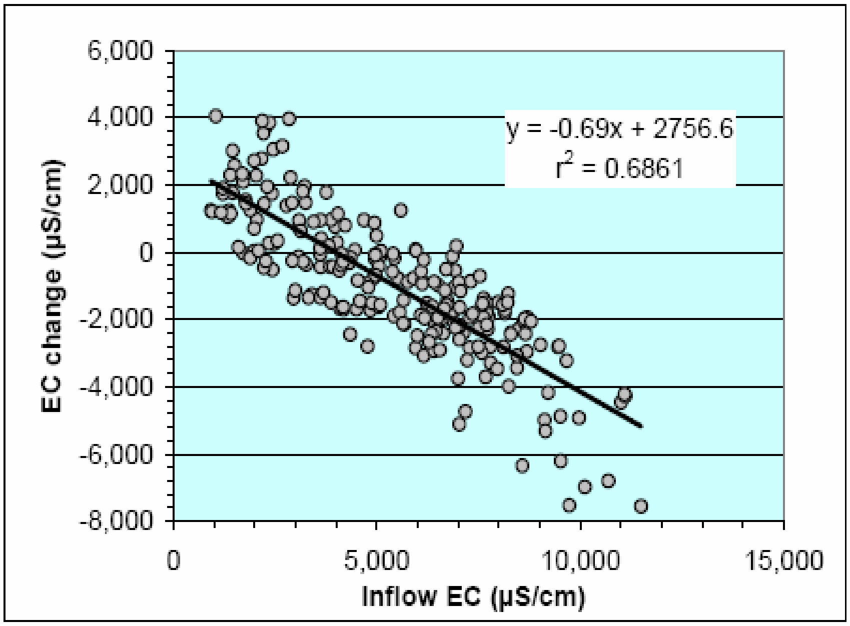


Figure 8. Regression of the change in EC in Brantley Reservoir on the Inflow EC (Yahnke, 2004).

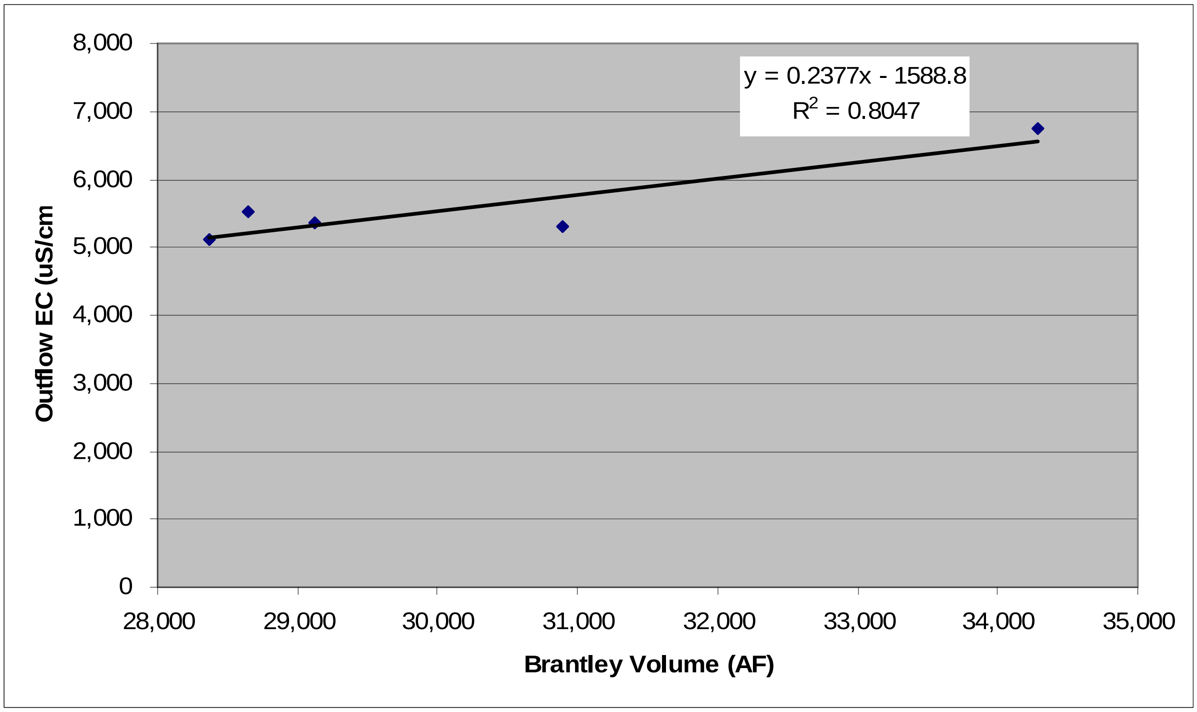


Figure 9. Plot of average outflow EC during block release versus Brantley volume at beginning of block release for early spring block releases.

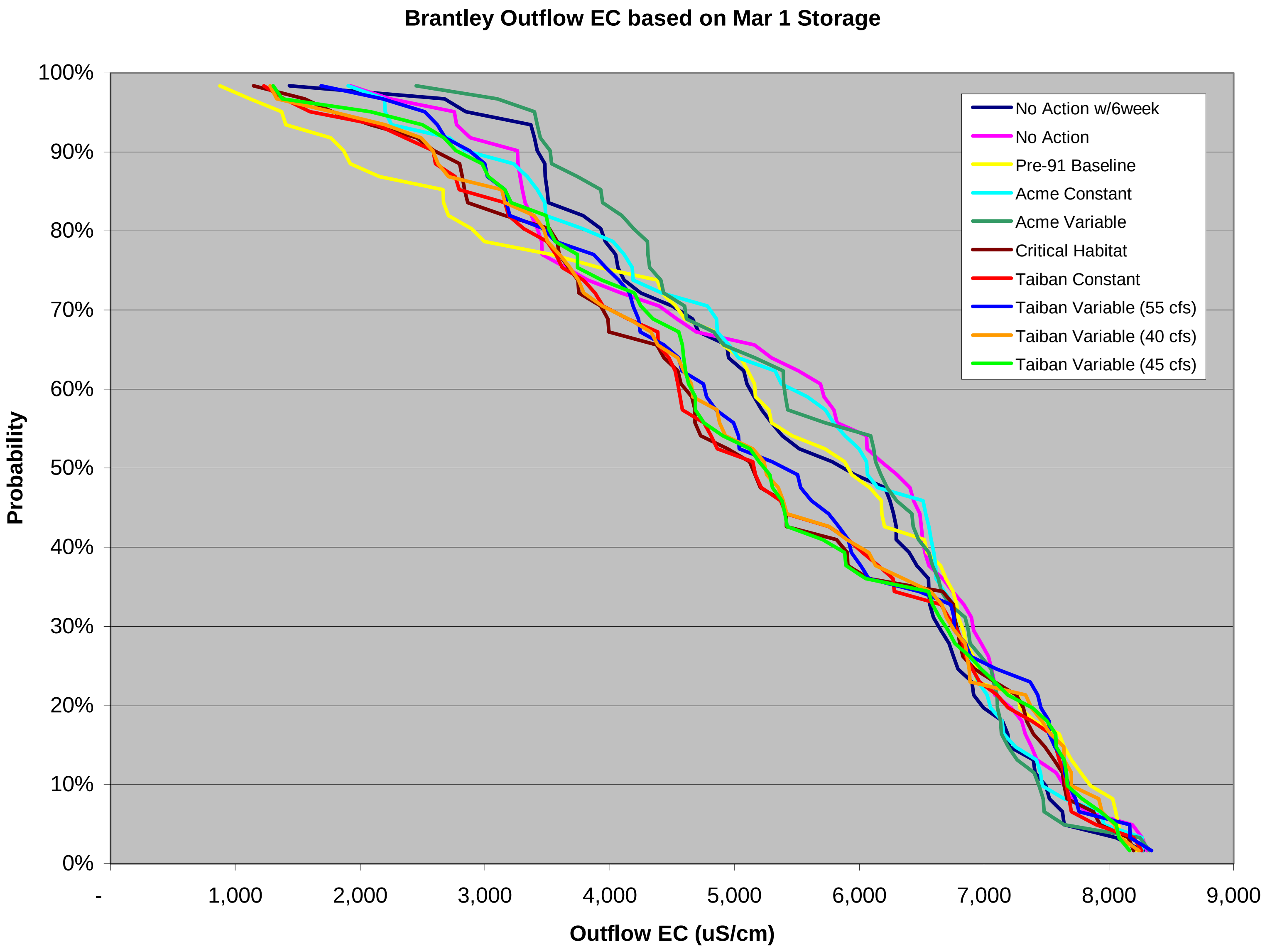


Figure 10. Exceedance curve of Brantley outflow EC based on March 1 storage.

Table 1. Mean early spring and average annual outflow EC with ranking for all scenarios.

Alternative	Mean Early Spring Outflow EC	Rank	Mean Average Annual Outflow EC	Rank
Critical Habitat	5,251	1	4,640	8
Taiban Constant	5,256	2	4,639	7
Taiban Variable (40 cfs)	5,321	3	4,640	9
Taiban Variable (45 cfs)	5,350	4	4,640	10
Taiban Variable (55 cfs)	5,428	5	4,635	6
Pre-91 Baseline	5,451	6	4,432	1
No Action w/6week	5,545	7	4,605	3
Acme Constant	5,676	8	4,580	2
No Action	5,703	9	4,619	5
Acme Variable	5,793	10	4,605	4
Range	541		208	

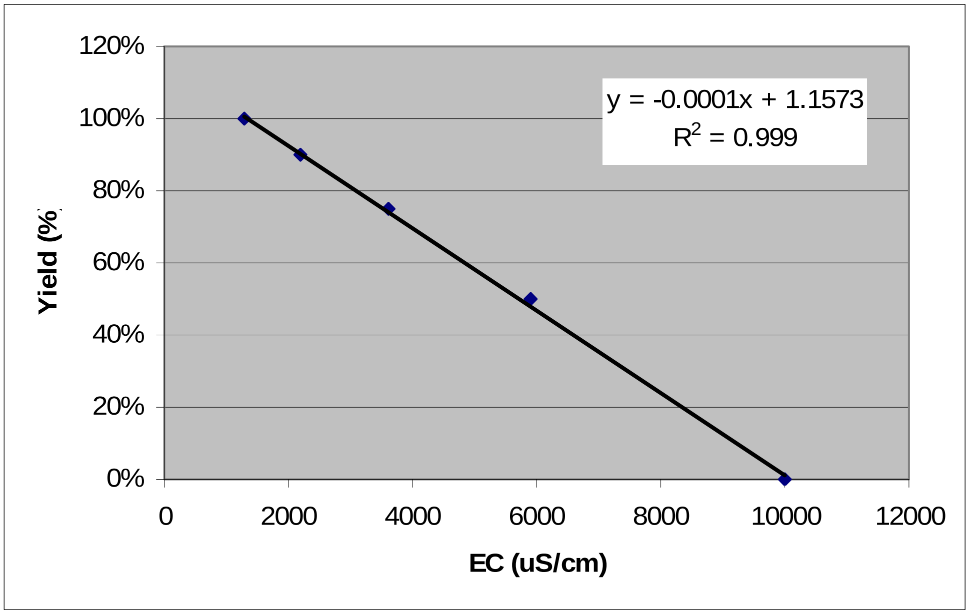


Figure 11. Effect of increased EC on alfalfa yield.

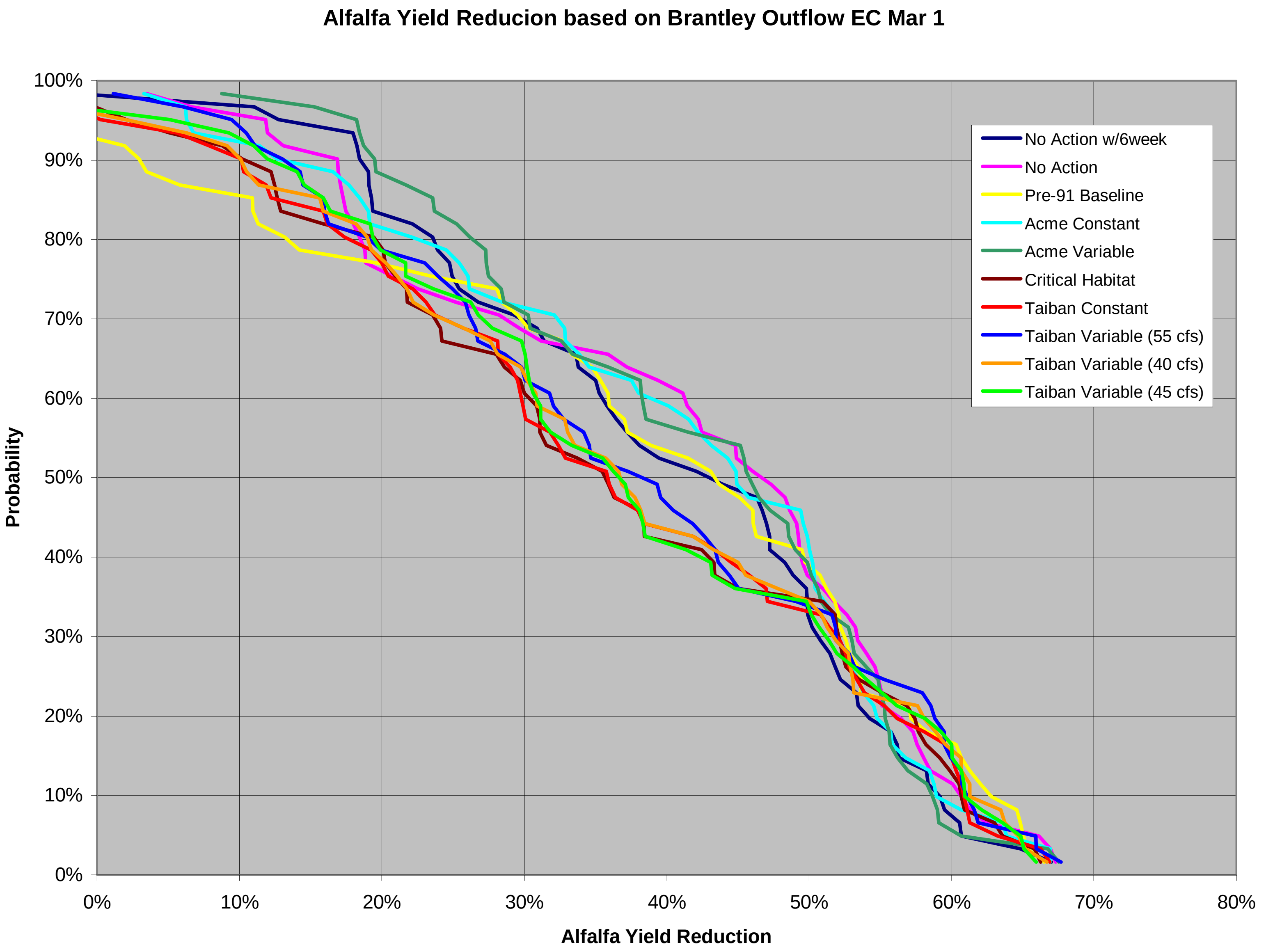


Figure 12. Exceedance curve of alfalfa yield reduction.

Appendix 5

Estimating Regional Economic Impacts

ESTIMATING REGIONAL ECONOMIC IMPACTS

The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (Principles and Guidelines) provide guidelines for the formulation and evaluation of water and land related projects. Four accounts are addressed in the Principles and Guidelines: national economic development (NED), environmental quality (EQ), regional economic development (RED), and other social effects (OSE).

The EQ account represents impacts on ecological and cultural resources, and the OSE account reflects impacts on the community in terms of life, health, and safety. These two accounts do not directly include economic analysis, although the impacts addressed in these two accounts can have economic effects, and changes in economic activity can affect environmental quality and can have other social effects. The NED account reflects economic effects on a national scale, and the RED account presents impact that only occurs within the study region.

The Distinction Between a NED and a RED Analysis

The National Economic Development (NED) account measures the economic benefits and costs of an action on the national economy. Therefore, a NED analysis accounts for offsetting gains and losses across different regions of the nation. A NED analysis is required for project justification (Principles and Guidelines, 1983). A project is justified if the benefits generated by the project are greater than or equal to the costs of the project. Benefits represent an increase in utility (welfare or satisfaction) to society from changes in resource use due to some action. Costs are represented as a loss in utility as measured by the opportunity cost (value of the resource use forgone) from an action. Many benefits and costs may not be easily quantifiable due to the lack of a market structure from which economic values can be obtained. However, these benefits and costs should be accounted for in a NED analysis.

The Regional Economic Development (RED) account measures the changes in the distribution of regional economic activity as a result of an action and does not account for gains or losses outside the region of study. Traditionally (as described in the Principles and Guidelines), the RED account includes measurement of income and employment impacts from an action. However, the overall impacts of an action on the value of industry output in a region as well as the value added (income generated by local factors of production and payments to government) by local production are also valid measures of regional economic activity. The RED account is a measure of regional activity, while the NED account is a measure of economic benefit to the nation as a whole.

The NED and RED accounts are not directly comparable because they do not measure the same effects. The NED account measures benefits which represent the value of a resource or resource related activity to society. The RED account measures regional impacts which are flows of money (or employment) into or out of a region. The regional impacts from an action may result in substantial increases in income or employment within a specific region, but may generate little or no benefits to society at the national level. It is also possible that an action may result in reduced regional output and income in a particular area, while generating positive benefits to the nation as a result of environmental enhancement or other improvements which are not translated into actual money flows.

A NED analysis is concerned with gains in economic efficiency and social welfare which are the result of employing resources in their highest and best uses. A RED analysis is concerned with the distribution of income and wealth, where the impacts of an action to a specific region are evaluated. A NED analysis results in estimates of economic values, while a RED analysis results in estimates of changes in money flows into and out of a region. Therefore, the benefits and regional impacts from an action are not directly comparable and the results from a RED analysis cannot generally be subtracted from the results of a NED analysis to accurately portray the impacts or benefits of an action on the rest of the nation outside the region considered in the RED analysis.

Importance of a RED Analysis

An RED analysis is important to local interests where an action is under consideration. An action that will attract new sources of revenues and activities to a region may result in increased employment, income, and production to that region. Local government officials, business leaders, and the general population would likely want to know the extent of these impacts for future planning purposes and how their community would be affected. If the local economy is currently experiencing high unemployment and low income levels, then the action may be encouraged locally. However, if the action is perceived as causing growth related problems such as overcrowding and high housing costs with little benefit, then the action may be opposed locally. The RED analysis provides information to local parties most affected by a proposed action and estimates the effect of the action on the local economy.

An RED analysis can also be used to address environmental justice issues. Environmental justice is similar to the equity concerns discussed above. It refers to the pursuit of equal protection under environmental laws for a clean environment for all people regardless of socioeconomic status, race, or ethnicity. An action that harms the environment and provides little or no improvement in income or employment in a low income area but provides economic improvements to a wealthy region may violate the intent of environmental justice. A RED analysis combined with a demographic analysis can be used to identify areas which have potential environmental justice concerns.

METHODS THAT CAN BE USED TO EVALUATE REGIONAL ECONOMIC IMPACTS FOR A RED ANALYSIS

There are a wide variety of methods that can be used to evaluate the regional economic effects of a proposed project or action. The applicability of each method to a particular analysis depends on several factors, including the size of the affected area included in the analysis, the number of activities within a region, the level of detail needed for the analysis, and the magnitude of the impacts generated by the project or action under consideration. The methods described include economic base analysis, income-expenditure analysis, input-output analysis, and computable general equilibrium models.

Economic Base Analysis

The economic base method of estimating the regional impacts from a project or action is based on simple macroeconomic income accounting relationships and assumptions about the sources of regional economic growth. The Gross Regional Product (GRP) of a regional economy can be represented as:

$$GRP = C + I + G + E - M$$

where: C = consumption
I = investment
G = local government spending
E = export sales
M = import purchases

Any of the five components of GRP represent potential sources of regional economic growth. It is assumed in the economic base model that exports are the primary source of regional economic growth. It is also assumed that the other four potential sources of growth can be ignored without introducing significant error into the analysis.

Conceptually, the base model approach divides the economy into two sectors: the export or base sector and the non-export or service sector. The base sector includes all economic activities that provide goods and services to individuals and businesses outside the region. The service sector includes all economic activities that serve only individuals and businesses within the region.

Assuming the proportion of service activity to base activity remains constant over the period of analysis, the ratio of service activity to export (base) activity can be expressed as a constant.

$$k = SIE$$

where: k = constant
E = export activity
S = service activity

Therefore, the change in total regional activity from a change in export activity can be expressed as:

$$Y = (l + k)EI$$

where: Y = total activity

Any change in total regional economic activity is assumed to be solely a function of a change in export activity, and the multiplier is $(1 + k)$. Since k is positive under normal circumstances, the multiplier will always be greater than one. The multiplier affects the impact of spending within the region that occurs when export expansion takes place within a region. Changes in export and service activities will affect the value of the multiplier. For example, a decrease in S and an increase in E will result in a smaller multiplier.

To estimate the regional impacts from an action using an economic base analysis, the analyst must know the change in spending associated with the action by good or service categories, the extent to which those goods and services are purchased within the region, and the extent of the service and base industries in each category of spending. These data are not easily obtainable, so professional judgment may be needed to estimate the multiplier effects of changes in spending and the amount which is actually spent in the region. These factors will be more difficult to estimate for larger economies because of the large number of interconnected activities and the difficulty in evaluating complicated trade patterns. Therefore, use of an economic base analysis is limited to relatively small and less diversified economies.

Fundamental Assumptions of an Economic Base Analysis

There are several assumptions associated with an economic base analysis that limit the applicability of an economic base analysis. Several of these assumptions and their resulting limitations are presented below.

- The assumption that exports are the sole source of regional economic growth. This limits the applicability of the approach to relatively small-scale economies that are highly dependent on exports. Examples of regions that could fit this assumption are: fishing villages, agricultural communities, timber areas, and some specialty tourist areas such as ski resorts.

- It is assumed that the export sector is very uniform and homogeneous, or, at the very least, a change in spending for one type of commodity sold outside of the region would have the same impact as the same change in spending for another export commodity. The impact on the economy is estimated in the base model to be the change in the volume of exports times the multiplier, $1 + k$, regardless of the type of commodity exported. However, it is likely that the leakages associated with different export activities probably differ because of differences in the proportions paid to local labor and suppliers of materials and because of differences in the expenditure patterns of the employees in the different activities. As a result, the multiplier would not be expected to be uniform for all exports.

- It is also assumed that the parameter k is constant over the period of analysis. However, as an economy grows and the local markets for various commodities grow, some goods and services that were previously imported into the region may be produced within the region. As a result, the value of k would probably rise as the economy grows.

- A change in the level of exports from the economy is assumed to have no effect on subsequent exports that could result from trade linkages between the study region and other regional economies. In other words, it is assumed that there are no interregional feedback effects.

- It is also assumed that a pool of underutilized resources exists and an increase in the demand for exports will result in a proportional increase in the quantity of goods and services needed to produce those exports. If, however, there are input constraints that prevent an increased level of production of exports, an increase in export demand may only result in an increase in the prices of exported commodities.

The Base Model is a comparative static model. The economy is assumed to initially be in equilibrium, and changes in export results in a new equilibrium level of activity. The two levels of activity are compared to evaluate regional impacts.

Potential Problems with the Methodology

There are several shortcomings associated with the economic base methodology apart from the assumptions listed above that can compromise the accuracy of regional impacts estimated using this methodology. First, it is sometimes difficult to determine the appropriate unit of measure for economic activity associated with producing exports. Jobs and income are frequently used measures of activity. However, the impacts using these two measures may be very different.

Another problem is distinguishing between the service and the base (export) activities in a region. Some goods and services may he produced for both within region and export use. Several techniques have been used to try to solve the problem of determining base and service sectors, including judgment, a survey of household and business spending patterns, a location quotient, and the minimum requirements method. Judgment simply requires the analyst to evaluate which goods and services are predominately exported, based on observations and available regional trade information. Surveys of spending patterns are an accurate method for determining where goods and services are purchased, although the cost of such a survey may be fairly high.

A location quotient is a ratio of the percentage of regional employment in a particular industry divided by the percentage of national employment in a particular industry. This can be represented as:

$$LQi = (RJR) / \{NjN)$$

where: LQ_i = location quotient
R_i = regional employment in sector i
R = total employment in the region
$N_,$ = national employment in sector i
N = total national employment

If the estimated location quotient for an industry is greater than 1, then a disproportionately high portion of employment in that industry is attributable to exports compared to the rest of the nation. As a result, that industry would be considered to be a base activity.

The minimum requirements technique for determining if a sector is part of the base is based on the estimated employment requirements to satisfy local demand for a good or service, and any employment beyond that number would be assumed to be required for meeting export demand. The minimum requirement would be determined by studying the sector employment data in a region similar in size and structure and calculating the ratio of sector employment to total employment. The region with the lowest ratio would represent the minimum requirement to meet local demand.

Advantages of the Economic Base Methodology

The primary advantage of the economic base methodology of estimating regional impacts is the simplicity of applying the method. If the service to export activity ratios for the goods and services affected are accurate, then the method can produce useful results. The logic behind the method is also fairly straightforward and easy to understand by non-economists (although not everyone may agree with the fundamental assumptions of the technique). Finally, although the method may be simplistic, the results can be sufficiently accurate to compare regional impacts between alternatives.

Summary of Economic Base Analysis

An economic base analysis is a suitable method of estimating regional impacts in areas with fairly simple trade patterns, easily identifiable base or export sectors, and a proposed action that have well-defined effects on input demands. When an economy is large or diversified, the simplifying assumptions of the methodology lead to errors in the impact estimates that are likely to be unacceptable for policy analysis.

Income-Expenditure Analysis

Income-expenditure analysis is an extension of the Keynesian multiplier model. In this model, expenditures derived from household income drive changes in regional economic activity. A multiplier similar to a multiplier used in macroeconomic analysis is estimated based on the marginal propensity to consume, base levels of consumption that would occur regardless of income level, tax rates, the marginal propensity to import, and any other factors influencing the level of local spending. The marginal propensity to consume represents the percentage of additional income that would be spent on consumption of goods and services (as opposed to income that is saved). The marginal propensity to import represents the percentage of additional income that is spent on goods imported into the region. A simple regional income multiplier can be represented by:

Income multiplier = 1/[1 - (1 - t)(c, - m,)]

where: t = tax rate
c_1 = marginal propensity to consume
rn, = marginal propensity to import.

The multiplier is inversely dependent on leakage rates and the marginal propensity to save (1 - c_1). Estimating a regional income multiplier can be demonstrated through a simple example.

Assume that the tax rate (t) within a region is 20 percent of income and that 10 percent of all income earned is saved (S). Further, assume that the purchase and consumption of locally produced goods and services (LC) represents 50 percent of income and the purchase of goods and service from outside the region (OC) represents 20 percent of total income.

To estimate regional impacts, the analyst must also know the proportion of inputs purchased from local (within a region) suppliers for each sector of consumption. For example, assume local consumption is divided into three sectors: 50 percent at food stores (F), 20 percent at general stores (G), and 30 percent at service stations (SS). Suppose that food stores import (F_{imp}) 90 percent of the inputs needed to produce food, general stores import (G_{imp}) 7.0 percent of inputs, and service stations import (SS_{imp}) 80 percent of inputs. This provides enough information to estimate a regional impact multiplier based on expenditures and saving of income in the region and the types of goods and services purchased with that income.

The multiplier can be calculated two ways, either on the basis of leakages outside of the region or on the basis of consumption expenditures within the region. The multiplier based on leakages outside the region would be calculated the above equation and the following relationships:

c_1 = (LC + OC)/(1- t)
m_1 = {OC + LC[(F x F_{imp}) + (G x G_{imp}) + (SS x SS_{imp})]}/(l-t).

Using the values from the example, the regional income multiplier is equal to:
1/{ 1 - [(l-.2) x (.875 - .76875)]} = 11.915 = 1.0929. The term c_1 is equal to: (.5 + .2)/ (1- .2) = .875. The term m_1 is equal to {.2+.5[(.5x .9) + (.2x .7) + (.3 x .8)]}/(1-.2)= .76875. This multiplier represents the impact of an increase in income which is spent on the three goods and services included in the example in the proportion presented in the example. Additional leakages representing expenditures that occur outside the region can be added to the model, as needed, to determine local impacts more accurately.

Using the consumption side, the percentage of expenditures for local consumption is multiplied by the weighted average of local input expenditures for each good or service produced. In the above example, the multiplier based on local consumption would be:

Regional multiplier = $1/ (1-\{LC \text{ x } [(F \text{ x } (1- F_{imp}))+(G \text{ x } (1 - G_{imp}))+(SS \text{ x } (1 - SS_{imp}))]\}\}$

or $1/\{1-\{.5x[(.5x.1)+(.2x.3)+(.3x.2)]\}\}=1/\{1-\{.5x[.17]\}\}= 1/(1-.085)= 1.0929$.

Fundamental Assumptions of an Income-Expenditure Technique

There are several simplifying assumptions that are necessary when using the income-expenditure technique. These include:

- The multiplier coefficients (the tax rate, the propensity to consume, the marginal propensity to import, and any other relevant factors) are assumed to be constant over the period of analysis. The constant-coefficients assumption further implies that the patterns of expenditures in the first round are identical in succeeding rounds.

- Each producing sector is homogeneous and there are no capacity constraints on the producing sectors of the model.

- Feedback effects between regions are negligible. The magnitudes of interregional feedback effects are positively related to the region’s share of national income and inversely related to the region’s self-sufficiency. For small and somewhat isolated regions, interregional feedback effects are not likely to be significant. If inter regional feedback effects are determined to be a factor, the data necessary to incorporate interregional feedback effects within the multiplier is typically difficult to obtain.

Potential Problems With the Methodology

The marginal propensities for consumption, savings, imports, and taxes for local residents are conceptually the correct measures for estimating regional multipliers because the project or action under consideration represents an addition to or subtraction from current economic activity and income. However, marginal propensities may be difficult to estimate, so average propensities are frequently used as an approximation of the marginal propensities. In some cases, these two numbers may be significantly different, and the multipliers may be off by a large percentage. For example, if unemployed resources are used to meet demand resulting from increased local .spending, it is possible that the propensities to consume, save, import, and pay taxes of those who were unemployed could be much different from the average propensities.

Another practical problem is the possibility that a significant amount of capital investment could be induced within a region, resulting in greater regional impacts compared to the assumption that leakages remain constant. These changes in capital investment and production within the region would need to be incorporated into a multiplier model.

The income-expenditure approach has some advantages over the economic base approach which is based primarily on employment data. First, using income as a unit of measurement provides a more sensitive indicator of change in economic activity than does employment. Second, a dollar of income is an unambiguous measure of economic activity, while employment is difficult to compare because of a mixture of full-time, part-time, and seasonal employment. Third, the income-expenditure model can incorporate consumption patterns which vary from the community average. Fourth, fiscal operations of the local government can be explicitly included in the model.

Advantages of the Income-Expenditure Methodology

As with the economic base methodology, an important advantage of the income-expenditure methodology is the relative simplicity of the method compared to input-output-based techniques. The categories of consumption and the marginal propensities to consume and import may be more intuitive than the base and service sectors in the economic base analysis. However, the basic foundation of both techniques are essentially the same: to determine the extent to which the production of goods and services in the region depend on inputs from the local region and to estimate the change in spending on specific goods and services.

Summary of the Income-Expenditure Methodology

The income-expenditure model is most appropriately applied to small-scale, regional economies where inter-sectoral relationships are simple enough to be modeled without the need for a large amount of data. The use of income as a measure of economic activity makes the income-expenditure method somewhat more flexible than the economic base methodology. However, the simplifying assumptions required for the technique limits the use of the model in larger and more complicated economies.

Input-Output Analysis

An input-output (1-0) model is a mathematical model that depicts the flows of money between the various sectors of a regional economy. These flows are estimated by determining the inputs needed by each industry from other industries to produce a dollar’s worth of output. 1-0 models also describe the proportions of sales that go to wage and salary income, proprietors’ income, and taxes based on the industry’s estimated production function. Multipliers can be estimated from 1-0 models based on input requirements for different activities and the propensity of firms and households to purchase goods and services from local sources (regional purchase coefficients). A region that is relatively self sufficient will have fewer leakages and larger multipliers relative to a region that depends heavily on imports. The multipliers can be used to estimate regional economic impacts from an action that results in changes in economic activities in a region.

I-O based multipliers capture the direct, indirect, and in some cases the induced effects of an economic activity. Direct effects are the production changes created by the original, first round, change in spending for goods and services. Indirect effects are the production changes resulting from various rounds of re-spending of the primary industry’s receipts in other backward-linked industries (industries supplying products and services to the primary industry). Induced effects are the changes in economic activity resulting from household spending of income earned directly or indirectly as a result of the change in spending for goods and services.

For example, the direct result of an increase in recreation visitation would be increased sales in the lodging sector. The additional lodging services result in associated payments for wages, taxes, and supplies and services that are direct effects of recreation spending. The increase in lodging activities lead to changes in sales, jobs, and income in the linen industry that represent indirect effects of changes in expenditures for lodging. Businesses that supply products for the linen industry represent another round of indirect effects. Eventually, all the economic sectors that can be linked to lodging are included as a part of indirect effects. Last, lodging and linen supply employees, supported directly or indirectly be recreation spending, spend their income in the local region for housing, food, and other household goods and services. The sales, income, and jobs resulting from household spending of added income are induced effects.

Together, the indirect effects and induced effects are called secondary effects. Through these secondary effects, a change in spending in one specific sector can have an impact on nearly every sector of the economy. The size of the multiplier depends on the propensity of households and businesses to purchase goods and services from local suppliers and can vary considerably from region to region and sector to sector. There are several different types of multipliers reflecting which secondary effects are included and which measure of economic activity is included. For example:

- Type I sales multiplier = (direct sales + indirect sales)/direct sales
- Type II sales multiplier = (direct sales + indirect sales + induced sales)/direct sales, where Type II multipliers include households as a sector of the economy
- Type Ill sales multiplier = (direct sales + indirect sales + induced sales)/direct sales, where Type EI multipliers treat households as exogenous
- Type III income multiplier = (total direct, indirect, and induced income)/direct sales
- Type III employment multiplier = (total direct, indirect, and induced employment)/ direct sales

Fundamental Assumptions of an Input-Output Analysis

There are several assumptions which are needed to use input-output analysis as a tool for estimating the regional impacts from changes in spending. Some of these assumptions are similar to those presented for the economic base and income-expenditure methodologies. These assumptions include:

- Fixed proportions exist in all production processes, and the direct requirements are constant over the period of analysis.

- All firms in a given industry employ the same production technology, usually a national average is used, and to produce identical products or bundles of products.

- There are constant returns to scale in production. This means that the average cost of production is the same at all output levels and any level of output is obtainable by simply adjusting all inputs proportionately to a new output level.

- There is no substitution among production inputs as the output level changes.

- There are no price effects from changes in output which would influence the use of inputs for production. Similarly, input substitution does not exist.

- I-O models represent one particular year and are based on the national system of accounts.

- Generally, jobs created by additional spending are new jobs which also represent new households in the area. Induced effects are computed using linear changes in household spending with changes in income. Spending by new households may be very different from existing spending patterns.

- An open input-output model does not take into account the increased spending in the economy via the consumption expenditures of households. That is, the open model considers only sales and purchase linkages within productive sectors of the regional economy and ignores consumption linkages. This can be compared to the economic base and income-expenditure models that account for the induced or consumer respending effect and ignore the indirect or inter-sector linkages. In the base and expenditure models the indirect effect must be determined outside the model.

Induced effects can be incorporated into an input-output model by closing the model with respect to the household sector. That is, the household sector is brought into the endogenous transactions matrix as a column from the exogenous final demands, and the personal income portion of the value-added row is incorporated into the transactions matrix as an additional row. The household sector is now treated as a producing sector, selling its product (labor) to other producing sectors and to final demands, and purchasing inputs from other sectors to maintain the flow of its product.

Potential Problems with the Input-Output Methodology

A major potential problem with an input-output based analysis is the assumption of fixed production coefficients combined with the assumption of no price effects on the mix of inputs used. The assumption of linear relationships is a problem when changes in final demand are large enough that the production relationships are no longer linear but are exhibiting increasing or decreasing returns to scale. If a regional impact analysis is completed for a large region which produces many goods and services, large exogenous changes in final demand for goods and services produced in the region could potentially affect prices and change the mix of production inputs. However, for changes in final demand that are relatively small, the input requirements may increase more or less in direct proportion to the increase in output. In addition, there is evidence that the average cost of producing some goods is independent of the scale of output in some cases.

A mistake that is frequently made when using input-output based techniques is to multiply a sales multiplier times total spending on an activity to get total sales effects. This will generate an inflated estimate of regional impacts because total spending is not the same as the direct effects appearing in the multiplier formula. To properly apply total spending to an input-output model, various margins must be deducted from the purchaser price to factor out returns to the producer. In an input-output model, retail margins accrue to the retail trade sector, wholesale margins to wholesale trade, and transportation margins to the transportation sector and producer prices are assigned to the sector that produces the good. In cases where the producer lies outside the local region, an immediate leakage is created in the first round of spending because the producer portion of the final cost is not a local impact.

Most regional impact models are based on fairly generalized production relationships derived from national data. As a result, production techniques that are unique to a region or more modem (or less modem) than the national average will not be well represented by the impact models. Examples of this problem include agricultural production and mining. Producing cotton in California is likely to require a different mix of inputs than producing cotton in Texas or the southeastern States, yet most general input-output based multiplier programs would use a general cotton production function. Similarly, many different types of coal are mined throughout the United States. The levels of availability vary, requiring very different production techniques.

As a result, the analyst must be aware of the type of production function used in the regional impact model, and the production function may need to be modified to better represent regional conditions. Without these modifications, the input requirements and the estimated regional impacts will not be correctly estimated. Trade associations, government agencies, university publications, and interviews of production managers are all potential sources of information for modifying generic production relationships used in a regional impact model. This effort may not be necessary for models developed at the State or local level.

The Need to Include Forward Linkages in a Regional Impact Analysis

An input-output multiplier type of analysis accounts for the relationship between an industry producing the good or service for which there is a change in final demand and the suppliers of inputs for production of that good or service. This relationship between producers and suppliers of inputs is referred to as a backward linkage. However, when the demand for a product or service changes, the linkage between the industry producing the final good or service and the consumer of that good or service may result in additional impacts. This linkage is referred to as a forward linkage. Forward linkages, which are not captured by an industry multiplier, can be thought of as additional activities beyond final production that are required by the ultimate users of the good or service to use the product or service. Examples could include transportation of goods after final purchase, wholesale distribution of final goods, or any other activity that adds to the cost of the good or service beyond what is accounted for in the multiplier analysis.

For example, suppose an analysis is needed to estimate the regional impacts from a proposed land retirement program. It is anticipated that the program will result in reduced alfalfa production. Assume that a large percentage of the input suppliers for alfalfa production are located in the study area and a trucking company that ships the alfalfa to dairies outside the region is also located in the study area. A standard multiplier type of analysis would generate estimates of the impact of reduced alfalfa production on local suppliers of inputs for alfalfa production. The impact of reduced trucking activities from reduced alfalfa production would not be included in the multiplier analysis; however, trucking impacts represent real impacts that would be felt in the region.

Forward linkages can be accounted for in a regional impact analysis by (1) identifying activities that are needed to provide the good or service under consideration that is not accounted for in the industry multipliers, (2) evaluating the extent to which the forward linked activity is needed to support the use of the final good or service, (3) determining the location of the forward linked activity (inside or outside the study region), and (4) estimating the payments required for the forward linked activity.

In the land retirement example, the change in demand for trucking services due to reduced alfalfa production needs to be included in the analysis to fully reflect the regional impacts from land retirement. Therefore, the value of the change in final demand for trucking services as a result of reduced alfalfa production could be input into the trucking sector of the 1-0 based model to account for that forward linkage.

If the trucking supplier were located outside the study region, the forward linkage would not be included in the analysis and the analysis including only backward linkages would correctly reflect regional impacts. Therefore, the extent to which forward linkages should be included in a regional impact analysis must be evaluated on a case-by-case basis. The accuracy of the estimated regional effects from forward linkages depends on the accuracy of the estimated change in the level of activity of the forward linked sector.

Advantages of the Input-Output Methodology

The I-O based method of estimating regional impacts has several important advantages over the economic base and income-expenditure approaches. The first and perhaps most important are the level of detail that can be represented in an 1-0 based analysis and the intricate transactions patterns that can be represented in an 1-0 model. Large regions with multiple production sectors can be represented more precisely using 1-0 models than by using the other two approaches.

Another important advantage of an 1-0 based analysis is the availability of computer packages and data sources for completing an 1-0 based impact analysis. Models such as IMPLAN from the Minnesota IMPLAN Group, Inc., and the Regional Input-Output Modeling System (RIMS II) from the U.S. Department of Commerce provide consistent and well documented estimates of multipliers and impacts that can be applied to regions of various sizes throughout the United States. The national level data that these computer packages are based on are updated frequently, providing recent information on the production relationships used to estimate impacts.

An I-O based analysis is a static analysis where the coefficients of production axe assumed not to change over the period of analysis. However, the analysis can be run using modified production relationships that account for anticipated changes in production technology. In this way, the analysis becomes less static, and realistic changes in future production can be taken into consideration.

Last, given the assumption of linear production functions that can accurately describe the interrelationships between all sectors of an economy, the 1-0 methodology produces theoretically valid and precise estimates of the inputs needed from each sector to meet a given final demand. In other words, assuming we have good data and linear production relationships, relatively simple matrix operations can be used to solve for the input requirements for production in very complex regional economies.

Summary of the Input-Output Methodology

Using input-output based models to estimate the regional impacts from a proposed project or action allows the analyst to account for inter-industry impacts that are not accounted for in the economic base and income-expenditure methods. Therefore, an input-output based analysis is more realistic in terms of the factors that are likely to generate regional economic impacts.

The input-output methodology is probably best suited for small to medium sized regions. The assumption that no price effects occur as a result of changes in final demand will generally not be a severe problem in smaller regions. However, the significant changes in demand in large regions are much more likely to result in significant input shortages and price effects. The potential for input substitution also increases in larger regions.

Analyses of impacts over a long period of time are complicated by the assumption of constant production coefficients. As a result, a relatively short period of analysis is preferred when using input-output analysis. In cases where changes in production coefficients are expected, an attempt should be made to re-analyze impacts at various intervals during the period of analysis to try to account for changes in production technology.

Computable General Equilibrium Analysis

A computable general equilibrium (CGE) model consists of a system of simultaneous equations representing cost of production functions, demands for factor inputs, and demand for household goods and services. An optimal mix of production inputs is generated by the model that meets the demands resulting from an exogenous shock caused by a project or action. A CGE model is a market clearing general equilibrium model. With this model all markets within the economy are simultaneously in equilibrium. While in equilibrium, all markets clear (supply equals demand), and prices and quantities do not have a tendency to change. Therefore, a CGE model can be used to estimate a new regional equilibrium after an exogenous disturbance.

There are three general characteristics of CGE models: (1) they include explicit specifications of how consumers and producers behave, (2) they describe how the prices of goods and services are determined through supply and demand decisions made by consumers and producers, and (3) they are computable in that there is a solution to the system of equations specified in the model. Generally, households are represented as utility maximizers, and firms are represented as profit maximizers or cost minimizers. Therefore, through optimizing behavior, the prices of goods, services, and input factors determine consumption and production decisions.

Generally, the basis of a CGE model is a set of input-output accounts, which, as described above, show the flows of goods and services between industries, households, governments, and importers/exporters. These standard input-output accounts are supplemented by elasticity estimates, including elasticities of substitution between production inputs, price and income elasticities for household goods and services, and elasticities of demand for products exported outside of the region. These elasticities are the basis for allowing for adjustment in quantities supplied and demanded as a result of changes in prices.

In the 1970’s, the CGE methodology gained interest largely because of major shocks from increased energy prices to the world economy. Modeling changes in the flows of goods and services under these circumstances required theoretically valid methods of accounting for these changes for accurate estimates of impacts.

The Basic Structure of a CGE Model

As an illustration, a CGE model could include five groups of equations representing consumption, production, prices, market clearing, and miscellaneous items such as trade equations and wage equations. Within the consumption group, a distinction may need to be made between imported commodities, domestically produced goods and services, and exports produced for consumption outside the region. Consumption functions must be estimated for each commodity included in the system and for each source of production. The consumption functions are derived from household utility functions and budget constraints and show the quantity of each commodity demanded at various prices. Demand for commodities outside the local region can be estimated similarly.

Production functions are used to estimate the demand for intermediate inputs and primary factors of production. Two aspects of production must be recognized, the activity level of each industry and the production level for each commodity in each industry. The activity level for each industry is constrained by commodity and factor inputs and the production level for each commodity is constrained by the industry activity level. Input factor substitution can be allowed within the specification.

The primary purpose of the price equations is to ensure that the value of all outputs in an industry equal the value of all intermediate and factor inputs. As prices of individual commodities and factor inputs change, substitution occurs based on the defined consumption and production relationships, and quantities and prices adjust until equilibrium is again reached at the new output levels and prices.

The market clearing equations require that the production of goods and services in the region equal use of those commodities as intermediate inputs. In addition, the use of labor and other capital resources for production is not allowed to exceed the availability of those resources. Other factors such as wages needed to employ labor resources can be included in the model similarly to price effects.

Fundamental Assumptions of a CGE Analysis

The primary assumption of CGE models is consistency with modem neoclassical microeconomic theory, where the demand and supply functions contained in the models are derived from utility and profit maximization characteristics. CGE model equations are generally specified such that a unique solution is found which is Pareto efficient. A Pareto efficient resource allocation is one that leaves no room for unambiguous improvement for either producers or consumers. Pareto efficiency is appealing because it does not require the welfare of one party to be compared against that of another. However, Pareto efficiency is limited in its usefulness because it cannot be satisfied in reality and it may not result in an optimal allocation.

Other assumptions in a CGE analysis include:

- Production technologies do not exhibit increasing returns to scale. This assumption can be relaxed, but solving the systems of equations can become very difficult.

- Firms are price takers, consumers and producers behave rationally, and that utility functions are similar (if not identical) for all individuals. These are assumptions of competitive markets and utility which are needed to obtain unique optimal solutions.

Potential Problems with the CGE Methodology

There are several potential problems associated with the application of a CGE analysis.

- CGE analysis can be difficult to apply in some areas because of the data requirements for accurately modeling linkages between sectors and estimating equilibrium. General equilibrium analysis is more difficult because all markets within the economic system must be considered and the linkages between markets must be modeled accurately to generate the correct equilibrium conditions.

- The microeconomic foundations upon which CGE analysis is based may not be very realistic.

- It is difficult to model increasing returns to scale and technical progress in a CGE model. Increasing returns can result in a positive feedback effect, where production costs are lowered so prices may decrease and quantity demanded increases. When increasing returns are present, some of the microeconomic foundations within the CGE framework are violated. It can also be very difficult to model increasing returns to scale in a dynamic context.

- A CGE model is very sensitive to the model specification. However, this sensitivity can actually be used to evaluate the robustness of the modeling results.

Advantages of a CGE Analysis

The primary advantage of a CGE analysis is that it can account for price changes and substitution of inputs and outputs which may result from a change in final demand for a good or service. The system of equations in a CGE analysis results in a solution where markets within the economy are in equilibrium and each of the markets clear at a new price and quantity after the change in final demand. This advantage may not be worth the time and effort of completing a CGE analysis if the change in demand is not likely to be sufficient to cause any of these effects throughout the economy. However, for larger changes in final demand and large impact areas, a CGE analysis may be warranted.

Another potential advantage of CGE analysis is the ability to incorporate non-linear production relationships which better represent actual production functions. However, as noted above, some functional forms violate some of the microeconomic foundations within the CGE framework. In addition, modeling non-linear production functions within a CGE framework can become very difficult mathematically.

Summary of the CGE Analysis

CGE models are useful because they depict the economy as a system of interrelated sectors, allowing a theoretically correct analysis of effects which account for price changes. CGE models can handle a large amount sectoral detail through the use of available national accounting data. Their advantage over input-output models, which rely on fixed coefficients, is the inclusion of market responses to changes in economic variables. These responses may be fairly general, such as elasticity estimates from previous studies, but they are important in understanding the response to exogenous impacts.

While some of the model specifications may not be completely correct, they can be sufficient to provide insight into the likely effects of exogenous changes in regional expenditures, which include price effects. While CGE modeling can be very data intensive because of the need to estimate large systems of equations, computer software and readily available input-output based data have greatly improved the efficiency of creating detailed regional CGE models.

A CGE analysis is best suited for relatively large and diverse economies for which there is a large amount of regional economic data. The CGE method requires a large amount of data from which market interdependencies can be estimated. In addition, the project or action under consideration, the exogenous shock, must be large enough that price effects would be expected within the region under consideration. Otherwise, an input-output model or other constant coefficient type model would probably be sufficient to estimate regional impacts.

COMPLETING A REGIONAL ECONOMIC IMPACT ANALYSIS

Regardless of the type of methodology used to estimate the regional economic impacts from a project or action, changes in the level of economic activities (final demand) must be estimated and used as input data for the regional impact models. In addition, the change in economic activities must represent the actual change in final demand from consumers outside the region or must represent a change in the distribution of final demands from within the region. A change in the distribution of final demands will result in a change in regional output and income if the demand sectors have different leakage rates. If demand shifts from a good or service sector which has a high level of leakages to a sector with few leakages, there will be a positive effect on overall regional output and income. A variety of issues must be addressed when completing a regional economic impact analysis in order to properly account for the change in final demand which will generate regional impacts.

When completing a regional economic impact analysis, there are three basic steps that must be followed. These steps are:

- Determine the impact region of concern.

- Identify the types of activities that will be affected by the action under consideration and the level of expenditures associated with each. Activity categories could include construction, agricultural production, recreation visitation, power generation, municipal and industrial water supplies, direct government payments to households or businesses in the region, and many others. Expenditure categories could include items such as groceries, gasoline, utilities, vehicles and other equipment, and many others.

- Determine the changes in expenditures that represent a true change in final demand. That is, expenditures that occur in the region must be separated from expenditures that occur outside the region.

Defining the Impact Area

There is no set rule for determining the correct area of consideration for a regional economic impact analysis. However, the region included in the study area should represent the primary area of concern to policy makers relying on the analysis for decision making purposes and should be reasonable in terms of the linkages between the site where the primary impacts occur and outlying areas that are economically and socially connected.

An impact region may be defined in terms of political boundaries. The primary reason for using political boundaries is because most data are gathered in terms of political units such as municipalities, counties, and States. Many economic and social linkages cross these boundaries. Therefore, political boundaries are not the best basis for defining an impact region in many cases. However, since most economic data are gathered at the city, county, State, or Federal level, political boundaries will frequently play a part in determining the impact region. It should be noted that some data are available at the postal Zip Code level. However, for larger studies aggregating Zip Code data can be very difficult and ultimately may be very similar to aggregated county data.

An impact region can also be defined as a set of small areas that share similar physical, social, cultural, or economic characteristics or one primary characteristic. For example, if an action is going to affect Native American government programs, then the impact area may be defined by the location of the Native American population. If an action is going to affect agricultural production, the impact area may include several counties that produce agricultural goods and provide agricultural services.

An impact area can also be defined in terms of economic linkages between areas as reflected through business and trade patterns and interdependency in production. For example, if a lumber mill is operated in a rural location and most of the labor comes from a city in an adjacent county, both counties may be considered as part of the impact region for an action that would affect the lumber mill.

The size of the region used for analysis is also important because it can have a significant influence on the magnitude of the estimated impacts. The region should be large enough to include all the direct impacts of the project or action under consideration; otherwise, some of the impacts will be ignored or the distribution of the impacts will be misspecified. It is nearly as important that the specified study area should not be too large. Using a study area that is too large may inflate the impact estimates and reduce the precision with which the relative location of impacts can be measured. Impacts measured over a large area may show relatively small impacts compared to current level of activity. However, if a large percentage of impacts occur in a much smaller region, then the impacts may be significant compared to current activity in the smaller region.

The size of the defined region can influence the value of the multipliers and the estimated regional impacts. Theoretically, the magnitude of the multipliers will increase as the size of the region included in the study area increases. This is because the number of economic activities within a region increases with the size of the region. The region becomes more self-sufficient with increasing size, and expenditure leakages outside of the region decrease. However, the multipliers generated by some regional impact computer programs may actually decrease with an increase in the size of the region because average multipliers are used as regions are added together. If a low multiplier region is added to a high multiplier region, the resulting larger region will have a multiplier that is lower than the high multiplier region.

In summary, there are two basic questions that need to be answered when determining the size of the impact region to be analyzed: (1) should the analysis show very site specific impacts or the magnitude of impacts over a larger area of influence, (2) should the analysis include a larger area of production with a wider range of production capability and input availability. Multipliers would generally be expected to be larger for larger regions because the leakages would be reduced due to more types of goods and services are produced (a more diverse and self-sufficient economy will have a larger multiplier).

Types of Activities and Expenditures Associated with Each Activity

Once the impact region is defined, the activities that are likely to be affected by a project or action must be identified, and the expenditures associated with each activity estimated. Activities which could be affected by changes in water resources include but are not limited to recreation visitation, agricultural production, direct government payments to households or businesses in the region, construction activities, municipal and industrial water service, and commercial fishing. Many other categories of impacts are possible, but these examples provide a range of impact assessment possibilities.

The expenditures associated with each of these activities need to be placed into categories that represent different sectors of production in the economy. The input requirements associated with different types of expenditures are very different in many cases. Therefore, the flows of goods and services throughout the economy required to produce the good or service demanded are different. Possible expenditure categories for six selected economic activities are presented in Table 4 below.

Illustrative Expenditure Categories

Recreation	**Agriculture**	**Direct Income**
Food - groceries Food - restaurants Lodging Gasoline Automobile repair and maintenance Privileges and other fees Boat launch, storage, etc. Bait, ice, heating and cooking fue1, other specialty items Small items such as fishing lures, lines, other small items	Livestock purchased Feed Seed Fertilizer Chemicals other than fertilizer Petroleum products Electricity Repair and maintenance Custom work Interest payments Property taxes	Food – groceries/restaurants Housing Utilities Furnishings Apparel Vehicles Gasoline Automobile repair and maintenance Health care Entertainment Insurance/pensions
Construction	**Municipal and industrial water supply**	**Commercial fishing**
Concrete Excavation Machinery/equipment Gasoline/diesel	Chemicals Electricity Distribution system	Boats Poles/lines/nets Marina rental Sheds/processing buildings

Labor	Valves and meters	Electric motors
Engineering work	Interest on borrowed debt	Fuel and oil
Steel	Operation/repair	Maintenance
Electrical	Excavation	Labor costs
Lumber, culverts, pipeline	Equipment	Local taxes/fees/licenses

The direct income category of activity presented in Table 4 represents any change in household income associated with an action. If the action being analyzed includes a Federal payment to local landowners, the portion of that payment that is distributed to households would be included as direct income. If the action resulted in increased agricultural output and higher regional farm income, the portion of income distributed to farm households would be included in the direct income category.

It is important that the expenditures used to estimate regional impacts represent the change in spending that is attributable to the project or action. For example, a project that would increase irrigated agricultural acreage and production may require increased fuel, fertilizer, seed, and other chemical usage. However, the current quantity of farm implements and custom services may be sufficient to serve the region with the project. Therefore, the projected increase in fuel, fertilizer, seed, and other chemical usage with the project can be attributed to the project, but a portion of farm implement cost estimated with the project is probably not attributable to the project. Therefore, simply using average farm expenditures per acre for various categories of use (for example, from the U.S. Census of Agriculture) may not be a good indicator of the change in expenditures for each expenditure category. The analyst must first determine the expenditure categories that will be affected by the action, then estimate a representative change in expenditures for the affected category.

In an impact analysis of changes in recreation visitation, it is important that the trip expenditures represent the variable expenditure actually associated with the trip. That is why the expenditure categories presented in table 4 do not include items that represent a fixed cost, such as boats, fishing poles, rifles, vehicles, and other items that would reasonably be expected to be purchased in the visitor’s home region and would be used for a large number of visits at many different sites. For example, including the cost of buying a boat for fishing as a part of fishing expenditures at a specific site will overstate the impacts of that activity to the region because it is unlikely that the visitor will buy the boat in the region being visited.

Some expenditure categories may not be as obvious as the boat example. Therefore, considerable professional judgment may be needed to evaluate the expenditures that are likely to occur within the study region. For example, gasoline expenditures per trip for visitors to a recreation site may occur in both the region they are coming from and the region they are visiting. One-half of the gasoline expenditures per trip may be attributable to the recreation site region. Another example is commercial fishing, where boats and other equipment may or may not be purchased in the local region, depending on the availability of suppliers and price differences of suppliers inside and outside the region.

In summary, some method for allocating expenditures to the study region and outside the region is needed for each category of expenditures.

It should also be noted that the expenditures listed under the municipal and industrial water supplies category in Table 4 refer to non-construction expenditures related to operation, maintenance, repair, and energy costs. The impacts related to building treatment plants, pumping plants, storage, and distribution systems would be covered in the construction impact category.

Sources of Expenditure and Distribution of Expenditure Information

Potential sources of expenditure information for completing regional impact analyses include:

Consumer Expenditure Surveys. - Bureau of Labor Statistics. Includes detailed summaries of household spending patterns for the United States at the national and State levels that can be used to evaluate impacts from increased income created directly by the project or action under consideration (for example, land retirement payments).

National Surveys of Fishing, Hunting, and Wildlife-Associated Recreation. - US. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census. Includes estimates of expenditures for various types of goods and services related to hunting, fishing, and wildlife-related recreation activities at the national and State level.

Census of Agriculture. - U.S. Department of Agriculture, National Agricultural Statistics Service (prior to 1997, the Census of Agriculture was the responsibility of the Bureau of the Census). Contains detailed data about farm revenues by type of operation, cropping patterns, input expenditures, and production at the county and State level.

Individual State recreation related agencies. - Many States conduct recreation surveys and studies **as** part of on-going efforts to evaluate the impact of recreation facilities on local economies and government revenues. The results of these studies can be useful in estimating the magnitude and types of recreation expenditures in an impact analysis. Agencies that may conduct these surveys include departments of recreation, parks, game and fish, tourism, commerce, and others.

Farm enterprise and budget studies. - Many State agricultural departments, in cooperation with State universities, produce farm enterprise studies that provide representative estimates of input requirements and costs for producing various crops in individual counties and States. These enterprise studies can be used to estimate the change in input costs resulting from a proposed project or action. The Bureau of Reclamation completes farm budget analyses for payment capacity and/or irrigation benefit estimates that portray representative costs and returns for farm operations. These input cost and income estimates can be used as data for a regional economic impact study.

Individual business/farm owners and trade associations. - Information from individual business and farm owners can be used to help determine where they get their supplies for production, the mix of inputs they require for their specific operation, and the cost of those inputs. Trade associations may also be able to provide similar information for areas where information is not available from individual owners or to verify information from individual owners.

Local development and employment agencies. - Local agencies may have information about the types of business and industry in the study area, the current and future location of business and industry in the area, infrastructure requirements including transportation of inputs and finished goods, and the employment requirements of local business and industry. This information can help determine trade patterns and the employment impacts of changes in final demand.

Local water utilities. - Utilities that provide municipal and industrial water service may be able to provide estimates of maintenance, operation, repair, and energy costs and the sources of goods and services for these activities. Similar information may be obtained for construction of water supply facilities.

Previous regional impact analyses. - Previously completed studies of regional impacts for similar types of activities can be useful for categorizing types of expenditures and estimating the magnitude of expenditures. These studies may be found in academic journals or in government publications.

What Expenditures Represent a True Change in Final Demand?

An increase in the demand for goods and services produced within a region by consumers from outside the region represents an exogenous change in demand for goods and services. These expenditures are treated as a change in final demand. The inflow of expenditures results in increased regional output and sales, generating positive regional economic impacts.

A change in the distribution of final demands within a region may result in changes in regional output and sales because of the variation in the multipliers associated with different goods and services. For example, if the value of final demand for agricultural production inputs increases by the same amount as the decrease in value of final demand for recreation goods, and the local region produces more agriculture inputs than recreation products, the end result may be positive impacts to the region.

Two general questions must be answered in order to estimate the expenditures which actually represent a change in final demand and influence regional output.

1. Is the money used to purchase goods and services coming from inside or outside the region of study? Money from outside the region which is spent on goods and services within the region will contribute to regional economic impacts while money which originates from within the study region is much less likely to

generate regional economic impacts. Spending from sources within the region generally represents a redistribution of income and output rather than an increase in economic activity, except as noted in the agriculture/recreation example above.

2. If the money used to purchase goods and services is determined to originate from inside the region, would those expenditures have otherwise flowed outside the region if the activity supported by the action did not exist? For example, if an action will result in improvements that will keep people who live in the study area recreating inside the area, and otherwise those people would have gone to recreation areas outside the study area, then those recreational expenditures retained in the study region represent a positive regional economic impact of the action.

Specific issues associated with these questions are addressed for different types of impact categories below.

Recreation

The recreation expenditures that generate regional economic impacts are the expenditures that occur in the region. Therefore, the spending patterns of visitors must be known. Several questions must be answered to establish spending patterns.

- What proportion of the visitation expenditures occur inside the study region?

- Where does the visitor come from, does he or she live in the study area? The regional economic impacts of expenditures at a recreation site made by a person living within the study region are likely to be very different from the impacts from the same level of expenditures made by a person living outside the study region. Those living within the region may be simply redirecting their spending from one activity to another, resulting in smaller regional impacts than if they live outside the region and bring money into the area. Recreation site managers and previous recreation studies may be good sources of information on the percentage of recreation visitation attributable to residents within the region and out-of-region residents.

- As mentioned above, there is an exception to the idea that recreation spending by local residents will result in relatively small regional impacts. If an action improves recreation opportunities in the study area and the improvement results in an increased study area visitation by local residents and decreased visitation to sites outside the study area, the end result is a net increase in regional spending in the study area. In this case, the recreation spending by local residents represents a net increase in local spending and should be included as an increase in final demand for local goods and services.

- If the visitor comes from the local region, would he or she have spent the money on another type of activity? This is the issue of the distribution of spending between activities within a region versus an actual increase in regional spending. An important related question is whether substitute recreation sites or activities are available. The availability of substitute sites within or outside the study area, as well as the availability of substitute activities, are important considerations.

An analysis of recreation impacts should be based on the changes in expenditures that actually are experienced in the region. For example, suppose that operations at a dam will be changed, and the change will reduce reservoir recreation and increase on-stream recreation activity within the same region. Also, suppose for simplification that all recreation visitation originates from outside the study area; that is, all recreation expenditures represent an increase in demand for final output. If there is a decrease in recreation activities at the reservoir resulting from reoperation of the dam, and at the same time an increase in on-stream recreation activity within the study region, the impact analysis must be based on the net change in recreation expenditures resulting from the change.

The same principle applies to a change that affects one resource in a study area but does not affect another substitute resource in the study region. Suppose one recreation site will be adversely affected by an action resulting in an estimated 1,000 fewer visitor days and $50,000 less in expenditures. Further, suppose that a substitute site in the study region which provides the same type of facilities as the adversely affected site will see 500 of those visitor days shift to the substitute site and the visitors will spend $25,000 at the substitute site. The impact analysis will be based on the change of 500 visitor days and $25,000 in reduced expenditures rather than the entire $50,000 loss at the affected recreation site. However, it should be noted that an analysis of the change in economic benefits would need to take into account the substitution of one site for another because visitors did not originally choose the substitute site; therefore, they must be obtaining a different level of benefit from recreation at the substitute site than they would have obtained at the preferred original site.

How do we estimate the recreation expenditures occurring within the region? For example, suppose a person from outside the region is going to take a trip into the study area of interest. That person will probably purchase fuel, food, and other trip related items in their home region in preparation for the trip. They may then purchase fuel for the return trip in the recreation site region and may purchase other items locally while they are visiting. However, to attribute all the trip-related expenditures to spending at the site region will overestimate the true regional economic impacts of the recreation visit. Some estimate is needed of the actual on-site recreation expenditures.

It could be assumed that half of the trip related fuel expenditures occur in the site region based on re-fueling on-site for the trip home. It could also be assumed that some types of spending, such as permits, fees, bait, and food at restaurants, will occur on-site. However, the pattern of spending for other types of items such as groceries, clothing, household supplies, and cooking supplies cannot be assumed with any confidence. Additional information is needed to estimate the percentage of these types of expenditures made locally.

Agriculture

There are two major considerations when estimating regional impacts from changes in agricultural production. The first is to account for the net change in input expenditures and farm income with the action under consideration compared to input costs and income without the action. The second is to determine where (within the study region or outside the region) the inputs are purchased and the farm income is spent.

A regional impact analysis must always account for the change in farm expenditures that would occur with an action compared to no action. If an action is going to increase or decrease irrigated agricultural activity, the change in activity from the original base is the amount that should be used to determine impacts. For example, if there was dryland agriculture in an area before a project was built that generated $1.0 million in income and input demand and total income and value of inputs with the project were projected to climb to $3.0 million, the regional impacts are based on the $2.0 million change rather than the $3.0 irrigated agriculture value.

The location where agricultural input purchases are made will depend on the cost and availability of the input item. More expensive input purchases may be made farther away from the farm operation to get better prices, but smaller items and farm services may be more likely to be purchased locally because the price difference is not as critical. Some input items may not be purchased within the study region because they are simply not available.

How farm income is spent and where it is spent, if the farm operation makes money, must also be determined. Net farm income needs to be separated into likely expenditure categories. These categories can be based on consumer expenditure surveys from the Department of Commerce, or perhaps from local sources.

In some cases, an alternative may include a nonstructural agricultural component, such as retiring agricultural land to free up water supplies. The land retirement component could include Federal Government payments to landowners to give up short-term or permanent rights to the land. In this case a regional economic impact analysis would need to include the negative regional impacts from reduced agricultural production, as well as any positive impacts from land purchase or lease payments to the land owner. However, the land retirement payments to the land owner would generate positive regional impacts only to the extent that those payments stay in the region. If the landowner sells the land to be retired and then takes the payment and moves out of the region, there would be no positive regional impacts generated by the government payment. However, if the landowner stays in the region and spends some or all of the land payment within the region, then the land payment will generate positive regional impacts.

Construction

When evaluating construction impacts, the most important decision is the location of suppliers of building materials and services and the source of construction funds.

- Where are the construction items purchased? Construction items are more likely to be purchased outside the region and brought to the construction site than some items associated with other activities because of the high cost of many construction items. If high cost items can be found outside the region at significantly lower costs, then the cost savings will justify purchases outside of the region. However, if the project or action is relatively small, labor and a significant amount of materials could be acquired from within the region.

- Where does the money for construction come from? If the project is funded with Federal or State money, the vast majority of construction expenditures represent money from outside the region. If the project is funded through local sources, the effect on the level of spending for other goods and services in the region must be taken into account.

- Over what period of time are the inputs purchased? This is important in determining the magnitude of regional impacts over a particular period of time. Some expenditures, such as operation and maintenance items, are annual expenses that occur over the life of the project. The impacts of annual expenditures over a long period of time need to be presented differently from one-time construction expenditures.

Municipal and Industrial Water Supplies

Municipal and industrial (M&I) water supplies can create regional economic impacts in several ways. The construction and continued operation, maintenance, and repair of M&I facilities can generate regional impacts. Changes in M&I water rates can have a significant impact on the composition of goods and services purchased by households and businesses, resulting in regional impacts. In addition, changes in the availability of reliable and good quality water service may have an important impact on the number and types of businesses locating in a region. Therefore, expanding water supplies may lead to increased commercial activity and positive regional impacts. However, in most cases the increase in commercial activity attributable to expanded water supplies will be very difficult to estimate. Increased supply and reliability problems would probably have the opposite effect, reducing commercial and industrial activity.

Commercial Fishing

The major areas of consideration when estimating the regional impacts from changes in commercial fishing are essentially the same as when completing an agricultural impact analysis. First, the net change in input expenditures and commercial fishing income with the action must be compared to input costs and income without the action. Second, inputs purchased from outside the region must be separated from the inputs purchased within the region. Only the within region purchases generate regional impacts. The location where commercial fishing input purchases are made will depend on the cost and availability of the input item. More expensive input purchases may be made further away from the fishery, and some input items may not be available in the local region. Third, the percentage of commercial fishing income spent in the region and the types of expenditures must be estimated.

Other Activities

Changes in the level of activities in addition to those presented above can result in regional economic impacts. Any action that influences economic activities within a region, such as power generation or municipal water supply, and results in a change in the flow of money into and out of a region (final demand) can lead to regional economic impacts.

COMPARABILITY OF CONSTRUCTION MPACTS AND IMPACTS FROM OPERATION AND MAINTENANCE EXPENDITURES

Regional impact analyses can become complicated if actions under consideration include sizable expenditures for annual costs, such as operation and maintenance. This complication is the result of estimating impacts that occur during different periods of time. When evaluating the benefits of a project in a NED type of analysis, the correct procedure is clear: bring all benefits into the same base year through a discounting procedure. However, when evaluating regional impacts, the impact values may loose some meaning if they are converted into a base year. A "discounted" estimate of the change in employment from an action may not be a very meaningful indicator of economic impacts. Similarly, the annual equivalent of income and output impacts over the life of a project from construction that occurs over a short number of years does not truly indicate the impacts that would be observed during construction and may linger after the project is completed. This question is potentially problematic in cases where there is no clear alternative and the local economic impacts are a major concern to the community. The choice may be between a large short-term gain in regional output and income and a much smaller long term gain.

The general question that needs to be answered is: what should be the basis for choosing between two projects where one project creates large one-time positive impacts as a result of construction but few annual impacts while a second project creates small initial construction impacts but large annual O&M related impacts over time? The impacts of each alternative need to be presented in comparable terms in order to compare various alternatives equally.

There are several ways in which the impacts can be presented. First, short-term construction related impacts can be kept separate from the impacts from annual expenditures occurring over a long period of time. Construction impacts would be presented in terms of total impacts over a few years while O&M impacts would be presented in terms of impacts per year. This method of presenting impacts does not address the problem of the comparability of impacts, but instead requires policy makers reading the analysis to decide for themselves if long-term or short-term impacts are most important.

A second possibility is to again separate the short-term construction types of impacts from the long-term impacts, but to present both short-term and long-term impacts in terms of an annual average impact or a total impact over the life of the project. This method ignores any discounting that would make the value of impacts comparable over time. However, the impacts are presented in terms of the actual average impacts that would be observed in the region (nominal terms). The primary problem with this type of analysis is that the time value of money, which is the discounting of future (present) dollars into present (future) value in order to make the dollar values comparable, is not recognized. However, this method is compatible with estimating employment impacts, which are measured in terms of jobs.

A third possibility would be to present long term and short term impacts as annual equivalent impacts or total impacts discounted to present (or future) value terms. This method of presenting impacts results in estimates that are comparable between alternatives, although they would not generally represent the impacts that would actually be observed in the study region. In addition, employment impacts could not be presented in this way. The discounted impacts could be presented along with the separated short-term and long term impacts to reflect the timing of impacts that would actually be observed.

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Appendix 6

Consultation Letters

MESCALERO Apache TRIBE
Sara Misquez, President | Mescalero, New Mexico 88340

ORIGINAL

TRIBAL HISTORIC PRESERVATION OFFICE
101 Central Avenue
P.O. Box 227
Mescalero, New Mexico 88340
Phone: 505/464-4494 ext. 279 or 270
Fax: 505/464-9191

Mr. Kenneth G. Maxey
Bureau of Reclamation
505 Marquette N.W. Suite 1313
Albuquerque, NM 87102-2162

Dear Mr. Maxey:

(X) The *Mescalero Apache Tribe* has determined that the proposed Carlsbad Project Water Operations and Water Supply Conservation EIS **WILL NOT AFFECT** any objects, sites, or locations important to our traditional culture or religion.

( ) The *Mescalero Apache Tribe* has determined that the proposed _______________ project by _______________ **WILL AFFECT** objects, sites, or locations important to our traditional culture or religion. We request that the _______________ undertake further consultations to evaluate the effects of the project on these sites.

In the future, we request that you minimally provide us with the following items to aid in our determination:

- Cultural Resource Survey Reports
- Site Forms
- Maps (Both General and Site Specific)
- Research Designs (If Applicable)
- Data Recovery Plans (If Applicable)
- Photographs

Thank you for providing the Mescalero Apache Tribe the opportunity to comment on this project. We look forward to reviewing and commenting on future Bureau of Reclamation projects.

CONCUR:

Donna Stern-McFadden
Name
Donna Stern McFadden
Signature

1/3/03
Date

Tribal Historic Preservation Officer
Title

COMMENTS:
Send all correspondence to my office. Thx.
DSM

10.6

ORIGINAL

ALBUQUERQUE AREA OFFICE
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Project EA
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12/27 105
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1/2/03 150
158

United States Department of the Interior
BUREAU OF INDIAN AFFAIRS
Southern Plains Regional Office
P.O. Box 368
Anadarko, Oklahoma 73005

IN REPLY REFER TO:
Natural Resources

DEC 16 2002

Mr. Ken Maxey
Area Manager
Albuquerque Area Office
Bureau of Reclamation
505 Marquette N.W., Suite 1313
Albuquerque, New Mexico 87102-2162

Subject: Consultation Invitation Regarding the Bureau of Reclamation's Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

Dear Mr. Maxey:

Thank you for the opportunity to comment on the subject document as expressed in your November 21st letter to our office. A review of the enclosures that accompanied your letter indicated that you have made a considerable effort to include a broad range of the affected public, in particular, the Native American community.

As a result of your extensive outreach to Native Americans in our Region, we decline to offer comments on your proposed re-operation of Sumner Dam and the implementation of a water acquisition program in New Mexico's Pecos River Basin. You have demonstrated through your contact list that the appropriate Native American community has been asked to provide comments and since impacts to cultural resources would be our primary concern with a project such as this that does not affect lands directly under our control, we feel that we should defer to their expertise. Further, you have solicited comments from our Southwest Regional Office and they are the appropriate office to provide watershed specific issues that may not be raised by the Tribal community.

Again, thank you for the opportunity to comment. If we can be of further service, please feel free to contact the Branch of Natural Resources office at (405)247-6673, extension 249.

Sincerely,

Dan Deerinwater

Regional Director

ALB-158
ENV-1.10

NOV 21 2002

Mr. Rob Baracker
Regional Director
Southwest Region
Bureau of Indian Affairs
P.O. Box 26567
Albuquerque, NM 875125-6567

Subject: Consultation Invitation Regarding the Bureau of Reclamation's Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

Dear Mr. Baracker:

Enclosed for your information is a copy of a letter in which the U. S. Bureau of Reclamation requests government-to-government consultation with various tribal governments regarding the Bureau of Reclamation's Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement. As well, the list of the Chairs and Natural Resource persons for the contacted tribes is included. In addition to exchanging information with tribal governments, we would also appreciate any feedback you may have regarding the proposed project and possible environmental effects, including the potential to affect Indian trust assets or cultural resources.

For further information, please contact Ms. Lori Robertson at (505) 248-5326.

Sincerely,

Ken Maxey
Area Manager

Enclosure

cc:

Bureau of Indian Affairs
Southwest Regional Office
Branch of Water Rights
Attention: John Collie or Art Martinez
P.O. Box 26567
Albuquerque, NM 87125-6567

Mr. Bill White
Southwest Regional Office
Bureau of Indian Affairs
P.O. Box 26567
Albuquerque, NM 87125-6567

Mr. Ron Toya, Superintendent
Mescalero Agency
Bureau of Indian Affairs
P.O. Box 189
Mescalero, NM 88340

Ms. Florine Gutierrez
Southern Pueblos Agency
Bureau of Indian Affairs
P.O. Box 1667
Albuquerque, NM 87103

Regional Director
Southern Plains Region
Bureau of Indian Affairs
W.C.D. Office Complex
P.O. Box 368
Anadarko, OK 73005

Ms. Jan Biella, Acting State Historic Preservation Officer
New Mexico Historic Preservation Division
228 E. Palace Avenue
Santa Fe, NM 87501

ALB-158
ENV-1.10

NOV 21 2002

Governor Paul Tosa
Pueblo of Jemez
P.O. Box 100
Jemez Pueblo, NM 87024

Subject: Consultation Invitation Regarding Bureau of Reclamation's Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement

Dear Governor Tosa:

In October 1999, the U.S. Bureau of Reclamation (Reclamation) wrote a letter to you requesting your views on our Pecos River Water Operations Environmental Impact Statement. Since then, and after long negotiations with the New Mexico Interstate Stream Commission (NMISC), we have decided to prepare two EIS documents rather than the one we had previously planned to prepare. The first new EIS, and the subject of this letter, is entitled the Carlsbad Project Water Operations and Water Supply Conservation Environmental Impact Statement. With this letter, we would like to re-initiate consultation with you on this new EIS. The second EIS, to be initiated in the future, will focus on the needs of NMISC and is entitled the Carlsbad Project Miscellaneous Purposes Act Contract EIS.

The Carlsbad Project Water Operations and Water Supply Conservation EIS will focus on the reoperation of Sumner Dam and the implementation of a water acquisition program in New Mexico's Pecos River Basin. The purpose of the reoperation of Sumner Dam is to conserve a threatened species, the Pecos bluntnose shiner, in compliance with the Endangered Species Act. The purpose of the water acquisition program is to conserve the Carlsbad Project water supply by acquiring water to make up for any new depletion, in keeping with Reclamation's requirements to deliver water to the Carlsbad Irrigation Project.

The EIS will address possible changes to operations of Sumner Dam on the Pecos River. The area of evaluation for the proposed action is within the Pecos River Basin from Santa Rosa Reservoir to the New Mexico-Texas state line. The evaluation will cover revised operations for Sumner Dam and any connected operations at Santa Rosa Dam (owned and operated by the U.S. Army Corps of Engineers), Brantley Dam, or Avalon Dam. Water acquisition activities will focus on those options that most effectively conserve project water supply.

The range of alternatives to be analyzed in the EIS would likely include various operational scenarios for Sumner Dam and various sources and quantities of water for the water acquisition program. Adjustments to the timing, magnitude, frequency, duration, and rate of change of releases from Sumner will likely be addressed, as will the quantity of water stored in Sumner Reservoir during low-flow periods. To the extent that revised operations diminish project water supply, the alternatives will include various water acquisition options involving willing sellers.

The purpose of this letter is to invite your tribe's involvement on a government-to-government basis to identify any concerns your tribe may have regarding the potential effects of our future activities on trust assets, cultural and biological resources, or tribal health and safety. Reclamation wants to ensure that you have the opportunity to help us identify and address any issues important to your tribe.

To assist us with NEPA analysis, Reclamation has been working closely with various partners, including NMISC, the Carlsbad Irrigation District, the U.S. Fish and Wildlife Service, the New Mexico Department of Game and Fish, the New Mexico Office of the State Engineer, the U.S. Army Corps of Engineers, the Fort Sumner Irrigation District, the Pecos Valley Artesian Conservancy District, Eddy County, Chaves County, and the Pecos Valley Water Users Organization. To receive additional input from interested organizations and individuals, public scoping meetings were held in Santa Rosa, Fort Sumner, Roswell, and Carlsbad, New Mexico from October 21 through 24, 2002.

As part of the environmental impact statement (EIS) process, potential effects to Indian trust assets, tribal health and safety, and cultural resources will be determined. Reclamation's preliminary assessment has not revealed any potential impacts. However, to fully address and analyze potential effects, Reclamation would appreciate your tribe's input regarding possible impacts to Indian trust assets, tribal health and safety, traditional cultural properties, sacred sites, and other aspects of the tribe's cultural heritage that may be associated with the proposed program.

To facilitate your identification of questions and concerns about the reoperation of Sumner Dam and the implementation of a water acquisition program in southeastern New Mexico, Reclamation will gladly provide any additional information needed by you or your staff. We would welcome an opportunity to meet with you and your staff to describe the EIS in further detail. To discuss the EIS or to arrange a meeting, please contact Ms. Lori Robertson, Manager, Environment and Lands Division at 505/ 248-5326.

Sincerely,

Kenneth G. Maxey
Area Manager

Copies of this letter sent to Chairs and Natural Resources contacts for the following tribes:

✓Governor Paul Tosa
Pueblo of Jemez
P.O. Box 100
Jemez Pueblo, NM 87024

Governor Albert Alvidrez
Pueblo of Ysleta del Sur
P.O. Box 17579
El Paso, Texas 79907

Cc: Rick Casada, Cultural Resources Coordinator
Pueblo of Ysleta del Sur
P.O. Box 17579
El Paso, Texas 79907

Governor Alvino Lucero
Pueblo of Isleta
P.O. Box 1270
Isleta Pueblo, New Mexico 87022

Cc: John Sorrell, Hydrologist
Pueblo of Isleta
P.O. Box 1270
Isleta Pueblo, New Mexico 87022

Earl Yeahquo, Chairman
Kiowa Business Committee
P.O. Box 369
Carnegie, OK 73015

Cc: George Daingkau
Kiowa NAGPRA Coordinator
Route 2, Box 74
Ft. Cobb, OK 73038

Sara Misquez, President
Mescalero Apache Tribe
P.O. Box 227
Mescalero, NM 88340

Cc: Donna McFadden
Tribal Historic Preservation Officer
Mescalero Apache Tribe
P.O. Box 227
Mescalero, NM 88340

Ruey Darrow, Chairman
Fort Sill Apache Business Committee
Route 2, Box 121
Apache, OK 73006

Johnny Wauqua, Chairman
Comanche Tribal Business Committee
P.O. Box 908
Lawton, OK 73502

Cc: Jimmy Arterberry
NAGPRA Coordinator
P.O. Box 908
Lawton, OK 73502

Chairman Wayne Taylor, Jr.
Hopi Tribe
P.O. Box 123
Kykotsmovi, AZ 86039

Cc: Leigh Kuwanwisiwma, Director
Hopi Cultural Preservation Office
P.O. Box 123
Kykotsmovi, AZ 86039