APPENDIX C
WATER BUDGET

C. Water Budget

C.1 Overview and Monitoring Commitment

The Draft Environmental Assessment included two partial water budgets constructed by the United States Fish and Wildlife Service (Service) for existing versus anticipated restoration conditions for this project (US Fish and Wildlife Service 2008c). The partial water budgets for Reaches 2, 3, and 4 along eight miles of the Pecos River within the Middle Unit consist of evapotranspiration (ET) estimates for two separate parameters: ET contribution from changes in surface water area and ET contribution from vegetation changes.

Initial ET estimates for changes in surface water area suggest a total depletion of 7.8 acre-feet per year (AFY). Initial ET estimates for changes to vegetation composition suggest a contribution of 867 AFY to the system. This latter estimate remains controversial because presently there is no science to show a sustained decadal increase in surface water flow due to riparian zone vegetation changes.

The hydrologic monitoring associated with the Oxbow 4 reconnection is expected to show additional groundwater contributions to the stream channel via channel incision that will remove additional groundwater from the local aquifer. Current estimates are based on the following:

- Existing and projected future land cover conditions;
- Evaporation data from the Bitter Lake NWR pan evaporation station;
- ET values from studies within the region; and
- Information from groundwater investigations on the Refuge (USFWS 2008c).

Because the "future condition" of the project is unknown and is expected to be variable with time, the Service and the New Mexico Interstate Stream Commission (NMISC) are reviewing necessary monitoring needs to assess true impacts of the project on the water budget.

The NMISC manages the state's limited water supply through a system of permits and licenses, which allows some portion of water to be permanently removed from the water budget. Some resource management activities may affect the overall water budget of a given basin by changing evapotranspiration patterns. In the Pecos River Basin, the NMISC is responsible for compliance with the Pecos River Compact (between New Mexico and Texas) and the Carlsbad Project Settlement Agreement. This requires that

the water budget be quantified and water resources carefully managed using the best available science. For this reason, depletion estimates for both phases of the restoration prepared by the NMISC are presented here in lieu of the water budget prepared by the Service, which included substantial contributions due to vegetation changes (US Fish and Wildlife Service 2008c). The Service and NMISC estimates are part of the hypothesis, which will be tested through monitoring, that there will be small changes to the water budget from this project.

Based on conservative estimates of water usage—that is, higher than would likely occur—the NMISC anticipates that Phase I restoration may consume 1.9 AFY, and Phase II may consume 7.6 AFY, for a total of 9.5 AFY . While the Service expects that less water would be used and benefits would be gained due to reduced evapotranspiration, the Service and the NMISC will monitor long-term effects and will address any depletions. The Service is committed to ensuring that any net depletions to the water budget resulting from the project will be compensated for and that there will be no adverse impact on downstream water rights or on interstate compact deliveries (Tashjian 2008).

To evaluate potential depletions from Pecos River restoration activities on the Refuge, a monitoring protocol that includes gathering baseline and long-term data will be used to evaluate effects on the local water budget. To quantify changes in the local water budget variables, such as open surface water area, depth of water within the oxbow and the present river channel, channel gradient, depth to groundwater, vegetation changes, and present and future geomorphology will be measured to evaluate a baseline condition and assess the status of the restoration effort and its effects over time. Stream channel measurements both upstream and downstream of the restoration site will be made, along with channel and oxbow cross sections. Using handheld flow meters to measure and record periodic instantaneous velocities and a line of piezometers to measure groundwater levels and flow direction, the responses to the restoration project may be observed. Photo interpretation will be used to evaluate vegetative and geomorphic response. ET will be estimated using the Bitter Lake NWR evaporation pan record.

Memorandum

Date: May 7, 2007

To: Estevan López, ISC Director

Through: Bhasker K. Rao, ISC Pecos Bureau Chief

From: Emile Sawyer, ISC Bitter Lake NWR Project Manager

Copy: Sara Rhoton, NEPA-ESA Project Manager

RE: Evaluation of Additional Net Depletions to Pecos River as a result of the Bitter Lake National Wildlife Refuge River Restoration Project at Oxbow #4

Purpose

This memorandum presents an evaluation of the water budget calculations provided to ISC by Paul Tashjian, Regional Hydrologist with the US Fish and Wildlife Service (**USFWS**) and makes recommendations regarding potential depletions created by the river restoration project at Oxbow #4 on the Bitter Lake National Wildlife Refuge River (**BLNWR)**.

Project

The BLNWR is located approximately seven miles east of Roswell, NM and contains approximately 12 Pecos River miles. Between 1942 – 1953 five meanders were cut off from the flow of the Pecos River by a channelization project.

The May 18, 2006 USFWS Biological Opinion on the preferred alternative of the Carlsbad Project Water Operations and Water Supply Conservation EIS states that, "*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 2*009". The USFWS provided the ISC with estimates of depletions to the Pecos River that could occur as a result of this project. ISC has evaluated the USFWS analysis and it is recommended that the State Engineer require offsets for these Additional Net Depletions.

The USFWS analysis multiplies the averaged monthly pan evaporation data (1950 –2002) from BLNWR (E_{mp}) times the monthly surface area of Oxbow #4 (SA_{mo}) plus the current channel surface area that contains the Pecos River along this reach (SA_{ch}). The result of this equation is a monthly evaporation volume ($E_{m)}$.

E_{mp} (feet) * (SA_{mo} (acres) + SA_{ch} (acres)) = E_m (acre-feet) Equation 1

Then each monthly evaporation volume ($E_{m(i)}$) is summed to provide a total annual evaporation value (E_t).

$\Sigma E_{m(i)} = E_t$ Equation 2

The sum (E_t) of 89.9 acre-feet/year of evaporation is calculated for the present river condition. The sum (E_t) of 91.8 acre-feet/year of evaporation is calculated for the future river condition. The smallest value, the present condition, is subtracted from the largest, the future condition, with a result of 1.9 acre-feet/year of evaporation.

The ISC does not recognize any credit for water salvage activities. While the current science surrounding evapotranspiration measurement continues to evolve, the salvage of water through vegetation management has yet to be defensibly quantified. Thus such activities have not been evaluated here.

The ISC was asked by USFWS to review possible increases in stream flow due to geomorphic changes that will likely result in a lowering of the stream bed and cause a temporary increase in ground water contribution to the Pecos River. The movement of water from one source to another does not constitute new water and therefore cannot be considered a credit against depletions caused by the project.

Whereas it is the responsibility of the State Engineer to be concerned about any depletions greater than 0.1 acre-feet/year in the Pecos River Basin; and

Whereas it is the policy of the State Engineer to manage the waters of New Mexico for the benefit of the public and has the authority to permit any and all beneficial use of the state's waters; and

Whereas any increase in depletions in the Pecos River Basin is a concern for interstate compact delivery obligations; and

Whereas the dynamic nature of rivers and the uncertainties surrounding the geomorphic and hydrologic response of the Pecos River channel to the aforementioned project makes future river conditions difficult to predict.

It is therefore recommended that:

1) A depletion value of 1.9 acre-feet/year should be assessed the Oxbow #4 river restoration project and that appropriate water rights be designated or obtained for the project; and

2) An evaluation of the effects on depletions by this project be revisited five (5) years from the project completion date to determine if unforeseen circumstances have created a larger than expected surface area and if so, that a larger depletion assessment be required to keep the Pecos River system whole.

References

Dunne and Leopold, 1978. Water in Environmental Planning. W.H. Freeman and Co., New York 818 pp.

Loheide, S. P., II, J. J. Butler Jr., and S. M. Gorelick, 2005. Estimation of groundwater consumption by phreatophytes using diurnal water table fluctuations: A saturated-unsaturated flow assessment, *Water Resources Research*, 41, W07030, doi:10.1029/2005WR003942.

Tashjian, P., Draft Environmental Assessment: Restoration of a Functioning Pecos River channel at Bitter Lake National Wildlife Refuge, Chaves County, New Mexico. September 3, 2002. 41 pp.

USFWS Biological Opinion for the Bureau of Reclamation's Proposed Carlsbad Project Water Operations and Water Supply Conservation, 2006-2016. May 18, 2006. 101 pp.

Bitter Lake National Wildlife Refuge Oxbow #4 River Restoration Evaporation calculation tables
Adapted by F.Emile Sawyer from tables submitted to ISC by Paul Tashjian, USFWS.

Current Condition					Future Condition				
Month	Avg Pan Evaporation *0.78 (feet)	Channel Surface Area Avg (acres)	Oxbow #4 Surface Area Avg (acres)	Total Monthly Evaporation (acre-feet)	Month	Avg Pan Evaporation *0.78 (feet)	Channel Surface Area Avg (acres)	Oxbow #4 Surface Area Avg (acres)	Total Monthly Evaporation (acre-feet)
January	0.17	6	13	3.2	January	0.17	4	14	3.0
Feb	0.23	6	13	4.5	Feb	0.23	4	14	4.2
March	0.41	6	12	7.4	March	0.41	4	14	7.4
April	0.56	6	12	10.1	April	0.56	4	14	10.1
May	0.66	6	11	11.2	May	0.66	4	14	11.8
June	0.72	6	11	12.3	June	0.72	4	14	13.0
July	0.64	6	11	10.9	July	0.64	4	14	11.5
August	0.57	6	11	9.7	August	0.57	4	14	10.3
September	0.45	6	12	8.1	September	0.45	4	14	8.1
October	0.34	6	12	6.1	October	0.34	4	14	6.1
Nov	0.20	6	13	3.7	Nov	0.20	4	14	3.6
Dec	0.14	6	13	2.7	Dec	0.14	4	14	2.5
Annual Values	5.10	6	12	89.9	Annual Values	5.10	4	14	91.8

Memorandum

Date: October 20, 2008

To: Estevan Lopez, ISC Director

Through: Bhasker Rao, ISC Pecos Bureau Chief

From: Emile Sawyer, ISC Bottomless Lakes NWR Project Manager
Markus Malessa, ISC Pecos Bureau Staff

RE: Evaluation of Additional Net Depletions to the Pecos River as a result of the Bitter Lake National Wildlife Refuge Phase II Restoration

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Purpose

This memorandum presents an evaluation of additional net depletions to the Pecos River resulting from Phase II restorations at the Bitter Lake National Wildlife Refuge (**BLNWR**). The memorandum also makes recommendations to address these additional net depletions. The Phase I evaluation is contained in a similar memorandum dated May 7, 2007. The additional net depletions calculated for Phase I are noted at the end of this document.

Project

The BLNWR is located approximately seven miles east of Roswell, New Mexico and contains approximately 12 Pecos River miles. Between 1942 – 1953 five meanders were cut off from the Pecos River by a channelization project to prevent flooding of migratory water fowl constructed wetlands habitat.

The BLNWR restoration project is to be implemented over a 10-year period. The project area is divided into five reaches. Activities in Reaches 2, 3 and 4 will be completed, according to the proposed plan, during two separate phases (Bureau of Reclamation, 2008). This memorandum was prepared to specifically address additional net depletions (**AND**) that could result from the restoration activities presented during Phase II. Phase II includes three major activities in Reaches 2 and 3 only. Activity number one (**Act #1)** includes an area that stretches from the north end of Reach 2 to the south end of Reach 3. This activity includes bank levee lowering to encourage interaction between the river channel and the surrounding floodplain at flows greater than 1,200 cubic feet per second (**cfs**). Activity number two (**Act #2**) includes the reconnection of a small oxbow at the north end of Reach 2, which has been cut off, due to sediment build up at the entrance and exit. Activity number three (**Act #3**) includes the reconnection of a small oxbow lake at the mid section of Reach 3, which currently holds spring water year round (Bureau of Reclamation, 2008).

Method of Calculations

To determine an open surface water evaporation factor for this area, the average yearly pan evaporation data, as observed at BLNWR Station # 922 (NM Climate Center, 2008), was used. It was determined that the average yearly pan evaporation is 7.3 feet. The yearly evaporation of 7.3 feet was then multiplied by the pan to lake evaporation factor of 0.77 (Boroughs and Stockton, 2005). The result is an average annual evaporation (**E_a**) of 5.6 feet per year (**ft/yr**) (Calculation 1).

E_a = 7.3 ft/yr * 0.77 Calculation 1

= 5.6 ft/yr

Act #1 is expected to increase channel-floodplain interaction to create a total of 54 acres (**ac**) of open surface water during flows of 1,200 cfs or more (Bureau of Reclamation, 2008), as observed at the USGS Acme Gauge (# 8386000). An analysis of the USGS Acme Gauge record, including discharge data from 1938 – 2007, shows that flows of 1,200 cfs or more occur approximately 2.1% of the time. Calculating 54 ac times 5.6 feet/year times 2.1%, resulting in an estimated additional net depletion of 6.4 acre-feet per year (**ac-ft/yr**). (Calculation 2) See Exhibit 1 for yearly total and monthly weighted factor.

AND for Act #1 = 54 ac * 5.6 ft/yr * 0.021 Calculation 2

= 6.4 ac-ft/yr

Act #2 it is expected to expand the small oxbow to approximately 3 ac of open surface water with flows of 1,200 cfs or more. (Bureau of Reclamation, 2008). The result is determined by multiplying 3 ac times 5.6 ft/yr times 2.1% for a subtotal of 0.4 ac-ft/yr AND (Calculation 3). See Exhibit 2 for annual total and monthly weighted factors.

AND for Act #2 = 3 ac * 5.6 ft/yr * 0.021
Calculation 3

= 0.4 ac-ft/yr

Act #3 will increase open surface water area 1 ac, from 5 ac to 6 ac, during flows of 300 to 1,200 cfs (Bureau of Reclamation, 2008). An analysis of the USGS Acme Gauge record, including discharge data from 1938 – 2007, shows that flows between 300 to 1,200 cfs occur approximately 14.4% of the time. Calculating 1 ac times 5.6 ft/yr times 14.4% results in 0.8 ac-ft/yr AND (Calculation 4). See Exhibit 3 for yearly total and monthly weighted factor.

AND for Act #3 = 1 ac * 5.6 ft/yr * 0.144

Calculation 4

= 0.8 ac-ft/yr

The total estimated AND determined for all three activities are 7.6 ac-ft/yr.

Total AND for Phase II

Calculation 5

Act #1 6.4 ac-ft/yr
Act #2 0.4 ac-ft/yr
Act #3 + 0.8 ac-ft/yr
= 7.6 ac-ft/yr

Although the project includes Tamarix spp. removal, the ISC does not recognize any credit for this type of water salvage activity at this time. While the current science surrounding evapotranspiration measurement continues to evolve, the salvage of water through vegetation management has yet to be defensibly quantified. Thus such activities have not been evaluated in this memorandum.

1.1.1.1.1.1.1.1 Observations

Whereas it is the responsibility of the State Engineer to be concerned about any depletions greater than 0.1 acre-feet/year in the Pecos River Basin (§1-15.6.4, OSE/ISC, 2006); and

Whereas it is the policy of the State Engineer to manage the waters of New Mexico for the benefit of the public and has the authority to permit any and all beneficial use of the state's waters; and

Whereas any increase in depletions in the Pecos River Basin is a concern for interstate compact delivery obligations; and

Whereas the dynamic nature of rivers and the uncertainties surrounding the geomorphic and hydrologic response of the Pecos River channel to the aforementioned project makes future river conditions difficult to predict.

It is therefore recommended that:

1) A depletion value of 7.6 ac-ft/yr should be assessed to the Bitter Lake National Wildlife Refuge Phase II restoration project and that appropriate water rights be designated or obtained for the project; and

2) An evaluation of the effects on depletions by this project be revisited five years from the completion date to determine if unforeseen circumstances have created a larger than expected surface area and if so, that a larger depletion assessment be required.

Note: The Phase I evaluation for this project is contained in a memorandum dated May 7, 2007. AND calculated for Phase I are 1.9 ac-ft/yr. Adding the above quantity of 7.6 ac-ft/yr plus 1.9 ac-ft/yr is equivalent to a total of 9.5 ac-ft/yr AND estimated for the implementation of both Phases I and II of this project.

References

U.S. Department of the Interior, Bureau of Reclamation, Albuquerque Area Office, Environment Division; Pecos River Channel Restoration at the Bitter Lake National Wildlife Refuge, Chavez County, New Mexico, Draft Environmental Assessment; September 2008

OSE/ISC; Rules and Regulations Governing the Appropriation and Use of Ground Water in New Mexico; Revised August 15, 2006

NM Climate Center; NMSU Weather Data; Bitter Lake Weather Station; Last updated: July 5, 2005; Accessed: September 12, 2008; http://weather.nmsu.edu/Pan_Evaporation/bitter_lakes_refuge_evap.htm

Craig B. Boroughs, PHD, PE; Thomas B. Stockton, PE; Pecos River RiverWare Model Draft Report; September 2005

Exhibit 1 Table of Monthly Depletion Calculations for Activity # 1

TOTAL ESTIMATED NEW DEPLETIONS **6.4 AC-FT/YR**

Current vs Future Depletions

Acres

Current: Vegetated Dry Area

Acres of Dry Vegetation	
January	0
Feb	0
March	0
April	0
May	0
June	0
July	0
August	0
September	0
October	0
Nov	0
Dec	0

Future: Open Surface Water Area

Acres of Open Water	
January	54
Feb	54
March	54
April	54
May	54
June	54
July	54
August	54
September	54
October	54
Nov	54
Dec	54

Consumption

Current: Vegetated Dry Evap

Acre-feet from Dry Vegetation		
January	0	
Feb	0	
March	0	
April	0	
May	0	
June	0	
July	0	
August	0	
September	0	
October	0	
Nov	0	
Dec	0	
Total	0	**0.0**

Future: Open Surface Water Evap

Acre-feet from Open Water		
January	0.19282725	
Feb	0.28596645	
March	0.49698495	
April	0.69199515	
May	0.8033256	
June	0.89282655	
July	0.8455293	
August	0.73710945	
September	0.57266055	
October	0.4176711	
Nov	0.2575881	
Dec	0.18555075	
Total	6.38	**6.4**

Exhibit 2 Table of Monthly Depletion Calculations for Activity # 2

TOTAL ESTIMATED NEW DEPLETIONS	0.4 AC-FT/YR

Current vs Future Depletions

Acres

Current: Vegetated Dry Area

Acres of Dry Vegetation	
January	0
Feb	0
March	0
April	0
May	0
June	0
July	0
August	0
September	0
October	0
Nov	0
Dec	0

Future: Open Surface Water Area

Acres of Open Water	
January	3
Feb	3
March	3
April	3
May	3
June	3
July	3
August	3
September	3
October	3
Nov	3
Dec	3

Consumption

Current: Vegetated Dry Evap

Acre-feet from Dry Vegetation		
January	0	
Feb	0	
March	0	
April	0	
May	0	
June	0	
July	0	
August	0	
September	0	
October	0	
Nov	0	
Dec	0	
Total	0	0.0

Future: Open Surface Water Evap

Acre-feet from Open Water		
January	0.010712625	
Feb	0.015887025	
March	0.027610275	
April	0.038444175	
May	0.0446292	
June	0.049601475	
July	0.04697385	
August	0.040950525	
September	0.031814475	
October	0.02320395	
Nov	0.01431045	
Dec	0.010308375	
Total	0.35	0.4

Exhibit 3 Table of Monthly Depletion Calculations for Activity # 3

TOTAL ESTIMATED NEW DEPLETIONS **0.8 AC-FT/YR**

Current vs Future Depletions

Acres

Current: Open Surface Water Area

Acres of Open Water	
January	5
Feb	5
March	5
April	5
May	5
June	5
July	5
August	5
September	5
October	5
Nov	5
Dec	5

Future: Open Surface Water Area

Acres of Open Water	(14.4%)	(85.6%)
January	6	5
Feb	6	5
March	6	5
April	6	5
May	6	5
June	6	5
July	6	5
August	6	5
September	6	5
October	6	5
Nov	6	5
Dec	6	5

Consumption

Current: Open Surface Water Area

Acre-feet from Open Water		
January	0.850208333	
Feb	1.260875	
March	2.191291667	
April	3.051125	
May	3.542	
June	3.936625	
July	3.728083333	
August	3.250041667	
September	2.524958333	
October	1.841583333	
Nov	1.13575	
Dec	0.818125	
Total	28.13066667	**28.1**

Future: Open Surface Water Evap

Acre-feet from Open Water	(14.4%)	(85.6%)	
January	0.146916	0.727778333	
Feb	0.2178792	1.079309	
March	0.3786552	1.875745667	
April	0.5272344	2.611763	
May	0.6120576	3.031952	
June	0.6802488	3.369751	
July	0.6442128	3.191239333	
August	0.5616072	2.782035667	
September	0.4363128	2.161364333	
October	0.3182256	1.576395333	
Nov	0.1962576	0.972202	
Dec	0.141372	0.700315	
Total	4.86	24.08	**28.9**