4C.10 Pipeline between Choke Canyon Reservoir and Lake Corpus Christi (N-10)

4C.10.1 Description of Strategy

Channel losses in streams that deliver water from Choke Canyon Reservoir (CCR) to Lake Corpus Christi (LCC) are often large. Previous studies[1] indicate that channel losses in the 63-mile reach of the Frio and Nueces Rivers downstream of CCR to LCC, which include seepage losses within LCC, can be significant. Recent analysis has shown that since the completion of CCR, these losses have averaged 37.8 percent for this reach.[2] The groundwater and surface water interaction downstream of CCR to LCC is very complex and could vary significantly based on seasonal events, antecedent drought or wet conditions and prolonged drought or wet conditions that could impact storage in LCC as documented in a channel loss study conducted by the Coastal Bend Regional Water Planning Group from CCR to LCC in March 2008 (described in Appendix B).

Since the majority of the surface water supply from the CCR/LCC System for the City of Corpus Christi and its customers is stored in CCR and delivered to LCC using the natural stream channel, the yield of the system is affected by these losses. However, if water could be delivered by a pipeline that bypasses the stream channels, it would not be subjected to these losses and would result in more water in storage and enhance the system yield. Past studies[3] have shown that a pipeline between CCR and LCC could provide a significant increase to the CCR/LCC System at a relatively low cost. In addition to the pipeline between CCR and LCC, several past studies[4,5,6] have evaluated the possibility of enhancing the CCR/LCC System yield by taking advantage of CCR's proximity to the Nueces River and diverting water from the Nueces River near Simmons or Three Rivers and storing it in CCR. The results of these studies have shown that enhancements to the CCR/LCC System are small and result in high unit costs. Analyses of streamflow records show that the main reason those yield increases are small is due to the fact that in drought conditions, flows in the Nueces River are limited and would be captured by

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[1] HDR Engineering, Inc. (HDR), "Regional Water Supply Planning Study, Phase I, Nueces River Basin," Vols. 1, 2, and 3, Nueces River Authority, et al., May 1991.

[2] CCR/LCC updates, 2005.

[3] HDR, Op. Cit., May 1991.

[4] HDR, "Diversion from Nueces River to Choke Canyon Reservoir," Memo to James Dodson, September 8, 1997.

[5] HDR, Op. Cit., May 1991.

[6] Raushchuder, D.G., "Potential for Development of Additional Water Supply from the Nueces River between Simmons and Calallen Diversion Dam," 1985.

available storage in LCC. Therefore, analysis of the pump-back from the Nueces River to CCR is not included in this evaluation.

The pipeline route between CCR and LCC is shown in Figure 4C.10-1. Going from CCR to LCC, the route follows a southeasterly direction from CCR, crosses the Nueces River, and terminates on the upper west side of LCC. The pipeline operation will require an intake at CCR and an outlet structure at LCC. In the 2001 Plan, the pipeline route extended an additional 12 miles to the lower west side of LCC (Figure 4C.10-1) to allow operation of a two-way pipeline with a deep-water pump station at LCC. The two-way option showed small additional yield and resulted in high unit costs attributable to additional costs for the extra pipeline length and pump station at LCC. Therefore, the two-way pipeline was removed from consideration from future plans.

CCR is required to continue its release of 33 cfs for senior water rights and environmental considerations even with the pipeline in operation to deliver water supply releases.

The analysis for a pump-back operation at Three Rivers in conjunction with the CCR to LCC pipeline showed that unlike the off-channel reservoir project described in Section 4C.11, which has the benefit of catching storm flows in LCC for later diversion over a long period of time, the pump back option could only divert the storm flows for a period of a few days as it traveled downstream. This resulted in significantly less flow being diverted into CCR than could be diverted into the off-channel reservoir. The results of the pump-back option analysis indicated that from hydrological and operational standpoints this option was not efficient in producing the desired additional water supply.

Based on results of the recent channel loss study[7], an overall channel loss was estimated to be between 2 and 3 percent for the 17.4 river mile stretch from CCR to the Nueces River near Sulphur Creek, which is about 1/10 of the channel losses from previous studies cited above. Based on the results from previous studies, a channel loss around 10.4% would have been expected for this reach (i.e. 17.4 river miles time 0.6 percent per river mile). However, the channel loss study was conducted when LCC was nearly full and during a fairly wet hydrologic cycle and therefore, would not be representative of drought conditions used to calculate firm yield. For this reason, it is important to qualify that data collected during the channel loss study

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[7] 2011 Regional Water Plan, Study 3 – “Implementation Analysis for Pipeline from CCR to LCC, Including Channel Loss Study Downstream of Choke Canyon Reservoir,” April 2009.

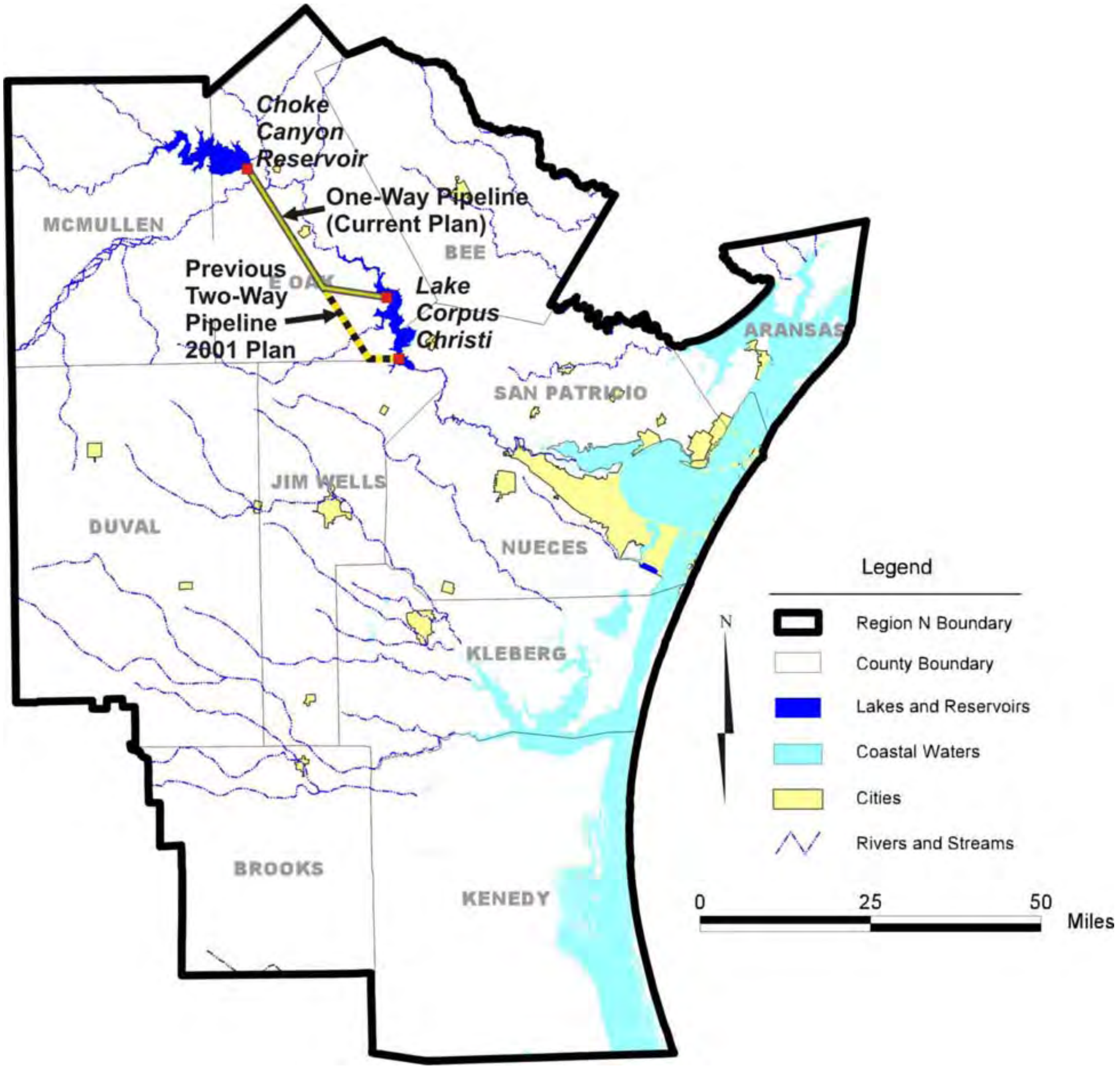

Figure 4C.10-1. Pipeline between Choke Canyon Reservoir and Lake Corpus Christi

in March 2008 may not represent long-term conditions since the data was collected during wet weather conditions and may not be appropriate for evaluating and assessing modifications or benefits of the CCR/LCC pipeline strategy. Based on the flow analysis and hydrogeologic evaluation conducted as part of the channel loss study, it is likely that the USGS Nueces River at Three Rivers gage underestimates flow passing down the Nueces River to Lake Corpus Christi.

For the 2011 Plan, a mass balance and water budget of LCC was evaluated including consideration of delivery factor of water supplies to LCC based on recent hydrology. The streamflow delivery factor is considered to be the percentage of water passing an upstream control point that arrives at the next downstream control point. In this study, a delivery factor was calculated using the described water budget methods for the period since the expansion of LCC (1959-2008). In this reach, a previous study using 1948-1989 data and a different method of estimating the runoff from the intervening area calculated a delivery factor of 0.74 which is included in the Corpus Christi Water Supply Model used to evaluate the CCR to LCC pipeline strategy, meaning that on average 74 percent of the water that passes the Nueces River near Three Rivers station passes the Nueces River near Mathis station. The delivery factor calculations from a recent study for the period from 1959-2008 produced a delivery factor of 0.76, which is about 2% higher than the delivery factor in the model. As one would expect, the delivery factor for lower flows is not considered to be representative any particular period or hydrologic condition because of the planned storage of water in LCC during high flow conditions and the release of the stored water during low flow conditions.

No change was made to this analysis due to the recent channel loss or mass balance studies. Future planning efforts should continue to evaluate long term hydrologic data including streamflow gage measurements (especially at Nueces River at Three Rivers), local geology, and water budgets and, if necessary, revisiting the delivery factors included in the Corpus Christi Water Supply Model.

4C.10.2 Available Yield

Yield analyses for this alternative were performed to meet the following objectives:

- Establish the optimum reservoir levels for operating the transmission system between the two reservoirs.
- Determine the delivery rate from CCR to LCC that will provide the largest yield increase at reasonable unit costs.

Simulations were made for the historical period from 1934 to 2003 using the City of Corpus Christi’s Phase IV Operations Plan, the 2001 TCEQ Agreed Order, and 2010 reservoir sedimentation conditions. After the optimum reservoir levels and delivery rates were obtained for the 2010 sediment conditions, they were analyzed at 2060 reservoir sediment conditions. For modeling purposes, it was assumed that the same channel loss and reservoir seepage functions would apply to any water released into the stream system in excess of the capacity of the pipeline. The operating guidelines for both reservoirs and the pipeline are detailed below. CCR and the pipeline were operated in the following manner:

1. A minimum 2,000 acft/month (33 cfs) was released from CCR to the Frio River, as specified in the existing permit;
2. When required, water supply releases from CCR larger than 2,000 acft in any month and less than pipeline capacity are delivered through the pipeline between the two reservoirs up to the capacity of the pipeline; and
3. When monthly releases at CCR exceed the capacity of the pipeline, the remaining portion of the release is delivered via the Frio and Nueces Rivers.

This release policy assumes that the instream flow requirements downstream of CCR are met by the 2,000 acft/month (33 cfs) minimum release requirement in the existing permit, and that this instream flow volume together with flows in excess of the pipeline capacity would satisfy instream flow requirements and senior water rights in the reach between the two reservoirs.

Table 4C.10-1 shows yields and costs for the pipeline delivery rates used in this analysis. The 300-cfs delivery rate results in the preferred delivery rate when cost and additional yield provided are taken into consideration. A detailed cost analyses for the one-way pipeline for the 300-cfs delivery rate is presented in Section 4C.10.4.

Table 4C.10-1.
Summary of Yield and Costs for
One-Way Pipeline from Choke Canyon Reservoir to
Lake Corpus Christi for 2010 Sediment Conditions

Delivery Rate (cfs)	*Pipe Diameter[1] (inches)*	*Firm Yield[2] (acft/yr)*	*2010 Yield Increase (acft/yr)*	*Annual Cost ($ Million)*	*Approximate 2010 Unit Cost ($/acft/yr)*	*Incremental Unit Costs[3] ($/acft/yr)*
200	84	204,400	30,200	$7.03	$232	—
250	90	209,700	35,500	$7.61	$214	$110
300	96	213,200	39,000	$8.78	$225	$336
350	108	215,700	41,500	$10.72	$258	$774

[1] Pipeline sized to maintain average velocity near 5 fps.

[2] Baseline yield without pipeline under phase IV operations policy, 2010 sediment conditions, and the 2001 Agreed Order equals 174,200 acft/yr.

[3] Incremental costs were calculated as the difference in Annual Cost ($ Million) between options divided by the difference in yield between options. Incremental unit costs were used to determine the optimal pipeline delivery rate that would provide additional water supply at a reasonable cost.

Table 4C.10-2 shows the yields for both 2010 and 2060 reservoir sediment conditions for each delivery rate, as well as the unit cost of water for 2060 conditions for the pipeline.

The increase in yield due to the pipeline in 2060 is greater than experienced in 2010. The benefit of the pipeline increases as the reservoirs fill with sediment. Comparison of unit and incremental cost for 2060 sediment conditions shows that the delivery rate of 300 cfs produces the preferred unit cost of water for the one-way pipeline.

Table 4C.10-2.
Summary of Yield Increases for
both 2010 and 2060 Sediment Conditions and
2060 Unit Costs for One-Way Pipeline

Delivery Rate (cfs)	2010		2060		Approximate 2060 One-Way Pipeline Unit Cost ($ per acft/yr)	Approximate 2060 Incremental Unit Costs[2] ($ per acft/yr)
	Firm Yield[1] (acft/yr)	Increase in Firm Yield Due to Pipeline	Firm Yield[1] (acft/yr)	Increase in Firm Yield Due to Pipeline		
0	174,200	—	168,500	—	—	—
200	204,400	30,200	200,000	31,600	$222	—
250	209,700	35,500	204,700	36,200	$210	$127
300	213,200	39,000	208,000	39,500	$222	$356
350	215,700	41,500	210,700	42,200	$254	$717

[1] Yield calculated under phase IV operations policy and the 2001 Agreed Order.

[2] Incremental costs were calculated as the difference in Annual Cost ($ Million) between options divided by the difference in yield between options. Incremental unit costs were used to determine the optimal pipeline delivery rate that would provide additional water supply at a reasonable cost.

An analysis was conducted during development of the 2006 Plan, which considered operating the optimal CCR/LCC pipeline with Nueces OCR project (Section 4C.11). The CCR/LCC pipeline could increase system yield by alleviating some of the channel losses incurred below CCR and above LCC. The OCR could create additional storage that would allow the system to take advantage of the large watershed of LCC. When combined and simulated in the Corpus Christi Water Supply Model, the yield of the system is increased by about 92% of the combined individual yields of the CCR/LCC pipeline and Nueces OCR project. Although a 300 cfs CCR/LCC pipeline is capable of delivering 39,500 acft/yr as a stand-alone project, when operated conjunctively with the Nueces OCR it would be expected to provide a firm yield of 33,700 acft/yr (or a reduction of 5,800 acft/yr).

4C.10.3 Environmental Issues

Environmental issues related to transferring water by pipelines from CCR to LCC can be categorized as follows:

- Effects related to pipeline construction and maintenance;[8] and
- Effects resulting from changes in Nueces River flows, including inflows to the Nueces Estuary.

The proposed pipeline corridor would be within Live Oak County. The construction of a pipeline from CCR to LCC would result in soil and vegetation disturbance within the approximately 226-acre pipeline construction corridor. Longer-term terrestrial impacts would be confined to the 115-acre maintained right-of-way.

The TPWD lists 16 threatened or endangered species potentially occurring in Live Oak County as shown in Table 4C.10-1. Of these 16, five (5) are listed by the USFWS as endangered.[9] In Live Oak County the jaguarundi (*Herpailurus yagouaroundi*) is listed as endangered by both state and federal government. This species prefers to inhabit thick brushlands near water, conditions found within the project area. Sightings of this species are documented near George West and a study[10] focusing on this cat has occurred within the County. The ocelot (*Felis pardalis*) a species which prefers dense chaparral thickets, is also listed as endangered within Live Oak County. The red wolf (*Canis rufus*) is now considered extirpated.

The Texas Department of Transportation (TxDOT) district in South Texas is working with the U.S. Fish and Wildlife Services (USFWS) to create “wildlife corridors” to help protect ocelots and jaguarundis.[11] The TxDOT district has created four cat crossings in Live Oak County for U.S. 281 widening project. The South Texas wildlife corridors consist of a culvert beneath roadways, were dense brush is allowed to grow up from the edge of right of way up to the end of the culvert. Where culverts open to the median, chainlink fences are installed to keep wildlife within the crossing. There were no reports readily available documenting the success of the TxDOT wildlife corridor program in Live Oak County.

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[8] “HDR, et al., “Trans-Texas Water Program – Corpus Christi Study Area – Phase II Report,” City of Corpus Christi, et al., September 1995.

[9] Inclusion in Table 4C.11-1 does not imply that a species will occur within the study area, but only acknowledges the potential for occurrence in Live Oak County.

[10] TPWD. 1988-1993. Endangered feline population and habitat enhancement. Performance Reports, Federal Aid Project No. W-103 and 125 and ESEC 6, Job No. 12. Texas Parks and Wildlife Department, Austin, Texas.

[11] **Env**ision newsletter, Summer 1995.

Table 4C.10-1
Endangered, Threatened, and Rare Species Listed for Live Oak County

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Listing Entity***		***Potential Occurrence In Counties***
			USFWS[1]	***TPWD[1]***	
Audubon's Oriole	*Icterus graduacauda audubonii*	Scrub, mesquite, nests in dense trees or thickets, usually along water courses			Resident
Black-Spotted Newt	*Notophthalmus meridionalis*	Ponds and resacas in south Texas		T	Resident
Coastal gay-feather	*Liatris bracteata*	Endemic: black clay soils of prairie remnants.			Resident
Golden orb	*Quadrula aurea*	Sand and gravel, Guadalupe, San Antonio, and Nueces river basins		T	Resident
Indigo Snake	*Drymarchon corais*	Thornbush-chaparral woodlands of south Texas in dense riparian corridors, moist microhabitats.		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	Subspecies is listed only when inland more than 50 miles from coastline. Nests along braided waterways.	LE	E	Resident
Jaguarundi	*Herpailurus yaguarondi*	South Texas thick brushlands, favors areas near water	LE	E	Resident
Mountain Plover	*Charadrius montanus*	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/ Migrant
Ocelot	*Leopardus pardalis*	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	LE	E	Resident
Peregrine falcon	*Falco peregrinus anatum (American)*	Open country; cliffs	DL	E	Nesting/ Migrant
	Falco peregrinus tundrius *(Arctic)*		DL	T	
Plains Spotted Skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas and tallgrass prairie.			Resident
Red Wolf	*Canis rufus*	Extirpated	LE	E	Historic Resident
Reticulate collared lizard	*Crotaphytus reticulates*	Requires open brush-grasslands; thorn-scrub vegetation.		T	Resident
Sheep Frog	*Hypopachus variolosus*	Predominately grassland and savanna; moist sites in arid areas		T	Resident

Table 4C.11-1 (Concluded)

Common Name	**Scientific Name**	**Summary of Habitat Preference**	**Listing Entity**		**Potential Occurrence In Counties**
			USFWS[1]	**TPWD[1]**	
South Texas Rushpea	*Caesalpinia phyllanthoides*	Shrublands or grasslands on very shallow soil over rock.			Resident
Spot-tailed earless lizard	*Holbrookia lacerata*	Moderately open prairie-brushland			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas Tortoise	*Gopherus berlandieri*	Open brush w/ grass understory; open grass/bare ground avoided		T	Resident
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna			Resident
White-faced Ibis	*Plegadis chihi*	Prefers freshwater marshes		T	Resident
White-tailed Hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	Nesting/ Migrant
Whooping Crane	*Grus americana*	Potential migrant	LE	E	Migrant
Wood Stork	*Mycteria americana*	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant

Source: TPWD, Annotated County List of Rare Species, Live Oak County, October 30, 2007.

LE/LT=Federally Listed Endangered/Threatened

E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance

DL, PDL=Federally Delisted/Proposed for Delisting

E, T=State Listed Endangered/Threatened

Blank = Rare, but no regulatory listing status

Temporarily wet areas or drainages in uplands and in wetland portions of the project area may provide habitat for several state-protected amphibians. Several reptile and amphibian species listed as threatened by the state may possibly be affected by the project. These include the Texas horned lizard (*Phrynosoma cornutum*), Texas tortoise (*Gopherus berlandieri*), black-spotted newt (*Notophthalmus meridionalis*), indigo snake (*Drymarchon corais*), reticulate collared lizard (*Crotaphytus reticulates*), and sheep frog (*Hypopachus variolosus*). Many of these reptile species are dependent on shrubland or riparian habitat, while amphibians prefer moist sites in ponds, resacas and grassland areas.

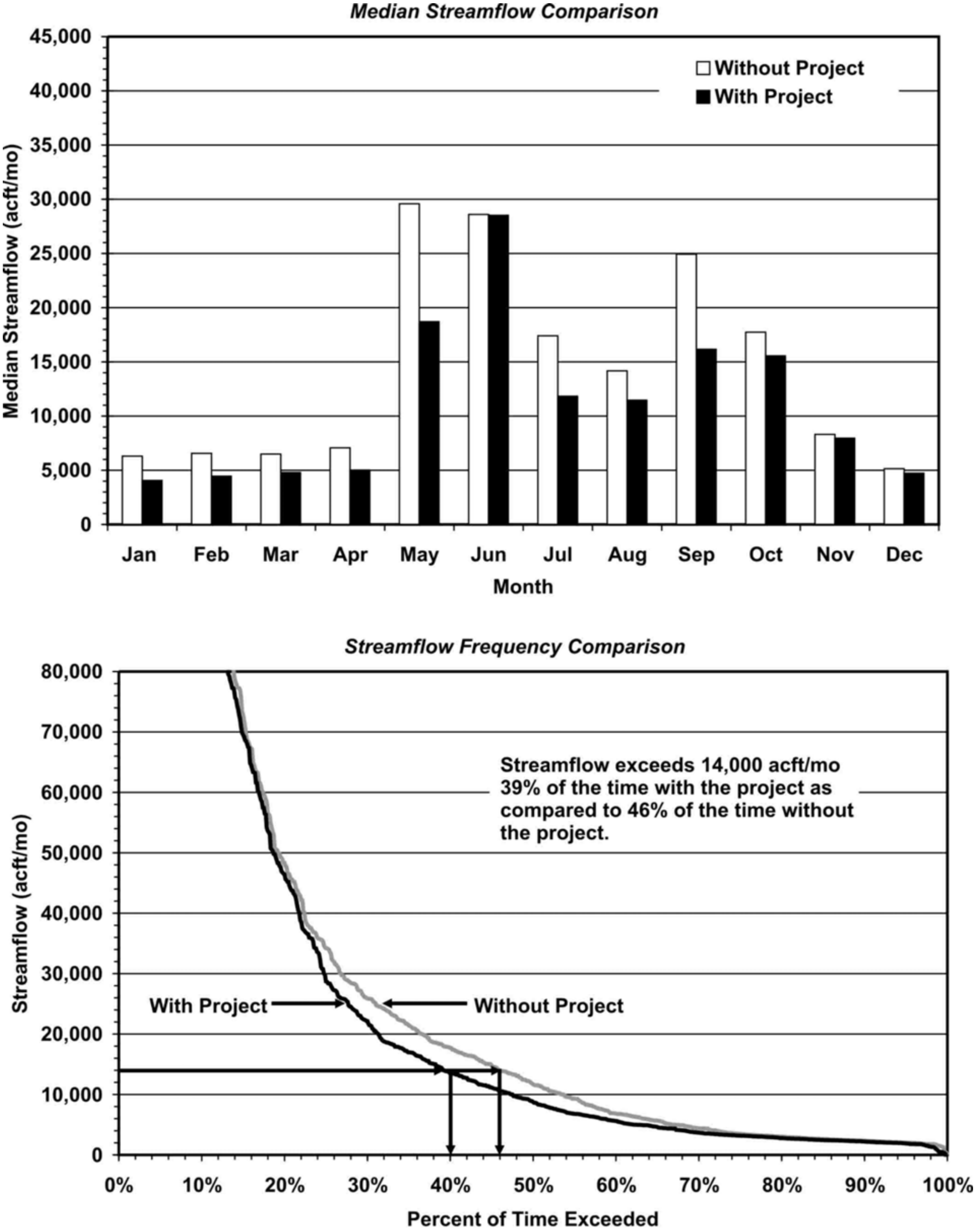
The black-spotted newt (*Notophthalmus meridionalis*) and Rio Grande lesser siren (*Siren intermedia texana*) are found in wet or temporally wet arroyos, canals, ditches, or small depressions. During dry periods, they aestivate underground. The sheep frog (*Hypopachus variolosus*) inhabits wet areas and freshwater marshes in the Rio Grande Valley, lower South Texas Plains, and Southern Coastal Prairie. The Mathis spiderling (*Boerhavia mathisiana*) is a possibly extinct plant that has been proposed for protection by USFWS. It inhabits open thorn shrublands with shallow sandy to gravely soils over limestone or on bare limestone or caliche outcrops. The Mathis spiderling was once found in the vicinity of LCC in San Patricio County.

One rare species, the golden orb (*Quadrula aurea*) has been the reason for the designation of the Nueces River from the headwaters of Lake Corpus Christi upstream to US 59 in Live Oak County (within TNRCC classified stream segment 2103) as a significant stream segment by TPWD. This species is restricted to five rivers in Texas. This segment of the Nueces River contains one of only four known remaining populations of this endemic mollusk.

Additionally, according to the TPWD Texas Natural Diversity Database, there have been sightings of the state and federally endangered jaguarundi in the immediate vicinity of the proposed pipeline route. Two rare plant species, the coastal gay-feather and the South Texas rushpea have been documented within two miles of the proposed pipeline area.

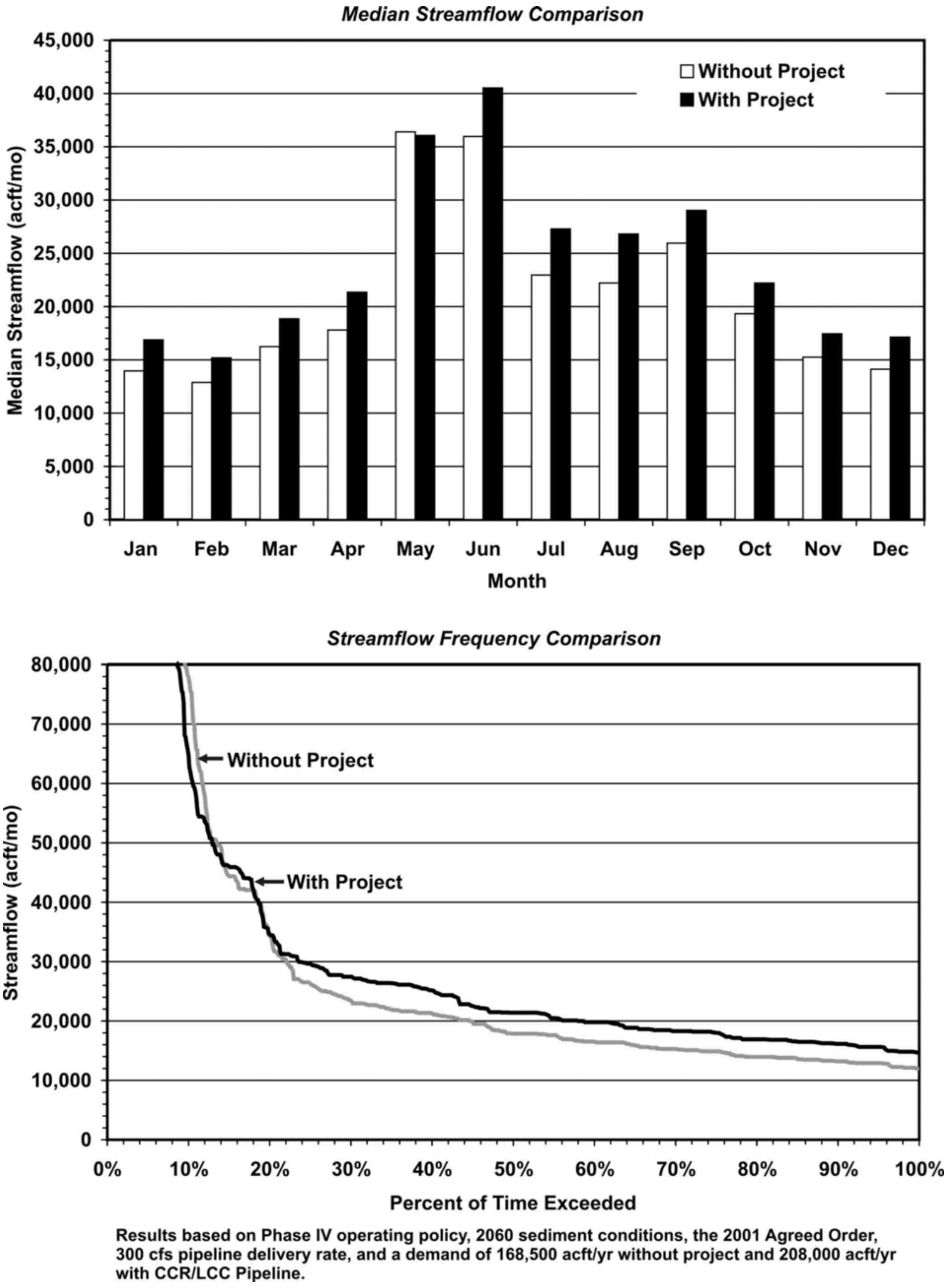
Texas Historical Commission GIS files identified the Balania cemetery and the Dinero historical marker within two miles of the proposed pipeline corridor. Several sites on or eligible for inclusion on the National Register of Historic Places are known from the vicinity of the pipeline corridor, and other types of cultural resource sites may be present, although none are known to be located within the corridor.

Use of pipeline transport will periodically reduce river flows between CCR and LCC. The presently required maintenance releases of 2,000 acft/month would be continued. However, historical monthly median flows will be reduced by up to 37 percent in some months, as shown in the top plot of Figure 4C.10-2 for the 300-cfs delivery option. The bottom plot of Figure 4C.10-2 shows the streamflow frequency at Three Rivers with and without the project. As shown by the arrows on the plot, the monthly median flow for the period of record of 14,000 acft is exceeded 46 percent of the time without the project and 39 percent with the project. River flows below LCC at Mathis and estuarine inflows would be increased. Considering return flows, the annual inflows to the Nueces Estuary are increased on average, 14,800 acft/yr, for years with annual flows less than 190,000 acft/yr. Both increases in flow result from the additional yield in the CCR/LCC System being delivered to Corpus Christi. Figures 4C.10-3 and 4C.10-4 display



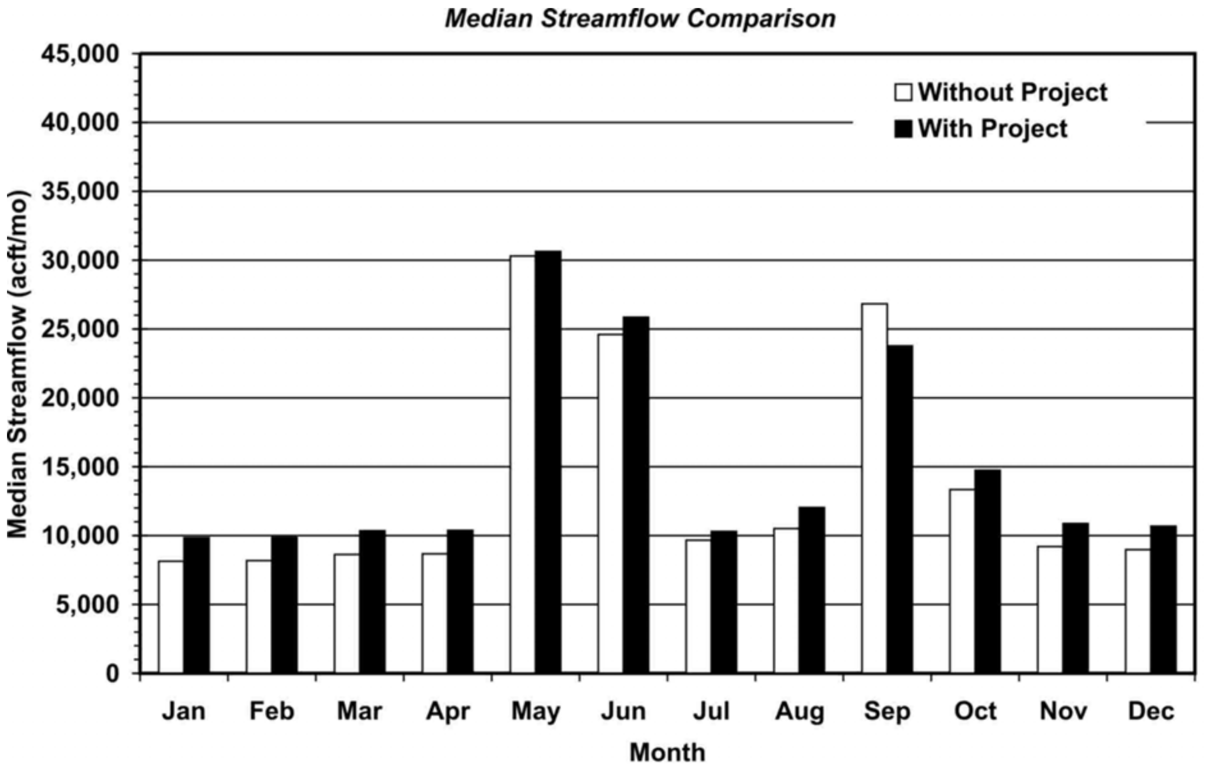
Results based on Phase IV operating policy, 2060 sediment conditions, the 2001 Agreed Order, 300 cfs pipeline delivery rate, and a demand of 168,500 acft/yr without project and 208,000 acft/yr with CCR/LCC Pipeline.

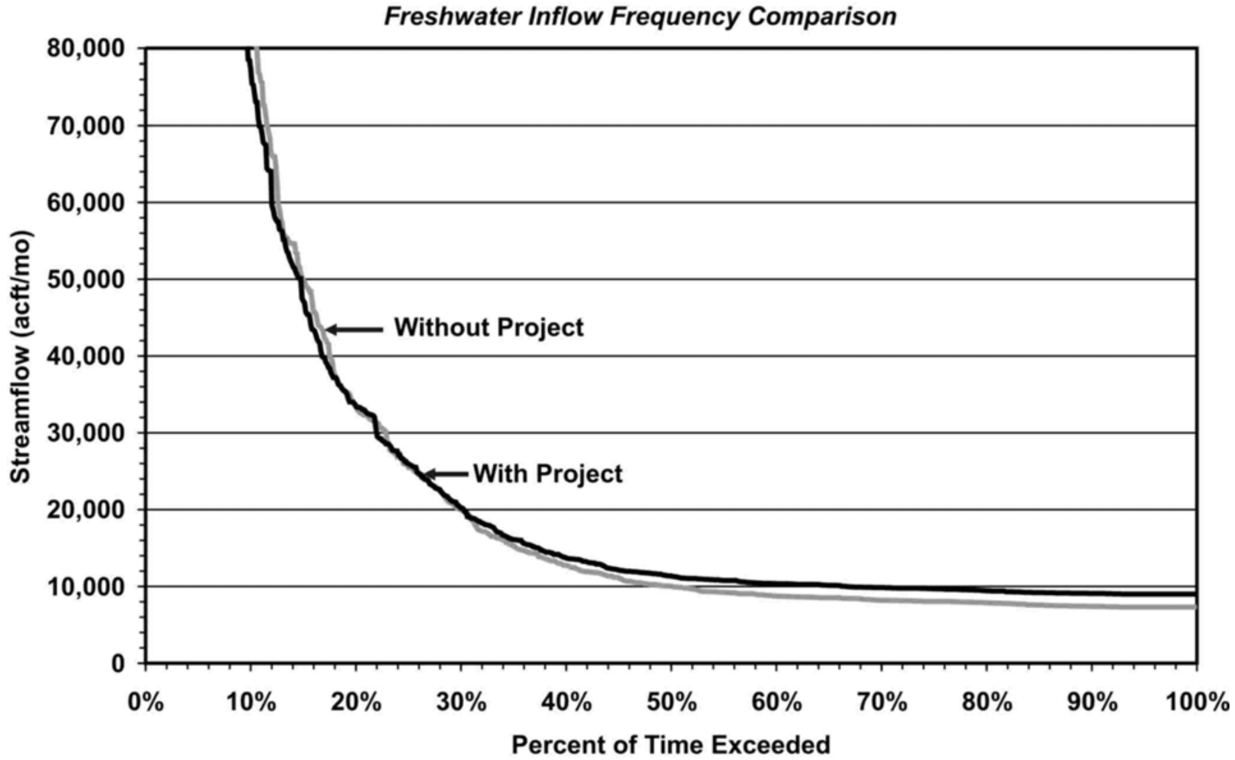
Figure 4C.10-2. Project Impacts on Streamflow, Nueces River at Three Rivers



Results based on Phase IV operating policy, 2060 sediment conditions, the 2001 Agreed Order, 300 cfs pipeline delivery rate, and a demand of 168,500 acft/yr without project and 208,000 acft/yr with CCR/LCC Pipeline.

Figure 4C.10-3. Project Impacts on Streamflow, Nueces River at Mathis





Results based on Phase IV operating policy, 2060 sediment conditions, the 2001 Agreed Order, 300 cfs pipeline delivery rate, and a demand of 168,500 acft/yr without project and 208,000 acft/yr with CCR/LCC Pipeline.

Figure 4C.10-4. Project Impacts on Freshwater Inflows into Nueces Estuary

the monthly median streamflows and streamflow frequency plots for river flows at Mathis and estuarine inflows. Implementation of the project will also impact reservoir levels in both CCR and LCC. Figure 4C.10-5 displays plots of water surface elevation versus time for each reservoir and a system storage frequency comparison. Figure 4C.10-6 shows the amount of water, on an annual basis, that is delivered through the pipeline to LCC from CCR.

4C.10.4 Engineering and Costing

A pipeline linking CCR to LCC with a delivery rate of 300 cfs is estimated to provide a firm yield of 33,700 acft at unit raw water cost of $402 per acft ($1.23 per 1000 gallons). With treatment costs assumed at $326 per acft, treated water supplies from this project would be $728 per acft ($2.23 per 1000 gallons).

The project cost could potentially be reduced through Federal or State participation. For this analysis, it was assumed that 65% of the firm yield would be available for public water supply with 35% dedicated for ecosystem restoration or other Federal or State purposes. The project cost for water supply interests was estimated to be 35% of the total cost, with the remaining 65% contributed by Federal or State participants. Annual operations and maintenance and pumping energy costs would be paid in full by water supply interests.

Table 4C.10-3 provides a detailed summary of the estimated costs to implement a pipeline between CCR and LCC with a delivery rate of 300 cfs with Federal or State participation.[12] With federal or state participation, this project is estimated to provide a firm yield of 21,905 acft at unit raw water cost of $262 per acft ($0.80 per 1000 gallons). With treatment costs assumed at $326 per acft, treated water supplies from this project would be $588 per acft ($1.80 per 1000 gallons). After 20 years of paying debt service for the pipeline, the raw water cost is reduced to $69 per acft ($0.21 per 1000 gallons) and treated water cost is reduced to $395 per acft ($1.21 per 1000 gallons).

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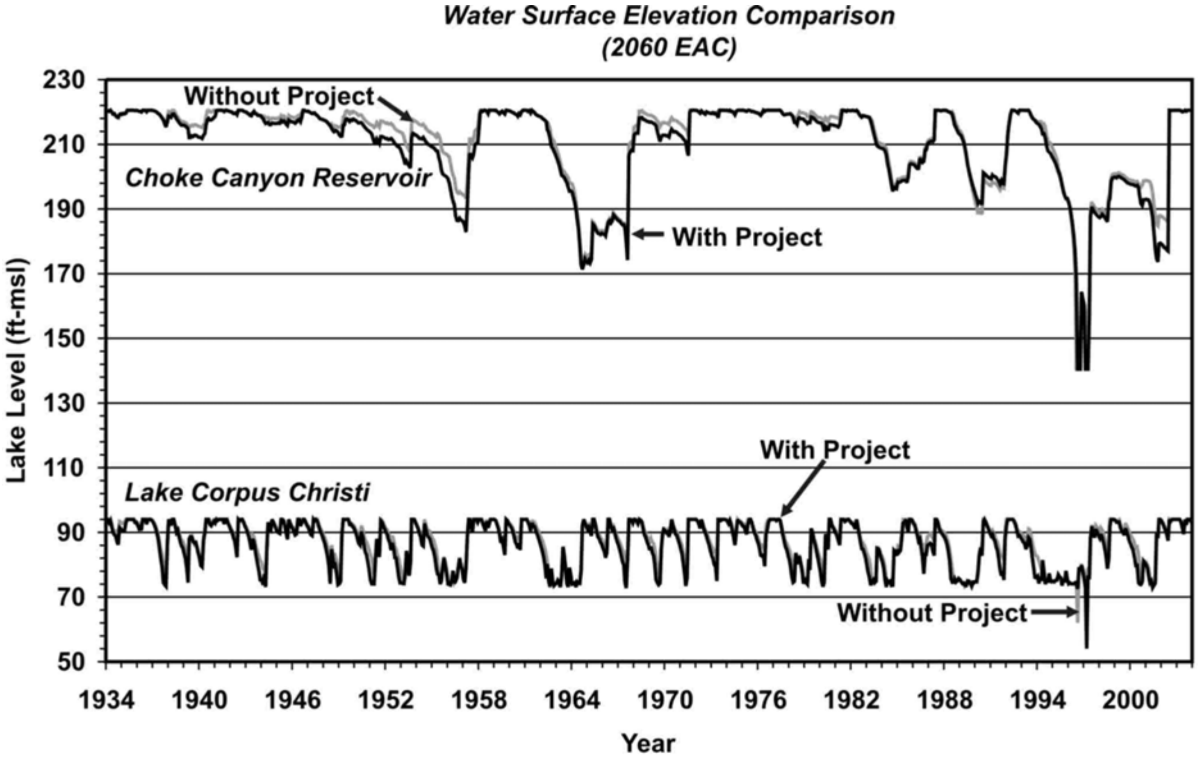
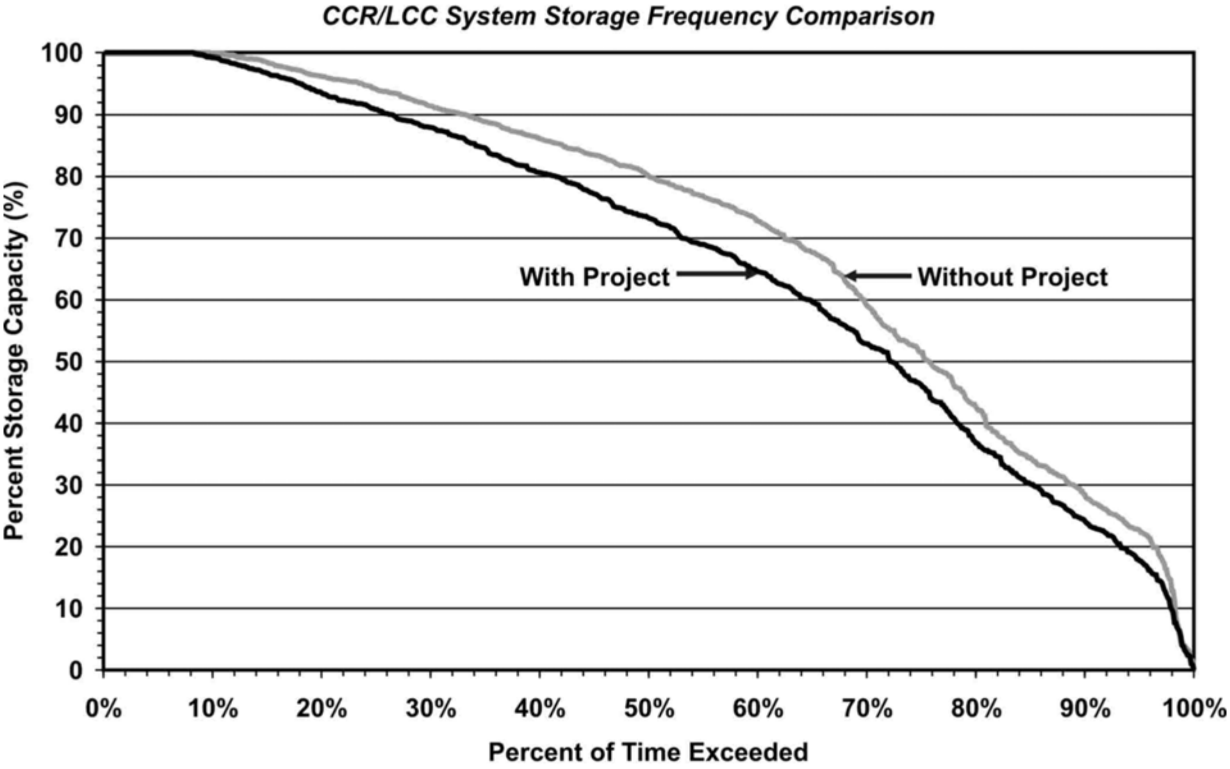
[12] The total project cost of a pipeline between CCR and LCC with a delivery rate of 300 cfs is $138,067,000. This strategy, as recommended, is considered with Federal or State participation with portion of the firm yield dedicated for ecosystem restoration or other Federal or State purposes. Without Federal or State participation, the unit treated water costs are $728.





Results based on Phase IV operating policy, 2060 sediment conditions, the 2001 Agreed Order, 300 cfs pipeline delivery rate, and a demand of 168,500 acft/yr without project and 208,000 acft/yr with CCR/LCC Pipeline.

Figure 4C.10-5. Project Impacts on Choke Canyon Reservoir and Lake Corpus Christi

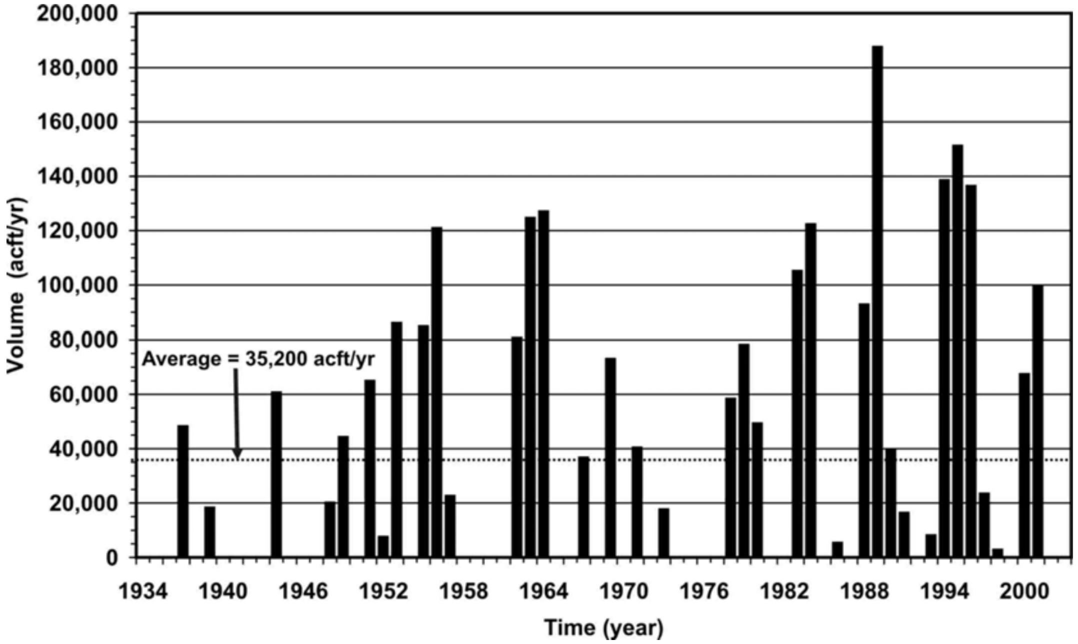


Figure 4C.10-6. Volume Pumped through LCC/CCR Pipeline (acft/yr) for 300 cfs Pipeline

Table 4C.10-3.
Cost Estimate Summary for Pipeline Linking CCR and LCC (300 cfs) With Federal or State Participation (September 2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Intake and Pump Station (194 MGD)	$18,160,000
Transmission Pipeline (96 in dia., 23 miles)	76,292,000
Relocations & Other	229,000
Total Capital Cost	**$94,681,000**
Engineering, Legal Costs and Contingencies	$29,324,000
Environmental & Archaeology Studies and Mitigation	585,000
Land Acquisition and Surveying (115 acres)	1,086,000
Interest During Construction (1.5 years)	7,541,,000
Reserve Fund (additional pumping energy costs for maximum 3 years)	4,850,000
Total Project Cost	$138,067,000
Total Project Cost (35%, With Federal or State Participation)	**$48,324,000**
Annual Costs	
Debt Service (6 percent, 20 years) 35%, With Federal or State Participation	$4,213,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	1,217,000
Pumping Energy Costs (3320165.66471607 kWh @ 0.09 $/kWh)	299,000
Total Annual Cost	**$5,729,000**
Available 2060 Project Yield (acft/yr) (65%, With Federal or State Participation)	**21,905**
Annual Cost of Water ($ per acft)	**$262**
Annual Cost of Water ($ per 1,000 gallons)	**$0.80**

4C.10.5 Implementation Issues

The primary implementation issue that would need to be addressed with this pipeline alternative would be the impact of the reduced flows in the Nueces River downstream of CCR. An evaluation of the impacts of reduced flows on the river habitat should be undertaken to fully investigate the consequences of implementing this alternative. In addition, the TCEQ permits may need to be amended depending on changes in locations of diversions. Additionally, before a significant expenditure of funds would be considered for either of these alternatives, detailed long-term investigations of channel losses should be undertaken to fully understand the seasonality and variability of channel losses that occur, particularly between Three Rivers and LCC. In order to better quantify the channel losses in this reach, the City is currently working with the U.S. Geological Survey (USGS) and has installed a new gage just upstream of LCC.

Requirements Specific to Pipelines

1. Necessary Permits:
   - USACE Sections 10 and 404 dredge and fill permits for stream crossings.
   - GLO Sand and Gravel Removal permits.
   - Coastal Coordinating Council review.
   - TPWD Sand, Gravel, and Marl permit for river crossings.
   - Cultural Resource Survey as required by Texas Antiquities Commission.
2. Right-of-way and easement acquisition.
3. Crossings:
   - Highways and railroads.
   - Creeks and rivers.
   - Other utilities.

4C.10.6 Evaluation Summary

An evaluation summary of this regional water management option is provided in Table 4C.10-4.

Table 4C.10-4.
Evaluation Summary for Pipeline between Choke Canyon Reservoir and Lake Corpus Christi

Impact Category	***Comment(s)***
a. Water supply:	
1. Quantity	1. Reduced Firm Yield (with Federal or State participation): 21,905
2. Reliability	2. Good reliability.
3. Cost of treated water	3. Generally low raw water cost of $262 per acft with Federal or State participation. With $326 added for treatment, cost of treated water is $588 per acft.
b. Environmental factors:	
1. Instream flows	1. Reduction in streamflows between Choke Canyon Reservoir and Lake Corpus Christi
2. Bay and estuary inflows	2. Increase in streamflows below Lake Corpus Christi and freshwater inflows to Nueces Estuary.
3. Wildlife habitat	3. Low impact to wildlife habitat.
4. Wetlands	4. Low impact to wetlands.
5. Threatened and endangered species	5. Low impact to threatened and endangered species.
6. Cultural resources	6. Cultural Resource Survey needed to avoid impacts.
7. Water quality	7. Low impact to water quality.
a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	7a-b. Will improve dissolved solids and salinity levels at CCR by reducing evaporation from reservoir.
c. State water resources	• No negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• None
e. Recreational	• None
f. Equitable comparison of strategies	• Standard analyses and methods used
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Reduces losses in the CCR/LCC System
j. Effect on navigation	• None

4C.11 Nueces Off-Channel Reservoir near Lake Corpus Christi (N-11)

4C.11.1 Description of Strategy

The Coastal Bend Region relies predominantly upon surface water supplies from two reservoirs located in the Nueces River Basin: Choke Canyon Reservoir (CCR) and Lake Corpus Christi (LCC). These two reservoirs, when operated as a system, currently provide water supplies to meet about one half of the total regional water demands including municipal and non-municipal use, with the remaining supplies coming from Lake Texana and, to a lesser extent, groundwater and local supplies.

CCR has a storage capacity of 695,271 acft at a conservation pool elevation of 220.5 ft-msl and a contributing drainage area of 5,490 square miles.[1] According to a volumetric survey conducted by the Texas Water Development Board (TWDB) in 2002, LCC has a storage capacity of 257,260 acft at a conservation pool elevation of 94.0 ft-msl and a contributing drainage area of 16,656 square miles. This configuration creates a situation where the smallest reservoir has the largest potential for capturing storm events because of the larger contributing drainage area.

The yield of the system is affected by the storage capacity of LCC and its limited ability to capture a significant portion of large storm events that travel down the Nueces River. Since LCC has the smaller capacity, many times it fills and spills during times when the bay has adequate freshwater inflow. However, if water could be pumped into a Nueces off-channel reservoir (OCR), it would result in more water in storage and enhance the system yield.[2] The Nueces OCR could be operated to capture water that would otherwise spill from LCC while still maintaining desired freshwater inflows to the Nueces Bay and Estuary (B&E) and could potentially be operated to reduce flood events downstream of LCC.

The 2006 Coastal Bend Regional Water Plan (2006 Plan) included an evaluation of preliminary Nueces OCR reservoir capacities and diversion pipeline delivery rates located near LCC. The most favorable options included Nueces OCR capacities ranging between 200,000 and 300,000 acft and a diversion pump station with a pipeline delivery rate from 750 to

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[1] United States Geological Survey Texas Water Science Center, http://tx.usgs.gov.

[2] The modeling analysis that was utilized in evaluating this option, and all other water management strategies of the Lower Nueces River Basin, has embedded logic that applies strict application of the prior appropriation doctrine to ensure that senior water rights are protected in all scenarios.

1,500 cfs. The 2006 Coastal Bend Regional Water Plan and the 2007 State Water Plan included the Nueces OCR near LCC as a recommended future water management strategy for the Coastal Bend Region to meet future water needs in the region.

During the 2007 Texas legislative session, the Nueces OCR was designated as one of 19 unique reservoir sites in the State of Texas. The TWDB Reservoir Site Protection Study[3] recommended the Nueces OCR as one of the top-ranked sites in Texas for protection or acquisition. The report findings showed an increase in system firm yield of 39,935 for a Nueces OCR capacity of 250,000 acft and diversion pipeline delivery rate of 1,000 cfs. The Nueces OCR has also been considered by federal interests for its potential benefits of flood damage reduction, ecosystem restoration, and/or water supply in South Texas.

As part of the Phase I development of the 2011 Plan, the CBRWPG conducted a study[4] (summarized in Appendix B) to determine the optimal size for the Nueces OCR and pump station facilities in addition to preferable reservoir operations to provide the greatest amount of additional water supply benefits to the CCR/LCC/Lake Texana system while minimizing environmental impacts and unit costs. This report has been updated based on the Phase I study, with opportunities for state or federal participation for project development.

Topographic maps, LCC volumetric survey, and other local studies were considered to identify preferred locations for the Nueces OCR, intake, pipeline, and pump station. The TWDB's LCC volumetric survey included cross-sectional contours and shaded water depth ranges, which was used to identify deep channel areas near the Nueces OCR and upstream of LCC to determine a suitable location for the intake and pump station. A desktop environmental analysis was conducted to identify area-specific environmental characteristics, which was considered as part of the preliminary Nueces OCR site selection.

The Nueces OCR site and pipeline route to and from LCC is shown in Figure 4C.11-1. The reservoir is located near the upper western section of LCC. The Nueces OCR will require an intake and pump station at LCC to pump available water from LCC.[5] After preferred location of

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[3] Texas Water Development Board, HDR Engineering, R.J. Brandes Company, et al "Reservoir Site Protection Study", TWDB Report 370, July 2008.

[4] Coastal Bend Regional Water Planning Group, "Study 2- Optimization and Implementation Studies for Off-Channel Reservoir," April 2009. This report can be accessed from the Nueces River Authority website (http://www.nueces-ra.org/)

[5] The 2006 Plan included an evaluation of the off-channel reservoir operating conjunctively with CCR/LCC pipeline.

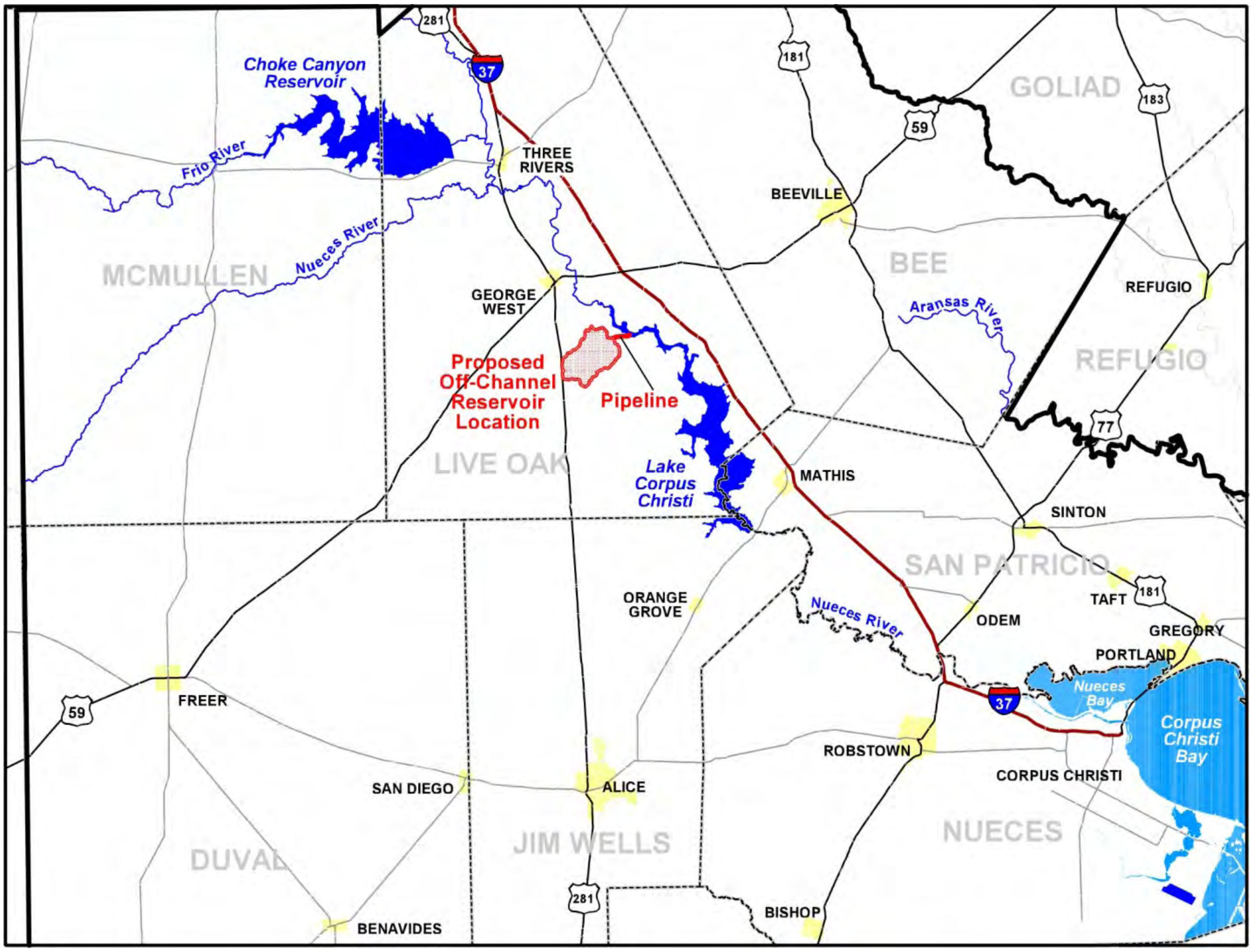

Figure 4C.11-1 Nueces Off-Channel Reservoir and Pipeline to Lake Corpus Christi

the Nueces OCR was determined, a detailed analysis of the Nueces OCR was performed to determine the optimal Nueces OCR capacity between 200,000 and 300,000 acft for pipeline delivery rates between 750 cfs and 1,500 cfs. Alternative reservoir operating policies, such as varying triggers for pipeline deliveries to and from the Nueces OCR, were evaluated to best manage water supply, water quality, and ecosystem restoration benefits.

4C.11.2 Available Yield

Yield analyses for this alternative were performed to meet the following objectives:

- Establish reasonable reservoir levels for operating the pump station to fill the Nueces OCR and also to then release water from the Nueces OCR back to LCC;
- Determine the pumping rate to the Nueces OCR that will provide the greatest yield increase at reasonable unit costs; and
- Determine the size of the Nueces OCR that will provide the greatest yield increase at reasonable unit costs.

Simulations were made for the historical period from 1934 to 2003 using the City of Corpus Christi's Phase IV Operations Plan, the 2001 TCEQ Agreed Order, and 2010 reservoir sedimentation conditions. These simulations were performed using an updated version of the Corpus Christi Water Supply Model (CCWSM)[6] that includes a capability to simulate the Nueces OCR.

Operational parameters for the reservoir and pipeline operations at the Nueces OCR were developed to identify the optimum set of LCC elevation triggers, pipeline capacity and Nueces OCR storage capacity. After several combinations were evaluated, the Nueces OCR, CCR and LCC were operated in the following manner:

1. LCC would attempt to fill the Nueces OCR, up to the capacity of the pump station and pipeline, anytime the elevation in LCC was 93 ft-msl or greater and storage was available in the Nueces OCR.
2. The Nueces OCR would release to LCC anytime the elevation in LCC was at or below 75 ft-msl or 83 ft-msl based on optimal yield analyses.
3. Releases from CCR were triggered when LCC elevation level was less than or equal to 74 ft-msl.

The CCWSM was used to simulate 24 combinations of Nueces OCR size and pipeline delivery rate to determine the firm yield water supply of each reservoir size and delivery rate combination. There were six Nueces OCR sizes from 200,000 acft to 300,000 acft (at 20,000 acft increments) for five pipeline delivery rates of 750 cfs to 1,500 cfs (at 250 cfs increments) that were evaluated. As expected, the increase in system yield is generally correlated with reservoir size and delivery rate (i.e., as reservoir size and delivery rate increases, firm yield increases) as shown in Figure 4C.11-2. However, as reservoir sizes increase above 280,000 acft, the increase in firm yield is minimal.

Total project costs[7] were calculated for each Nueces OCR size and delivery rate combination. Unit costs of firm raw water supply were calculated for each Nueces OCR size and pipeline delivery rate combination by dividing the annual cost by the increase in system yield. The unit costs of additional water supply decrease substantially for a Nueces OCR sized at

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[6] Formerly the City of Corpus Christi's Lower Nueces River Basin and Estuary (NUBAY) Model

[7] Project costs include capital costs, engineering/legal costs and contingencies, environmental mitigation, land acquisition, interest during construction (4 years), and initial filling of reservoir. Engineering and legal costs and contingencies are 30% for pipeline and pump station, and 35% for reservoirs.

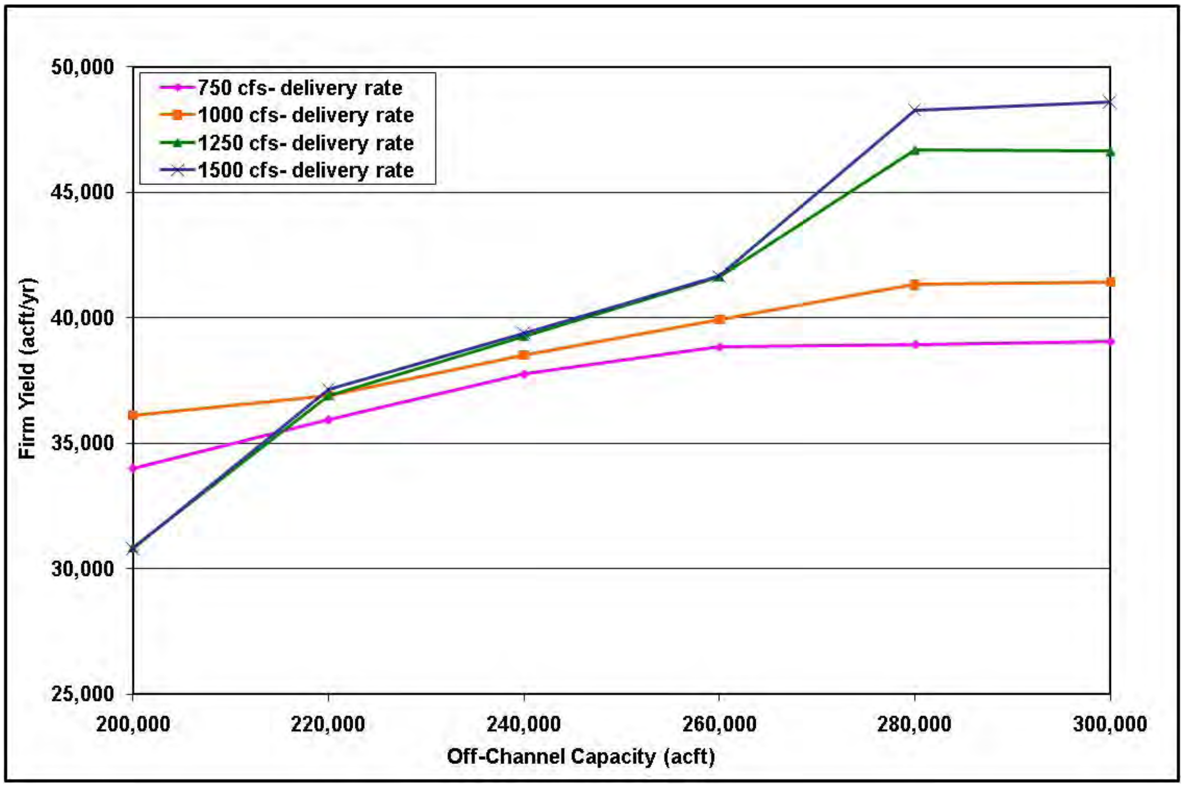

Figure 4C.11-2. Firm Yield Summary of Off-Channel Reservoir Sizes

280,000 acft with pipeline delivery rates of 1,250 cfs and 1,500 cfs. To confirm the results of the unit cost evaluation, incremental costs were calculated for each reservoir size to determine the optimal pipeline delivery rate that would provide additional water supply at a reasonable cost. Incremental costs are calculated as the difference in annual cost ($ million) between each alternative divided by the difference in yield. The incremental costs of the 280,000 acft Nueces OCR are the lowest among other Nueces OCR sizes between 200,000 and 300,000 acft as shown in Figure 4C.11-3. With Federal participation, a Nueces OCR sized at 280,000 acft is cost competitive with other regional water supply projects and provides additional firm yield than the Nueces OCR sized at 200,000 acft.[8]

Of the 24 combinations of reservoir size and pipeline delivery rate, the preferred size for a Nueces OCR is 280,000 acft with a pipeline delivery rate between 1,250 cfs and 1,500 cfs.

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[8] The least unit cost of raw water is about $400 per acft for a Nueces OCR sized at 200,000 acft and pipeline delivery rate of 750 cfs.

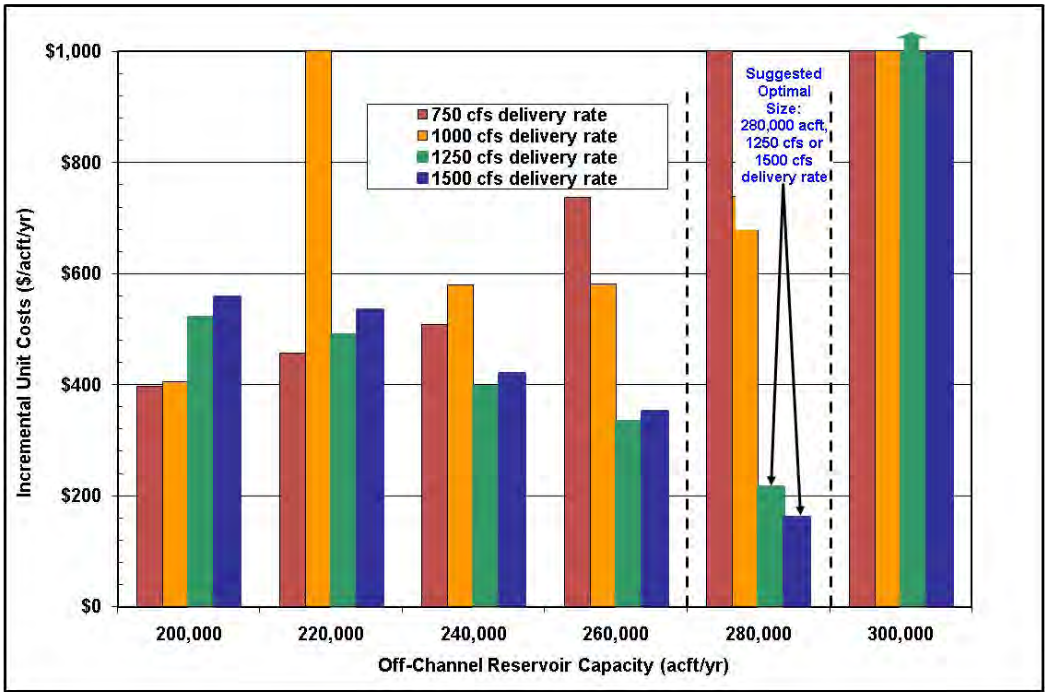

Figure 4C.11-3 Incremental Costs of Water[9] for Off-Channel Sizes for Pipeline Delivery Rates of 1,250 cfs and 1,500 cfs

There was not an appreciable cost or firm yield difference (less than 5% difference) between delivery rates of 1,250 cfs and 1,500 cfs and therefore, both were considered optimal size(s).

Based on local topography and Nueces OCR capacity of 280,000 acft (location shown in Figure 4C.11-1), the proposed conservation pool elevation is 281.1 ft-msl with an average water depth of 50 feet and a surface area of 5,627 acres. Relocation costs for product transmission pipeline, powerlines, and active oil and gas wells will need to be considered for Nueces OCR during preliminary design.

4C.11.3 Off-Channel Reservoir Operations

Monthly Nueces OCR storage values simulated by the CCWSM were evaluated to determine how often the Nueces OCR will be utilized based on historical hydrologic conditions from 1934-2003 for LCC water level triggers of 75 ft-msl and 83 ft-msl based on studies for optimizing yield at the two pipeline delivery rates of 1,250 cfs and 1,500 cfs. As shown in Figure 4C.11-4, if the Nueces OCR were operated at a pipeline pumping capacity of 1,250 cfs

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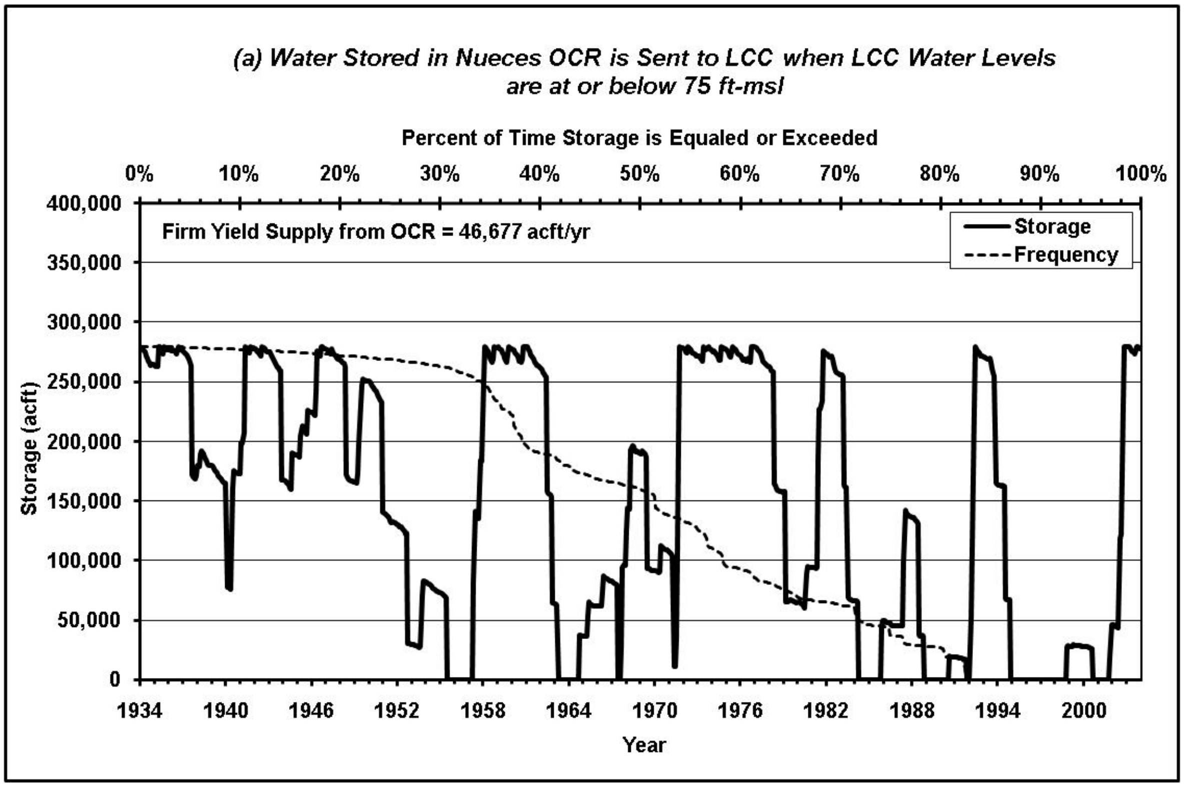
[9] Note: The incremental cost comparison was completed for the Phase I Study using Second Quarter 2007 Dollars.


(a) Water Stored in Nueces OCR is Sent to LCC when LCC Water Levels are at or below 75 ft-msl

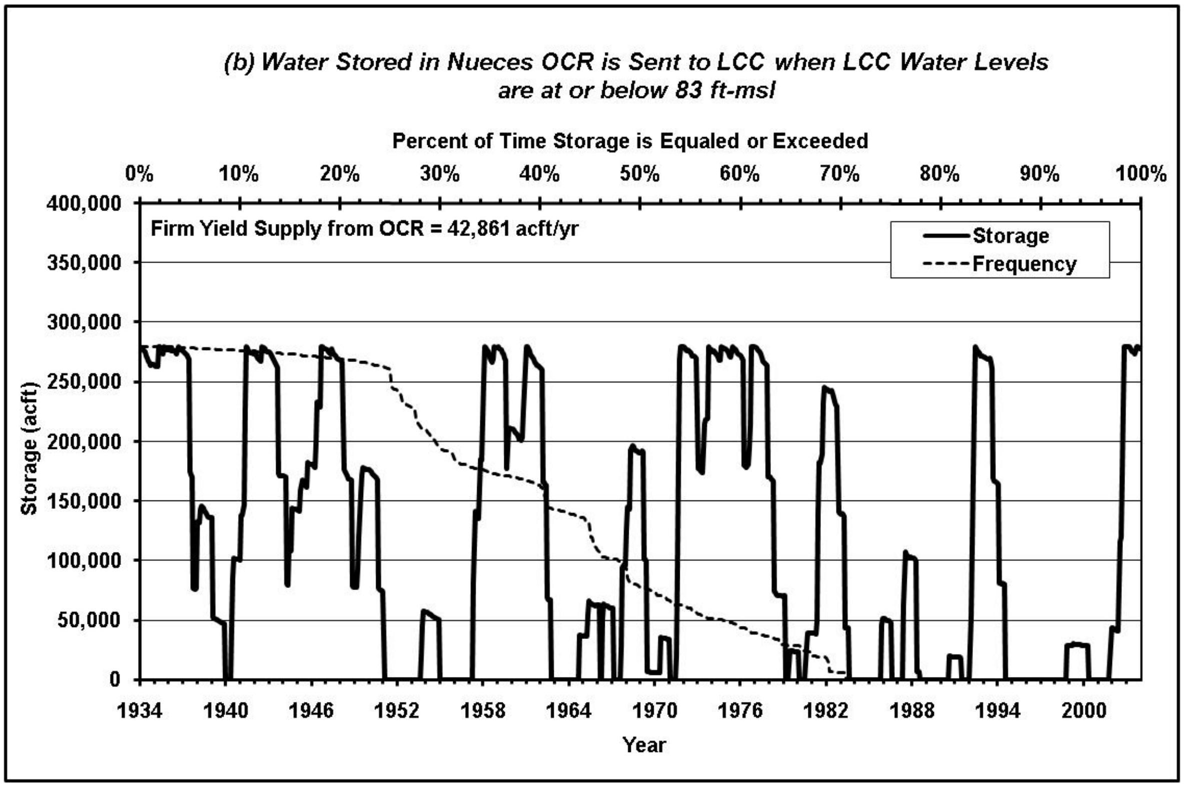

(b) Water Stored in Nueces OCR is Sent to LCC when LCC Water Levels are at or below 83 ft-msl

Figure 4C.11-4. Storage and Frequency Plot of Operating Nueces OCR (280,000 acft Capacity at 1,250 cfs Pipeline Rate)

with a 75 ft-msl LCC water level trigger then it would be empty about 16% of the time with median storage of about 168,026 acft (or 56% full). For the same pipeline pumping capacity with an 83 ft-msl LCC water level trigger, the Nueces OCR would be empty about 25% of the time with a median storage of about 91,897 acft (or 31% full). The Nueces OCR would have less stored water with the higher LCC trigger, because the Nueces OCR would be filling LCC more often.

Similar trends were observed for a pipeline pumping capacity of 1,500 cfs as shown in Figure 4C.11-5. With the 75 ft-msl LCC trigger level, the Nueces OCR would be empty about 16% of the time with median storage of about 159,785 acft (or 53% full). With the 83 ft-msl trigger level for filling LCC, the Nueces OCR would be empty about 30% of the time with median storage of about 78,054 acft (or 26% full).

4C.11.4 Environmental Issues

Environmental issues related to transferring water by pipeline from the Nueces OCR to LCC and construction of an off-channel reservoir can be categorized as follows:

- Effects related to pipeline construction and maintenance;[10]
- Effects related to off-channel reservoir construction and maintenance, and
- Effects resulting from changes in Nueces River flows, including inflows to the Nueces Estuary.
- Effects related to inundating approximately 5,600 acres for the Nueces OCR.

The proposed pipeline corridor would be within Live Oak County. The construction of a pipeline from the Nueces OCR to LCC would result in soil and vegetation disturbance within the approximately 60-acre pipeline construction corridor. Longer-term terrestrial impacts would be confined to the 20-acre maintained right-of-way, and the approximately 5,000 acres that would be inundated by construction of the Nueces OCR.

The Texas Parks and Wildlife Department lists 16 threatened or endangered species potentially occurring in Live Oak County as shown in Table 4C.11-1. Of these 16, five (5) are listed by the U.S. Fish and Wildlife Service (USFWS) as endangered.[11] In Live Oak County the jaguarundi (*Herpailurus yagouaroundi*) is listed as endangered by both the state and federal

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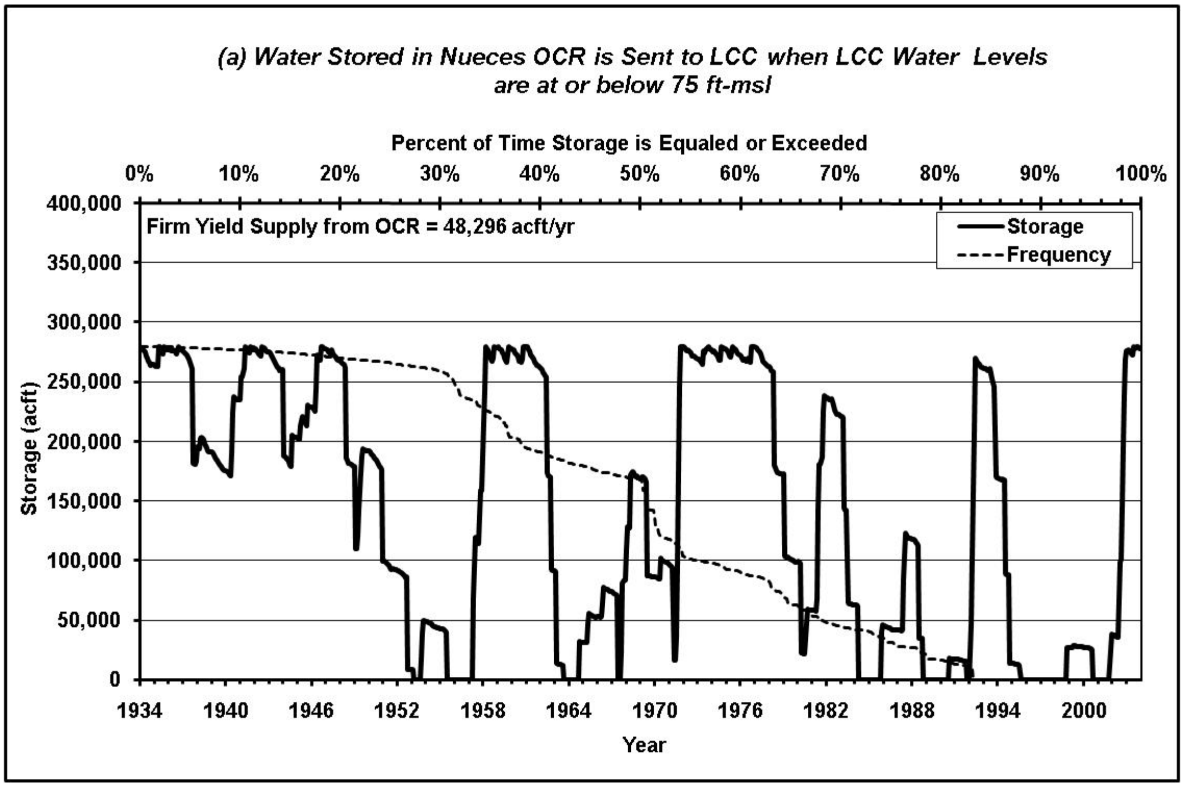
[10] Ibid.

[11] Inclusion in Table 4C.11-1 does not imply that a species will occur within the study area, but only acknowledges the potential for occurrence in Live Oak County.



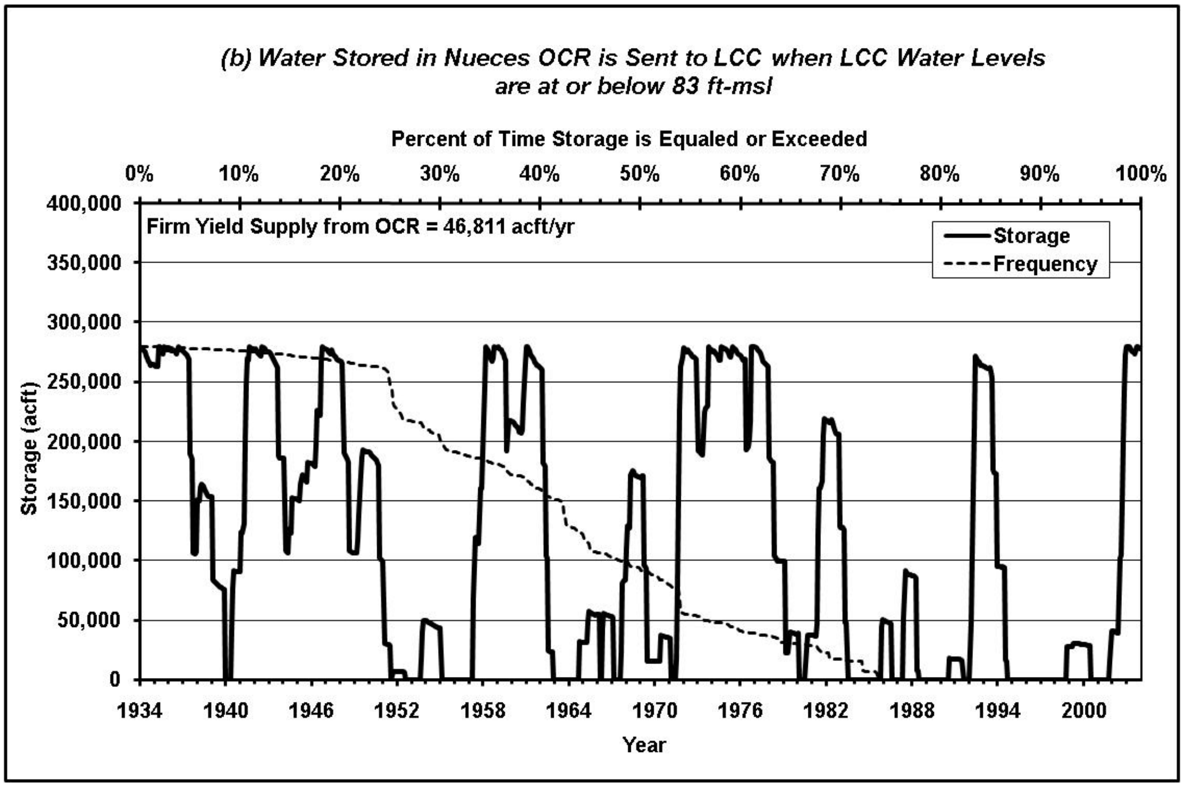


Figure 4C.11-5. Storage and Frequency Plot of Operating Nueces OCR (280,000 acft Capacity at 1,500 cfs Pipeline Rate)

Table 4C.11-1
Endangered, Threatened, and Rare Species Listed for Live Oak County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence In Counties
			USFWS[1]	TPWD[1]	
Audubon's Oriole	*Icterus graduacauda audubonii*	Scrub, mesquite, nests in dense trees or thickets, usually along water courses			Resident
Black-Spotted Newt	*Notophthalmus meridionalis*	Ponds and resacas in south Texas		T	Resident
Coastal gay-feather	*Liatris bracteata*	Endemic: black clay soils of prairie remnants.			Resident
Golden orb	*Quadrula aurea*	Sand and gravel, Guadalupe, San Antonio, and Nueces river basins		T	Resident
Indigo Snake	*Drymarchon corais*	Thornbush-chaparral woodlands of south Texas in dense riparian corridors, moist microhabitats.		T	Resident
Interior Least Tern	*Sterna antillarum athalassos*	Subspecies is listed only when inland more than 50 miles from coastline. Nests along braided waterways.	LE	E	Resident
Jaguarundi	*Herpailurus yaguarondi*	South Texas thick brushlands, favors areas near water	LE	E	Resident
Mountain Plover	*Charadrius montanus*	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts			Nesting/ Migrant
Ocelot	*Leopardus pardalis*	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	LE	E	Resident
Peregrine falcon	*Falco peregrinus anatum (American)*	Open country; cliffs	DL	T	Nesting/ Migrant
	Falco peregrinus tundrius *(Arctic)*		DL	T	
Plains Spotted Skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas and tallgrass prairie.			Resident
Red Wolf	*Canis rufus*	Extirpated	LE	E	Historic Resident
Reticulate collared lizard	*Crotaphytus reticulates*	Requires open brush-grasslands; thorn-scrub vegetation.		T	Resident
Sheep Frog	*Hypopachus variolosus*	Predominately grassland and savanna; moist sites in arid areas		T	Resident

Table 4C.11-1 (Concluded)

Common Name	**Scientific Name**	**Summary of Habitat Preference**	***Listing Entity***		**Potential Occurrence In Counties**
			USFWS[1]	***TPWD[1]***	
South Texas Rushpea	*Caesalpinia phyllanthoides*	Shrublands or grasslands on very shallow soil over rock.			Resident
Spot-tailed earless lizard	*Holbrookia lacerata*	Moderately open prairie-brushland			Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, grass, cactus, brush		T	Resident
Texas Tortoise	*Gopherus berlandieri*	Open brush w/ grass understory; open grass/bare ground avoided		T	Resident
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna			Resident
White-faced Ibis	*Plegadis chihi*	Prefers freshwater marshes		T	Resident
White-tailed Hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	Nesting/ Migrant
Whooping Crane	*Grus americana*	Potential migrant	LE	E	Migrant
Wood Stork	*Mycteria americana*	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant

Source: TPWD, Annotated County List of Rare Species, Live Oak County, October 30, 2007.
LE/LT=Federally Listed Endangered/Threatened
E/SA, T/SA=Federally Listed Endangered/Threatened by Similarity of Appearance
DL, PDL=Federally Delisted/Proposed for Delisting
E, T=State Listed Endangered/Threatened
Blank = Rare, but no regulatory listing status

government. This species prefers to inhabit thick brushlands near water, conditions found within the project area. Sightings of this species are documented near George West and a study[12] focusing on this cat has occurred within the County. The ocelot (*Felis pardalis*) a species which prefers dense chaparral thickets, is also listed as endangered within Live Oak County. The red wolf (*Canis rufus*) was once found in this County, but is now considered extirpated.

The Texas Department of Transportation (TxDOT) district in South Texas is working with the U.S. Fish and Wildlife Services (USFWS) to create “wildlife corridors” to help protect

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[12] TPWD. 1988-1993. Endangered feline population and habitat enhancement. Performance Reports, Federal Aid Project No. W-103 and 125 and ESEC 6, Job No. 12. Texas Parks and Wildlife Department, Austin, Texas.

ocelots and jaguarundis.[13] The TxDOT district has created four cat crossings in Live Oak County for U.S. 281 widening project. The South Texas wildlife corridors consist of a culvert beneath roadways, were dense brush is allowed to grow up from the edge of right of way up to the end of the culvert. Where culverts open to the median, chainlink fences are installed to keep wildlife within the crossing. There were no reports readily available documenting the success of the TxDOT wildlife corridor program in Live Oak County.

Temporarily wet areas or drainages in uplands and in wetland portions of the project may provide habitat for several state-protected amphibians. Several reptile and amphibian species listed as threatened by the state may possibly be affected by the project. These include the Texas horned lizard (*Phrynosoma cornutum*), Texas tortoise (*Gopherus berlandieri*), black-spotted newt (*Notophthalmus meridionalis*), indigo snake (*Drymarchon corais*), reticulate collared lizard (*Crotaphytus reticulates*), and sheep frog (*Hypopachus variolosus*). Many of these reptile species are dependent on shrubland or riparian habitat, while amphibians prefer moist sites in ponds, resacas and grassland areas.

The black-spotted newt (*Notophthalmus meridionalis*) and Rio Grande lesser siren (*Siren intermedia texana*) are found in wet or temporally wet arroyos, canals, ditches, or small depressions. During dry periods, they aestivate underground. The sheep frog (*Hypopachus variolosus*) inhabits wet areas and freshwater marshes in the Rio Grande Valley, lower South Texas Plains, and Southern Coastal Prairie. The Mathis spiderling (*Boerhavia mathisiana*) was a possibly extinct plant that has been proposed for protection to USFWS. It inhabits open thorn shrublands with shallow sandy to gravely soils over limestone or on bare limestone or caliche outcrops. The Mathis spiderling was once found in the vicinity of LCC in San Patricio County.

One rare species, the golden orb (*Quadrula aurea*) has been the reason for the designation of the Nueces River from the headwaters of Lake Corpus Christi upstream to US 59 in Live Oak County (within TNRCC classified stream segment 2103) as a significant stream segment by TPWD. This species is restricted to five rivers in Texas. This segment of the Nueces River contains one of only four known remaining populations of this endemic mollusk.

According to the TPWD Texas Natural Diversity Database, there have been no sightings reported of any state or federal listed threatened or endangered species within five miles of the potential Nueces OCR site. The local vegetation and wildlife habitats are primarily shrub and brush rangeland that may provide suitable habitat for some rare species.

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[13] **Env**ision newsletter, Summer 1995.

A review was conducted of United States Geologic Survey (USGS), USFWS, and Federal Emergency Management Agency (FEMA) maps to evaluate water quality and aquatic habitats. There are no open water features, on-channel impoundments, or upland ponds found within the potential Nueces OCR site. However, the FEMA maps show a possibility that pipeline alignments for Nueces OCR would be located in a 100 year floodplain area.

The Texas Historical Commission identified two recorded cultural resources sites in Live Oak County. These include Fort Merrill, a fort established as protection for settlers against Indians which is listed in the National Register of Historic Places. This fort is located on the George West quad approximately 3.5 miles northwest of Dinero off FM 534. The second cultural resource site is located south of both the Missouri Pacific railroad tracks and the Nueces River. Neither of these archeological sites is within proposed Nueces OCR area or pipeline alignment.

The desktop environmental analysis did not indicate anticipated impacts to protected environmental and cultural resources requiring mitigation based on the proposed project location.[14] Prior to design and implementation of the project, a more detailed evaluation of the inundated area and habitats will be necessary.

The maximum system storage with a 280,000 acft Nueces OCR added to the CCR/LCC system in the Nueces River Basin would be 1,232,531 acft, of which 56% would be stored in CCR, 21% in LCC, and 23% in the Nueces OCR. A comparison of system storage and desired Nueces B&E inflow criteria is shown in Figure 4C.11-6. With the Nueces OCR added to the CCR/LCC system, stored water would be above 70% system storage less often than without a Nueces OCR project. Although reservoir system operations may impact Nueces OCR storage as discussed above, the overall impact of changing trigger levels to release Nueces OCR stored water to LCC does not significantly impact the overall total reservoir system storage in the Nueces River Basin.

The Nueces OCR impacts to the Nueces B&E are shown in Figures 4C.11-7 and 4C-11.8. The Nueces Bay includes the freshwater inflow to the Nueces B&E and fixed return flows pursuant to the 2001 Agreed Order provisions, whereas the Nueces Estuary also includes return flows based on a percentage of water demand (currently set to 52% of demand). With the OCR

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[14] A more detailed discussion of the desktop environmental analysis is included in the Phase I Study 2 Report, which can be accessed on the Nueces River Authority website.

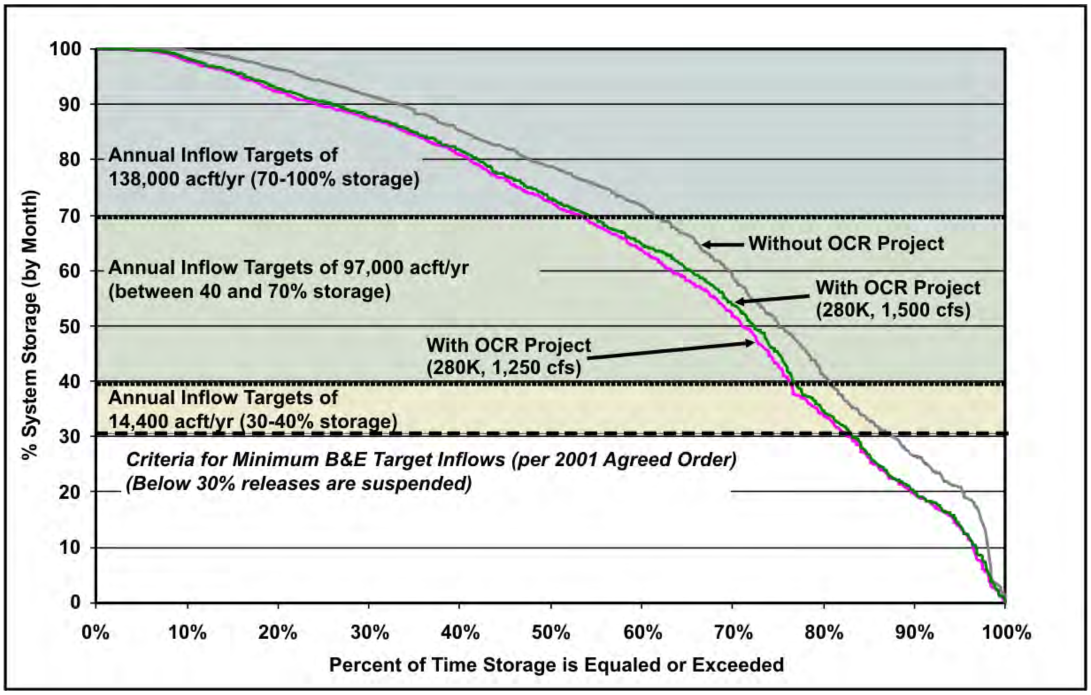

Figure 4C.11-6. Frequency Distribution of Combined Reservoir System (CCR/LCC/Nueces OCR) With and Without Nueces OCR Project

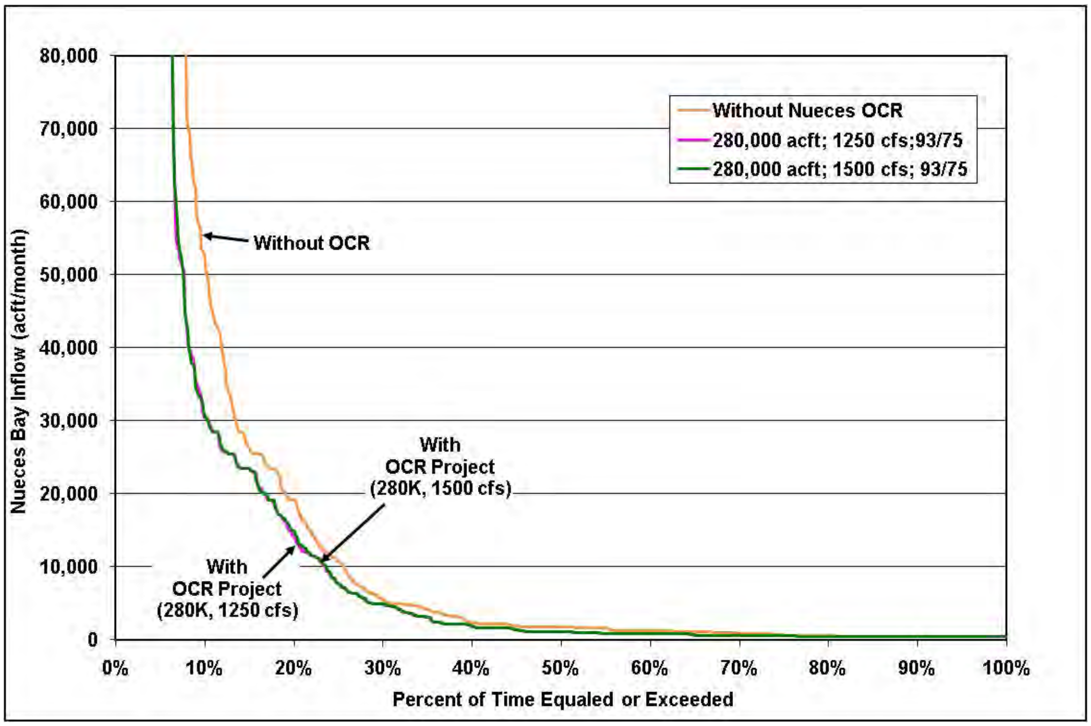

Figure 4C.11-7. Project Impacts on Freshwater Inflows into the Nueces Bay

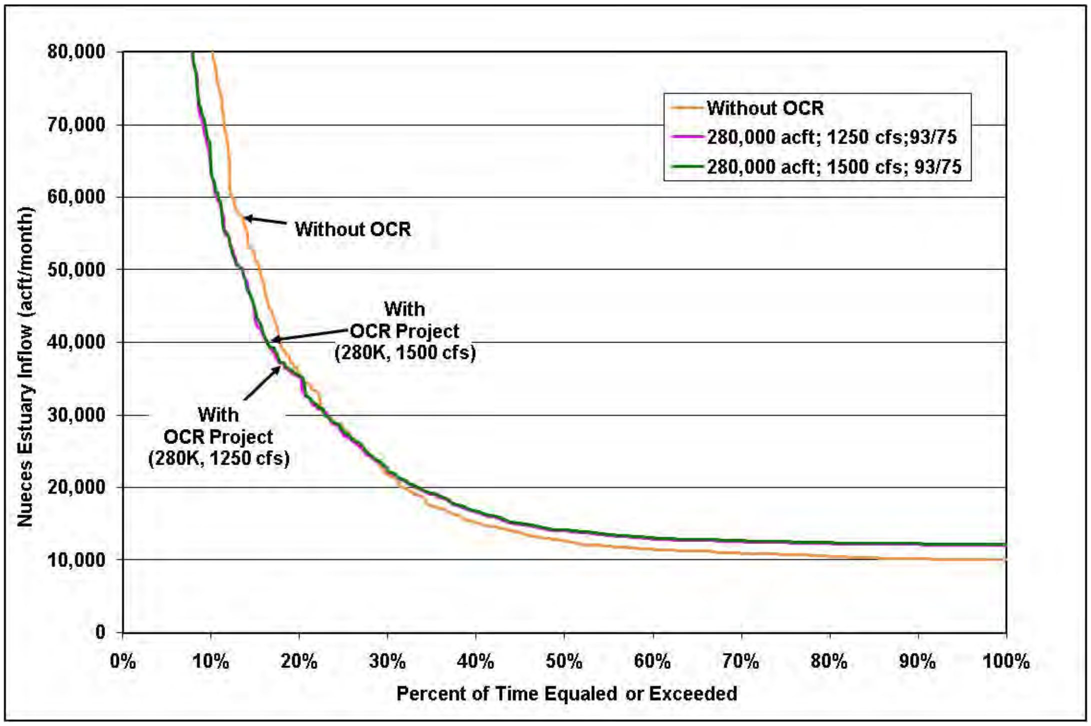

Figure 4C.11-8. Project Impacts on Freshwater Inflows into the Nueces Estuary

operated as part of the reservoir system, monthly inflows to the Nueces Bay would be slightly lower than without Nueces OCR as shown in Figure 4C.11-7. However, with increased utilization of firm yield associated with the Nueces OCR and increased return flows, the flows to the Nueces Estuary are anticipated to be higher about 80% of the time as compared to without the Nueces OCR as shown in Figure 4C-11.8. The annual inflows to the Nueces Estuary, which include return flows, are increased on average by 45,808 acft with the Nueces OCR for years with annual flows less than 190,000 acft/yr.[15] Alternative Nueces OCR operations for different pipeline delivery rates and LCC water level triggers do not show appreciable differences to freshwater inflows into the Nueces Estuary.

4C.11.5 Engineering and Costing

A 280,000 acft Nueces OCR at pipeline delivery rate of 1,250 cfs is estimated to provide a firm yield of 46,677 acft at unit raw water cost of $570 per acft ($1.75 per 1000 gallons). A 280,000 acft Nueces OCR at a pipeline delivery rate of 1,500 cfs is estimated to provide a firm

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[15] Annual inflow to Nueces Estuary less than 190,000 acft/yr are assumed to be representative of drought conditions. In the 70 year hydrologic period from 1934-2003, there are 17 years when annual inflow (without off-channel reservoir project) was less than 190,000 acft/yr.

yield of 48,296 acft at unit raw water cost of $598 per acft ($1.48 per 1000 gallons). With treatment costs assumed at $326 per acft, treated water supplies from a 280,000 acft Nueces OCR range from $896 to $924 per acft ($2.75 to $2.84 per 1000 gallons).

The project cost could potentially be reduced through Federal or State participation. For this analysis, it was assumed that 65% of the firm yield would be available for public water supply with 35% dedicated for ecosystem restoration or other Federal or State purposes. The project cost for water supply interests was estimated to be 35% of the total cost, with the remaining 65% contributed by Federal or State participants. Annual operations and maintenance and pumping energy costs would be paid in full by water supply interests.

Tables 4C.11-2 and 4C.11-3 provide detailed summaries of the estimated costs to implement a 280,000 acft Nueces OCR at pipeline delivery rates of 1,250 cfs and 1,500 cfs, respectively, for 75 ft-msl LCC trigger level with Federal or State participation.[16] The annual costs include pumping energy costs that would be required to initially fill the Nueces OCR. The project requires a four mile transmission pipeline to pump water from LCC to the Nueces OCR, an intake near LCC and in the Nueces OCR, and an outfall in the Nueces OCR. An average cost of $5 per cubic yard was assumed for embankment fill.

With federal or state participation, a 280,000 acft Nueces OCR at pipeline delivery rate of 1,250 cfs is estimated to provide a firm yield of 30,340 acft at unit raw water cost of $389 per acft ($1.19 per 1000 gallons). A 280,000 acft Nueces OCR at a pipeline delivery rate of 1,500 cfs is estimated to provide a firm yield of 31,392 acft at unit raw water cost of $408 per acft ($1.25 per 1000 gallons). With treatment costs assumed at $326 per acft, treated water supplies from a 280,000 acft Nueces OCR range from $715 to $734 per acft ($2.19 to $2.25 per 1000 gallons) depending on pipeline delivery rate. After 20 years of paying debt service for the pipeline, the raw water cost is reduced to $252 to $256 per acft ($0.77 to $0.79 per 1000 gallons) and treated water cost is reduced to $578 to $582 per acft ($1.77 to $1.79 per 1000 gallons).[17]

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[16] The total project cost of a 280,000 acft OCR at pipeline delivery rates of 1,250 cfs and 1,500 cfs is $300,577,000 and $323,201,000, respectively. This strategy, as recommended, is considered with Federal or State participation with portion of the firm yield dedicated for ecosystem restoration or other Federal or State purposes. Without Federal or State participation, the unit treated water costs are $896 to $924 per acft.

[17] After debt service has been paid for both the pipeline and reservoir (40 years), the raw water cost is reduced to $126 to $133 per acft ($0.39 to $0.41 per 1000 gallons) and treated water cost is reduced to $452 to $459 per acft ($1.39 to $1.41 per 1000 gallons).

Table 4C-11.2.
Cost Estimate Summary for
Nueces Off-Channel Reservoir (280,000 acft) and Pipeline (1,250 cfs)
September 2008 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 200000 acft, 5627 acres, 265 ft. msl)	$85,819,000
Intake and Pump Station (1212 MGD)	$66,550,000
Transmission Pipeline (3 pipes, 114 in dia., 1.4 miles)	$25,092,000
Total Capital Cost	**$177,461,000**
Engineering, Legal Costs and Contingencies	$60,857,000
Environmental & Archaeology Studies and Mitigation	$12,700,000
Land Acquisition and Surveying (5649 acres)	$13,142,000
Interest During Construction (4 years)	$32,849,000
Initial Filling of Reservoir	$3,568,000
Total Project Cost	$300,577,000
Total Project Cost (35%, With Federal or State Participation)	**$105,201,950**
Annual Costs	
Debt Service (6 percent, 20 years) 35%, With Federal or State Participation	$4,152,750
Reservoir Debt Service (6 percent, 40 years), 35%, With Federal or State Participation	$3,826,200
Operation and Maintenance	
Intake, Pipeline, Pump Station	$1,915,000
Dam and Reservoir	$1,287,000
Pumping Energy Costs (6944277.6028259 kW-hr @ 0.09 $/kW-hr)	$625,000
Total Annual Cost	**$11,805,950**
Available Project Yield (acft/yr)(65%, With Federal or State Participation)	30,340
Annual Cost of Water ($ per acft)	$389
Annual Cost of Water ($ per 1,000 gallons)	$1.19

Table 4C-11.3.
Cost Estimate Summary for
Nueces Off-Channel Reservoir (280,000 acft) and Pipeline (1,500 cfs)
September 2008 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 200000 acft, 5627 acres, 265 ft. msl)	$86,813,000
Intake and Pump Station (1455 MGD)	$78,665,000
Transmission Pipeline (3 pipes, 120 in dia., 1.4 miles)	$27,482,000
Total Capital Cost	**$192,960,000**
Engineering, Legal Costs and Contingencies	$66,162,000
Environmental & Archaeology Studies and Mitigation	$12,700,000
Land Acquisition and Surveying (5649 acres)	$13,142,000
Interest During Construction (4 years)	$34,700,000
Initial Filling of Reservoir	$3,537,000
Total Project Cost	$323,201,000
Total Project Cost (35%, With Federal or State Participation)	**$113,120,350**
Annual Costs	
Debt Service (6 percent, 20 years) 35%, With Federal or State Participation	$4,793,250
Reservoir Debt Service (6 percent, 40 years)35%, With Federal or State Participation	$3,864,350
Operation and Maintenance	
Intake, Pipeline, Pump Station	$2,241,000
Dam and Reservoir	$1,302,000
Pumping Energy Costs (6944166.90719416 kW-hr @ 0.09 $/kW-hr)	$625,000
Purchase of Water (acft/yr @ $/acft)	$0
Total Annual Cost	**$12,825,600**
Available Project Yield (acft/yr) (65%, With Federal or State Participation)	31,392
Annual Cost of Water ($ per acft)	$409
Annual Cost of Water ($ per 1,000 gallons)	$1.25

4C.11.6 Implementation Issues

The primary implementation issue that would need to be addressed with this project alternative would be the impact of the inundated area of the Nueces OCR. A detailed evaluation of the impacts of this inundated area and its habitat would have to be undertaken to fully investigate the consequences of implementing this alternative. In addition, the TCEQ permits will need to be amended to obtain the right to impound additional water in the Nueces OCR. Additionally, before a significant expenditure of funds would be considered for either of these alternatives, detailed investigations of the possibility of seepage from the off-channel reservoir into the surrounding Gulf Coast Aquifer should be undertaken to fully understand the impact on the project.

4C.11.6.1 Requirements Specific to Reservoirs

1. It will be necessary to obtain these permits:
    a. TCEQ Water Right and Storage permits, including interbasin transfer authorization.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
    c. General Land Office Sand and Gravel Removal permits.
    d. General Land Office Easement for use of state-owned land.
    e. Coastal Coordination Council review.
    f. Texas Parks and Wildlife Department Sand, Gravel, and Marl permit.
2. Permitting, at a minimum, will require these studies:
    a. Assessment of effects on bays and estuaries.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the reservoir may include:
    a. Highways and railroads.
    b. Petroleum pipelines.
    c. Other utilities.
    d. Structures of historical significance.
    e. Cemeteries.

4C.11.6.2 Requirements Specific to Pipelines:

1. Necessary Permits:
   1. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   2. General Land Office Sand and Gravel Removal permits.
   3. Coastal Coordinating Council review.
   4. Texas Parks and Wildlife Department Sand, Gravel, and Marl permit for river crossings.
   5. Cultural Resource Survey as required by Texas Antiquities Commission.
2. Right-of-way and easement acquisition.
3. Crossings:
   1. Highways and railroads.
   2. Creeks and rivers.
   3. Other utilities.

4C.11.7 Evaluation Summary

An evaluation summary of this regional water management option is provided in Table 4C.11-4.

Table 4C.11-4.
Evaluation Summary for Nueces Off-Channel Reservoir 280,000 acft With Pipeline Delivery of 1,250 or 1,500 cfs

Impact Category	*Comment(s)*
a. Water supply: 1. Quantity 2. Reliability 3. Cost of water	 1. Reduced Firm Yield (with Federal or State Participation): 30,340 to 31,392 acft/yr 2. Firm Supply 3. Generally low raw water cost between $389 to $408 per acft. With $326 added for treatment, cost of treated water is $715 to $734 per acft.
b. Environmental factors: 1. Instream flows 2. Bay and estuary inflows 3. Wildlife habitat 4. Wetlands 5. Threatened and endangered species 6. Cultural resources 7. Water quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	 1. Generally decreases streamflows below LCC. 2. Slight decrease in freshwater inflows to Nueces Bay. Increase freshwater inflows to Nueces Estuary, primarily attributable to increased return flows with increased water demands. 3. Some impact to wildlife habitat. Inundated land area for off-channel reservoir. 4. Low impact to wetlands. 5. Low impact to threatened and endangered species. 6. No cultural resources identified in project area based on Texas Historical Commission data. 7. Minimal impact to water quality.
c. State water resources	• No negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• None
e. Recreational	• Benefits with higher LCC water level with 83 ft-msl trigger
f. Equitable comparison of strategies	• Standard analyses and methods used
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Maximizes opportunities to capture water from a large drainage area.
j. Effect on navigation	• None

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4C.12 Voluntary Redistribution of Available Supplies and Federal or State Opportunities to Participate in Regional Projects (N-12)

4C.12.1 Description of Strategy

In order to increase available supply, this option evaluates opportunities to reallocate surface water through utilization of unused supply and sales of existing water rights; and the potential trading/transfer of surface water with the South Central Texas Regional Water Planning Area including consideration of federal or state participation in Coastal Bend Regional projects.

4C.12.2 Available Yield

4C.12.2.1 Utilization of Unused City of Three Rivers' Supply

Of the 215,812 acft of surface water in 2060 available in the region, the City of Corpus Christi directly or indirectly supplies 93 percent of the total. The City has a contract with the City of Three Rivers to supply up to 3,363 acft/yr. This water is provided out of the CCR/LCC System and constitutes Three Rivers' 2-percent stake in the CCR/LCC System. Three Rivers has the ability to purchase an additional 2,240 acft/yr without a renegotiation of the existing contract. The City of Three Rivers also holds run-of-river rights in the Nueces Basin for municipal uses at 700 acft, which is available for delivery on a firm yield basis. The supply listed in Section 4 (Table 4A-16) shows the yield of permitted and contracted supplies of 4,063 acft, including the 3,363-acft contract amount and 700 acft from Nueces Basin permit. Three Rivers municipal demands range from 465 acft in 2010 to 399 acft in 2060. In January 2004, the City of Three Rivers acquired Choke Canyon Water Supply Corporation (WSC). Choke Canyon WSC has a maximum water demand of 477 acft (in 2030) distributed between Live Oak and McMullen Counties. They receive between 40 and 50 percent of their water supplies from groundwater, with the remaining amount supplied by the City of Three Rivers.

There is also a significant projected manufacturing demand in the City of Three Rivers, which increases each decade to a maximum of 2,194 acft in 2060. Three Rivers has a run-of-river water permit in the Nueces Basin amounting to 800 acft for industrial uses, which is available for firm yield delivery. Based on 2010 water demand projections for the City of Three Rivers, 3,353 acft of Three Rivers' contract could be made available to other entities, including local industries. In 2060, up to 3,463 acft could be available to other entities. As shown in Table 4B.9-2, a reallocation of a portion of the Three Rivers surplus for local manufacturing needs is recommended. An evaluation summary of the utilization of unused surface water is presented in Table 4C.12-1.

Table 4C.12-1.
Evaluation Summary of the Utilization of Unused Surface Water

Impact Category	*Comment(s)*
a. Water Supply	
1. Quantity	1. Firm yield: Reallocation of up to 3,463 acft CCR/LCC System firm yield
2. Reliability	2. Good reliability
3. Cost of treated water	3. Cost: Not applicable
b. Environmental factors:	
1. Instream flows	1. Negligible. Utilization of surface water supplies that would not otherwise be used may have a minimal to low impact on downstream flows.
2. Bay and estuary inflows	2. No impacts.
3. Wildlife habitat	3. No impacts.
4. Wetlands	4. No impacts.
5. Threatened and endangered species	5. No impacts.
6. Cultural resources	6. No impacts.
7. Water quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	7. No change to water quality.
c. State water resources	• No impacts
d. Threats to agriculture and natural resources in region	• No impacts
e. Recreational	• No impacts
f. Equitable comparison of strategies	• Standard analyses and methods used
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None

4C.12.2.2 Use or Purchase of Underutilized Nueces County WCID #3 Water Right

Nueces County WCID #3 (the District) has two municipal water rights and two irrigation water rights which authorize a total diversion of 11,546 acft/yr. For the purposes of the following analysis, it is assumed that the irrigation permits can be amended for any use. Two of the diversions (one municipal, one irrigation) have a priority date of February 7, 1909 (senior to Corpus Christi), the other two (one municipal, one irrigation) have a priority date of January 28, 1925 (junior to Corpus Christi). The Nueces River Basin water availability model (TCEQ's WRAP model), shows a minimum annual firm yield diversion of 7,103 acft/yr for the District.

The irrigation demands for Nueces County total 1,449 acft in 2010 and decrease to 692 acft by 2060. This report assumes surface water supplies for Nueces County irrigation are provided by the District. The irrigation demand placed on the District is 692 acft in 2060.

The municipal demands placed on the District by their customers—City of North San Pedro, City of Robstown, and River Acres WSC— total 3,091 acft in 2060 as shown in Table 4A-24. This results in a total 2060 surplus of 4,012 acft. Assuming the same proportion to total water right diversion, a purchase of 6,522 acft water right would have an approximate firm yield of 4,012 acft.

For this surplus to be fully utilized, three options are available. One is for the District to increase its water contract with River Acres WSC to meet their current and projected needs, which shows a shortage of 590 acft in 2060. Another option is for the District to expand its existing distribution system to serve the County-Other population, provided County-Other users fall within service area boundaries of the District. The last option is for the City of Corpus Christi or other wholesale water providers to purchase the unutilized 4,012 acft/yr of firm water and make it available to meet manufacturing or mining needs of the region. At $685 per acft,[1] the one-time purchase price of 6,522 acft is $4,467,570. Annual cost for 20 years is $389,500. With 4,012 acft in availability, cost per acft per year is $97. An evaluation summary for this option is presented in Table 4C.12-2.

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[1] Purchase price is based on estimated cost of Garwood project, with $326 for treatment (see Table ES-3).

Table 4C.12-2.
Evaluation Summary of
Use/Purchase of Nueces County WCID #3 Water Right

Impact Category	***Comment(s)***
a. Water Supply 1. Quantity 2. Reliability 3. Cost of treated water	 1. Firm yield: 4,012 acft 2. Good reliability 3. Costs: • Nueces County WCID #3: costs of additional distribution system • If purchased by others, $97 acft/yr for purchase of water right plus costs of distribution
b. Environmental factors: 1. Instream flows 2. Bay and estuary inflows 3. Wildlife habitat 4. Wetlands 5. Threatened and endangered species 6. Cultural resources 7. Water quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	 1. Negligible. Utilization of surface water supplies that would not otherwise be used may have a minimal to low impact on downstream flows. 2. No impacts. 3. No impacts. 4. No impacts. 5. No impacts. 6. No impacts. 7. No change to water quality.
c. Impacts to State water resources	• No impacts
d. Threats to agriculture and natural resources in region	• No impacts
e. Recreational impacts	• No impacts
f. Equitable Comparison of Strategies	• Standard analyses and methods used
g. Interbasin transfers	• Not significant
h. Third party social and economic impacts from voluntary redistribution of water	• Willingness of Nueces County WCID #3 to serve County-Other population • Willingness of Nueces County WCID #3 to sell rights.
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None

4C.12.2.3 Trades/Transfers with South Central Texas Region

The Nueces River Basin covers three Regional Water Planning Areas: Coastal Bend, South Central Texas, and Rio Grande. Options have been developed for the South Central Texas Region (Region L) that would trade/transfer water between the South Central Texas and Coastal Bend Regions. Below is a summary of those options.

4C.12.2.3.1 Recharge Enhancement in Exchange for Other Water

This option involves the decrease of firm yield to the CCR/LCC System by building recharge enhancement projects over the Edwards Aquifer in the upper reaches of the Nueces River Basin. These recharge enhancement projects would result in additional supply for the South Central Texas Region. Three separate enhancement project programs have been developed by Region L, one of which would be built if the option is determined to be a management supply solution. The South Central Texas Regional Water Planning Group has recommended a program that includes recharge enhancement of five tributaries in the Nueces River Basin (Indian Creek, Lower Frio, Lower Sabinal, Lower Hondo, and Lower Verde). This program would impound combined maximum recharge pool storage of 94,000 acft and periodically inundate 5,776 acres in the Nueces Basin. By capturing water before it arrives at the CCR/LCC System, the firm yield of the system is decreased from anywhere between 1,355 acft/yr to 4,308 acft/yr, depending on which program is built.[2] Available yield to the South Central Texas Region would range from 13,451 acft/yr to 21,577 acft/yr. The maximum impact on average inflow to the Nueces Estuary is a reduction of about 14,590 acft/yr, or 6 percent.

Numerous options exist to replace the decrease in firm yield to the CCR/LCC System resulting from the recharge enhancement projects. The first option involves diversion and transmission of water from sources located along the Mary Rhodes Pipeline, including the Guadalupe River, groundwater from the Gulf Coast Aquifer, Colorado River water, or additional Lake Texana water. This water would be delivered to the City's O.N. Stevens Water Treatment Plant. Additional options involve potential enhancements to streamflow associated with brush management and/or weather modification programs on the Upper Nueces River. If studies are pursued and results are favorable, this additional supply could be used to benefit the Coastal Bend Region and partially mitigate effects of recharge enhancement projects.

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[2] Based on period from 1934- 1989, does not reflect drought of the 1990's.

Although not fully analyzed, the alternative exists for the City of Corpus Christi to trade their 35,000-acft/yr Garwood water right to the South Central Texas Regional Water Planning Area in exchange for 35,000 acft/yr of Guadalupe River water. Under this option, Guadalupe River water would need to be pumped via a new pipeline approximately 7 miles in length to the Mary Rhodes Pipeline. The cost of the 7-mile pipeline would be significantly less than either the 42-mile or 17-mile pipelines necessary to transport Garwood water to the existing Mary Rhodes Pipeline. This option is not currently being considered by Region L during this planning cycle.

As can be seen in Table 4C.12-3, the mixing of Guadalupe River water, Colorado River, or Lake Texana water with Nueces River Water at the O.N. Stevens Water Treatment Plant poses minimal water quality issues.

Table 4C.12-3.
General Statistics on
Water Quality at Potential Water Sources

Location		***Chloride***	***Hardness***	***Sulfate***
Nueces River @ Stevens	Max	338	312	—
	Med	162	219	—
	Min	67	138	—
Guadalupe River @ Victoria	Max	72	297	56
	Med	36	221	29
	Min	9	75	8
Lake Texana	Max	96	216	27
	Med	21	75	10
	Min	1	37	6
Colorado River @ Wharton	Max	140	280	110
	Med	48	210	38
	Min	11	75	12

4C.12.2.3.2 Federal or State Opportunities to Participate in Regional Projects

Several proposed projects identified in this regional water plan, have been studied by federal interests to evaluate opportunities for flood damage reduction, ecosystem restoration, and/or benefit water supplies in South Texas. These projects include:

- Desalination Facilities
- CCR/LCC Pipeline
- Nueces Off Channel Reservoir
- Recharge Enhancement Projects
- Brush Control Opportunities

The TWDB has participated in pilot programs and feasibility studies of seawater and brackish groundwater desalination projects in the South Texas region.

Four projects considered as separate water management strategies for this plan (Nueces off-channel reservoir, CCR/LCC pipeline, seawater desalination, and brackish groundwater desalination) include discussion of opportunities for federal or state participation. Some of these projects could potentially serve to mitigate the effects of the recharge enhancement projects. Costs to implement these projects could potentially be reduced through federal or state participation. For example, the total project cost of the Nueces off-channel reservoir (Section 4C.11) is estimated at $300,577,000 for a yield of 46,677 acft/yr. When considering annual program costs, the unit cost would be approximately $896 per acft for treated water supplies.[3] Assuming federal funding participation of 65%, the total project cost would be reduced to $105,201,950. For the purposes of the plan, it was assumed that with federal or state participation, 35% of the total project water supply is dedicated for ecosystem restoration or other federal or state designated purpose. The annual cost (including operations and maintenance costs and reduced debt service) would be $11,805,950, which results in a unit cost of $389 per acft for raw water supplies ($715 per acft for treated water supplies), or about 80% of the unit cost without federal participation. For federal participation of multiple projects, the savings potential for the Coastal Bend Region could be significant.

For brackish groundwater and seawater desalination options, based on assumptions of 65% of federal or state funding participation for debt service costs and water supplies of 65% of project potential (with 35% dedicated for ecosystem restoration or other purposes), federal or state participation would not be anticipated to reduce annual unit costs of water and therefore was not recommended for these water management strategies in the water supply plans presented in Sections 4B.11 and 4B.12.

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[3] Assumes a cost of $326 per acft for treatment.

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4C.13 Palmetto Bend Stage II (Lavaca-Navidad River Basin), and Lavaca River Diversion and Off-Channel Reservoir Project (N-13)

This section addresses two options for Stage II of Lake Texana, both an on-channel option (Palmetto Bend Stage II) and an off-channel option that is currently being considered by the Lavaca Region (Region P). The Palmetto Bend Stage II option is described in Section 4C.13.1. The Lavaca River Diversion and Off-Channel Reservoir Project is described in Section 4C.13.2. The text for the off channel description was provided by the Lavaca-Navidad River Authority (LNRA)[1].

4C.13.1 Palmetto Bend Stage II

4C.13.1.1 Description of Strategy

The Texas Water Development Board (TWDB) and the LNRA hold Texas Commission on Environmental Quality (TCEQ) Certificate of Adjudication #16-2095B, for the completion of Palmetto Bend Stage II Dam and Reservoir (Palmetto Bend Stage II) on the Lavaca River. Stage I, now known as Lake Texana, was completed in 1981 and is located on the Navidad River. Lake Texana is operated by LNRA primarily for water supply purposes and has a firm yield of 79,000 acft/yr. In 1998, the Mary Rhodes Memorial Pipeline (MRP) was completed to deliver an initial 41,840 acft/yr from Lake Texana to the City of Corpus Christi.

The LNRA has expressed a renewed interest in the potential development of Palmetto Bend Stage II. In the 2006 Coastal Bend Regional Water Plan, water supply from the development of Palmetto Bend Stage II was evaluated as part of an interregional water supply by both the Coastal Bend Regional Water Planning Group (Region N) and the South Central Texas Regional Water Planning Group (Region L). Previously, Region L considered two Palmetto Bend Stage II water delivery options: to coastal irrigation areas near the Colorado River at Bay City and to the Guadalupe River near the Saltwater Barrier. However, Region L is no longer actively pursing these options. Palmetto Bend Stage II could be developed by Region N on its own or could contribute to a cooperative water supply between the two regions as follows:

- Exchanging Palmetto Bend Stage II water for coastal area surface water rights and/or options owned by Corpus Christi for Colorado River streamflow that might be diverted at an upstream point near Columbus and delivered to the South Central Region. The Palmetto Bend Stage II water would be delivered to the City of Corpus Christi's water treatment plant via the MRP.

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[1] Lavaca Navidad River Authority, "Lavaca River Diversion and Off-Channel Reservoir" provided January 21, 2010

Originally, the U.S. Bureau of Reclamation proposed that Palmetto Bend Stage II would be located on the Lavaca River and share a common pool with Stage I (Lake Texana). However, previous studies have shown that Palmetto Bend Stage II could be constructed more economically if operated separately from Lake Texana and located further upstream at an alternative site on the Lavaca River.[2] As proposed, at the original site, the Certificate of Adjudication states:

> *"Upon completion of the Stage 2 dam and reservoir on the Lavaca River, owner Texas Water Development Board is authorized to use an additional amount of 18,122 acft/yr, for a total of 48,122 acft/yr, of which up to 7,150 acft/yr shall be for municipal purposes, up to 22,850 acft/yr shall be for industrial purposes, and at least 18,122 acft/yr shall be for the maintenance of the Lavaca-Matagorda Bay and Estuary System. The entire Stage 2 appropriation remains subject to release of water for the maintenance of the bay and estuary system until a release schedule is developed pursuant to the provisions of Section 4.B of this certificate of adjudication."*[3]

For the purposes of this study, Palmetto Bend Stage II is assumed to be constructed at the alternative site located approximately 1.4 miles upstream of the original site. Since this site results in a different yield than stated in the certificate, the conditions in the certificate will need to be revised to account for the change in yield of Stage II. The revisions to the certificate should also reflect the impacts that joint operations of Lake Texana and Palmetto Bend Stage II could have on the releases necessary to maintain the bay and estuary system downstream of the projects. In 1997, a study[4] was conducted by the LCRA to estimate target and critical freshwater inflow needs for the Matagorda Bay System from the Colorado River. Target inflow is defined based on criteria established for salinity and nutrient inflow, in addition to necessary long-term inflow to produce 98% of maximum population for nine key estuarine species. Critical freshwater inflow is the minimum inflow, based on salinity levels, necessary to provide for fish habitat during drought conditions. Recent studies of Matagorda Bay and Lavaca-Colorado Estuary[5] indicate that releases to the bay and estuary (from 1941-1987), on average, exceed

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[2] HDR Engineering, Inc., "Regional Water Planning Study Cost Update for Palmetto Bend Stage 2 and Yield Enhancement Alternative for Lake Texana and Palmetto Bend Stage 2," Lavaca-Navidad River Authority, et al., May 1991.

[3] Texas Natural Resource Conservation Commission Certificate of Adjudication No. 16-2095B, 1994.

[4] LCRA, "Freshwater Inflow Needs of the Matagorda Bay System," December 1997.

[5] TWDB, "Texas Bay and Estuary Program- Matagorda Bay and Lavaca-Colorado Estuary", 1998.

target inflow by over 50% with an average inflow of 3,080,301 acft as compared to a target inflow of 2,000,100 acft.[6] These inflows, which include releases from Lake Texana, exceed mitigation requirements and may enhance the productivity of certain species in the bay and estuary. These results indicate that releases from Palmetto Bend Stage II for maintaining the bay and estuaries may be less restrictive than those called for in the Environmental Water Needs Criteria of the Consensus Planning Process.[7] However, in addition to the bay and estuary requirements, releases from Palmetto Bend Stage II might be required for the 3.5-mile reach of the Lavaca River downstream of the dam site to the confluence with the Navidad River.[8] Additional inflow requirements will likely be determined by the Senate Bill 3 process. Therefore, it is assumed that releases from Palmetto Bend Stage II will be in accordance with the Consensus Criteria for maintenance of the river reach just below the dam. The Freshwater Inflow Needs for the Matagorda Bay System is currently undergoing a revision which should be considered in future water planning efforts.

TWDB conducted a study to evaluate and select the most promising reservoir sites in Texas to satisfy future water supply needs. The TWDB Reservoir Site Protection Study[9] recommended Palmetto Bend Stage II as one of the top-ranked sites in Texas for protection or acquisition. During the 2007 Texas legislative session, Palmetto Bend Stage II was designated as one of 19 unique reservoir sites in the State of Texas. .

Figure 4C.13-1 shows the location of Palmetto Bend Stage II and route of the MRP. This option will require an intake station at the Stage II reservoir site, a transmission line, and an outlet structure.

This report has been updated based on the TWDB Reservoir Site Protection Study.

4C.13.1.2 Available Yield

The elevation-area-capacity relationship for Palmetto Bend Stage II is shown in Table 4C.13-1 and was developed from 10-foot contour digital hypsography data from the Texas Natural Resources Information System.[10] These data are derived from the 1:24,000-scale

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[6] The monthly average inflow exceeds target monthly inflow for all months, except April which is slightly less than target levels.

[7] Texas Water Development Board (TWDB), "Environmental Water Needs Criteria of the Consensus Planning Process," January 1996.

[8] Personal communications with Gary Powell, TWDB, July 1999.

[9] Texas Water Development Board, HDR Engineering, R.J. Brandes Company, et al "Reservoir Site Protection Study", TWDB Report 370, July 2008.

[10] Ibid.

(7.5 minute) quadrangle maps developed by the U.S. Geological Survey. At the conservation pool elevation of 44 feet, Palmetto Bend Stage II will inundate 4,564 acres and have a capacity of 52,046 acft. The specific location evaluated for Palmetto Bend Stage II is shown in Figure 4C.13-2.

The monthly median flows (Zone 1) and 25th percentile flows (Zone 2) used to define the Consensus Criteria release requirements were computed from the monthly naturalized flows from the Lavaca-Navidad River Basin Model distributed to a daily time step. The Zone 3 requirement (7Q2) was taken from TCEQ's published water quality standards.[11] Table 4C.13-2 shows the daily release (inflow passage) requirements from Palmetto Bend Stage II.

The firm yield of Palmetto Bend Stage II was estimated by using the TCEQ Lavaca River Basin water availability model (BOR, 2001; February 24, 2003 version) data sets and the Water Rights Analysis Package. The water availability model simulates a repeat of the natural streamflows over the 57-year period of 1940 through 1996, accounting for the appropriated water rights of the Lavaca River Basin with respect to location, priority date, diversion amount and pattern, storage, and special conditions, including instream flow requirements. Palmetto Bend Stage II is simulated with the priority date as provided by the TCEQ in Certificate of Adjudication No. 16-2095B. The TWDB study evaluated four potential conservation storage capacities associated with 50, 44, 40, and 35 foot conservation pool elevations. Current planning envisions a conservation elevation of 44 feet for Palmetto Bend Stage II, thereby yielding a water supply of 22,964 acft/yr.

The development of Palmetto Bend Stage II will result in approximately 22,964 acft of water. There is currently an industrial need of approximately 10,000 acft for an existing industrial customer of LNRA in Calhoun County, leaving 12,964 acft of water supply for contract and/or project participation by other interested parties. It is currently expected that this excess water will be used for municipal and agricultural uses to meet future needs in Region P (Jackson County), Region L, or Region N.

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[11] Texas Administrative Code, Chapter 307, Texas Surface Water Quality Standards.

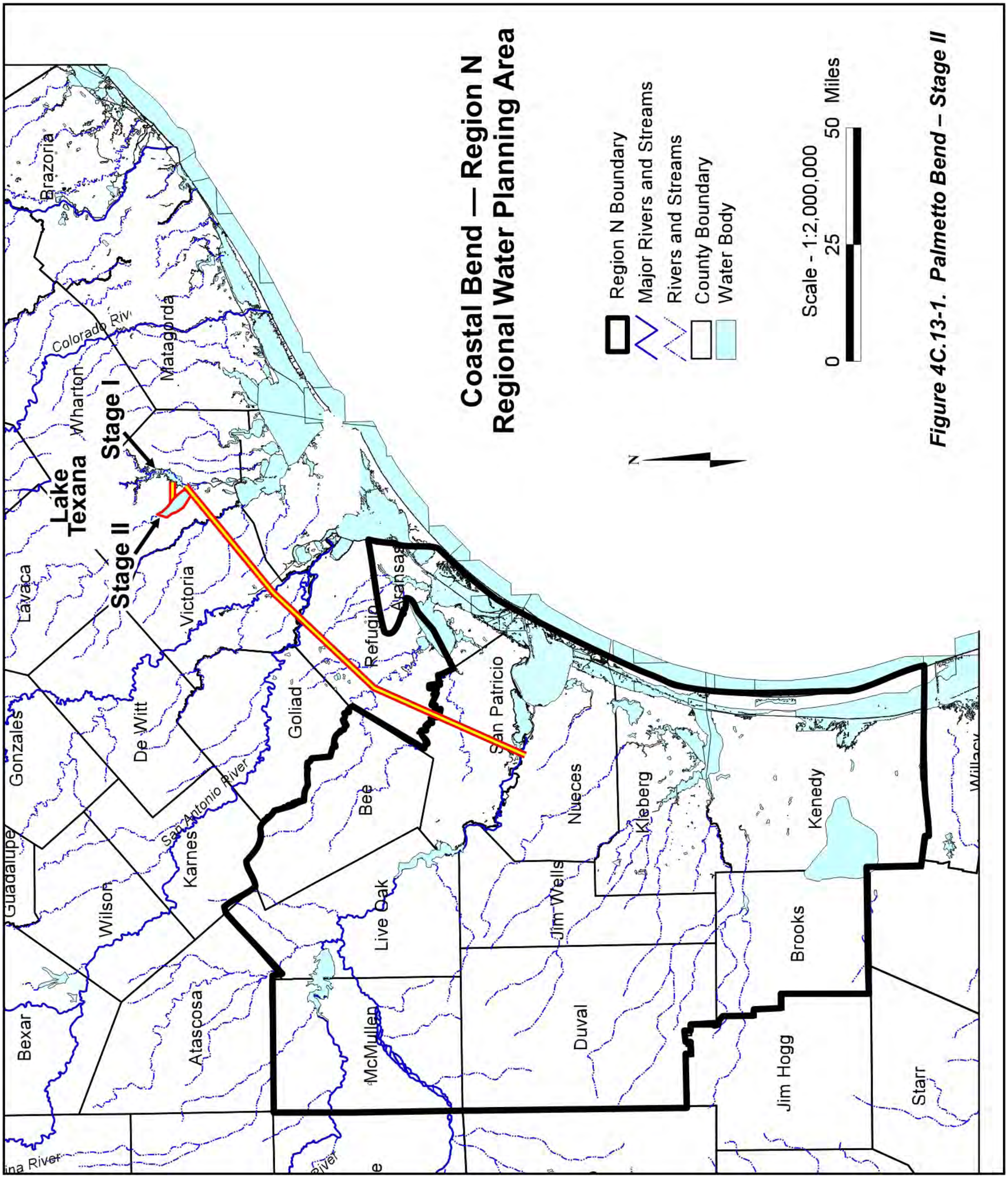

Figure 4C.13-1. Palmetto Bend – Stage II

Table 4C.13-1.
Palmetto Bend Stage II
Elevation, Area, and Capacity Table

Elevation (ft-msl)	***Area (acres)***	***Capacity (acft)***
4	0	0
5	16	5
10	49	161
15	92	507
20	159	1,127
25	609	2,927
30	1,649	8,360
35	2,725	19,182
40	3,688	35,152
44	4,564	52,046
45	4,783	56,269
50	5,868	82,851

Source: TWDB Reservoir Site Protection Study, 2008.

Palmetto Bend Stage II was evaluated by the Coastal Bend Regional Water Planning Group in the 2006 Regional Water Plan. The reported firm yield of Palmetto Bend Stage II was reported as 28,000 acft/yr at a conservation elevation of 44 feet. The firm yield estimate in this plan differs from the 2006 Regional Water Plan because the previous study used SIMDLY (a daily reservoir simulation model) rather than the Water Rights Analysis Package. In addition, the refined elevation-area-capacity relationship in this plan has reduced the conservation capacity at an elevation of 44 feet from 57,676 to 52,046 acft.

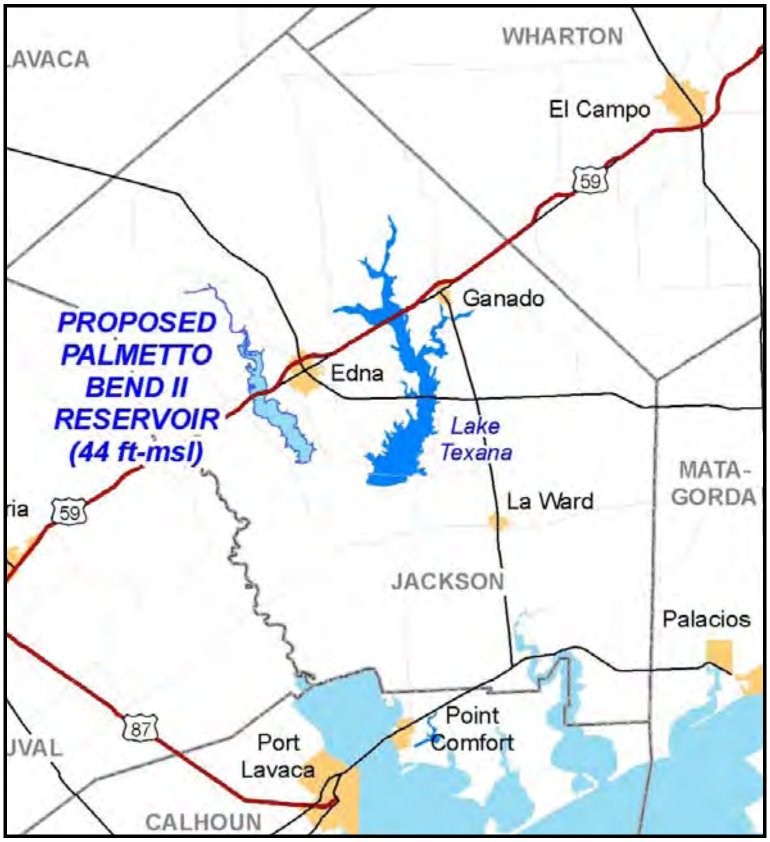

Figure 4C.13-2. Palmetto Bend Stage II Reservoir (Large Scale)

Table 4C.13-2.
Consensus Criteria Release Requirements (cfs) for Palmetto Bend Stage II

Month	***Consensus Criteria Zone***		
	1	***2***	***3***
	>80% Capacity Median	***<80% to >50% Capacity 25th Percentile***	***<50% Capacity 7Q2***
January	63.0	26.1	21.6
February	92.8	39.0	21.6
March	76.9	37.6	21.6
April	78.9	36.8	21.6
May	92.2	35.4	21.6
June	85.6	36.7	21.6
July	47.5	22.7	21.6
August	37.3	21.6	21.6
September	41.2	21.6	21.6
October	39.2	21.6	21.6
November	48.3	21.6	21.6
December	55.1	24.3	21.6
Note: Consensus Criteria published in 2001 Coastal Bend Regional Water Plan.			

4C.13.1.3 Environmental Issues

Environmental issues associated with the construction of Palmetto Bend Stage II can be categorized as follows:

- Effects of the construction and operation of the reservoir;
- Effects on the Lavaca River downstream from the dam; and
- Effects on Lavaca Bay.

The proposed dam would create a 4,564-acre conservation pool area at 44 ft-msl, inundating about 22 miles of the Lavaca River channel. Landcover for the reservoir site is dominated by grassland (42 percent), with broad-leaf evergreen forest (34 percent) and upland deciduous forest (11 percent) concentrated along the Lavaca River. Although no federal or state protected species are known to be present within the reservoir area, important species may be present in the surrounding areas and are listed in Table 4C.13-3. Suitable habitat for protected species may be present at the reservoir site. Several species of migratory birds, marine turtles, and mammals considered by the USFWS and National Marine Fisheries Service to be endangered or threatened are believed to utilize the Lavaca Estuary.

Palmetto Bend Stage II will inundate a portion of the TCEQ classified stream segment 1601 on the Lavaca River. Texas Parks and Wildlife Department listed the segment of the Lavaca River immediately downstream of the reservoir as ecologically significant. Palmetto Bend Stage II could have the following effects to Texas Parks and Wildlife Department criteria:

- Biological function — Extensive freshwater wetland habitat displays significant overall habitat value.
- Threatened or endangered species/ unique communities to the diamond back terrapin species of concern.

The importance of the flow reductions to the bay and estuary system is a complex function of bay physiography (estuarine volume, area/depth ratio, substrate composition, constrictions or compartmentalization), regional climate, and the flushing energy provided by tidal action, the effects of multiple freshwater inflows, and the estuarine population examined. The operating regime for Palmetto Bend Stage II meets the Consensus Criteria for both streamflow and estuary requirements, based on the results of "Freshwater Inflow Needs of the Matagorda Bay System."[12] The changes in streamflow in the Lavaca River and the inflows into

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[12] LCRA, Op. Cit., December 1997.

Table 4C.13-3.
Important Species* Having Habitat or Known to Occur in Counties Potentially Affected by Option Stage II Reservoir

Common Name	Scientific Name	Summary of Habitat Preference	Listing Agency USFWS[1]	Listing Agency TPWD[1]	Listing Agency TOES[2,3,4]	Potential Occurrence in County
A Mayfly	*Tortopus circumfluus*	mayflies distinguished by aquatic larval stage; adult stage generally found in shoreline vegetation				Resident
American Peregrine Falcon	*Falco peregrinus anatum*	Open country; cliffs	DL	T	E	Nesting/Migrant
American Eel	*Anguilla rostrata*	Coastal waterways to Gulf				Resident
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	Open country; cliffs	DL		T	Nesting/Migrant
Atlantic Hawksbill Sea Turtle	*Eretmochelys imbricata*	Coastal waters	E	E	E	Resident
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	Gulf coastal prairies	E	E	E	Resident
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	DL	T	E	Nesting/Migrant
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushlands, forests	T/SA;NL	T	T	Resident
Black Lace Cactus	*Echinocereus reichenbachii var albertii*	Grasslands, thorn shrublands, mesquite woodlands on sandy, somewhat saline soils on coastal prairie	E	E		Resident
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T		Resident
Brown Pelican	*Pelecanus Occidentalis*	Coastal islands; shallow Gulf and bays	DL	E	E	Resident
Cagle's Map Turtle	*Graptemys caglei*	Guadalupe River System; short stretches of shallow water with swift to moderate flow and gravel or cobble bottom, connected by deeper pools with a slower flow rate and a silt or mud bottom		T		Resident
Coastal Gay-feather	*Liatris bracteata*	Black clay soils of midgrass grasslands on coastal prairie remnants			WL	Resident
Creeper (Squawfoot)	*Strophitus undulatus*	Small to large streams, prefers gravel or gravel and mud in flowing water; Colorado, Guadalupe, San Antonio, Neches (historic), and Trinity (historic) River basins				Resident
Elmendorf's Onion	*Allium elmendorfii*	Texas endemic; grassland openings in oak woodlands on deep, loose, well-drained sands				Resident
Eskimo Curlew	*Numenius borealis*	Coastal prairies	E	E	E	Migrant
False Spike Mussel	*Quadrula mitchelli*	Possibly extirpated in Texas; probably medium to large rivers; substrates varying		T		Resident
Golden Orb	*Quadrula aurea*	Sand and gravel in some locations and mud at others; intolerant of impoundment in most instances; Guadalupe, San Antonio, and Nueces River basins		T		Resident
Green Sea Turtle	*Chelonia mydas*	Gulf Coast	T	T	T	Resident
Gulf Saltmarsh Snake	*Nerodia clarkii*	Coastal waters			NL	Resident
Henslow's Sparrow	*Ammodramus henslowii*	Weedy fields or cut over areas; bare ground for running and walking			NL	Nesting/Migrant
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	Coastal dunes, Barrier islands and sandy areas			NL	Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Coastal waters; bays	E	E	E	Resident
Leatherback Sea Turtle	*Dermochelys coriacea*	Coastal and offshore waters	E	E	E	Resident
Lila de los llanos	*Echeandia chandleri*	among shrubs or in grassy openings in subtropical thorn shrublands Gulf Coast; also in a few upland coastal prairie remnants on clay soils				Resident

Table 4C.13-3 (Continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Agency USFWS[1]	TPWD[1]	TOES[2,3,4]	Potential Occurrence in County
Loggerhead Sea Turtle	*Caretta caretta*	Coastal waters; bays	T	T	T	Resident
Louisiana Black Bear	*Ursus americanus luteolus*	Possible as transient; bottomland hardwoods and large tracts of inaccessible forested areas	T	T		Transient
Manfreda Giant-skipper	*Stallingsia maculosus*	Skipper larvae usually feed inside a leaf shelter and pupate in a cocoon made of leaves fastened together with silk				Resident
Maritime Pocket Gopher	*Geomys personatus maritimus*	Fossorial, in deep sandy soils				Resident
Mexican Mud-Plantain	*Heteranthera mexicana*	Wet clayey soils of resacas and ephemeral wetlands in South Texas				Resident
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scrubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	E	Resident
Opossum Pipefish	*Microphis brachyurus*	Brooding adults found in fresh or low salinity waters and young move or are carried into more saline waters after birth; southern coastal areas		T		Resident
Pistolgrip	*Tritogonia verrucosa*	Stable substrate, rock, hard mud, silt, and soft bottoms, often buried deeply; east and central Texas				Resident
Plains Gumweed	*Grindelia oolepis*	Coastal prairies on heavy clay soils, often in depressional areas, sometimes persisting in areas where management maintains or mimics natural prairie disturbance regimes				Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas and tallgrass prairie.				Resident
Northern Aplamado Falcon	*Falco femoralis septentrionalis*	Open country, especially savannah and open woodland	E	E		Nesting/Migrant
Peregrine Falcon	*Falco peregrinus*	Open country, cliffs, occasionally cities[5]	NL	T	NL	Nesting/Migrant
Piping Plover	*Charadrius melodus*	Beaches, flats	T	T	T	Resident
Red Wolf (extirpated)	*Canis rufus*	Woods, prairies, river bottom forests	E	E	E	Resident
Reddish Egret	*Egretta rufescens*	Coastal islands for nesting; shallow areas for foraging		T	NL	Nesting/Migrant
Rock Pocketbook	*Arcidens confragosus*	Mud, sand, and gravel substrates of medium to large rivers in standing or slow flowing water, may tolerate moderate currents and some reservoirs				Resident
Sennet's Hooded Oriole	*Icterus cucullatus sennetti*	Often builds nests in Spanish moss.				Nesting
Sheep Frog	*Hypopachus variolosus*	Moist sites in arid areas.				
Shinner's Sunflower	*Helianthus occidentalis ssp plantagineus*	mostly in prairies on the Coastal Plain				Resident
Slender Rushpea	*Hoffmannseggia tenella*	Coastal prairie grasslands on level uplands and on gentle slopes along drainages, usually in areas of shorter or sparse vegetation	E	E		
Smalltooth Sawfish	*Pristis pectinata*	Different life history stages have different patterns of habitat use;	E	E		Resident
Snowy Plover	*Charadrius alexandrus*	Beaches, flats, streamsides			NL	Winter resident
Sooty Tern	*Sterna fuscata*	Coastal islands for nesting; deep Gulf for foraging		T	WL	Resident
Southeastern Snowy Plover	*Charadrius alexandrus tenuirostris*	Wintering migrant on Texas Gulf Coast beaches and bayside mud or salt flats				Migrant
Southern Yellow Bat	*Lasiurus ega*	Associated with trees which provide daytime roosts.		T		Migrant
South Texas Ambrosia	*Ambrosia cheiranthifolia*	Grasslands and mesquite-dominated shrublands on various soils ranging from heavy clays to lighter textured sandy loams	E	E		Resident

Table 4C.13-3 (Continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Agency			Potential Occurrence in County
			USFWS[1]	TPWD[1]	TOES[2,3,4]	
South Texas Siren (large form)	*Siren sp 1*	Wet or sometimes wet areas, such as arroyos, canals, ditches, or even shallow depressions		T		Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	Moderately open prairie-brushland; fairly flat areas free of vegetation or other obstructions, including disturbed areas				
Texas Asaphomyian Tabanid Fly	*Asaphomyia texanus*	Near slow moving water, wait in shady areas for host			WL	Resident
Texas Botteri's Sparrow	*Aimophila botterii texana*	Grassland and short-grass plains with scattered bushes or shrubs		T		Nesting
Texas Diamondback Terrapin	*Malaclemys terrapin litoralis*	Bays and coastal marshes			T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, grass, cactus, brush		T		Resident
Texas Indigo Snake	*Drymarchon melanurus erebennus*	Texas south of the Guadalupe River and Balcones Escarpment; thornbush-chaparral woodlands of south Texas		T		Resident
Texas Pimpleback	`*Quadrula petrina*	Mud, gravel and sand substrates, generally in areas with slow flow rates		T		Resident
Texas Pipefish	*Syngnathus affinis*	Corpus Christi Bay; seagrass beds				Resident
Texas Scarlett Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils		T		Resident
Texas Tortoise	*Gopherus berlandieri*	Open brush with a grass understory is preferred; open grass and bare ground are avoided		T		Resident
Texas Windmill-grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants, often on roadsides				Resident
Tharp's Rhododon	*Rhododon angulatus*	Deep, loose sands in sparsely vegetated areas on stabilized dunes of Pleistocene barrier islands				Resident
Threeflower Broomweed	*Thurovia triflora*	Texas endemic; near coast in sparse, low vegetation on a veneer of light colored silt or fine sand over saline clay				Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	swamps, floodplains, upland pine and deciduous woodlands, riparian zones, abandoned farmland; limestone bluffs, sandy soil or black clay; prefers dense ground cover, i.e. grapevines or palmetto		T		Resident
Welder machaeranthera	*Psilactis heterocarpa*	Texas endemic; grasslands , varying from midgrass coastal prairies, and open mesquite-huisache woodlands on nearly level, gray to dark gray clayey to silty soils				Resident
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna				Resident
Western Snowy Plover	*Charadrius alexandrinus nivosus*	Uncommon breeder in the Panhandle; potential migrant; winter along coast				Migrant
West Indian Manatee	*Trichechus manatus*	Gulf and bay system	E	E		Resident
White-faced Ibis	*Plegadis chihi*	Prefers freshwater marshes		T		Resident
White-nosed Coati	*Nasua narica*	Woodlands, riparian corridors and canyons; most individuals in Texas probably transients from Mexico		T		Transient
White-tailed Hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf coastal plain		T		Nesting/ Migrant
Whooping Crane	*Grus americana*	Potential migrant	LE	E		Migrant
Wood Stork	*Mycteria americana*	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T		Migrant

Table 4C.13-3 (Concluded)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Agency			Potential Occurrence in County
			USFWS[1]	TPWD[1]	TOES[2,3,4]	

[1] Texas Parks and Wildlife Department. County Data, July 2010.
[2] Texas Organization for Endangered Species (TOES). 1995. Endangered, threatened, and watch list of Texas vertebrates. TOES Publication 10. Austin, Texas. 22 pp.
[3] TOES. 1993. Endangered, threatened, and watch list of Texas plants. TOES Publication 9. Austin, Texas. 32 pp.
[4] TOES. 1988. Invertebrates of Special Concern. TOES Publication 7. Austin, Texas. 17 pp.
[5] Peterson, R.T. 1990. A Field Guide to Western Birds. Houghton Mifflin Company, Boston. pg. 86.

* E = Endangered
T = Threatened
C1 = Candidate Category, Substantial Information
C2 = Candidate Category
C3 = No Longer a Candidate for Protection
PE/PT = Proposed Endangered or Threatened
WL = Potentially endangered or threatened
Blank = Rare, but no regulatory listing status
NL = Not listed

Lavaca Bay resulting from Palmetto Bend Stage II operation are shown in Figure 4C.13-3. Both plots display the reduction in flows downstream of Palmetto Bend Stage II when operating in accordance with Consensus Criteria and simulating the TWDB seasonal demands. The top charts show the monthly median flows in the Lavaca River and Lavaca Bay downstream of Palmetto Bend Stage II with and without the project, while the bottom plot shows the reduction in combined Lavaca-Navidad River flows into Lavaca Bay, with Lake Texana in full operation, and with or without Palmetto Bend Stage II.[13] It is important to note that the Figure 4C.13-3 is consistent with how the reservoir was modeled in the 2006 Regional Water Plan. Although a different model was used to determine an updated yield for this plan, the downstream flows should be similar.

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[13] R.J. Brandes Company, "Analysis of Lavaca Bay Salinity Impacts of a Proposed Release Program from Lake Texana," Texas Parks and Wildlife Department, Austin, TX, November 1990.

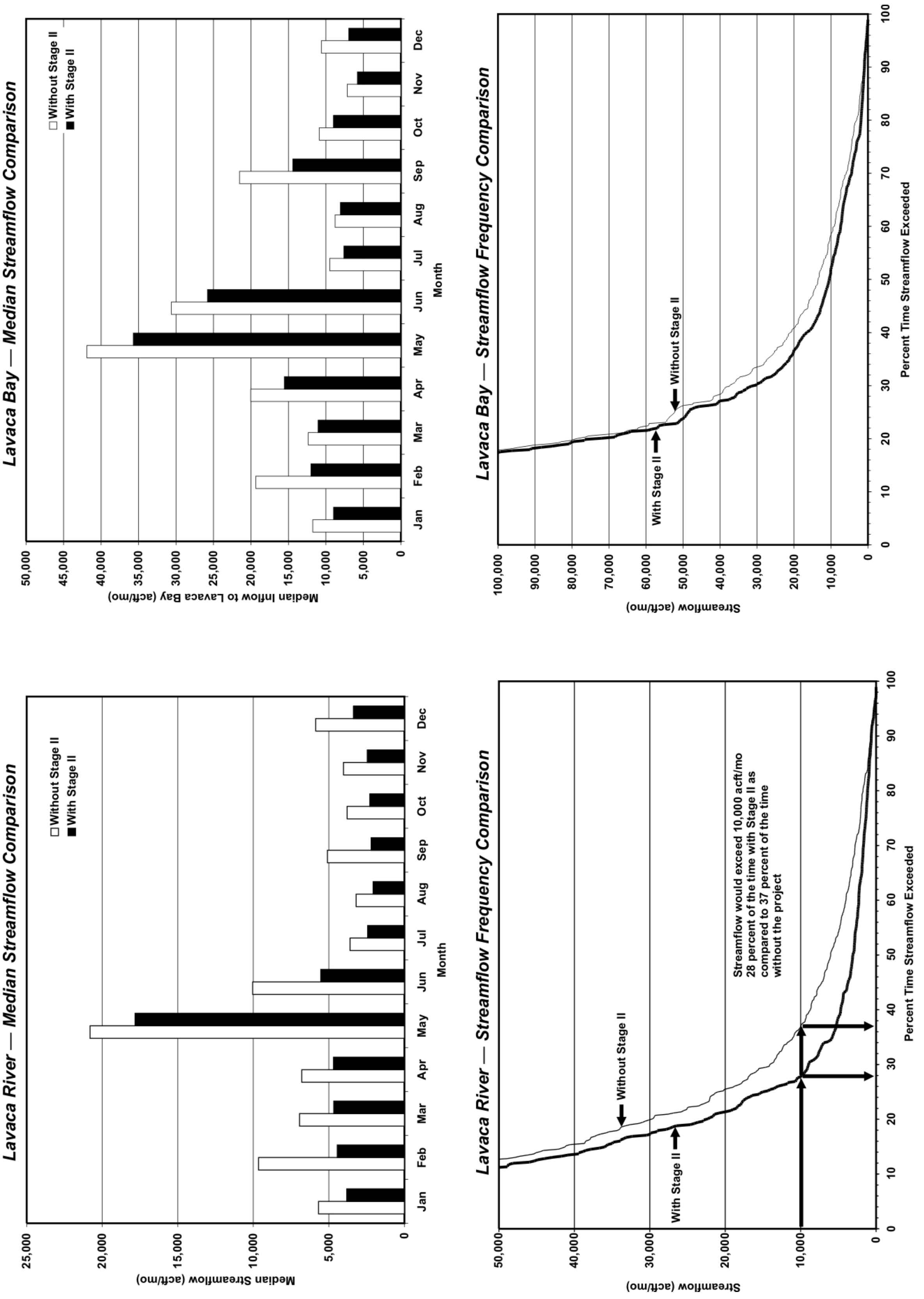

Figure 4C.13-3. Palmetto Bend - Stage II Streamflow Comparisons

Freshwater inflows play an important role in determining the distribution and abundance of estuarine populations. Most importantly, inflows interact with the tidal regime to produce a range of salinity gradients that generally exhibit more or less predictable seasonal patterns. Freshwater inflows may also be important in transporting sediments that play a role in maintaining tidal marsh elevations against subsidence and erosion, and nutrients that may support high levels of planktonic production and respiration.

The Lavaca River is tidally influenced at the proposed dam site; consequently, its biota is variable depending on its recent history of tidal stages and stream discharge, but is typically dominated by a brackish or salt-tolerant fauna. Following completion of the dam for Palmetto Bend Stage II, a continuous release requirement might prevent the development of adverse salinity and dissolved oxygen conditions below the dam that now accompany episodes of very low flow. Streamflows will tend to be more uniform over time than would be the case without the project, with most of the reduction occurring at flows above the median, while storage is taking place.

The characteristically large runoff events typical of this region have produced sufficient spills and releases from Lake Texana to maintain the Navidad River channel below the dam, and Palmetto Bend Stage II is expected to operate similarly. Migration will be blocked in the Lavaca River as it is in the Navidad River by Lake Texana, but strongly migratory species do not have any particular community importance in the present river-estuary system, and none are known that would be eradicated by construction of Palmetto Bend Stage II.

The slight decrease in estuarine inflows associated with implementation of Palmetto Bend Stage II (Figure 4C.13-3) would have no net adverse effect on Lavaca Bay or the larger Matagorda Estuarine System. Inflows from the Lavaca, Navidad, and Colorado Rivers, together with inflows from Tres Palacios and Garcitas Creeks and numerous, small local drainages are more than sufficient to maintain historic productivity levels with Palmetto Bend Stage II in place.[14]

In addition to the Palmetto Bend Stage II reservoir, this option includes diversion of water by pipeline to Lake Texana. The reservoir and pipeline route are in the Gulf Prairies vegetational area, the Western Gulf Coastal Plan ecoregion, and the Texan biotic province. Post oak savannah and tall grass prairies dominated by oaks, mesquites (*Prosopis glandulosa*),

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[14] LCRA, Op. Cit., December 1997.

acacias and prickly pears (*Opuntia spp.*) characterize the Gulf Prairies vegetational area. This vegetation is supported by acidic clays and clay loams interspersed by sandy loams.

Plant and animal species listed by TPWD, USFWS, and TOES that may be within the vicinity of the pipeline route or the reservoir are listed in Table 4C.13-3. The Texas Natural Heritage Program (NHP) maps two plants, the Threeflower Broomweed (*Thurovia triflora*) and Welder Machaeranthera (*Psilactis heterocarpa*), in the vicinity of the pipeline route. The Threeflower Broomweed is found in black clay soils of remnant coastal prairie grasslands, while the Welder Machaeranthera thrives in shrub-invaded grasslands in clay and silt soils. This proposed route is located near two rookeries, a wildlife management area, and an area where endangered Attwater's Greater Prairie Chickens have been sighted.

The pipeline route passes through or in the vicinity of Bald Eagle (in 1999, downgraded from endangered to threatened status) habitat. The NHP has mapped Bald Eagle habitat, which extends south from Lake Texana along the Lavaca and Navidad Rivers, and could be affected by the construction of Palmetto Bend Stage II Reservoir or the proposed pipeline to Lake Texana. Bald Eagles usually inhabit areas around large bodies of water with nearby resting sites.

Other protected species that were not mapped in the project area but that could have habitat in the vicinity of the reservoir or proposed pipeline, includes the Black Bear, Jaguarundi, Ocelot, and the Texas Tortoise. The animals depend on brushland and mesquite scrubland habitats in the coastal prairies. The Texas Tortoise occupies shallow depressions at the base of bushes and cacti and underground burrows. Another reptile, the Timber/Canebrake Rattlesnake is usually found in bottomland habitats that support hardwoods.

The White-tailed Hawk (*Buteo albicaudatus*), Interior Least Tern (S*terna antillarum athalassos*), and Eskimo Curlew (*Numensis borealis*) also inhabit the coastal prairies. The White-tailed Hawk can be found in open prairies and mesquite/oak savannah, while the Interior Least Tern inhabits barren to sparsely vegetated sandbars along river, lake, and reservoir shorelines. The Eskimo Curlew has historically migrated through the coastal prairies in March and April.

Implementation of this option is expected to require field surveys for protected species, vegetation, habitats, and cultural resources during right-of-way selection to avoid or minimize impacts. When potential protected species habitat or other significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use or eligibility for inclusion in the National Register for Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and vegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

4C.13.1.4 Engineering and Costing

Costs associated with constructing Palmetto Bend Stage II at the site 1.4 miles upstream of the original site are shown in Table 4C.13-4. In order to deliver Palmetto Bend Stage II water to Corpus Christi via the existing transmission facilities from Lake Texana to Corpus Christi, an intake pump station at the reservoir, a 4.5-mile transmission line, and an outlet structure would be necessary to transfer water to Lake Texana. The total project cost with the reservoir is $232,828,000. The annual debt service with the transmission facilities financed over 20 years at 6 percent interest and the reservoir costs financed at 6 percent over 40 years comes to $15,832,000. The annual costs for operations and maintenance and power are estimated at $4,545,000, which includes $2,610,000 of annual power costs incurred at the existing facilities for delivering the additional water. The total annual cost of constructing Palmetto Bend Stage II and delivering the firm yield to Corpus Christi is $20,377,000. Dividing annual cost by the Year 2060 firm yield of 22,964 equates to an annual cost of $887 per acft or $2.72 per 1,000 gallons (Table 4C.13-4).

The option to deliver the water to Corpus Christi has a low annual cost since there are existing facilities in place at Lake Texana that can be upgraded to deliver the Palmetto Bend Stage II raw water to Corpus Christi. It should be noted that the costs reported in this option only reflect the costs for Palmetto Bend Stage II and the delivery of raw water to Corpus Christi. Since the 2006 Plan, the annual cost of water increased by $324 per acft (from $563 to $887 per acft) due to adjusting cost index to September 2008 prices, increases in unit power costs, revision to non-reservoir financing to 20 years based on TWDB criteria, and increases in land costs.

4C.13.1.5 Implementation Issues

Implementation of Palmetto Bend Stage II with potential delivery of raw water to Corpus Christi (via Lake Texana) could directly affect the feasibility of other water supply options under consideration by the Coastal Bend Region. Since the alternative site of Palmetto Bend involves a different yield than that stated in Certificate of Adjudication #16-2095B, the certificate would

Table 4C.13-4.
Cost Estimate Summary for
Palmetto Bend Stage II Dam and Reservoir to Lake Texana
(September 2008 Prices)

Item	*To Lake Texana*
Capital Costs	
Dam and Reservoir (Conservation Pool: 57,676 acft; 4,679 acres; 44 ft-msl)	$71,354,000
Dam and Reservoir Conflicts	47,505,000
Intake and Pump Station (33 MGD; 858 HP)	3,630,000
Outlet Structure	197,000
Transmission Pipeline (54-inch 4.5-mile)	6,125,000
Improvements to Lake Texana System	2,315,000
Total Capital Cost	**$131,126,000**
Engineering, Legal Costs, and Contingencies	$45,588,000
Environmental & Archaeological Studies and Mitigation	14,725,000
Land Acquisition and Surveying (8,224 acres)	15,082,000
Interest During Construction (4 years)	26,307,000
Total Project Cost	**$232,828,000**
Annual Costs	
Debt Service for Transmission Facilities (6 percent for 20 years)	$1,504,000
Reservoir Debt Service (6 percent for 40 years)	14,328,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	152,000
Dam and Reservoir	1,783,000
Pumping Energy Costs (298,817 MWh @ $0.09 per kWh)	2,610,000
Total Annual Cost	**$20,377,000**
Available Project Yield (acft/yr)	**22,964**
Annual Cost of Water ($ per acft) Raw Water Delivered	**$887**
Annual Cost of Water ($ per 1,000 gallons) Raw Water Delivered	**$2.72**

need to be amended to reflect the yield at the proposed site and release requirements necessary for the bay and estuary system. An interbasin transfer permit from TCEQ will also be required to deliver Palmetto Bend Stage II water (in Region P) to Corpus Christi.

For the Coastal Bend Region, Palmetto Bend Stage II is recommended as an alternative water management strategy to meet projected Year 2060 shortages for City of Corpus Christi and SPMWD customers. Water supply from Palmetto Bend Stage II requires an interbasin transfer from the Lavaca Region (Region P) to the Coastal Bend Region. In accordance with Texas Water Code provisions, the projected shortage in the Lavaca Region is 67,740 acft/yr and is assigned to Jackson and Wharton County- Irrigation users.[15] The shortages are projected by Region P to be met by groundwater supplies. However, the LNRA has been approached by local industries requesting additional supplies of 10,000 acft/yr. Accordingly, the potential available supply from Palmetto Bend Stage II for Region N purposes is 12,964 acft/yr.

4C.13.1.5.1 Requirements Specific to Reservoirs

1. It will be necessary to obtain these permits:
   a. TCEQ Water Right and Storage permits, including interbasin transfer authorization.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   c. General Land Office Sand and Gravel Removal permits.
   d. General Land Office Easement for use of state-owned land.
   e. Coastal Coordination Council review.
   f. Texas Parks and Wildlife Department Sand, Gravel, and Marl permit.
2. Permitting, at a minimum, will require these studies:
   a. Assessment of effects on bays and estuaries.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the reservoir may include:
   a. Highways and railroads.
   b. Petroleum pipelines.
   c. Other utilities.
   d. Structures of historical significance and cemeteries.

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[15] Lavaca Regional Planning Group Draft Initially Prepared Plan, draft estimates provided January 2010.

4C.13.1.5.2 *Requirements Specific to Pipelines*

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. General Land Office Sand and Gravel Removal permits.
   c. Texas Parks and Wildlife Department Sand, Gravel and Marl permit for river crossings.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and railroads.
   b. Creeks and rivers.
   c. Other utilities.

4C.13.1.6 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Table 4C.13-5.

Table 4C.13-5.
Evaluation Summary of Palmetto Bend Stage II

Impact Category	***Comment(s)***
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Firm yield: 22,964 acft/yr. 2. Good reliability. 3. Raw water cost is $887 per acft. Assuming $326 per acft for treatment, treated water cost is $1,213 per acft.
b. Environmental factors 1. Instream flows 2. Bay and Estuary Inflows 3. Wildlife Habitat 4. Wetlands 5. Threatened and Endangered Species 6. Cultural Resources 7. Water Quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	 1. Reduces instream flows. Stage II releases in accordance with the Consensus Criteria were considered prior to determining yield. 2. Negligible impact to Lavaca Bay. 3. Construction of reservoir may have a negative impact on wildlife habitat. 4. None or low impact. 5. No federal or state protected species are known to be present within the reservoir area. 6. Cultural resources will need to be surveyed and mitigation for significant sites before this project is implemented. 7. Impacts to water quality will need to be evaluated prior to implementing project.
c. Impacts to State water resources	• No apparent negative impacts on other water resources • Potential benefit to river segment before dam due to increased low flows
d. Threats to agriculture and natural resources in region	• Purchase of reservoir land will result in reduced agricultural uses
e. Recreational impacts	• Increase in recreational use opportunities
f. Equitable comparison of strategies	• Standard analyses and methods used.
g. Interbasin transfers	• Requires transfer of water from Lavaca-Navidad River Basin to Nueces River Basin
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• Pipeline from Stage II to Lake Texana may impact wildlife habitat. Field surveys should be conducted to minimize impacts to protected species and vegetation.

4C.13.2 Lavaca River Diversion and Off-Channel Reservoir Project[16]

4C.13.2.1 Description of Strategy

The Lavaca River Diversion Off-Channel Reservoir Project (Lavaca River OCR) is currently being developed by the LNRA as a potential alternative configuration to the current recommended strategy for Palmetto Bend Stage II Reservoir. The Lavaca River Diversion project involves building a large off-channel reservoir approximately 10 miles west of Lake Texana. The reservoir is assumed to be square in order to minimize design and construction costs, with the exact sizing to be discussed in further detail below. The proposed Lavaca River OCR would be constructed in a manner allowing LNRA to divert high flows from the Lavaca-Navidad River to the reservoir, where it can then be pumped at a constant rate to end users of the water. This creates a mechanism to firm up what is an otherwise interruptible water source in order to serve area needs. The pump station and pipeline sizing will also be discussed further in the following text.

4C.13.2.2 Proposed Off-Channel Reservoir

The proposed location for the Lavaca River OCR is approximately 10 miles to the west of Lake Texana. Four alternative reservoir sizes were assessed as part of this study, including a 25,000 acft, 50,000 acft, 75,000 acft, and 100,000 acft storage reservoir. The process of determining the optimum size of the reservoir is discussed in further detail below. The location and orientation of the proposed Lavaca River OCR can be seen in Figure 4C.13-4. The Lavaca River OCR will be generally square in shape, have side slopes of 4:1, and will include provisions for hurricane protection as discussed below.

4C.13.2.2.1 Reservoir Wave Run-Up Protection

The freeboard[17] for the Lavaca River OCR was determined based upon the wave action from potential hurricanes. Categories 4 and 5 were reviewed, with these categories referring to maximum wind speeds of 145 and 179 mph, respectively. Because of the location and final configuration of the Lavaca River OCR, this situation would require freeboard levels of 10 feet

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[16] The text for this report was provided by the Lavaca-Navidad River Authority (LNRA) in “Lavaca River Diversion and Off-Channel Reservoir” provided on January 21, 2010.

[17] Freeboard is the height of the crest of a structure above conservation pool water level.

for a category 4 hurricane and 12 feet for a category 5 hurricane. For the estimate of probably cost, a category 4 hurricane was assumed.

4C.13.2.3 Proposed River Intake and Pump Station

The river intake pumping station, which will be located approximately 50 feet off of the east bank of the Lavaca River, will be required to pump a maximum of 309 cfs of water to the reservoir. This flowrate was determined while choosing the reservoir size, which is discussed further in Section 4C.13.2.5. Using this maximum flowrate, the optimal pipe size will be 66” in diameter. This was chosen because it is the largest diameter pipe that can be practically used while also reducing the yearly electricity costs to LNRA. The design of the pumping station for this intake will include a 50 ft wide by 85 ft long building that will house the pumps and electrical equipment.

4C.13.2.4 Proposed Raw Water Delivery System

The raw water delivery system will transport the water from the Lavaca River OCR using a pumping station located on the reservoir, and pump the raw water approximately 7 miles to the East Delivery System Pump Station. This water will be pumped at a rate of 6,200 gpm, which equates to 10,000 acft/yr. The pipeline transporting the water will be 42” in diameter.

This pipeline will be made of poly-coated steel and bar-wrapped concrete cylinder piping. The pipeline will also be required to cross back under the Lavaca River in order to connect to the existing delivery system located on Lake Texana. The pumping station will be housed in a building approximately 30 ft wide by 60 ft long, and will house the pumps and the electrical equipment.

4C.13.2.5 Available Yield

Firm yields were determined for the proposed off-channel reservoir by running the Lavaca River Basin Water Availability Model (WAM) with modifications to account for the proposed Lavaca River OCR. The firm yield estimates are based on the premises and assumptions reflected in the model. In addition to the four storage scenarios previously discussed (i.e., 25,000 acft, 50,000 acft, 75,000 acft, and 100,000 acft), five pump station diversion rates were modeled (i.e., 50 mgd, 100 mgd, 200 mgd, 500 mgd, and no limit) for a total of 20 simulations. The results of the analyses are presented in Table 4C.13-6.

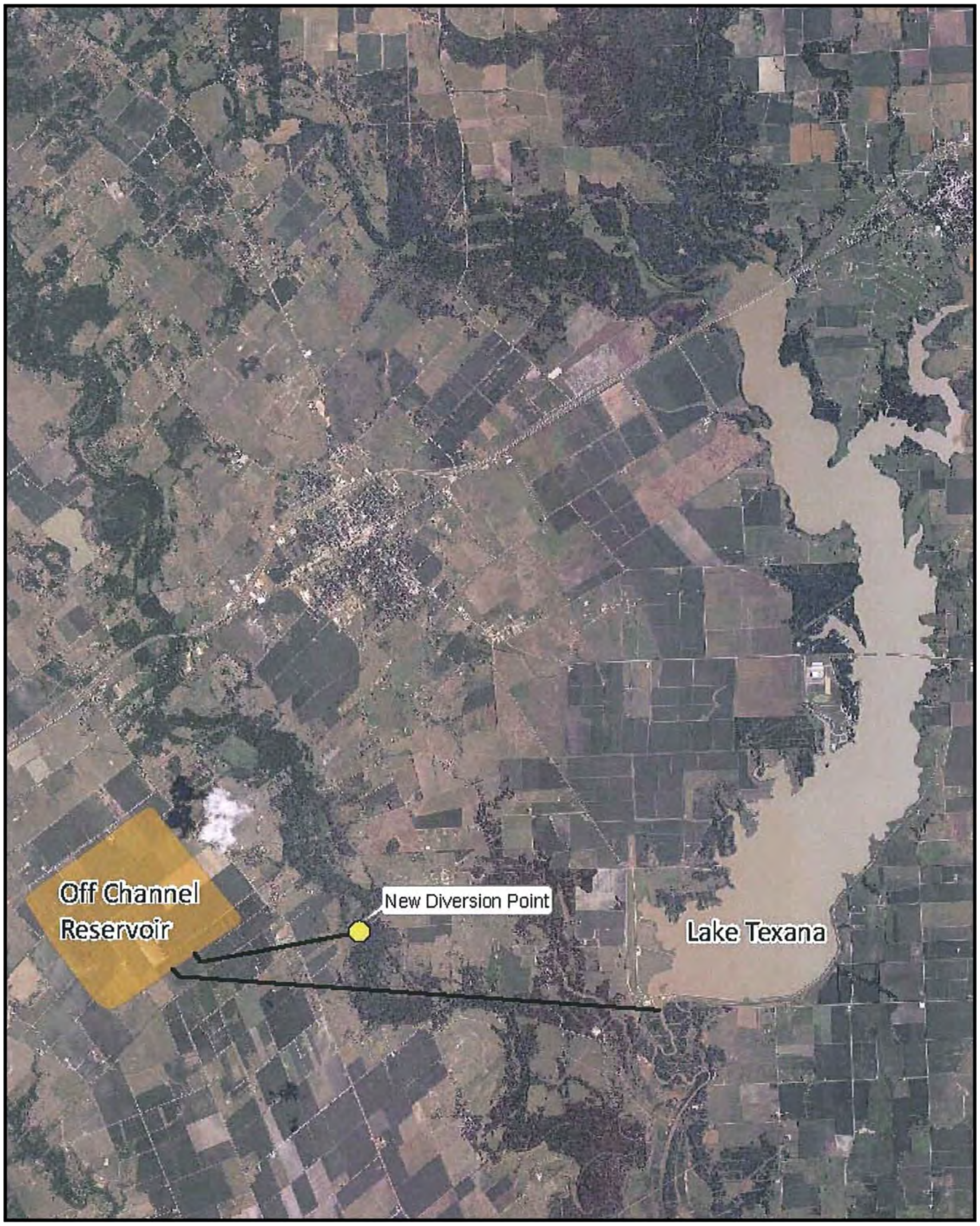

Figure 4C.13-4. Map of Proposed Off-Channel Reservoir

Table 4C.13-6.
Firm Yields for Different Storages and Pumping Rates

Storage (acft)	***Pumping Rate (mgd)***	***Firm Yield (acft/yr)***
25,000	0	0
	50	9,818
	100	13,050
	200	14,308
	500	14,308
	No limit	14,308
50,000	0	0
	50	11,222
	100	17,235
	200	20,510
	500	20,510
	No limit	20,510
75,000	0	0
	50	11,572
	100	18,154
	200	26,242
	500	26,483
	No limit	26,483
100,000	0	0
	50	11,076
	100	17,838
	200	26,632
	500	32,459
	No limit	32,459

The maximum theoretical firm yield considering instream flow requirements occurs when the pumping rate is not limited by the capacity of the pump. This situation is represented by the "no limit" simulations. Table 4C.13-6 shows that for a reservoir with a capacity of 25,000 acft, a pump capable of diverting 200 mgd is needed to maximize the firm yield. In other words, a pump with a larger capacity is unnecessary in this case. For a reservoir with a capacity of 50,000 acft, a pump capable of diverting 200 mgd is needed to maximize the firm yield. A pump capable of diverting just over 200 mgd is also necessary to maximize the firm yield of a reservoir with a capacity of 75,000 acft. For a reservoir with a capacity of 100,000 acft, a pump capable of diverting 500 mgd is needed to maximize the firm yield.

Table 4C.13-6 shows that as reservoir capacity increases by increments of 25,000 acft, maximum firm yield increased by around 6,000 acft/yr. The firm yield for a reservoir with a storage capacity of 100,000 acft and a pumping rate of 100 mgd is smaller than a reservoir of 75,000 acft with the same pumping rate. This is more likely due to greater evaporation rates from the reservoir with 100,000 acft of storage. Based on the results of the yield study, the optimum yield for the Lavaca River Diversion and Off-Channel Reservoir Project is approximately 26,242 acft when coupled with an off-channel reservoir of 75,000 acft and a 309 cfs diversion rate from the Lavaca River. This size reservoir is estimated to take up approximately 3,000 acres of land. While the 75,000 acft reservoir is the most optimal in terms of cost per acft of water, a different size may be chosen based upon the final decision of how much water is ultimately needed.

4C.13.2.6 Environmental Issues[18]

The Lavaca River Diversion and Off-Channel Reservoir project involves the building of an approximately 3,000 acre Lavaca River OCR approximately ten miles west of Lake Texana in Jackson County. The purpose of this reservoir is to store excess river water available during high flow events via an intake and pipeline from the Lavaca River. The stored water would then be transferred via a pipeline to Lake Texana to serve area needs and stabilize an otherwise interruptible water source. Facilities in this plan include the development a new pump station and diversion pipeline from the Lavaca River to the off-channel reservoir, a pump station associated with the OCR, a roughly 7 mile 48-inch diameter raw water pipeline from off-channel reservoir to Lake Texana, and an approximately 3,000 acre off-channel storage reservoir.

The proposed Lavaca River OCR and associated pipeline routes are situated within the Western Gulf Coastal Plain Ecoregion, in an area designated as the Northern Humid Gulf Costal Prairies.[19] Deltaic sands, silts, and clays underlie much of this area, which occurs on a gently sloping coastal plain. The original vegetation within this region included primarily grasslands with a few clusters of oaks (*Quercus* spp.) or maritime woodlands. Historically dominant grassland species include little bluestem (*Schizachyrium scoparium*), yellow Indiangrass (*Sorghastrum nutans*), brownseed paspalum (*Paspalum plicatulum*), gulf muhly (*Muhlenbergia*

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[18] A desktop environmental analysis was conducted by HDR Engineering to be consistent with RWPG guidelines.

[19] Griffith, G.E., Bryce, S.A., Omernik, J.M., Comstock, J.A., Rogers, A.C., Harrison, B., Hatch, S.L., and Bezanson, D., 2004, Ecoregions of Texas (color poster with map, descriptive text, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:2,3000,000).

capillaris), and switchgrass (*Panicum virgatum*). The majority of this region is now utilized as cropland, rangeland, pasture, or urban land, with woodlands occurring only as remnant riparian strips.[20] Construction of the off-channel reservoir is planned within an area normally used for agriculture; however the pipeline and pump station construction may include the clearing and removal of some areas of riparian vegetation along the Lavaca River and areas southwest of Lake Texana.

The project also lies within an area known as the Texan Biotic Province.[21] Mammals typical of this province include the Virginia opossum (*Didelphis virginiana*), fox squirrel (*Sciurus niger*), fulvous harvest mouse (*Reithrodontomys fulvescens*), and swamp rabbit (*Sylvilagus aquaticus*). Typical anuran species within this area include the Gulf Coast toad (*Bufo valliceps*), green treefrog (*Hyla cinerea*), bullfrog (*Rana catesbeiana),* and eastern narrowmouth toad (*Microhylla carolinensis*).

In addition, the Lavaca River locations where the new diversion pipeline to the Lavaca River OCR originates, and the area crossed by the raw water pipeline running from the Lavaca River OCR to Lake Texana, are listed by Texas Parks and Wildlife Department (TPWD) as occurring within an Ecologically Significant Stream Segment.

Table 4C.13-7 lists 18 state listed endangered and threatened wildlife and plant species, five federally listed endangered or threatened wildlife and plant species, and state and federal species of concern that may occur in Jackson County. Information found within this table originates from the county lists of rare species provided by the Texas Parks and TPWD online in the "Annotated County Lists of Rare Species."

Inclusion in Table 4C.13-7 does not mean that a species will occur within the project area, but only acknowledges the potential of its occurrence in Jackson County. In addition to the county lists, the TPWD Natural Diversity Database (NDD) was reviewed for known occurrences of listed species within or near the project area.

Listed species may have habitat requirements or preferences that suggest they could be present within the project area. The presence or absence of potential habitat does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report. Surveys for protected species should be conducted within the proposed construction corridors where preliminary evidence indicates their existence.

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[20] Gould, F. W., "The Grasses of Texas," Texas A&M University Press, College Station, Texas, 1975.
[21] Blair, W. Frank, "The Biotic Provinces of Texas," Texas Journal of Science 2(1):93-117, 1950.

Table 4C.13-7.
Endangered, Threatened, and Species of Concern for Jackson County

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Listing Entity***		***Potential Occurrence in County***
			USFWS	***TPWD***	
American eel	*Anguilla rostrata*	Coastal waterways below reservoirs to gulf.			Resident
American Peregrine Falcon	*Falco peregrinus anatum*	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	Migrant throughout the state.	DL		Possible Migrant
Bald eagle	*Haliaeetus leucoephalus*	Found primarily near rivers and large lakes.	DL	T	Possible Migrant
Brown pelican	*Pelecanus occidentalis*	*Largely coastal and near shore areas.*	DL	E	Resident
Green sea turtle	*Chelonia mydas*	Gulf and bay systems.	LT	T	Resident
Gulf saltmarsh snake	*Nerodia clarkia*	Found on saline flats.			Resident
Henslow's Sparrow	*Ammodramus henslowii*	Found in weedy fields or cut-over areas			Resident
Interior least tern	*Sterna antillarum athalassos*	Nests along sand and gravel bars in braided streams	LE	E	Resident
Kemp's Ridley sea turtle	*Lepidochelys kempii*	Found in gulf and bay systems.	LE	E	Resident
Loggerhead sea turtle	*Caretta caretta*	Gulf and bay systems for juveniles, ocean for adults.	LT	T	Resident
Mountain Plover	*Charadrius montanus*	Non-breeding, shortgrass plains and fields			Nesting/ Migrant
Reddish Egret	*Egretta rufescens*	Resident of Texas Gulf coast.		T	Resident
Rock pocketbook	*Arcidens confragosus*	Mud and sand, Red through Guadalupe River basins.			Resident
Shinner's sunflower	*Helianthus occidentalis ssp. Plantagineus*	Found on prairies on the Coastal Plain			Resident
Snowy Plover	*Charadrius alexandrines*	Potential migrant, winters along coast			Migrant
Sooty Tern	*Sterna fuscata*	Usually flies or hovers over water.		T	Resident
Southeastern Snowy Plover	*Charadrius alexandrines tenuirostris*	Wintering migrant along the Texas Gulf Coast.			Migrant
Texas diamondback terrapin	*Malaclemys terrapin littoralis*	Found in coastal marshes and tidal flats.			Resident
Texas fatmucket	*Lampsilis bracteata*	Streams and rivers on sand, mud and gravel, Colorado and Guadalupe River basins.		T	Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands.		T	Resident
Texas scarlet snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils.		T	Resident
Texas tortoise	*Gopherus berlandieri*	Open brush w/ grass understory.		T	Resident
Threeflower broomweed	*Thurovia triflora*	Endemic: near coast.			Resident
Timber/Canebrake rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones.		T	Resident
Welder machaeranthera	*Psilactis heterocarpa*	Texas endemic found on grasslands.			Resident
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna			Resident
White-faced Ibis	*Plegadis chihi*	Prefers freshwater marshes.		T	Resident

Table 4C.13-7 (Concluded)

Common Name	**Scientific Name**	**Summary of Habitat Preference**	***Listing Entity*** ***USFWS***	 ***TPWD***	***Potential Occurrence in County***
White-tailed hawk	*Buteo albicaudatus*	Found near the coast on prairies, cordgrass flats, and scrub-live oak.		T	Resident
Whooping Crane	*Grus americana*	Potential migrant	LE	E	Potential Migrant
Wood Stork	*Mycteria americana*	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	Migrant

LE/LT=Federally Listed Endangered/Threatened

DL, PDL=Federally Delisted/Proposed for Delisting

E, T=State Listed Endangered/Threatened

Blank = Considered rare, but no regulatory listing status

Source: TPWD, Annotated County List of Rare Species, Jackson County (1/15/2010).

The Migratory Bird Treaty Act protects most bird species, including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds. Migratory bird pathways, stopover habitats, wintering areas, and breeding areas may occur within and adjacent to the project area, and may be associated with wetlands, ponds, shorelines, riparian corridors, fallow fields and grasslands areas. Although construction of the proposed off-channel reservoir could remove some habitats utilized by certain migratory bird species, it would create additional habitats for others.

Three bird species federally or state listed as endangered are included in the project area county. These include the brown pelican (*Pelecanus occidentalis*), interior least tern (*Sterna antillarum athalassos*), and whooping crane (*Grus americana*). The brown pelican, a consistent coastal resident, is listed as endangered by the State, but has recently been delisted by the United States Fish and Wildlife Service. The interior least tern and whooping crane are seasonal migrants which could pass through the project area. The interior least tern typically nests on bare or sparsely vegetated areas associated with streams or lakes, such as sand and gravel bars, beaches, islands, and salt flats. The main whooping crane flock nests in Canada and migrates annually to their wintering grounds in and around the Aransas National Wildlife Refuge near Rockport on the Texas coast. Whooping cranes occasionally utilize wetlands as an incidental rest stop during this migration.

Avian species listed by the State of Texas as threatened include the peregrine falcon (*Falco peregrinus*), bald eagle (*Haliaeetus leucocephalus*), reddish egret (*Egretta rufescens*), sooty tern (*Sterna fuscata*), white-faced ibis (*Plegadis chihi*), white-tailed hawk (*Buteo albicaudatus*), and wood stork (*Mycteria Americana*). Resident bird species include the reddish egret, sooty tern and white-faced ibis. The peregrine falcon, bald eagle, snowy plover, southeastern snowy plover, and wood stork are migratory species expected to occur infrequently within the project area. The peregrine falcon includes two subspecies which migrate across the state from more northern breeding areas in the U.S. and Canada to winter along the coast. The majority of nesting bald eagle pairs currently reported are found along major rivers and near reservoirs in Texas. Bald eagles are opportunistic predators, feeding primarily on fish captured in the shallow water of both lakes and streams or scavenged food sources. These birds may utilize tall trees near perennial water as roosting or nesting sites. Bald eagles are documented by the NDD in areas above and below Lake Texana.

Many of the listed species found within the project area, such as the Texas Tortoise (*Gopherus berlandieri*), Texas scarlet snake (*Cemophora coccinea lineri*), timber/canebrake rattlesnake (*Crotalus horridus*), and the Texas Horned Lizard (*Phrynosoma cornutum*), are dependent on shrubland or riparian habitats which should be avoided wherever possible. The NDD indicates that the Texas diamondback terrapin (*Malaclemys terrapin littoralis)* has been documented near the mouth of the Lavaca-Navidad River where it empties into the Gulf of Mexico. This reptilian species of concern prefers a habitat which consists of coastal marshes and tidal flats.

Destruction of potential habitats has been minimized by the selection of a Lavaca River OCR project area which lies within previously disturbed areas of cropland. Care should be taken to ensure minimum impacts from construction to the existing riparian and wetland areas located along the Lavaca River and below Lake Texana. It is not anticipated that this project will have any permanent adverse effect on any state or federally listed threatened or endangered species, its habitat, or designated habitat.

Habitat studies and surveys for protected species and cultural resources may need to be conducted at the proposed off channel site, and along the pipeline routes. Specific project features, such as pipelines, and off-channel reservoirs generally have sufficient design flexibility to avoid most impacts or significantly mitigate potential impacts to geographically limited environmental and cultural resource sites. Field surveys conducted at the appropriate phase of development should be employed to minimize the impacts of construction and operation on sensitive resources.

Potential wetland impacts are expected to primarily include the raw water pipeline river crossing and wetland areas found south of Lake Texana. These impacts can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

A review of the Texas Historical Commission Texas Historic Sites Atlas database indicated that there are two historical markers within one mile of the proposed pipeline route. There are no National Register Properties listed within one mile of the proposed pipeline route, however this database indicates that there are two small cemeteries recorded within one mile of the proposed pipeline. Avoidance of these areas should be possible through appropriate siting of the project pipelines.

4C.13.2.7 Engineering and Costing[22]

The major facilities included in this project are:

- Off-Channel storage reservoir with a river intake and pump station;
- Transmission pipeline from the river intake to the Lavaca River OCR and;
- Intake, pump station, and transmission pipeline from the Lavaca River OCR to Lake Texana.

A study completed by LNRA provided costs of the Lavaca River Diversion and Off-Channel Reservoir Project in November 2009 dollars. The costs were then prorated to reflect September 2008 Prices. The estimated capital cost for building the facilities identified above is $154,187,000 as shown in Table 4C.13-8. The off-channel storage reservoir is estimated to cost $124,059,000. After land acquisition costs and cost for engineering, legal, environmental mitigation, and interest during construction, the total project cost is estimated at $224,183,000.

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[22] This section was updated and added by HDR Engineering.

Table 4C.13-8.
Cost Estimate Summary for Lavaca River Diversion and Off-Channel Reservoir (September 2008 Prices)

Item	*To Lake Texana*
Capital Costs	
Off-Channel Storage	$124,059,000
River Intake and Pump Station	9,470,000
River Intake Transmission Pipeline to Lavaca River OCR	2,760,000
Lavaca River OCR Intake and Pump Station	5,494,000
Lavaca River OCR Transmission Pipeline to Lake Texana	12,404,000
Total Capital Cost	**$154,187,000**
Engineering, Legal Costs, and Contingencies	$52,729,000
Environmental & Archaeological Studies and Mitigation	1,023,000
Land Acquisition and Surveying	1,117,000
Lavaca River OCR Interest During Construction (2 years)	13,528,000
Non-OCR Interest During Construction (1 year)	1,599,000
Total Project Cost	**224,183,000**
Annual Costs	
Non-OCR Debt Service (6 percent for 20 years)	$3,623,000
Lavaca River OCR Debt Service (6 percent for 40 years)	12,138,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	510,000
Dam and Lavaca River OCR	1,861,000
River Intake Pumping Energy Costs (1,077,307 kW-hr @ 0.09 per kWh)	97,000
Lavaca River OCR Intake Pumping Energy Costs (1,752,876 kW-hr @ 0.09 per kWh)	158,000
Total Annual Cost	**$18,387,000**
Available Project Yield (acft/yr)	**26,242**
Annual Cost of Water ($ per acft) Raw Water Delivered	**$701**
Annual Cost of Water ($ per 1,000 gallons) Raw Water Delivered	**$2.15**

The debt service at 6 percent over 20 years for non-OCR facilities and at 6 percent for 40 years for the Lavaca River OCR[23], and the annual operations and maintenance costs, including energy, result in a total annual cost of $18,387,000. Dividing by 26,242 acft/yr equates to an annual raw water cost of $701 per acft. Assuming treatment costs of $326 per acft, the treated water cost is $1,027 per acft. The values presented in Table 4C.13-8 are slightly different than what was provided in the study completed by LNRA. This is primarily due to differences in assumptions used for contingency costs and other non-capital costs.

4C.13.2.8 Potential Water Use

The development of the Lavaca River OCR will result in approximately 26,242 acft of water. There is currently an existing industrial need of approximately 10,000 acft for an existing industrial customer of LNRA in Calhoun County, leaving 16,242 acft of water supply for contract and/or project participation by other interested parties. It is currently expected that this excess water will be used for municipal and agricultural uses to meet future needs in Region P (Jackson County), Region L, or Region N.

4C.13.2.9 Local Issues and Concerns

The development of the Lavaca River OCR would result in an increased water supply of approximately 26,242 acft for the area. However, 10,000 acft of this supply is being developed for an industrial entity located in Calhoun County, with the remaining 16,242 acft available for contract by other interested parties. While Jackson County has a relatively large demand for agricultural water, demand in Jackson County for municipal and/or industrial water supply is low. In addition, the Lavaca River OCR would result in a unit cost of water far in excess of what agricultural interests could afford. Therefore, it is very likely that the water supply created by the construction of the Lavaca River OCR would benefit other regions outside of Jackson County. The construction of the Lavaca River OCR is expected to inundate approximately 3,000 acres of land at 75,000 acft of storage capacity, therefore impacting landowners in Jackson County.

While potential property impacts from this option are less than those expected for Palmetto Bend Stage II Reservoir, this option is also likely to result in at least some local

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[23] For this round of regional water planning, non-reservoir infrastructure improvements include debt service for 20 years. Costs for reservoirs include 40 years of debt service.

resistance. The transport of a local resource (i.e., local surface water) for the economic benefit of other regions is an issue of significant importance to many people. It is expected that concessions, economic or otherwise, would be required by the ultimate end users and benefactors of the project, to enhance the acceptance of this project by the local community.

4C.13.2.10 Water Rights Permit Modifications

Under Certificates of Adjudication No. 16-2095, 16-2095A, 16-2095B, 16-2095C, and 16-2095D, LNRA is authorized to impound and divert water in the Lavaca and Navidad River basins for municipal, industrial, and recreational uses. These permits allow the use of water from two separate reservoirs, one on the Navidad River (existing Lake Texana and Palmetto Bend Dam) and one on the Lavaca River (proposed Stage II).

LNRA is authorized to impound up to 170,300 acft of water in Lake Texana on the Navidad River and an additional 93,340 acft in the proposed Stage II reservoir on the Lavaca River. LNRA is authorized to divert and use up to 79,000 acft from Lake Texana for municipal and industrial uses and an additional 36,000 acft (not including bay and estuary maintenance flows) from Stage II reservoir for municipal and industrial uses. Diversions are currently limited by location to two points on Lake Texana (East and West Delivery System Pump Stations) and by rate to up to 330 cfs total from Lake Texana. The impoundment and diversions of water each have a priority date of May 15, 1972.

In addition to the permit limitations specified above, the impoundment and diversion of water from Lake Texana is further subject to a bay and estuary release schedule. Inflows into Lake Texana are subject to release from Lake Texana as a function of both reservoir capacity and season. The existing permits further specify that prior to commencement of construction of Palmetto Bend Stage II reservoir, or any diversion of water from Stage II reservoir, upon the joint recommendation of LNRA, TWDB, and Texas Parks and Wildlife Department (TPWD), LNRA shall submit an application to the TCEQ to establish a schedule for the release of freshwater inflows from Stage II reservoir. In establishing the Stage II release schedule, the TCEQ may consider the modification to the Lake Texana release schedule. LNRA shall retain the right to withdraw its application at any time prior to any final decision by the TCEQ and upon withdrawal, the Lake Texana release schedule shall remain unchanged.

The existing water rights permits for Lake Texana and Stage II reservoirs would need to be modified to incorporate changes associated with the proposed Lavaca River Off-Channel

Reservoir project. These modifications may include an additional diversion point on the Lavaca River, the impoundment of water in an off-channel reservoir as opposed to the currently permitted on-channel Stage II reservoir, likely changes in the amounts and distribution currently permitted for industrial and municipal uses, potential addition of agricultural use, and a proposed bay and estuary (i.e., pass through) schedule for the proposed Lavaca River Off-Channel Reservoir project.

It should be noted that these changes in conditions to the existing permit would likely require a major permit modification and require public notification. In addition, it should also be noted that any of these permit modifications, and specifically the required bay and estuary release schedule, could potentially reduce the project yield from the existing Lake Texana and/or the proposed Lavaca River Off-Channel Reservoir project.

4C.13.2.11 Impact of the Lavaca River Off-Channel Reservoir Project to the Yield of Palmetto Bend Stage II Reservoir

Table 4C.13-9 provides the impact and reduction in projected firm yield of the Stage II reservoir as a result of implementing the proposed Lavaca River Off-Channel Reservoir project. Based on the results of this analysis and depending on the storage capacity and diversion rate for the Lavaca River Off-Channel Reservoir project, the firm yield of Stage II is reduced from between 38% and 78% of its original amount. The optimum configuration specified as a result of this study for the Lavaca River Off-Channel Reservoir project of 75,000 acft and a 200 mgd diversion rate, results in a reduction in the firm yield of Stage II of 42%.

This reduction in yield of Stage II due to implementation of the proposed Lavaca River Off-Channel Reservoir project will likely result in any future consideration of Stage II not feasible. The reduction in yield for Stage II would further increase the unit cost of the project and likely make it no longer economically viable compared to other alternatives. Therefore, it is likely that the implementation of the proposed Lavaca River Off-Channel Reservoir would negate the future construction of Stage II. Based on this, the assessment of Stage II and the proposed Lavaca River Off-Channel Reservoir should probably be evaluated as an either/or condition, with the potential for implementing both projects very remote.

Table 4C.13-9.
Firm Yields for Lavaca River OCR and Palmetto Bend Stage II Reservoir for Different Storages and Pumping Rates

Storage (acft)	Pumping Rate (mgd)	Firm Yield (acft/yr)	Firm Yield Stage II (acft/yr)	Stage II Yield (% Reduction due to OCR)
25,000	0	0	18,529	0
	50	9,818	11,566	38
	100	13,050	10,664	42
	200	14,308	10,664	42
	500	14,308	10,664	42
	No limit	14,308	10,664	42
50,000	0	0	18,529	0
	50	11,222	10,995	41
	100	17,235	10,664	42
	200	20,510	10,664	42
	500	20,510	9,608	48
	No limit	20,510	9,608	48
75,000	0	0	18,529	0
	50	11,572	10,995	41
	100	18,154	10,664	42
	200	26,242	10,664	42
	500	26,483	7,698	58
	No limit	26,483	7,698	58
100,000	0	0	18,529	0
	50	11,076	10,995	41
	100	17,838	10,664	42
	200	26,632	10,664	42
	500	32,459	3,936	79
	No limit	32,459	4,166	78

4C.13.2.12 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Table 4C.13-10.

Table 4C.13-10.
Evaluation Summary of Lavaca River Diversion and Off-Channel Reservoir Project

Impact Category	***Comment(s)***
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	1. Firm yield: 26,242 acft/yr. 2. Good reliability. 3. Raw water cost is $701 per acft. Assuming $326 per acft for treatment, treated water cost is $1,027 per acft.
b. Environmental factors 1. Instream flows 2. Bay and Estuary Inflows 3. Wildlife Habitat 4. Wetlands 5. Threatened and Endangered Species 6. Cultural Resources 7. Water Quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	1. Possibly reduces instream flows. Project crosses area TPWD has designated as an ecologically significant stream segment. 2. Negligible impact to Lavaca Bay. 3. Construction of OCR and pipelines may have a negative impact on wildlife habitat. 4. None or low impact. 5. No federal or state protected species are known to be present within the OCR area. 6. Cultural resources will need to be surveyed and mitigation for significant sites before this project is implemented. 7. Impacts to water quality will need to be evaluated prior to implementing project.
c. Impacts to State water resources	• No apparent negative impacts on other water resources • Implementation of project will make the construction of Stage II infeasible
d. Threats to agriculture and natural resources in region	• Purchase of reservoir land will result in reduced agricultural uses
e. Recreational impacts	• Increase in recreational use opportunities
f. Equitable comparison of strategies	• Standard analyses and methods used.
g. Interbasin transfers	• Requires transfer of water from Lavaca-Navidad River Basin to Nueces River Basin
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• Pipeline from OCR to Lake Texana may impact wildlife habitat. Field surveys should be conducted to minimize impacts to protected species and vegetation.

4C.14 Garwood Pipeline (Colorado River Basin) and Other Interbasin Transfers (N-14)

4C.14.1 Description of Strategy

Interbasin transfer of water is a part of the Coastal Bend Region's water supply. In 1998, the Mary Rhodes Memorial Pipeline was completed and began to deliver 41,840 acft/yr from Lake Texana in the Lavaca-Navidad River Basin to the City of Corpus Christi (City) in the Nueces River Basin. On July 24, 2001, a contract for an additional 12,000 acft of interruptible water was approved between the City and the Lavaca-Navidad River Authority (LNRA). The transmission facilities were designed with the anticipation that additional surface water owned or purchased by the City outside the Nueces Basin would be pumped to the Coastal Bend Region via the LNRA's West Water Delivery System and the City's Mary Rhodes Memorial Pipeline (MRP).

In September 1992, the City entered into an option agreement for the potential purchase of up to 35,000 acft/yr from the Garwood Irrigation Company. The Garwood Irrigation Company (Garwood) held the most significant senior water right in the Lower Colorado River Basin, with a priority date of November 1, 1900. This water right authorized the diversion of 168,000 acft/yr from the Colorado River at a maximum rate of 750 cfs, or 1,488 acft per day. Most of Garwood's service area lies outside the Colorado River Basin, and a large part of its right is used for irrigation of land that is located in the Lavaca-Navidad River Basin. In 1993, TCEQ authorized an amendment to Garwood's water right that allows for the use of 35,000 acft of its right to be used for municipal and industrial purposes. On October 7, 1998, TCEQ approved the City's purchase of the 35,000 acft/yr from the Garwood Irrigation Company, herein referred to as the Garwood Purchase.[1] The amendment of the certificate of adjudication authorizes the City to divert 35,000 acft/yr from the Colorado River for irrigation, municipal and industrial purpose at a rate not to exceed 150 cfs. The certificate also subordinates the 35,000 acft/yr to the remaining portion of the original Garwood Irrigation water right by giving it a priority of November 2, 1900.

A cooperative water supply between the Coastal Bend Region and the South Central Texas Region would also involve interbasin transfers. Options for the South Central Texas

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[1] Texas Natural Resource Conservation Commission, Amended Certificate of Adjudication No. 14-5434B, Garwood Irrigation Company, October 7, 1998.

Region of potential interest to the Coastal Bend Region that may involve transfer of water across basin boundaries are described below:[2]

- Sharing transmission facilities for the Lower Colorado River Authority (LCRA)-San Antonio Water System (SAWS) Water Project with the City's Garwood Project. Assuming integrated concurrent or phased development of these two projects is feasible, shared facilities could include an intake pump station and a 90' inch 37-mile segment of the transmission pipeline from Matagorda County to the pump station at Lake Texana.
- Sharing transmission facilities for the LCRA-SAWS Water Project, Lower Guadalupe Water Supply Project (LGWSP), and City's Garwood Project. Assuming integrated concurrent or phased development of these two projects is feasible, shared facilities could include an intake pump station and a 90' inch 37-mile segment of the transmission pipeline from Matagorda County to the pump station at Lake Texana.

These two options involve enhancing the CCR/LCC/Lake Texana System yield in the Coastal Bend Region through imports from the Garwood Pipeline project, with potential opportunities for cost savings by sharing capital and operating costs with interests in the South Central Texas Region. Figure 4C.14-1 is a map with proposed interregional project locations.

The TCEQ permit for use of the Garwood water prevents the water purchased by the City from entering Lake Texana. This requirement requires routing the pipeline and transmission facilities around Lake Texana and joining the pipeline from the Colorado River to the MRP. The Colorado River diversion site is located at an existing diversion dam near Bay City, and a new pipeline (hereinafter referred to as the Garwood Pipeline) is needed to deliver the water to the MRP at a point just downstream of Lake Texana for transmission to Corpus Christi.

In November 2004, the City's Phase 1 study[3] evaluated delivery options for the Garwood water including: (1) intake pump station locations along the Colorado River or existing irrigation canals; (2) delivery methods of operating including peak pumping from the Colorado River, the use of off-channel storage, or constant pumping from the river; and (3) partnership scenarios allowing combined facilities with other water providers. Three options were recommended for additional study to include combined facilities with LCRA/SAWS (Option 1), Garwood Town Canal to West Mustang Creek (Option 5), and Gulf Coast Furbor Canal to MRP (Option 6).

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[2] HDR Engineering, Inc. (HDR), et al., "South Central Texas Regional Water Planning Area Initially Prepared Regional Water Plan, Volume III – Technical Evaluations of Water Supply Options," San Antonio River Authority, et al., June 2005.

[3] Freese and Nichols, Garwood Water Project – Phase 1 Report: Pipeline Route Screening Report, November 2004.

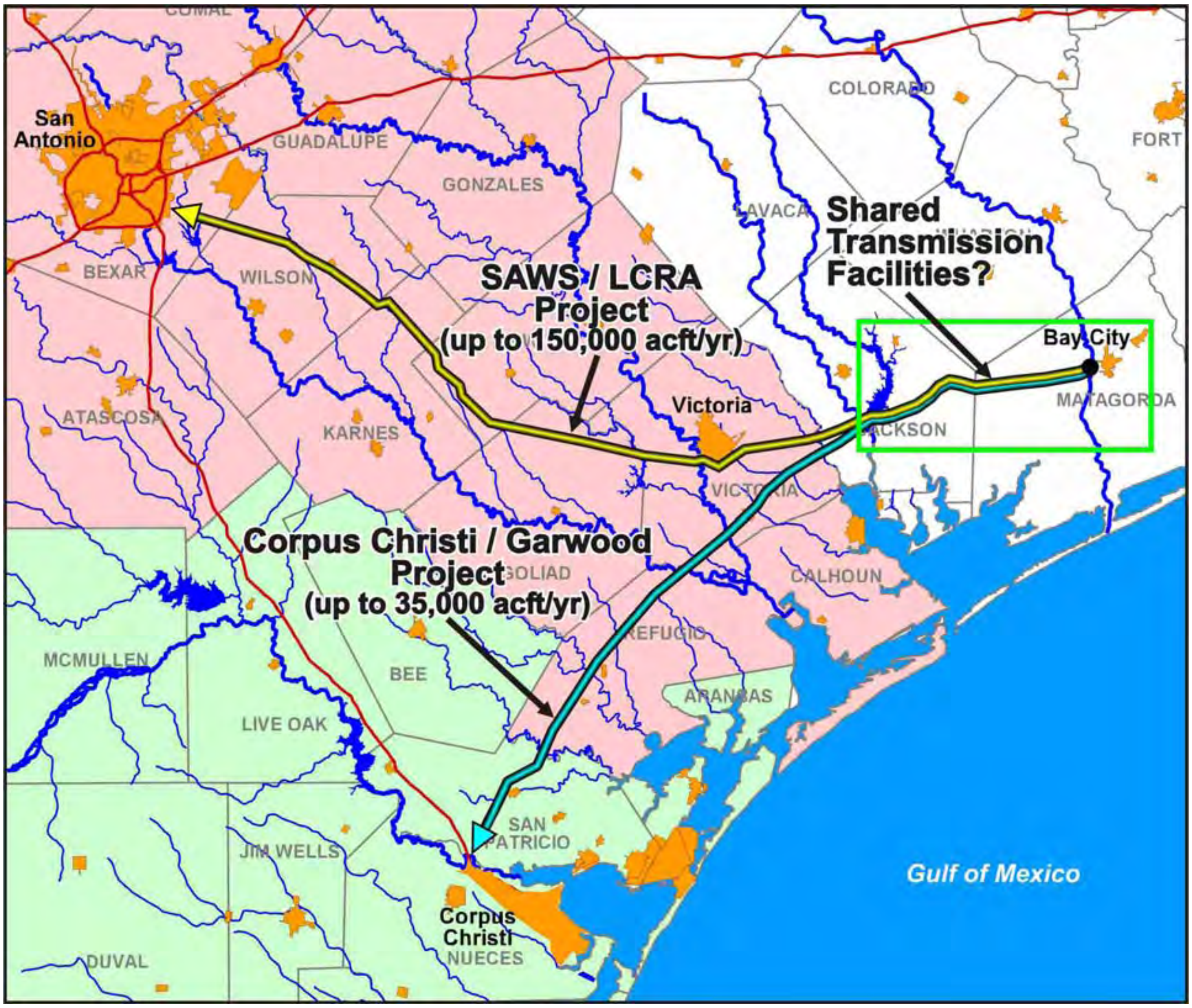

Figure 4C.14-1. Interregional Map of Conceptual Garwood Projects

The option previously included in the 2006 Regional Water Plan for delivery of water through the Garwood Town Canal to West Mustang Creek is no longer under consideration by the City. Prior to removing the West Mustang Creek delivery option, Region P conducted a study as part of their 2011 Plan of the impacts of Garwood Project supplies on surface water resources in the Lavaca-Navidad River Basin with delivery through West Mustang Creek.[4] The Region P plan indicates that the West Mustang Creek delivery option is no longer under consideration.

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[4] Results of Region P's West Mustang Creek delivery analysis is included in Appendix 4D of the Region P Initially Prepared Plan, March 2010.

In June 2009, the City of Corpus Christi Pipeline Route Study Report[5] (Pipeline Route Report) included an evaluation of multiple delivery options for Garwood supplies. Two primary corridors between the Colorado River and LNRA's West Water Delivery System were evaluated. Pipeline Option 1 has two pipeline options (1A and 1B) for the first 4 miles of pipeline closest to the Colorado River originating at two pump station intake locations (Pump Station Options 1 and 2) and then becomes the same pipeline route to the West Water Delivery System. Pump Station Option 2 is located about 2 ½ river miles downstream of Pump Station Option 1 and closer to the existing Bay City Channel Dam. Pipeline Option 2 is about 5 miles to the south and roughly parallels Pipeline Option 1 before heading north along County Road 420 near Lake Texana. Pump Station Option 2 as previously mentioned is also considered for Pipeline Option 2. Alternately, an existing LCRA intake pump station (Pump Station Option 3) is considered for Pipeline Option 2. Figures 4C.14-2 and 4C.14-3 show proposed pipeline options and intake pump station locations. Based on the routing study, it was determined that both primary corridors are acceptable options for the proposed pipeline. It was further recommended that environmental analyses are conducted for both corridors as necessary for permitting.

This report has been updated based on the City's 2009 Pipeline Route Report.[6]

4C.14.1.1 Pipeline Routes (Option 1A, 1B, and 2)

Pipeline Option 1A is approximately 37.4 miles long and crosses approximately 110 parcels. The route follows existing utility easements, where possible, and generally travels through sparsely populated areas. Pipeline Option 1B is approximately 37.7 miles long and crosses approximately 120 parcels. Similarly, the route follows existing utility easements where possible through sparsely populated areas. There is a forested corridor north of La Ward within the Pipeline Option 1B route.

Pipeline Option 2 is approximately 41.6 miles long and crosses approximately 130 parcels. Option 2 begins in a moderately populated area with heavy tree cover along the Fondren Lock Canal and then crosses heavily wooded corridor east of La Ward (paralleling FM 616).

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[5] Freese and Nichols, Garwood Water Supply Project Pipeline Route Study Report, June 2009.
[6] Ibid.

Figure 4C.14-2 (11x17) (pdfs are in the Volume II Figures folder)

Figure 4C.14-3 (11x17) (pdfs are in the Volume II Figures folder)

4C.14.1.2 Pump Station Routes (Option 1,2,and 3)

Pump Station Option 1 is located close to existing utility pipeline corridors. The profile is steep enough for a variety of intake design options, while also helping to avoid flooding of associated facilities during storm events. The straight stretch of river may reduce bank scour potential and improve intake operations.

Pump Station Option 2 is also located close to existing utility pipeline corridors about 2 ½ river miles downstream of Pump Station Option 1 and closer to the Bay City Channel Dam, which provides for deeper water during low flow conditions. Other benefits are similar to those of Pump Station Option 1 described above.

Pump Station Option 3 is the existing LCRA Pump Station at the Fondren Local Canal. New pump improvements and expansion of the pump station would be required, in addition to negotiations and coordination with LCRA.

4C.14.2 Available Yield

Previous studies[7,8] have analyzed the impacts and the water availability of the Garwood right under numerous diversion scenarios and priority dates. The results of this previous work were used to evaluate the availability of the Garwood Purchase for the conditions set forth in the amended Certificate of Adjudication No. 14-5434B. The availability of the Garwood Purchase was evaluated using the Corpus Christi Water Supply Model, a multi-basin model used to simulate the City's current water supply yield for the CCR/LCC/Lake Texana System with provisions of the 2001 Agreed Order pass-through for the Nueces Bay and Estuary. The Corpus Christi Water Supply model predicts that the full 35,000 acft/yr of the Garwood Purchase can be diverted during nearly all conditions including the critical drought under the maximum diversion rate of 150 cfs when included as part of the CCR/LCC/Lake Texana System operations.[9]

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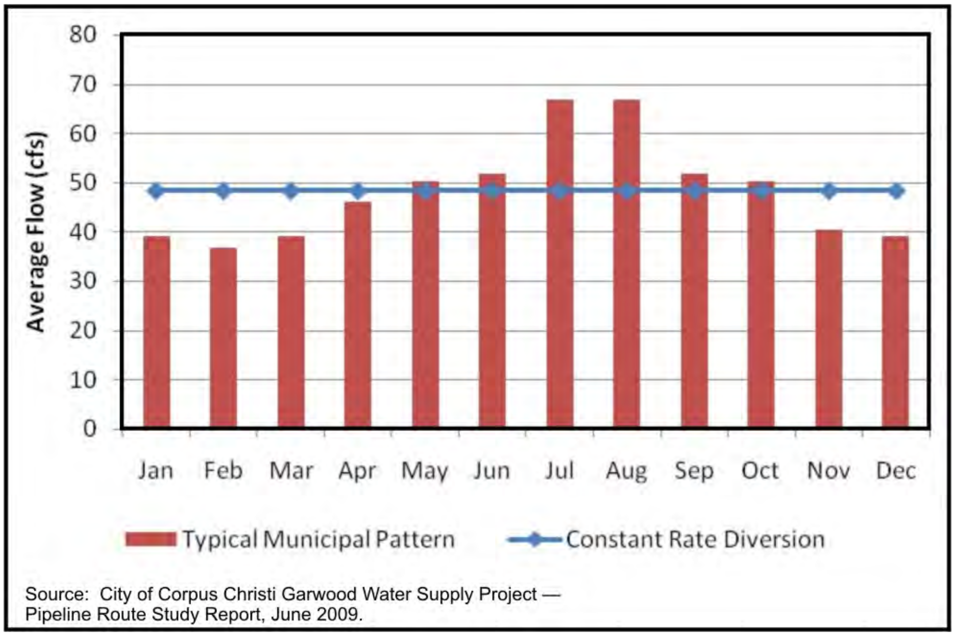
[7] HDR, "Trans-Texas Water Program—Corpus Christi Study Area—Phase II Report," City of Corpus Christi, et al., September 1995.

[8] HDR, "Dependability and Impact Analyses of Corpus Christi's Purchase of the Garwood Irrigation Company Water Right," Draft Report, September 1998.

[9] The increase in *system* yield is 35,000 acft/yr using the Corpus Christi Water Supply Model. This additional yield is primarily attributed to the critical drought occurring during different periods for the Nueces, Lavaca-Navidad, and Colorado Basins. For instance, when the drought of record occurs for the Colorado Basin, additional system supplies are available within the existing CCR/LCC/Lake Texana System to boost reliability. The Colorado River information in the Corpus Christi Water Supply Model is somewhat dated, and should be updated in future planning cycles based on the most recent, approved Water Availability Model version.

The City's Pipeline Route Report[10] considered two delivery options for pipeline sizing as shown in Figure 4C.14-4: (1) a constant flow rate of 48.3 cfs, and (2) a typical municipal water demand pattern with higher demands during summer months. The municipal pattern has a maximum flow rate of 66.9 cfs in July and August. A 54-inch diameter pipeline was the optimal size for both demand patterns for all three pipeline options. The study did not include costs for off-channel storage facilities to improve reliability of Garwood diversions. For the two delivery options considered by the City, the Garwood right was about 99 percent reliable.[11] However, in one year during the drought of record the full demand would not be satisfied during summer months. The shortage varied based on demand pattern with a larger shortage occurring during higher demands in summer months. The analysis showed an average yield of 34,670 acft/yr (or 99%) and drops to below 26,000 acft/yr during the critical drought.



Source: City of Corpus Christi Garwood Water Supply Project — Pipeline Route Study Report, June 2009.

Figure 4C.14-4. Demand Patterns

Various diversion rates and off-channel storage volumes were analyzed to determine the most dependable uniform delivery of 35,000 acft/yr Garwood water. According to the City's Pipeline Routing Report, 10,000 acft of storage provides a supply of 34,400 acft/yr available

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[10] Freese and Nichols, Garwood Water Supply Project Pipeline Route Study Report, June 2009.

[11] The City's analysis was based on Region K "Cutoff" Model, a version of the TCEQ Colorado WAM developed by Region K for planning purposes, which assumes water rights upstream of Lakes Ivie and Brownwood do not pass water to senior water rights in the lower basin. The Corpus Christi Water Supply Model includes an older modified version of the TCEQ Colorado WAM, and considers adding Garwood supplies in conjunction with the CCR/LCC/Lake Texana System.

during the drought with the constant monthly demand pattern. Using a municipal pattern demand, 15,000 acft of storage provides a supply of 34,200 acft/yr and adequately "firms up" the uniform delivery of the Garwood Purchase during periods when it is not available directly from the Colorado River.[12] In addition, it was determined that the pump station and delivery to off-channel storage should be sized to divert at a maximum diversion rate of 70 cfs. The maximum diversion rate allowed in the Garwood permit (Certificate of Adjudication No. 14-5434B Condition (2)(b)) is 150 cfs.

4C.14.3 Environmental Issues

The following discussion of potential environmental issues related to diverting the Garwood Purchase from the Colorado River and delivering it directly to the MRP intake pumping station was developed during previous regional water planning efforts, unless indicated otherwise, and can be enumerated as follows:

- Effects to the Colorado River downstream from the diversion, including the Lavaca-Colorado Estuary;
- Effects to the Nueces Estuary;
- Effects along the pipeline right-of-way from the diversion point on the Colorado River to the delivery point at the MRP intake pumping station.

Although no federal or state protected species are known to be present within the project area, important species may be present in the surrounding areas and are listed in Table 4C.14-1. Several species of migratory birds, marine turtles, and mammals considered by USFWS and National Marine Fisheries Service to be endangered or threatened are believed to utilize the Lavaca-Colorado Estuary.

4C.14.3.1 Colorado River, Lavaca-Colorado Estuary

The Colorado River flows from west to southeast through Texas from the Llano Estacado in New Mexico, across the Western High Plains Ecoregion through the Central Plains and across the Central Texas Plateau before crossing the Balcones Escarpment and flowing through the Blackland Prairies and East Central Plains to the Western Gulf Plains. In Wharton County, the Colorado River is a large, low gradient stream generally exhibiting fine-grained sediments in

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[12] Coastal Bend Regional Water Plan, January 2001.

Table 4C.14-1.
Important Species Having Habitat or Known to Occur in Counties Potentially Affected by Interbasin Transfer of Garwood Purchase*

Common Name	Scientific Name	*Summary of Habitat Preference*	*Listing Agency*			*Potential Occurrence in County*
			USFWS[1]	*TPWD*[1]	*TOES*[2,3,4]	
A Crayfish	*Cambarellus texanus*	Prefers standing water of ditches in which there is emergent vegetation				Resident
A Mayfly	*Tortopus circumfluus*	mayflies distinguished by aquatic larval stage; adult stage generally found in shoreline vegetation				Resident
American Peregrine Falcon	*Falco peregrinus anatum*	Open country; cliffs	DL	T	E	Nesting/Migrant
American Eel	*Anguilla rostrata*	Coastal waterways to Gulf				Resident
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	Open country; cliffs	DL		T	Nesting/Migrant
Atlantic Hawksbill Sea Turtle	*Eretmochelys imbricata*	Coastal waters	E	E	E	Resident
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	Gulf coastal prairies	E	E	E	Resident
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	DL	T	E	Nesting/Migrant
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushlands, forests	T/SA;NL	T	T	Resident
Black Lace Cactus	*Echinocereus reichenbachii var albertii*	Grasslands, thorn shrublands, mesquite woodlands on sandy, somewhat saline soils on coastal prairie	E	E		Resident
Black Rail	*Laterallus jamaicensis*	Salt, brackish, and freshwater marshes, pond borders, wet meadows, and grassy swamps				Resident
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods		T		Resident
Blue Sucker	*Cycleptus elongatus*	Larger portions of major rivers in Texas; usually in channels and flowing pools with a moderate current; bottom type usually of exposed bedrock		T		Resident
Brown Pelican	*Pelecanus Occidentalis*	Coastal islands; shallow Gulf and bays	DL	E	E	Resident
Cagle's Map Turtle	*Graptemys caglei*	Guadalupe River System; short stretches of shallow water with swift to moderate flow and gravel or cobble bottom, connected by deeper pools with a slower flow rate and a silt or mud bottom		T		Resident
Coastal Gay-feather	*Liatris bracteata*	Black clay soils of midgrass grasslands on coastal prairie remnants			WL	Resident
Creeper (Squawfoot)	*Strophitus undulatus*	Small to large streams, prefers gravel or gravel and mud in flowing water; Colorado, Guadalupe, San Antonio, Neches (historic), and Trinity (historic) River basins				Resident
Elmendorf's Onion	*Allium elmendorfii*	Texas endemic; grassland openings in oak woodlands on deep, loose, well-drained sands				Resident
Eskimo Curlew	*Numenius borealis*	Coastal prairies	E	E	E	Migrant
False Spike Mussel	*Quadrula mitchelli*	Possibly extirpated in Texas; probably medium to large rivers; substrates varying		T		Resident
Golden Orb	*Quadrula aurea*	Sand and gravel in some locations and mud at others; intolerant of impoundment in most instances; Guadalupe, San Antonio, and Nueces River basins		T		Resident
Green Sea Turtle	*Chelonia mydas*	Gulf Coast	T	T	T	Resident
Gulf Coast Clubtail	*Gomphus modestus*	Medium river, moderate gradient,and streams with silty sand or rocky bottoms				
Gulf Saltmarsh Snake	*Nerodia clarkii*	Coastal waters			NL	Resident
Henslow's Sparrow	*Ammodramus henslowii*	Weedy fields or cut over areas; bare ground for running and walking			NL	Nesting/Migrant

Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	E	Resident
Keeled Earless Lizard	*Holbrookia propinqua*	Coastal dunes, Barrier islands and sandy areas			NL	Resident
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	Coastal waters; bays	E	E	E	Resident
Leatherback Sea Turtle	*Dermochelys coriacea*	Coastal and offshore waters	E	E	E	Resident
Lila de los llanos	*Echeandia chandleri*	among shrubs or in grassy openings in subtropical thorn shrublands Gulf Coast; also in a few upland coastal prairie remnants on clay soils				Resident
Loggerhead Sea Turtle	*Caretta caretta*	Coastal waters; bays	T	T	T	Resident
Louisiana Black Bear	*Ursus americanus luteolus*	Possible as transient; bottomland hardwoods and large tracts of inaccessible forested areas	T	T		Transient
Manfreda Giant-skipper	*Stallingsia maculosus*	Skipper larvae usually feed inside a leaf shelter and pupate in a cocoon made of leaves fastened together with silk				Resident
Maritime Pocket Gopher	*Geomys personatus maritimus*	Fossorial, in deep sandy soils				Resident
Mexican Mud-Plantain	*Heteranthera mexicana*	Wet clayey soils of resacas and ephemeral wetlands in South Texas				Resident
Northern Aplamado Falcon	*Falco femoralis septentrionalis*	Open country, especially savanna and open woodland, grassy plains and valleys with scattered mesquite, yucca, and cactus	E	E		Migrant
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scrubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	E	Resident
Opossum Pipefish	*Microphis brachyurus*	Brooding adults found in fresh or low salinity waters and young move or are carried into more saline waters after birth; southern coastal areas		T		Resident
Pistolgrip	*Tritogonia verrucosa*	Stable substrate, rock, hard mud, silt, and soft bottoms, often buried deeply; east and central Texas				Resident
Plains Gumweed	*Grindelia oolepis*	Coastal prairies on heavy clay soils, often in depressional areas, sometimes persisting in areas where management maintains or mimics natural prairie disturbance regimes				Resident
Plains Spotted Skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas and tallgrass prairie.				Resident
Northern Aplamado Falcon	*Falco femoralis septentrionalis*	Open country, especially savannah and open woodland	E	E		Nesting/Migrant
Peregrine Falcon	*Falco peregrinus*	Open country, cliffs, occasionally cities[5]	NL	T	NL	Nesting/Migrant
Piping Plover	*Charadrius melodus*	Beaches, flats	T	T	T	Resident
Red Wolf (extirpated)	*Canis rufus*	Woods, prairies, river bottom forests	E	E	E	Resident
Reddish Egret	*Egretta rufescens*	Coastal islands for nesting; shallow areas for foraging		T	NL	Nesting/Migrant
Rock Pocketbook	*Arcidens confragosus*	Mud, sand, and gravel substrates of medium to large rivers in standing or slow flowing water, may tolerate moderate currents and some reservoirs				Resident
Sennet's Hooded Oriole	*Icterus cucullatus sennetti*	Often builds nests in Spanish moss.				Nesting
Sheep Frog	*Hypopachus variolosus*	Moist sites in arid areas.				
Shinner's Sunflower	*Helianthus occidentalis ssp plantagineus*	mostly in prairies on the Coastal Plain				Resident
Slender Rushpea	*Hoffmannseggia tenella*	Coastal prairie grasslands on level uplands and on gentle slopes along drainages, usually in areas of shorter or sparse vegetation	E	E		
Smalltooth Sawfish	*Pristis pectinata*	Different life history stages have different patterns of habitat use;	E	E		Resident
Snowy Plover	*Charadrius alexandrus*	Beaches, flats, streamsides			NL	Winter resident

Sooty Tern	*Sterna fuscata*	Coastal islands for nesting; deep Gulf for foraging		T	WL	Resident
Southeastern Snowy Plover	*Charadrius alexandrus tenuirostris*	Wintering migrant on Texas Gulf Coast beaches and bayside mud or salt flats				Migrant
Southern Yellow Bat	*Lasiurus ega*	Associated with trees which provide daytime roosts.		T		Migrant
South Texas Ambrosia	*Ambrosia cheiranthifolia*	Grasslands and mesquite-dominated shrublands on various soils ranging from heavy clays to lighter textured sandy loams	E	E		Resident
South Texas Siren (large form)	*Siren sp 1*	Wet or sometimes wet areas, such as arroyos, canals, ditches, or even shallow depressions		T		Resident
Spot-tailed Earless Lizard	*Holbrookia lacerata*	Moderately open prairie-brushland; fairly flat areas free of vegetation or other obstructions, including disturbed areas				
Texas Asaphomyian Tabanid Fly	*Asaphomyia texanus*	Near slow moving water, wait in shady areas for host			WL	Resident
Texas Botteri's Sparrow	*Aimophila botterii texana*	Grassland and short-grass plains with scattered bushes or shrubs		T		Nesting
Texas Diamondback Terrapin	*Malaclemys terrapin litoralis*	Bays and coastal marshes			T	Resident
Texas Fatmucket	*Lampsilis bracteata*	Streams and rivers on sand, mud, and gravel substrates; intolerant of impoundment; broken bedrock and course gravel or sand in moderately flowing water; Colorado and Guadalupe River basins.		T		Resident
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, grass, cactus, brush		T		Resident
Texas Indigo Snake	*Drymarchon melanurus erebennus*	Texas south of the Guadalupe River and Balcones Escarpment; thornbush-chaparral woodlands of south Texas		T		Resident
Texas Pimpleback	*`Quadrula petrina*	Mud, gravel and sand substrates, generally in areas with slow flow rates		T		Resident
Texas Pipefish	*Syngnathus affinis*	Corpus Christi Bay; seagrass beds				Resident
Texas Scarlett Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils		T		Resident
Texas Tortoise	*Gopherus berlandieri*	Open brush with a grass understory is preferred; open grass and bare ground are avoided		T		Resident
Texas Windmill-grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants, often on roadsides				Resident
Tharp's Rhododon	*Rhododon angulatus*	Deep, loose sands in sparsely vegetated areas on stabilized dunes of Pleistocene barrier islands				Resident
Threeflower Broomweed	*Thurovia triflora*	Texas endemic; near coast in sparse, low vegetation on a veneer of light colored silt or fine sand over saline clay				Resident
Timber/Canebrake Rattlesnake	*Crotalus horridus*	swamps, floodplains, upland pine and deciduous woodlands, riparian zones, abandoned farmland; limestone bluffs, sandy soil or black clay; prefers dense ground cover, i.e. grapevines or palmetto		T		Resident
Welder machaeranthera	*Psilactis heterocarpa*	Texas endemic; grasslands , varying from midgrass coastal prairies, and open mesquite-huisache woodlands on nearly level, gray to dark gray clayey to silty soils				Resident
Western Burrowing Owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie, plains and savanna				Resident
Western Snowy Plover	*Charadrius alexandrinus nivosus*	Uncommon breeder in the Panhandle; potential migrant; winter along coast				Migrant
West Indian Manatee	*Trichechus manatus*	Gulf and bay system	E	E		Resident
White-faced Ibis	*Plegadis chihi*	Prefers freshwater marshes		T		Resident

White-nosed Coati	*Nasua narica*	Woodlands, riparian corridors and canyons; most individuals in Texas probably transients from Mexico		T		Transient
White-tailed Hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf coastal plain		T		Nesting/ Migrant
Whooping Crane	*Grus americana*	Potential migrant	LE	E		Migrant
Wood Stork	*Mycteria americana*	Forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T		Migrant

extensive sandy braided reaches and occasional cobble and gravel riffles. As is commonly the case in coastal plain reaches, pool-riffle sequences are poorly developed. Low head dams impound two significant reaches of the river below Wharton. In addition to the numerous impoundments on the upper river and on major and minor tributaries, the Highland Lakes (large mainstream reservoirs constructed on the Edwards Plateau) are operated by the LCRA to provide hydropower, flood control, and water storage in the Lower Colorado River Basin. Operation of these reservoirs, particularly winter storage and summer releases of water for rice irrigation in Colorado, Wharton, and Matagorda Counties, has substantially altered the annual hydrography of the lower river (below Austin) from its historical condition.[13]

In order to establish minimum flow guidelines that would protect existing biological communities in the Lower Colorado River while continuing to provide water for its traditional uses, LCRA conducted extensive instream flow studies on Segments 1428 and 1402 (from Austin to Bay City).[14] Also, based on the distribution and abundance of habitat suitable for the maintenance of populations of a set of representative native riverine species, LCRA divided the lower river into five distinct reaches, of which the lowest—the Egypt reach—encompasses the proposed intake location for this alternative. Instream flow guidelines were established for each reach based on evaluations of habitat use by representative fish species, coupled with an assessment of the effect of river discharge on the amount of suitable habitat at selected locations within each reach. In the Egypt reach, monthly target flows (those to be maintained when supplies are adequate, but to be considered interruptible subject to demand curtailment during drought periods) range from 160 cfs during August to 670 cfs in May and 540 cfs in June. The target flows are substantially lower than the corresponding modern monthly medians at Columbus and lower than the target flows developed for the upstream reaches. The disparity is due to the general lack of suitable habitat for the primary evaluation species (blue sucker, Cycleptus elongatus) and other flow-sensitive forms in the Egypt reach. The proposed diversion of water held under existing water rights will meet the LCRA's instream flow targets.

Below Bay City, the Colorado River is tidally influenced (Segment 1401), and its aquatic community is characterized by more marine species. The river mouth has recently been relocated by the USCOE so that it no longer discharged directly into the Gulf of Mexico but into the

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[13] Mosier, D.T. and R.T. Ray, "Instream flows for the Lower Colorado River," Lower Colorado River Authority (LCRA), Austin, Texas, 1992.

[14] Ibid.

eastern arm of Matagorda Bay, as it did prior to its rapid delta progradation some 60 years ago. This action is expected to increase Colorado River inflows to Matagorda Bay by about 30 percent (from an average of 1.2 million to approximately 1.7 million acft/yr).[15]

4C.14.3.2 Nueces Estuary

Following use in the Corpus Christi area, a portion of the combined Lake Texana and Garwood water would be returned to the Nueces Estuary system as treated wastewater. Previous studies reported that average monthly salinities in Upper Nueces Bay would decrease with the implementation of this option. Increased freshwater inflows into Nueces Estuary are expected to benefit shrimp and some other aquatic species.

4C.14.3.3 Proposed Pipeline Route

The pipeline routes identified in the City's Pipeline Route Report generally follow existing pipeline rights-of-water, county roads and/or state roads through most of its length, when practicable. Between 21 and 28 stream crossings were identified based on route option and many stream crossings will be located in conjunction with prior pipeline or road crossings to minimize impacts. Depending on pipeline alignment option, it is estimated between 10 and 20 acres of riparian area may be disturbed. Limited disturbances (less than 1 acre) are estimated for each proposed pump station. Although a mitigation plan has not been developed, proposed restoration would address: revegetation of disturbed areas with native herbaceous species, planting of native trees and shrubs and herbaceous species within any disturbed wooded areas, and/or stabilization of disturbed stream bank areas from pipeline crossing disturbances. Design and construction options to further minimize impacts will also be considered.

The potential pipeline route includes the gulf Prairies vegetational area, the Western Gulf Coastal Plan ecoregion, and the Texan biotic province. Post oak savannah and tall grass prairies dominated by oaks, mesquites (*Prosopis glandulosa*), acacias and prickly pears (*Opuntia spp.*) characterize the Gulf Prairies vegetational area. This vegetation is supported by acidic clays and clay loams interspersed by sandy loams.

Plant and animal species listed by TPWD, USFWS, and TOES that may be within the vicinity of the pipeline routes were listed in Table 4C.14-1.

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[15] Texas Water Development Board (TWDB), Unpublished data, "Bay and Estuaries Study Program," TWDB, Austin, Texas, 1990.

All potential route passes through or is in the vicinity of Bald Eagle (in 1999, downgraded from endangered to threatened status) habitat. The NHP has mapped Bald Eagle habitat from Lake Texana along the Lavaca and Navidad Rivers. Construction of either pipeline could disturb this habitat. Other protected species that were not mapped in the project area but that could have habitat in the vicinity either of the proposed alternatives, include the black bear, jaguarundi, ocelot, and the Texas tortoise. The animals depend on brushland and mesquite scrubland habitats in the coastal prairies. The Texas tortoise occupies shallow depressions at the base of bushes and cacti and underground burrows. Another reptile, the timber/canebrake rattlesnake is usually found in bottomland habitats that support hardwoods.

The white-tailed hawk (*Buteo albicaudatus*), interior least tern (*Sterna antillarum athalassos*), and Eskimo curlew (*Numensis borealis*) also inhabit the coastal prairies. The white-tailed hawk can be found in open prairies and mesquite/oak savannah, while the interior least tern inhabits barren to sparsely vegetated sandbars along river, lake, and reservoir shorelines. The Eskimo curlew has historically migrated through the coastal prairies in March and April.

Most of the affected land would be expected to be returned to agricultural uses following construction. Pipeline construction would include some impact to woods; however, such impacts would be reduced from the figures given above by judicious pipeline alignment. Several small creeks would be crossed by the proposed pipeline. Vegetation in cropland and pastures, and animal species associated with these habitats, would be expected to return to near original condition following seeding.

4C.14.3.4 Archeological and Cultural Resources

A cultural resource/archeological survey will need to be conducted prior to implementing the project according to Antiquities Code of Texas requirements. Archeological or historical sites should be avoided in the design phase of the project.

4C.14.4 Engineering and Costing

The major facilities required for pumping the Garwood Project to the MRP facilities and then to the City via the MRP are:

- Surface water intake and pump station on the Colorado River;
- Transmission pipeline from the Colorado River to the MRP intake pumping station and;
- Junction piping and appurtenances to tie the Garwood Pipeline to the MRP.

The City's study provided costs of the Garwood Water Supply Project in Summer 2009 dollars. The costs were then prorated to reflect September 2008 Prices. The estimated capital cost for building the 54-inch diameter transmission pipeline and facilities to deliver the water to the MRP is $61,560,000 as shown in Table 4C.14-2. The intake and pump station is estimated to cost $14,048,000. After land acquisition costs and cost for engineering, legal, environmental mitigation, and interest during construction, the total project cost is estimated at $112,993,000. The debt service at 6 percent over 20 years and the annual operations and maintenance costs, including energy, result in a total annual cost of $12,548,000. The additional power costs necessary to deliver the 35,000 acft/yr through the MRP are included in the annual energy costs at a rate of $0.09 per kW-hr. Dividing by 35,000 acft/yr equates to an annual raw water cost of $359 per acft. Assuming treatment costs of $326 per acft, the treated water cost is $685 per acft.

The City's study did not include costs for off-channel storage facilities to improve reliability of Garwood diversions.

4C.14.5 Implementation Issues

This option requires the construction of new facilities as well as the upgrade and use of the pumping facilities owned and operated by the LNRA. Implementation of this option would require an agreement with the LNRA.

Table 4C.14-2. Cost Estimate Summary for Garwood Pipeline (September 2008 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Intake and Pump Station (3,000 Horsepower)	$14,048,000
Transmission Pipeline (54 in dia., 38 miles)	$61,560,000
Total Capital Cost	**$75,608,000**
Engineering, Legal Costs and Contingencies	$23,565,000
Environmental & Archaeology Studies and Mitigation	$1,892,000
Land Acquisition and Surveying (368 acres)	$3,513,000
Interest During Construction (2 years)	$8,415,000
Total Project Cost	**$112,993,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$9,904,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$967,000
Pumping Energy Costs (18638064 kW-hr @ 0.09 $/kW-hr)	$1,677,000
Purchase of Water (acft/yr @ $/acft)	$0
Total Annual Cost	**$12,548,000**
Available Project Yield (acft/yr)	35,000
Annual Cost of Water ($ per acft)	$359
Annual Cost of Water ($ per 1,000 gallons)	$1.10

Water treatment operations associated with delivery should be analyzed in greater detail. Delivery of the Colorado River water at a uniform annual rate to the MRP offers a significant benefit to the operations of the City's O.N. Stevens Water Treatment Plant by reducing rapidly changing raw water characteristics that could occur with the Colorado River water delivered directly to the MRP at a peak flow rate. The only opportunities for the Lake Texana water and Colorado River water to blend would be in the MRP and in the pre-sedimentation basin at the water treatment plant. As part of Phase I development of the 2011 Plan, the Coastal Bend Regional Water Planning Group performed a special study[16] to evaluate potential blending issues with the addition of new regional water supplies to water currently being delivered through the MRP from Lake Texana. The blending analysis did not indicate any large treatment issues at the O.N. Stevens Water Treatment Plant when blending surface water supplies from the Garwood Project. Overall, the addition of water supplies from the Garwood Project would be expected to decrease chloride levels when compared to existing chloride levels of the CCR/LCC/Lake Texana System.

4C.14.5.1 Requirements Specific to Interbasin Transfer of Water

1. It will be necessary to obtain these permits:
    a. Coastal Coordinating Council review.
    b. TPWD Sand, Gravel, and Marl permit.
    c. GLO Sand and Gravel Removal permits.
2. Permitting, at a minimum, will require these studies:
    a. Evaluation of instream flow impacts.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Land and easements will need to be acquired by negotiations or condemnation.

4C.14.5.2 Requirements Specific to Pipelines

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. General Land Office Sand and Gravel Removal permits.
    c. General Land Office easement if pipeline crosses any state owned riverbeds.

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[16] Coastal Bend Regional Water Planning Group, "Study 1- Evaluation of Additional Potential Regional Water Supplies for Delivery through the MRP, Including Gulf Coast Groundwater and Garwood Project," April 2009. This report can be accessed from the Nueces River Authority website (http://www.nueces-ra.org/)

   d. Coastal Coordinating Council review and Coastal Zone Management Consistency Certification.
   e. Texas Parks and Wildlife Department Sand, Gravel, and Marl permit for river crossings.
   f. Section 401 water quality certification for the intake structure on the Colorado River and pipeline crossings of waters of the U.S., if an individual permit is required under Section 404.[17]

2. Run-of-river and easement acquisition.
3. Approval from various agencies for these crossings:
   a. Highways and railroads.
   b. Creeks and rivers.
   c. Other utilities.

Tables 4C.14-3 and 4C.14-4 show pipeline route and intake pump station location factors, respectively, for each option evaluated in the Pipeline Route Report. Schedule is largely dependent upon the willingness of TxDOT to allow placement of pipeline in their right-of-way.

Additional consideration of project limitations associated with utilizing TxDOT right-of-way will need to be addressed beyond those described in the Pipeline Route Report including evaluation of impacts of future TxDOT road expansions and costs of relocating portions of the pipeline, if necessary.

Table 4C.14-3.
Pipeline Route Factors

	Option 1A	***Option 1B***	***Option 2***
Pipeline Length	37.4 Miles	37.7 Miles	41.6 Miles
Easement Acquisition	Private landowners along existing utility corridor	Private landowners along existing utility corridor	Potential for routing within TxDOT right-of-way
Environmental Conflicts	Limited impacts along existing utility corridors and cultivated agricultural lands; 28 identified stream crossings.	Limited impacts along existing utility corridors and cultivated agricultural lands; 28 identified stream crossings.	Pipeline corridor crosses approximately 20 acres of riparian and upland forest areas. These areas might include wetlands. Impacts may be significantly reduced by construction in TxDOT right-of-way. 21 stream crossings.
Schedule Ramification	Shortest pipeline length and rural construction.	Shortest pipeline length and rural construction.	Longest pipeline route and routing around urban areas; may reduce easement acquisition time, but will require coordination with TxDOT for construction in right-of-way.
Access for Maintenance	Access through private property and county roads.	Access through private property and county roads.	Access along state highways.

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[17] City of Corpus Christi Pipeline Route Study Report, June 2009.

Table 4C.14-4.
Intake Pump Station Location Factors

	Option 11	Option 2	Option 3
Location Upstream of Existing Channel Dam	Located greater than 4 miles upstream within zone of influence of dam; relatively shallow water depth during low river flows.	Located approximately 1 mile upstream within zone of influence of dam and deep water portion of the river.	Located immediately upstream in deepest area of impoundment.
River Alignment	Located on straight stretch of river with little evidence of bank erosion and sediment deposits.	Located on straight stretch of river with little evidence of bank erosion and sediment deposits.	Located on outside bank of bend in river with moderate evidence of bank scour.
River Topography	Steep banks to allow for construction near river and above frequently flooded area; allows for flexibility in pump station configuration.	Steep banks to allow for construction near river and above frequently flooded area; allows for flexibility in pump station configuration.	Steep banks to allow for construction near river and above frequently flooded area; new station configuration needs to be compatible with existing facility.
Proximity to Existing Utility Easements	Close proximity to existing utility line corridors.	Close proximity to existing utility line corridors.	Requires coordination with irrigation canals, public golf course, and neighborhoods.
Space for Facilities	Adequate space for constructing new pump station facilities with moderate tree clearing.	Adequate space for constructing new facilities with moderate tree clearing; slightly confined by existing pipe bridge.	Constrained site with existing pump station and neighboring public facilities.

4C.14.6 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Table 4C.14-5.

Table 4C.14-5.
Evaluation Summary of the Garwood Pipeline

Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Firm Yield: 35,000 per acft/yr when operated with system.
2. Reliability	2. Good reliability.
3. Cost of Treated Water	3. Raw water cost of $359 per acft, or $685 per acft for treated water.
b. Environmental factors	
1. Instream flows	1. Some impact to Colorado River, due to utilization of water rights. Possible adverse impact to instream flows during drought conditions.
2. Bay and Estuary Inflows	2. Negligible impacts to Lavaca-Colorado Estuary. Possible adverse impact to bay and estuary inflows during drought conditions. Potential benefit to Nueces Estuary from increased freshwater inflows.
3. Wildlife Habitat	3. Some impacts due to pipeline (and/or off-channel).
4. Wetlands	4. Some impacts due to pipeline (and/or off-channel).
5. Threatened and Endangered Species	5. Low impact to threatened/endangered species.
6. Cultural Resources	6. Cultural resource surveys will be required to avoid any significant sites.
7. Water Quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	7. Low water quality impacts unless water delivered at high flow rates.
c. Impacts to State water resources	• No apparent negative impacts on water resources
d. Threats to agriculture and natural resources in region	• None
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Standard analyses and methods used
g. Interbasin transfers	• Rights to transfer Colorado River water to Nueces River Basin were obtained.
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None

4C.15 Brush Management (N-15)

4C.15.1 Description of Strategy

The interest in brush management as a means to increase water supply has its roots in (1) the belief that Texas rangelands changed after settlement and use by Europeans from predominantly open grasslands to increasing domination of brush, and (2) the significantly greater interception of water by brush than grasses. The former suggests that the "natural" character of Texas rangelands would be grassland. The latter suggests the possibility of increasing aquifer recharge and streamflow by controlling and limiting growth of brush and trees in areas where grasslands would have naturally dominated. For this brush management option, brush management methods will be described, and estimates of cost and potential water supply effects will be presented.

Documentation of early European settlers[1] described Texas rangelands as grasslands. Prior to settlement by Europeans, with its associated grazing, significant brush growth was inhibited due to several natural conditions. Tree seeds commonly die following germination in grass cover because they cannot compete with grasses for sunlight and moisture. Also, any surviving seedlings are destroyed typically in periodic wildfires that occur in natural grasslands. Heavy grazing lessens the competitiveness of grass relative to brush and removes the fuel (grass) from rangeland wildfires. The result of heavy grazing is the increased dominance of trees and brush in grasslands.[2] This pattern of vegetation was common worldwide with the advent of European settlement of rangelands.[3]

In view of the consequences of heavy grazing on rangelands, ranchers have a compelling interest in controlling brush (i.e., the livestock-carrying capacity of rangeland is reduced by large increases in woody cover).[4] The brush in the Coastal Bend Region includes but is not limited to common species such as blackbrush, granjeno, mesquite, live oak, and pricklypear. The effect

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[1] Smiens, F., S. Fuhlendorf, and C. Tayor, Jr., "Environmental and Land Use Changes: A Long-Term Perspective," Juniper Symposium Proceedings, Texas A & M Agricultural Experiment Station, Sonora, Texas, 1997.

[2] Thurow, T. L., "Assessment of Brush Management as a Strategy for Enhancing Water Yield," Proceedings of the 25th Water for Texas Conference, Texas Water Resources Institute, Texas A & M University, 1998.

[3] Archer, S., "Woody Plant Encroachment into Southwestern Grasslands and Savannas: Rates, Pattern and Proximate Causes," Ecological Implications of Livestock Herbivory in the West, M. Vavra, W. Laycock, and R. Piper (editors), Society for Range Management, Denver, Co, 1994.

[4] Redecker, E. J., "The Effects of Vegetation on the Water Balance of an Edwards Plateau Watershed: A GIS Modeling Approach," M.S. Thesis, Texas A & M University, 1998.

on livestock-carrying capacity results from the decrease in grasses that are of significant nutritional value to the livestock. Livestock avoid grazing the brush and thus provide these brush species a competitive advantage over the grasses preferred by livestock. For a unit grazing area, fewer livestock can be supported as the percentage of brush increases. This suggests there would be some economic incentive for ranchers to control brush, and to the extent that reductions in brush cover on rangeland results in larger quantities of recharge to aquifers and run-off to streams, brush management may result in increased water supplies for municipal, industrial, irrigation and other uses.

More problematic for brush management, however, is the evidence that more Texas ranches are being purchased for reasons other than grazing.[5] A survey of the Edwards Plateau[6] found that ranch owners who are not dependent on livestock income are less interested in investing in brush management. Some within this group of ranchers may practice brush management, but they do so for reasons other than agricultural economics.

According to previous studies, brush management may have detrimental effects on certain types of wildlife. Brush species constitute a significant portion (>58 percent) of nutritious forage for white tailed deer, and provide shelter and hiding cover for wildlife. In 1996, hunting and wildlife watching contributed $2.6 billion to the Texas economy. Hunting is popular in South Texas and reportedly generates approximately 75 percent of total income to landowners in the Coastal Bend Region.[7] Previous studies recommend maintaining 40 to 60 percent brush to provide good deer habitat.[8] Consequently, it may provide greater regional benefits to leave more untreated brush to maintain diversity essential to good wildlife habitat and hunting.

Brush management is one of many land management practices, collectively referred to as "voluntary land stewardship", that can provide water supply at its origin. Voluntary land stewardship includes (but is not limited to) absorbing rainfall, reducing run-off, using prescribed fire properly, planning and managing grazing, brush management, managing erosion, wildlife and habitat management, and protecting springs and creek banks. With an optimal, voluntary

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[5] Rowen, R. C., "Are Small-Acreage Livestock Producers Real Ranchers?," Rangelands 16:161-166, 1994.

[6] Garriga, M. D., "Tradeoffs Associated with Increasing Water Yield from the Edwards Plateau, Texas: Balancing Private Costs and Public Benefits," M.S. Thesis, Texas A & M University, 1998.

[7] Josephine Miller, CBRWPG meeting, May 2004.

[8] Lyons, Robert K. and Tim F. Ginnett, "Integrating Deer, Quail, and Turkey Habitat: Brush Management Effects on Deer Habitat", Texas Agricultural Extension Service E-98, September 2001.

land stewardship program, floods are reduced, aquifers are replenished, and water is released more slowly and steadily into streams, rivers, lakes and bays.[9] Although this water management strategy specifically addresses supplies attributable to brush management, additional water supply benefits, including additional inflow to reservoir systems, may be achieved with a comprehensive land stewardship program.

4C.15.2 Potential Water Yield from Brush Management

In terms of water supply, yield is the quantity of water available in a year for municipal, industrial, agricultural, and other uses. Firm yield is the quantity of water available during a critical drought. From the water supply perspective, yield is expressed as acre-feet (acft) per year. However, increasing the quantity of water that is not intercepted by brush on rangelands does not necessarily increase yield as defined by water supply. This is because there are other factors that could prevent this water from being available. For example, the water could enter the soil as deep percolation. It could also be captured in a rangeland impoundment.

A water balance is used to estimate the runoff and/or deep percolation from rangeland. The water balance is described in the following equation,[10]

$$\text{Runoff} + \text{Deep Percolation} = \text{Precipitation} - \text{Evapotranspiration}$$

and its variables are defined as follows:

- Runoff is water that leaves the watershed through surface flow;
- Deep Percolation is water that leaves the watershed by percolating through soil beyond the reach of the root zone; and
- Evapotranspiration is water vapor entering the atmosphere through both leaf tissue and the drying of wet soil.

According to the water balance, runoff and/or deep percolation can be increased by decreasing evapotranspiration, which can be accomplished by managing vegetation. There are large differences in interception loss (water in the canopy that can be evaporated) among the common brush (mesquite, blackbrush, and granjeno) and grasses. Interception losses in Texas range from 14 percent for grass to 46 percent for live oak and 73 percent for juniper.[11] Thus, a

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[9] Letter from Texas Wildlife Association to Ms. Carola Serrato, Co-Chair Region N, September 21, 2005.

[10] Thurow, T.L., Op. Cit., 1998.

[11] Thurow, T. L. and Hester, J. W., "How an Increase in Juniper Cover Alters Rangeland Hydrology," Proceedings Juniper Symposium, Texas A & M Agricultural Experiment Station Technical Report 97-1, 1997.

strategy of limiting brush cover and increasing grass cover would presumably increase runoff and/or deep percolation.

There has been significant research on the effects of controlling juniper on water yield. Some of the information generated from juniper research will apply to the Coastal Bend Region, even though there is no evidence of juniper in the region. The seasonal water use differences among trees, brush, and grasses common to the Edwards Plateau and northern Rio Grande Plains is demonstrated in Table 4C.15-1. The average unit water consumption for mesquite and Ashe Juniper is more than twice the average of the common grasses in the region. Also notable is the impact of goat grazing (biological brush management) on water consumption. At the Sonora Research Station, there were 309 Ashe Juniper trees per acre in an ungrazed enclosure and 114 per acre in a nearby pasture having a history of grazing by Angora goats.[12] Converting these densities to leaf area in order to calculate the transpiration rate, it was determined that water use in the ungrazed tract was 1.12 acft/acre and only 0.28 acft/acre in the grazed tract for the growing season period, approximately April through September.[13]

Table 4C.15-1.
Densities and Seasonal Water Use for Common Plant Species

Species	***Density***	***Seasonal Water Use[1] (acft)***
Mesquite	307 plants/acre	0.93
Juniper (no grazing)	309 plants/acre	1.12
Juniper (goat grazing)	114 plants/acre	0.28
Oak	50 plants/acre	0.96
Sideoats grama grass	890 lbs./acre	0.20
Kleingrass	1,525 lbs./acre	0.59
Buffalograss	1,340 lbs./acre	0.53

[1] The growing season of April through September.

Source: (Owens and Knight, 1992)

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[12] Smiens, F., “Ashe Juniper: Consumer of Edwards Plateau Rangeland,” Grazing Management Field Day, Sonora, Technical Report 90-1, Pages 17-21, 1990.

[13] Owens, M.K. and R.W. Knight, “Water Use on Rangelands,” Water for South Texas, The Texas Agricultural Experiment Station, Pages 1-13, October 1992.

4C.15.2.1 Areas in Coastal Bend Region Where Potential Yield Increase Exists

An increase in runoff resulting from brush management could result in two potential water supply benefits: increasing recharge of groundwater due to increased sheet and/or stream flow traversing recharge outcrops or faults, or enhancing stream flows and existing water supply reservoirs. In addition, the construction of catchment dams at appropriate locations to redirect floodwaters into the aquifer would increase recharge. Consequently, additional water might be available for recharge due to increased runoff from rangeland where brush could be reduced in favor of grass. In the Coastal Bend Region nearly all the groundwater is in either the Gulf Coast or Carrizo-Wilcox Aquifers. Neither of these aquifers offers the same degree of recharge that the Edwards Aquifer offers due to its karst characteristics.

Reservoir water supply could also be enhanced. In 1985, the Texas State Soil and Water Conservation Board (TSSWCB) and the Texas Water Development Board identified a list of water supply reservoirs that might benefit from brush management. In the Coastal Bend Region, Lake Alice was listed for enhancing the water supply of the City of Alice.

4C.15.2.2 Best Management Practices for Brush Management

In Texas, brush management authorization was granted in 1985 by the Legislature to the TSSWCB. The purpose of the program is to provide “selective control, removal, or reduction of noxious brush such as mesquite, salt cedar, or other brush species that consume water to a degree that is detrimental to water conservation.” The draft State plan delineates a critical area in Texas for brush management. The counties in the area are those having 16 to 36 inches of precipitation per year. Cost of brush management in the draft plan would be shared between landowners and the State. Local soil conservation districts would determine the maximum and average costs for different control methods and the cost share rates. The methods of brush management that the TSSWCB can approve are those that:

1. Are proven effective and efficient for brush management,
2. Are cost effective,
3. Have beneficial impact on wildlife habitat,
4. Will maintain topsoil to prevent erosion or siltation, and
5. Will allow for revegetation of the area with plants that are beneficial to livestock and wildlife.[14]

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[14] Texas State Soil and Water Conservation Board, “Draft State Brush Control Plan,” April 1, 1999

Acceptable brush management methods vary depending upon the extent of control needed as well as the type of brush present. The U.S. Department of Agriculture, Natural Resources Conservation Service has a conservation practice standard for brush management.[15] The standard includes biological, chemical, mechanical and burning methods for brush management. The biological method describes the use of goats for specific vegetation goats eat. The method involves defoliation of brush systematically. Another standard is for the use of herbicides for brush management. A review of Texas Agricultural Extension Service on-line Expert System for Brush and Weed Control Technology Selection, Version 1.09 (Excel)[16] for Jim Wells County provided information on chemical agents for control of brush (Table 4C.15-2).

The mechanical standard prescribes plowing, grubbing, chaining, and dozing as primary brush management methods. Studies on plowing and chaining have shown negative effects on white-tailed deer habitat destroying cover and diminishing availability of forage affecting wildlife food supply.[17] In most cases Natural Resources Conservation Service recommends burning to control sprouts. Prescribed burning is a very cost-effective method for controlling the sprouts and is desirable for deer habitat since it results in vegetation diversity. In addition, it is how nature controlled the brush before the grassland fires were suppressed.

Table 4C.15-2.
Chemical Agents for Control of Brush

Brush	Chemical Agent	Control Level [1]
Blackbrush	Remedy (triclopyr) Spike 20P	Very high control level Very high control level
Granjeno	Spike 20P	Very high control level
Live Oak	None recommended	
Mesquite	Remedy (triclopyr) Reclaim (clopyralid) Tordon 22K Velpar L	Very high control level Very high control level Very high control level High control level
Post Oak	Velpar L Spike 20P Crossbow	Very high control level Very high control level High control level

[1] Very high means 76 to 100 percent of plants killed; High means 56 to 75 percent killed.

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[15] Natural Resources Conservation Service, Conservation Practice Standard, Brush Management (Acre) Code 314.

[16] http://cnrit.tamu.edu/rsg/exsel/work/exsel.cgi

[17] Richardson, C.L, "Brush Management Effects on Deer Habitat", Texas Agricultural Extension Service L-2347, 1990.

The State of Texas, through the TSSWCB, approaches the cost of brush management on a cost-sharing basis with the ranchers. The presumption in the state brush management program is to equate rancher costs with rancher benefits. The benefit to ranchers would be the increases in income from cattle, sheep, and wildlife businesses that result from brush management. For the livestock businesses, other things being equal, increasing the amount of useable vegetation could increase the net economic return to the rancher because the grazing capacity of the rangeland would be expanded through controlling brush. Economic benefits received by ranchers who practice brush management will be attributed largely to the economy of scale realized through increased production without a corresponding increase in costs. Once the total cost of brush management is determined, then the difference between the total cost and the benefit to the rancher would be the cost that might be attributed to the additional water yield. Rangeland owners who do not depend on agricultural income may not have direct economic benefits from brush management. Presumably, if the rancher receives no benefits, then the rancher would not be interested in engaging in practices that increase costs. Furthermore, if a land is predominantly used for hunting then brush management may be detrimental and result in income loss to landowner. Brush control costs in this case would probably be borne by the State or the regional water authority that would benefit from the increased water supply resulting therefrom.

4C.15.2.3 Cost of Brush Management

Studies have been done to determine brush management costs for rangelands in Texas.[18,19] Since these studies have occurred in the Edwards Plateau area, which overlays part of the Coastal Bend Region and contains a similar vegetation profile, including watersheds within the Nueces and Frio River watersheds, the evaluation of this option is based on the assumption that the costs developed from these studies are relevant for use in evaluating this option. Nueces and Frio River watersheds were subdivided into Upper (Edwards) and Lower watersheds and costed separately. Table 4C.15-3 shows the present value in September 2008 prices for controlling three different levels of mesquite based on previous study of the Lower Nueces River

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[18] Texas Agricultural Experiment Station Blackland Research and Extension Center, "Brush Management/Water Yield Feasibility Studies for Eight Watersheds in Texas", Compilation of Papers/Chapters by Various Authors, November 2000.

[19] Walker, J.W., F. B. Dugas, F. Baird, S. Bednarz, R. Muttiah, and R. Hicks, "Site Selection for Publicly Funded Brush Control to Enhance Water Yield," Proceedings, Water for Texas Conference, Austin, Texas, December 1998.

Watershed near junction at Three Rivers (downstream of Choke Canyon Reservoir). The costs for brush management of Lower Frio River watershed, which drains into Choke Canyon Reservoir, were the same. Costs are presented on a present worth basis because brush management requires an initial (year "0") investment plus a periodic future investment to maintain control.

4C.15.2.4 Potential Increased Runoff and/or Deep Percolation Due to Brush Management

Computer simulations for estimating runoff and/or deep percolation were undertaken for several watersheds: the North Concho River Basin in the northern Edwards Plateau near San Angelo, Texas;[20] Seco Creek watershed in Medina County;[21] Nueces River at confluence with Frio River at Three Rivers; and Frio River near Choke Canyon Reservoir.[22] The results of these simulations were then used in an economic analysis of brush management undertaken to increase the quantity of runoff and/or deep percolation.[23]

Table 4C.15-3.
Initial and Interim Costs[1] for Various Brush Management Methods

	One Time Costs		Recurring Costs	
Brush Condition (method)	Year 0 ($/acre)	Year 4 ($/acre)	Periodic Cost ($/acre)	Frequency of Control (years)
Heavy mesquite	61.64	54.79	34.24	7
Moderate mesquite (chemical then prescribed burn)	54.79	54.79	34.24	7
Light mesquite (chemical then prescribed burn)	54.79	54.79	34.24	7

[1] Initial and recurring costs were adjusted to September 2008 Dollars.

Source: Bach, Joel P. and J. Richard Connor, "Nueces and Frio River Watershed—Economic Analysis," Brush Management/ Water Yield Feasibility Studies for Eight Watersheds in Texas, November 13, 2000.

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[20] Bach, Joel P. and J. Richard Connor, "Economic Analysis of Brush Control Practices for Increased Water Yield: The North Concho River Example," Proceeding, Water for Texas Conference, Austin, Texas, December 1998.

[21] Walker, et al., Op. Cit., December 1998.

[22] Rosenthal, Wesley, "Frio and Nueces River Watershed- Hydrologic Simulation", Brush Management/Water Yield Feasibility Studies for Eight Watersheds in Texas, November 13, 2000.

[23] Bach, Joel P. and J. Richard Connor, Op. Cit., November 2000.

The estimated runoff and/or deep percolation from these brush management simulations varied significantly between the four sites. The runoff and/or deep percolation per unit area of brush management ranged from 7,495 gallons/acre in the North Concho simulation to 82,561 gallons/acre in the Frio River simulation (Table 4C.15-4). The values reported in Table 4C.15-4 represent an estimate of the enhanced runoff and/or deep percolation that could be expected from brush management (i.e., the difference between the current condition with brush and the condition without brush).

Other studies in Texas have shown similar effects to those simulated for the Frio River site. For example, at the Texas Agriculture Experiment Station at Sonora, a 10-year catchment-level study of brush removal in concert with grass replacement showed an estimated 100,500 gallons per acre per year of increased deep percolation in soils with high infiltration rates.[24] However, improvements in deep percolation and runoff quantities would not necessarily result in an increase in aquifer or reservoir yields.

Table 4C.15-4.
Annual Runoff and/or Deep Percolation
for Brush Management Watersheds

Site	***Brush Management Scenario***	***Annual Runoff and/or Deep Percolation***	
		gallons/ acre	***acft/acre***
North Concho[1]	Remove all brush	7,495	0.023
Seco Creek[2]	Remove all brush	35,192	0.108
Nueces River (to confluence with Frio River at Three Rivers)[3]	Remove all brush	66,791	0.205
Frio River (to Choke Canyon Reservoir) [3]	Remove all brush	82,561	0.253

[1] Source: Bach and Connor, December 1998.
[2] Source: Walker, et al., December 1998.
[3] Source: Bach and Connor, November 2000.

In November 2000, SWAT models[25] were used to simulate effects of brush removal on increased runoff water for Upper Nueces River watershed (at junction with Frio River just below Choke Canyon Lake) and Frio River (upstream of Choke Canyon Lake) during 1960 through 1998. For the upper Nueces River watershed, the results indicated that if 74 percent of the

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[24] Thurow, T. L., Op. Cit., 1998

[25] Rosenthal, Wesley, "Nueces and Frio River Watershed- Hydrologic Simulation", Brush Management/Water Yield Feasibility Studies for Eight Watersheds in Texas, Nov 2000.

4,283,000 acre watershed was treated for brush removal (i.e., 3,188,800 acres) then an additional flow of 523,141 acft to Lake Corpus Christi could be expected.[26] The Frio River results indicated that if 66 percent of the 1,329,094 acre watershed was treated for brush removal (i.e., 882,883 acres) then an additional average flow of 59,806 acft to Choke Canyon could be expected.[27] Over 50 percent of the watershed area where brush removal was simulated contained slopes less than 10 percent, replacing brush with grass.

For the 2006 South Central Texas Regional Water Plan[28], an Hydrologic Simulation Program – Fortran (HSPF) model was used to evaluate Nueces and Blanco River Watersheds for a 65-year simulation (1934 – 1998) to determine the effects of brush management. The Nueces Basin shady area included contributing watershed area upstream of USGS Gage 08192000 (Nueces River below Uvalde). The Blanco Basin study area included Blanco River watershed area upstream of USGS Gage 08171300 (Blanco River near Kyle).

According to HSPF model results, brush management on the Nueces River watersheds is estimated to increase recharge in the Nueces Recharge Basin an average of 9,862 acft/yr (or 8.6% increase when compared to recharge without brush management. For the 5-year drought period[29] (1952 – 1956), the estimated increase in Edwards Recharge in the Nueces Basin is 920 acft/yr (or 2.2%).

Brush management on the Blanco River watershed is estimated to increase recharge in the Blanco Recharge Basin an average of 4,815 acft/yr. For the 5-year drought (1952 – 1956), the estimated increase in Edwards Recharge in the Blanco Basin is 2,215 acft/yr (or 7.3%).

This recharge enhancement information was then processed by an Edwards Aquifer model (GWSIM4) to quantify potential increases in sustained yield.[30] GWSIM4 Edwards Aquifer groundwater flow model developed by the Texas Water Development Board simulates Edwards Aquifer response in terms of water levels and springflows for specified recharge and

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[26] Assumes a delivery rate of 80 percent, which accounts for stream channel transmission losses from junction at Three Rivers to Lake Corpus Christi and shallow soils that allow for percolation.

[27] Assumes a delivery rate of 26 percent to account for stream channel losses that occur after water leaves each subbasin.

[28] South Central Texas Regional Water Plan, 2006.

[29] The Nueces and Blanco Basins drought of record was from 1952 through 1956, according to NWS precipitation gage data (16.8 inches of rainfall in Nueces Basin and 25.4 inches of rainfall in Blanco Basin, based on 5-year precipitation average from 1934 – 1998).

[30] Sustained yield of the Edwards aquifer is defined as the amount of pumped from the Edwards such that a simulated minimum flow at Comal Springs is protected during the drought of record (in this case, 60 cfs).

pumping rates. The brush management option evaluated for the Nueces and Blanco Basins is calculated to increase sustained yield by 1,728 acft/yr and 540 acft/yr, respectively. It is emphasized, however, that these recharge estimates pertain only to the Edwards Aquifer area and are not necessarily applicable to other aquifers.[31]

Although these brush management projects[24,27] could potentially provide additional water opportunities for Region N, to determine these benefits would require additional studies to translate increased annual flow to Choke Canyon Reservoir and Lake Corpus Christi to firm yield.

As part of the 2011 Regional Water Planning process, the South Central Texas Region completed additional studies of brush management on the upper reaches of the Guadalupe River.

4C.15.2.5 Preliminary Evaluation of Areas within the Coastal Bend Region where Brush Management Can Potentially Increase Runoff and/or Deep Percolation

There are an estimated 4.26 million acres of brush cover located on 10 percent slopes in the Coastal Bend Region (Table 4C.15-5).

4C.15.3 Environmental Issues

The process of brush management targets blackbrush, mesquites and other brush that compete with native grasses for water and nutrients. Recent studies conducted on Blackland prairie demonstrated both a rebound of grasses and increased surface water. However, there are concerns about the techniques used to remove brush. These concerns are mention and described below.

Chaining, cabling, disking and other mechanical methods that strip brush also remove wildlife habitat and expose surfaces to erosion by wind and water. Species that reside in brush habitat can be killed by these techniques. Low impact, hand techniques, that clear brush in a patchwork fashion, leaving brush berms to control erosion and provide protection for wildlife have proven effective in allowing native range recovery and would be consistent with the brush management option. A range management plan to protect well-populated species, and federal and state protected species should be designed to implement this option and avoid taking

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[31] For a more detailed discussion of this brush management study, see Section 4C.28 in the 2006 South Central Texas Regional Water Plan.

Table 4C.15-5. Approximate Brush Covered Areas with Slopes less than 10 Percent[1]

County	*Live Oak Woods/ Parks (acres)*	*Mesquite and Blackbrush Brush (acres)*	*Mesquite, Live Oak, and Blue Wood Parks (acres)*	*Mesquite and Granjeno Parks (acres)*	*Mesquite and Granjeno Woods (acres)*	*Totals*	*Percentage of Total County Area (percent)*
Aransas	37,692	0	0	10,050	0	47,742	30
Bee	0	137,430	118,344	0	0	255,774	45
Brooks	121,823	2,331	0	434,802	0	558,956	93
Duval	0	667,796	0	84,884	22,201	774,881	68
Jim Wells	0	64,153	0	36,472	173,228	273,853	49
Kenedy	217,111	0	0	662,644	4,512	884,267	95
Kleberg	2,021	0	0	362,302	97,794	462,117	83
Live Oak	0	262,232	0	0	0	262,232	40
McMullen	0	510,629	0	0	7,539	518,168	73
Nueces	2,689	36,807	0	29,567	0	69,063	13
San Patricio	17,738	34,212	40,970	0	0	92,920	21
Totals	399,074	1,715,590	159,314	1,620,721	305,274	4,199,973	—

[1] Based on Texas Parks and Wildlife GIS database, assuming 15 percent of total areas are suitable for viable grasses replacing brush (i.e., slopes less than 10percent).

protected species. Important species that could possibly be affected by a decrease in brushland are notable. The endangered Ocelot and Jaguarundi reside in dense brushlands, along with the Texas Horned Lizard, Texas Tortoise and Spot-tailed Earless Lizard to name a few. Conversely, allowing the brush to remain may also yield consequences. Brush populations that rapidly expand can result in a decrease in favorable vegetation for livestock and wildlife.[32] Occasionally the overwhelming density of brush can even limit the movement of wildlife within the vicinity. A survey of species that may inhabit any possible study areas would need to be conducted and evaluated.

The chemical method of controlling brush should be implemented only after very thorough evaluation because of the risk of chemical runoff into streams and penetration into the

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[32] Hart, Charles and Allan McGinty, “Treatment Life Following Control of Mixed Brush in the Davis Mountain Area,” 1998.

underlying aquifers. The chemicals used to remove unwanted vegetation may also be detected in surface water sources or affect air quality as they can be sprayed from the air or directly onto the brush. The concentration, type and quantity of chemicals applied should be very carefully assessed to determine exact consequences.

4C.15.4 Engineering and Costing

The 2011 South Central Texas Regional Water Plan estimates unit water costs range from $799 to $897 per acft at a participation level of 50% and 25% over the study period respectively. These costs are based on enhancements to the firm yield at Canyon Reservoir of 12,180 acft/ye with a 50% participation rate and 5,590 acft/yr with a 25% participation rate. These costs are not necessarily applicable to other basins and effects of brush management projects would be different for other aquifer systems.

The cost of enhanced water yield from brush management cannot be estimated for the Coastal Bend Region because associated hydrologic data are not adequate to determine any increases in water supply yield for Choke Canyon Reservoir/Lake Corpus Christi system. However, the costs of brush management can be reasonably estimated because of the studies of brush management practices in Texas, for Nueces and Frio River watersheds (Table 4C.15-6). The costs in Table 4C.15-6 were computed using 20 years as the project horizon, 6 percent interest, and the initial, year 4, and periodic costs in Table 4C.15-3 for brush management.

Table 4C.15-6.
Present Worth and Uniform Annual Costs for
30-Year Brush Management Projects under Varying Brush Conditions

Brush Condition	Total Discounted Present Value Per Acre (September 2008 Costs)	Discounted (Uniform) Annual Cost (per acre)[1]
Heavy mesquite	$214	$19
Moderate mesquite	$204	$18
Light mesquite	$204	$18

[1] Amortized over 20 years at 6 percent interest.

Three assumptions have been made to simplify the estimation of brush management cost:

1. The removal of the brush in the Coastal Bend Region that contains a significant population of live oak trees would cost about the same as removal of heavy mesquite ($19/acre/year, September 2008 prices), as with the mesquite and granjeno woods.

2. The “mesquite and blackbrush” and the “mesquite and granjeno parks” areas in the Texas Parks and Wildlife Department database are the equivalent of moderate growths shown in Table 4C.15-7 and are estimated to cost $18 per year per acre.

The average annual cost per acre for each county (Table 4C.15-8) is determined by dividing the total annual costs in Table 4C.15-7 by the estimated acreages in Table 4C.15-5, which are the estimated areas that might increase runoff and/or deep percolation as a result of brush management. Estimated annual costs of brush management in counties in the Coastal Bend Region range from $881,269 in Aransas County to $15.9 million in Kenedy County (Table 4C.15-7).

Table 4C.15-7.
Annual Cost of Brush Management for Counties in the Coastal Bend Region (Updated to September 2008 Prices)

County	*Live Oak Woods/ Parks*	*Mesquite and Blackbrush Brush*	*Mesquite, Live Oak, and Blue Wood Parks*	*Mesquite and Granjeno Parks*	*Mesquite and Granjeno Woods*	*Totals*
Aransas	$702,948	—	—	$178,321	—	$881,269
Bee	—	$2,438,481	$2,207,097	—	—	$4,645,577
Brooks	$2,271,975	$41,361	—	$7,714,866	—	$10,028,202
Duval	—	$11,848,970	—	$1,506,129	$414,053	$13,769,152
Jim Wells	—	$1,138,290	—	$647,130	$3,230,661	$5,016,080
Kenedy	$4,049,079	—	—	$11,757,551	$84,139	$15,890,769
Kleberg	$37,700	—	—	$6,428,462	$1,823,832	$8,289,994
Live Oak	—	$4,652,891	—	—	—	$4,652,891
McMullen	—	$9,060,297	—	—	$140,599	$9,200,896
Nueces	$50,149	$653,076	—	$524,623	—	$1,227,848
San Patricio	$330,818	$607,046	$764,083	—	—	$1,701,947
Totals	**$7,442,668**	**$30,440,412**	**$2,971,179**	**$28,757,082**	**$5,693,284**	**$75,304,625**

Table 4C.15-8.
Average Annual Cost of Brush Management for Counties in the Coastal Bend Region (Updated to September 2008 Prices)

County	*Annual Average Cost per Acre*	*County*	*Annual Average Cost per Acre*
Aransas	$18.46	Kleberg	$17.94
Bee	$18.16	Live Oak	$17.74
Brooks	$17.94	McMullen	$17.76
Duval	$17.77	Nueces	$17.78
Jim Wells	$18.32	San Patricio	$18.32
Kenedy	$17.97		

4C.15.5 Implementation Issues

Several implementation issues pertain to this potential water supply option. *In situ* brush management studies are only available for catchment-level examples comprising an area 1,000 acres or less. It is not proven that a large-scale brush management program would be practical because it would require the cooperation of many different landowners having different interests in their property. To make a significant impact upon increasing the yield of recharge to the Carrizo-Wilcox, Gulf Coast Aquifers and/or the CCR/LCC System, brush management would have to be practiced over a considerable area. In a specific target watershed, there may be property owners who are not dependent on grazing income and therefore have limited interest in brush management. To ensure cooperation of these ranch owners, additional subsidies or other consideration may be required which could alter the cost profiles for brush management.

Another issue is that most of the assumptions and results presented above are based on computer modeling rather than *in situ* examples that have the benefit of several years of performance to demonstrate results. It would be recommended that much more research be performed *in situ* at specific sites before public funds are invested in major projects.

One critical implementation issue is how the increase in runoff and/or recharge resulting from brush management would be related to water supply yield. Key questions that need answers are:

- How are the increased runoff and/or recharge verified?
- How much of the increased runoff and/or recharge results in yields of affected aquifers and/or reservoirs? and
- How is the increased yield of the affected aquifers and/or reservoirs verified?

4C.15.6 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Table 4C.15-9.

Table 4C.15-9.
Evaluation Summary of Brush Management to
Enhance Water Supply Yield

Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Indeterminate reliable quantity
2. Reliability	2. Unknown
3. Cost of Treated Water	3. Unknown
b. Environmental factors	
1. Instream flows	1. May increase water runoff and instream flows
2. Bay and Estuary Inflows	2. May increase bay and estuary inflows.
3. Wildlife Habitat	3. Brush control techniques may adversely affect existing wildlife populations
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. May have negative affect on habitats for endangered species.
6. Cultural Resources	6. Chemical brush management methods may result in residual chemicals in aquifers and streams.
7. Water Quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	7. None or low impact.
c. Impacts to State water resources	• No apparent negative impacts on other water resources • Potential benefit to Gulf Coast and Carrizo-Wilcox water resources due to increased water for recharge • Potential benefits to surface reservoirs from increased runoff
d. Threats to agriculture and natural resources in region	• Potential threats to habitat due to removal of brush
e. Recreational impacts	• Could impact hunting
f. Equitable comparison of strategies	• Cost model for brush management is based on literature values • No estimate made for cost of water supply yield because yield not determined
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions
j. Effect on navigation	• None

4C.16 Weather Modification (N-16)

4C.16.1 Description of Strategy

Weather modification as it has been applied in Texas over the past 25 to 30 years involves cloud seeding to increase rain above what would have naturally occurred. The result of cloud seeding is referred to as rainfall enhancement. The concept of how this occurs is described below.

In natural rainfall, droplets are created from the presence of ice particles (crystals) in the cloud. These crystals are formed when freezing water contacts particles of dust, salt or sand. The ice crystals form a nucleus around which water droplets attach to make the size of the droplet increase. When the size of a droplet increases sufficiently, it becomes a raindrop and falls from the cloud. Cloud seeding is thought to increase the number of these “nuclei” available to take advantage of the moisture in the cloud to form raindrops that would not have otherwise formed. To be effective, seeding must be done at the correct time and in the correct manner.

As a cloud grows taller, the air temperature in the cloud cools and falls below the freezing point of water. This cooling effect means that the cloud droplets, which are much too small to fall as rain, are also cooled to a point where they respond to crystallization when contacted by an ice particle. Consequently, when there are fewer crystals to act as nuclei for raindrops, there will be less rain than would have been if more crystals were present. Although crude experiments to enhance rainfall were attempted in the U.S. as early as the mid-1800s, modern weather modification was begun in 1946 through an unintended laboratory event.

In 1946, V. Schaefer was involved with the General Electric Laboratory doing research to create artificial clouds in a chilled chamber. During one experiment, Schaefer believed the chamber was too warm and, to cool it, he placed dry ice in the chamber. With the chilled water vapor in the chamber, ice crystals formed a cloud around the dry ice. Believing dry ice would not be practical to transport to emerging rain clouds, Schaefer’s colleague, Bernard Vonnegut, searched for a chemical that almost exactly matched the chemical structure of ice crystals. It was found that silver iodide (AgI) was such a chemical.[1] Silver iodide is termed “glaciogenic” because its chemical structure is like ice crystals. The other seeding chemical used when the cloud temperature is too warm for forming ice is calcium chloride (CaCl). Calcium chloride is “hygroscopic,” which means it attracts water.

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[1] Jensen, Ric, “Does Weather Modification Really Work?” Texas Water Resources, Summer 1994.

When silver iodide is introduced into a cloud, the number of ice crystals increases and the crystals contact water vapor causing it to freeze to the crystal. Considerable heat is released to the atmosphere during the freezing and crystal formation phase. The released heat causes the cloud to grow taller and its vertical wind velocity (updraft) to increase. This results in the cloud being able to pull in more moist air and, thus, create more raindrops. However, not all clouds are potential rainmakers. Generally, cloud seeding is performed with a meteorologist working in tandem with the pilot of the cloud seeding aircraft so that, with direction from the meteorologist, the pilot can target the most promising cloud(s).[2] The criteria used in Texas to find promising clouds, is to locate "feeder" cells near developing cloud formations that have temperatures below 23^o F. The target cloud must also have sufficient moisture and airflow to be a candidate. About 20 or 30 minutes prior to the desired rainfall event, the candidate cloud is seeded when the airplane releases silver iodide particles in a plume, typically at the base of the cloud so the updraft can draw the particles upward and make more contact with water in the cloud. Seeding has another effect on large, potentially dangerous thunderstorms capable of causing hail. Seeding tends to mitigate the extreme freezing that results in forming large particles of ice (hail) and makes the moisture more likely to fall as rain.

The criteria for cloud seeding based on experience in Texas since the early 1970s are the following:

- The cloud must be "convective," meaning that it displays instability in the atmosphere.
- Temperature at the top of the cloud must be 23^o F or less.
- The base of the cloud must be less than 12,000 feet elevation.

Clouds having the characteristics listed above exhibit a warm base, a strong updraft, and sufficient heat to carry water vapor to the cloud top.

A summary of recent cloud seeding experiments in Texas, Florida, Cuba, and Southeast Asia has been presented by TCEQ.[3] The TCEQ concludes the following:

- Cloud seeding with silver iodide increases rain generated by these clouds by extending the life of the clouds, by allowing the clouds to enlarge laterally so that they cover more area, and by slightly increasing the height of the clouds.

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[2] Clouds may also be seeded using ground-based silver iodide dispensers. However, in this discussion, only the aircraft method is considered.

[3] Bomar, George, "Some Facts about Cloud Seeding from Recent Research on Rain Enhancement in Texas," Texas Commission on Environmental Quality, 1999.

- Rain production of seeded clouds is more efficient than for non-seeded clouds.
- The timing of seeding and the selection of clouds are fundamental. These are such critical factors that "…seeding at the wrong time and in the wrong place(s) may actually decrease the rainfall."[4]

4C.16.2 Potential Rainfall Quantities from Weather Modification

The findings from several Texas cloud seeding programs are summarized below. This information provides a basis for evaluating the reasonableness of assumptions for weather modification in the Coastal Bend Region. The programs to be discussed are the Southwest Cooperative Program (SWCP), the Texas Experiment in Augmenting Rainfall through Cloud-Seeding (TEXARC), the Colorado River Municipal Water District (CRMWD) Program, the Edwards Aquifer Authority (EEA) Program, the South Texas Weather Modification Association (STWMA) Program, and the Southwest Texas Rain-Enhancement Association (SWTREA) Program. Each of these programs is described below.

Southwest Cooperative Program (SWCP): The program was begun in 1986 as a cooperative effort between Oklahoma and Texas "…to develop a scientifically sound, environmentally sensitive, and socially acceptable, applied weather modification technology for increasing water supplies…in the southern High Plains."[5] The area involved was 5,000 square miles located between Midland-Odessa and Lubbock. Random cloud seeding experiments were conducted in 1986, 1987, 1989, 1990, and 1994.

During the period 1987 through 1990, 183 experiments were made (93 seeded, 90 non-seeded). The criteria for selection were the following:

- Liquid water content had to be at least 0.5 gm/m^3 and updrafts had to be at least 1,000 ft/min.
- The target had to be a multiple-cell convective unit.
- No cloud or cell height could exceed 10 km (above ground level).
- Some of the tops had to have temperatures -10^{o} C or colder.

The results confirmed increased rainfall. Compared to the non-seeded cells, the seeded cells displayed an increase in maximum height of 7 percent, an increase in the coverage of the rainfall

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[4] Ibid.

[5] Bomar, George, William L. Woodley, and Dale L. Bates, "The Texas Weather Modification Program: Objectives, Approach, and Progress," Journal of Weather Modification, April 1999.

event of 43 percent, an increase in the storm duration of 36 percent, and an increase in rain volumes of 130 percent.[6]

Texas Experiment in Augmenting Rainfall through Cloud Seeding (TEXARC): The State of Texas implemented the program in 1994 and 1995 to investigate physical processes within large storms in the San Angelo area. This research was focused on understanding the best ways of seeding clouds to make them more efficient producers of water, rather than quantifying the results. The results showed that seeding must be within the super-cooled updraft region of the cloud in order to increase rainfall. From this research it was shown that the seeding agent must be carefully placed either directly in the top of the updraft, or at the entrance to the updraft at the base of the cloud.

Colorado River Municipal Water District (CRMWD) Program: Having been started in 1971, this is the longest-running operational weather modification program in Texas. The target area is roughly the upper Colorado River Basin upstream from Spence Reservoir, comprising some 3,600 square miles. The goals for the program have always been first, to increase water supplies to Lake Thomas and Spence Reservoir, and secondly, to increase rainfall to agricultural areas. The reported long-term results are that there was a 34 percent increase (above normal historic precipitation) in the seeded areas and a 13 percent increase in non-seeded areas.[7,8]

Edwards Aquifer Authority (EAA) Program: (*substantial portions of this program description were reproduced from the EEA web page, e-aquifer.com, and are presented here unedited*)

"The Edwards Aquifer Authority board of directors voted in the fall of 1997 to obtain a permit to conduct precipitation enhancement, or cloud seeding, from the Texas Natural Resources Conservation Commission (now TCEQ). The Authority contracted with Weather Modification, Inc., to complete and submit the permit application on the Authority's behalf, and work with the TCEQ. The permit was granted by TCEQ in October 1998 and was valid for 4 years from January 1999 through December 2002. The permit allowed the Authority to conduct precipitation enhancement anytime during the year, including the traditional period of

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[6] Rosenfeld, D. and W. L. Woodley, "Effects of Cloud Seeding in West Texas: Additional Results and New Insights," Journal of Applied Meteorology, 1993.

[7] Jones, R., "A Summary of the 1988 Rainfall Enhancement Program and a Review of the Area Rainfall and Primary Crop Yield," Report 88-1 of the Colorado River Municipal Water District, 75 pages, 1988.

[8] Jones, R., "A Summary of the 1997 Rainfall Enhancement Program and a Review of the Area Rainfall and Primary Crop Yield," Report 97-1 of the Colorado River Municipal Water District, 54 pages, 1997.

April through September. The Authority committed $500,000 for the 1999 program with half the expenses reimbursed by the TCEQ."

"Each county in the target and South Central Texas Water Advisory Committee (SCTWAC) areas of the program can appoint a representative to sit on a Precipitation Enhancement Advisory Group. The group will work with the Authority in alerting the contractor about local conditions. The ways this committee has worked included communicating saturation conditions so that flights are suspended to avoid flood conditions and suspending flights during harvesting of crops. The assumption for enhanced aquifer recharge was 10 percent above the recharge quantity, which would occur without enhancement."

From 1999 through 2001, the Edwards Aquifer Authority contracted Weather Modification Inc. to perform weather modification services for the EAA Precipitation Enhancement Program over the 12 target counties presented in Table 4C.16-1. Woodley Weather Consultants[9] evaluated the data collected, which included 39 seeding events for the Blanco Basin and 21 seeding events for the Nueces Basin. This study area included six of the 12 target counties, including Kendall, Blanco, Hays, Comal, Real, and Uvalde Counties. In 2003, a study[10] was conducted to determine enhanced recharge attributable to the 1999 to 2001 seeding events, which concluded that the total increased recharge during the 3-year period was 1,972 acft in the Nueces Basin (a 0.29 percent increase) and 1,332 acft in the Blanco Basin (1.13 percent increase).[11]

Table 4C.16-1.
Edwards Aquifer Authority Weather Modification Program Counties

Target Counties	*Operational Counties*	*SCTWAC Counties*[1]
Bandera, Bexar, Blanco, Caldwell, Comal, Guadalupe, Hays, Kendall, Kerr, Medina, Real (east of U.S. Highway 83), and Uvalde	Gillespie, portions of Atascosa, Burnet, Frio, Kimble, Llano, Real, Wilson, and Zavala	Calhoun, DeWitt, Goliad, Gonzales, Karnes, Nueces, Refugio, San Patricio, Victoria, Atascosa, Wilson, Uvalde, Medina, Bexar, Comal, Hays, Guadalupe, and Caldwell
[1] Coastal Bend Water Advisory Committee (SCTWAC), as created by Senate Bill 1477.		

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[9] Edwards Aquifer Authority, "Rainfall Data Summary and Assimilation," December 2002.

[10] LBG-Guyton Associates, "Assessment of Recharge Benefit from Enhanced Rainfall," June 2003.

[11] Note: Only half of the Nueces Basin was in the cloud seeding zone, which may have reduced the impact of cloud seeding on recharge in that basin.

In 2002, the Authority's Precipitation Enhancement Program was reduced to target Bandera, Bexar, Medina, and Uvalde Counties. South Texas Weather Modification Association was contracted by the Authority to seed Bexar, Bandera, and Medina Counties. Southwest Texas Rain Enhancement Association was contracted to seed Uvalde County. The current weather modification programs in South Central Texas and counties where they operate are presented in Figure 4C.16-1.

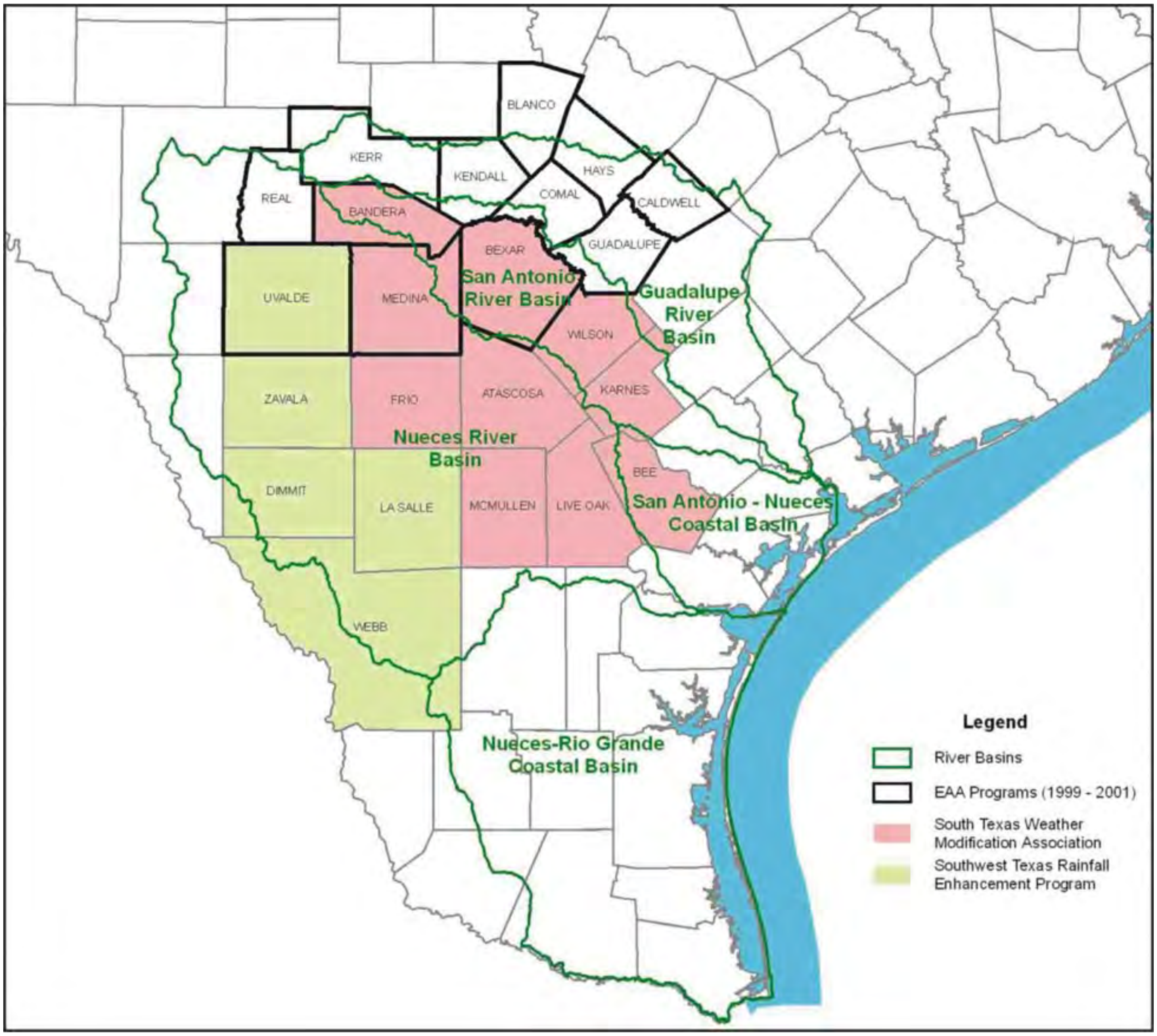

Figure 4C.16-1. South Central Texas Weather Modification Programs

South Texas Weather Modification Association (STWMA) Program: This program started in 1997 when the Evergreen Water District hired a contractor to conduct cloud seeding. In 1998, the addition of two pilots, a meteorologist, and the purchase of two planes enhanced this program considerably. The counties involved in the cloud seeding include Atascosa, Bee, Frio, Karnes, Live Oak, McMullen, and Wilson Counties. Since 2002, Bexar, Bandera, and Medina Counties have been added to the program. According to the 2004 STWMA Annual Evaluation Report, an increase of 1,225,900 acft (2.23 inches) was reported across the ten-county program area attributable to 45 seeding events between April 2, 2004, and October 27, 2004. This translates to a precipitation increase of 10.4 percent, on average, with the weather modification program. The highest precipitation increase was recorded for Atascosa County, at 14.8 percent. The three counties in Region N included in the program with reported precipitation increases are presented in Table 4C.16.2. The last documented seeding mission by STWMA occurred in August 2009, and cloud seeding was performed over Live Oak, Wilson, Medina, Bexar, Bee, Karnes, San Patricio, McMullen, Atascosa, DeWitt, Bandera, Frio, and Goliad counties.

Table 4C.16-2.
Weather Modification Precipitation Enhancements in Region N Counties (2004)

Region N Counties	Increases in Precipitation		
	(acft)	(inches)	(% increase)
Bee	123,900	2.64	12.2
Live Oak	117,500	2.13	11.0
McMullen	126,800	2.14	10.2

Southwest Texas Rainfall Enhancement Association (SWTREA) Program: This program began in 1999 and is currently operated by the Wintergarden Groundwater Conservation District in Carrizo Springs, Texas. This program was the first of the nine existing weather modification programs in Texas to evaluate the suppression of hail. The original program consisted of Dimmit, LaSalle, and Webb Counties but was expanded in 2002 to include Uvalde County. According to the 2003 SWTREA Annual Evaluation Report, an increase of 36,773 acft (0.78 inches)[12] was reported over Uvalde County associated with 18 seeding events between

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[12] Precipitation increase (in inches) was calculated by dividing acft increase by area of seeded sample (acres).

May 26, 2003, and October 6, 2003. This translates to a precipitation increase of 5 percent for Uvalde County with the SWTREA weather modification program. The SWTREA four-county program area lies within the Nueces River Basin, and although it may increase water availability in Region N, it is difficult to quantify the additional supply produced by weather modification programs due to high variability in additional rainfall and lack of reliability. With operational seasons running from March 15 through November 15, the year 2010 marks the eleventh season of SWTREA operations.

Rainfall Enhancement Programs in Texas during Spring 2004: There were nine cloud seeding programs in Texas that were funded, at least partially, by State funds from the Texas Department of Licensing and Regulation in the spring of 2004. The funds were apportioned in amounts up to $0.045 per acre to help counties pay for weather modification programs. The State contributed $1.82 million to sponsoring programs during the spring and summer of 2003. No new funds were appropriated during the 78th Legislative Session. The programs, the counties they cover and the approximate areas of coverage are presented in the Table 4C.16-3.

Although rainfall enhancement through cloud seeding has been practiced and studied in Texas and other states for many years, the benefits of rainfall enhancement for increasing water yield are not well determined. There is documentation regarding other benefits of cloud seeding, particularly with regard to impacts on agricultural production. The following section provides descriptions of quantified benefits resulting from cloud seeding in Texas and an estimate of the benefits to the region.

4C.16.3 Potential Quantities of Water Supply Resulting from Weather Modification in the Coastal Bend Region

The benefits resulting from cloud seeding in the Coastal Bend Region may include improvements in environmental and economic conditions. Environmental conditions in a stream, estuary, or lake can be improved by increased freshwater flows and the improvements can be measured using water quality parameters and aquatic life. Economic conditions can be improved by increasing crop production, by increasing animal production as a result of increasing the food supply, and by increasing ground and surface water supplies. Increasing water supplies can further improve economic conditions by affecting recreation, agriculture, municipal, and industrial activities in beneficial ways.

Table 4C.16-3.
Cloud Seeding Programs in Texas (Spring 2004)

Cloud Seeding Program	Counties Involved	Area (sq. miles)
Colorado River Municipal Water District	Borden, Mitchell, and parts of Dawson, Howard, Sterling, Nolan, and Scurry	3,500
West Texas Weather Modification Association	Glasscock, Reagan, Crockett, Sutton, Schleicher, Irion and part of Tom Green	9,688
South Texas Weather Modification Association	Frio, Atascosa, McMullen, Live Oak, Bee, Karnes, Wilson, Bexar, Medina, Bandera	10,318
Southern Ogallala Aquifer Rain Program	Gaines, Terry, and Yoakum (Texas); and 2 million acres in eastern New Mexico near Gaines and Yoakum Counties	3,192 (in Texas)
North Plains Groundwater Conservation District	Dallam, Sherman, Hansford, Ochiltree, Lipscomb, and parts of Hartley, Moore, and Hutchinson	6,563
Panhandle Groundwater Conservation District	Carson, Donley, Gray, Roberts, and Wheeler	6,309
West Central Texas Weather Modification Association	Nolan, Taylor, Callahan, Eastland, Coke, Runnels, Coleman, Brown, and Comanche	7,656
Trans Pecos Weather Modification Association	Culberson, Loving, Reeves, and Ward	7,958
Southwest Rain Enhancement Association	Uvalde, Dimmit, La Salle, Zavala, and Webb	9,141

Performance data from cloud seeding programs typically focus on the rainfall event and parameters such as storm duration, cloud height, storm coverage (cloud area), and rainfall amount, rather than water supply parameters like increased stream flows and increased reservoir storage. Where water supply parameters have been measured in cloud seeding programs, the results appear to be positive. For example, CRMWD reservoir storage increased from 14,000 acft to 200,000 acft in Lake Spence and from 26,000 acft to 30,000 acft in Lake Thomas since the inception of cloud seeding in the Big Spring and Snyder areas.[13] Also, the Twin Buttes and Fisher Reservoirs increased from a combined 40,000 acft to a combined 230,000 acft during a cloud seeding program sponsored by the City of San Angelo between 1985 and 1989.[14]

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[13] Jensen, Ric, Op. Cit., Summer 1994.
[14] Ibid.

To determine how much additional water supply can be developed from weather modification in the Coastal Bend Region requires a sequence of information. This information sequence includes: (1) the quantity of additional rainfall developed through cloud seeding; (2) the quantity of additional runoff; and (3) the quantity of additional runoff that was ultimatelytransported to a reservoir or was recharged to an aquifer. Both the STWMA and SWTREA Programs have reported additional rainfall through cloud seeding, described above, that could have potential benefits to the Coastal Bend Region. Further studies are necessary to quantify additional water supply in the Coastal Bend Region attributable to these programs. To consider enhanced rainfall as a water management strategy would require the additional water supply to be reliable, dependable, and consistent over long-term, all of which are current limitations to weather modification programs.

In the 1994 Edwards Aquifer Recharge Enhancement Project, Phase IV A, normal and enhanced recharge rates were computed for target recharge sites. The enhanced rates were developed to simulate the additional quantities of recharge that would naturally enter the aquifer without the benefit of manmade recharge structures. This 1994 Edwards Aquifer recharge study provides a baseline case from which to compute an example of potential water supply development from weather modification, as is explained below.

One way to estimate the potential for enhancing recharge through weather modification would be to increase the precipitation at an assumed rate and recompute enhanced recharge. The EAA program described above covers the same region as the areas modeled in the 1994 study. Therefore, an estimate has been made using the Sabinal River watershed (241 square miles) model with an assumed increase in rainfall over the same years studied previously in order to determine whether estimates for recharge would show increases if rainfall increased. This modeling and resulting computations show an annual average increase in estimated recharge of 9 percent, assuming a 15 percent increase in rainfall during the warm months (April through September) for the years 1990 through 1996 (Table 4C.16-4). The model shows an annual average estimated increase of 3,173 acft (0.02 acft/acre) of recharge from the Sabinal River watershed. Although the EAA cloud seeding program covers the same areas previously modeled, an estimate of total increase in recharge resulting from the program was not developed. Since the increase in rainfall in an area where there is no pre- or post- cloud seeding data can only be assumed, it would be an inequitable comparison with most other options to extrapolate computer modeling results for the Sabinal River over the entire region. To be an equitable comparison, the results of cloud seeding in terms of increased rainfall, aquifer recharge, and reservoir storage would have to be predictable, verifiable, and comparable to unit firm yields developed from other options. Since these criteria cannot be met at this time, no such estimates can be made.

Table 4C.16-4.
Simulation of Increased Annual Edwards Aquifer Recharge Due to a 15 Percent Increase in Precipitation — Sabinal River Watershed

Year	*Baseline Recharge Estimate (acft)*	*Recharge Estimate with 15 percent Increased Precipitation (acft)*	*Difference (acft)*	*Percent Difference*
1990	32,526	35,822	3,296	10%
1991	41,319	45,361	4,042	10%
1992	67,724	72,719	4,995	7%
1993	27,761	29,745	1,984	7%
1994	24,219	26,833	2,614	11%
1995	30,855	33,574	2,719	9%
1996	10,537	13,093	2,556	24%
Average	33,563	36,736	3,173	9%

[1] The Sabinal River watershed has an area of 241 square miles, or 154,240 acres.

The 2006 South Central Texas Regional Water Plan included a more detailed analysis of a long-term weather modification program for the South Central Texas Region.[15] This effort included application of HDR's Pilot Recharge Models of the Nueces and Blanco River Basin[16] to quantify increases in streamflow and recharge enhancement to the Edwards Aquifer associated with weather modification. The Nueces Basin shady area included contributing watershed area upstream of USGS Gage 08192000 (Nueces River below Uvalde). The Blanco Basin study area included Blanco River watershed area upstream of USGS Gage 08171300 (Blanco River near Kyle).

According to HSPF model results, weather modification on the Nueces River watersheds is estimated to increase recharge in the Nueces Recharge Basin an average of 7,659 acft/yr (or 6.7% increase when compared to recharge without weather modification. For the 5-year drought

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[15] 2006 South Central Texas Regional Water Plan, Section 4C.29.

[16] HDR Engineering Inc., "Pilot Recharge Models of the Nueces and Blanco River Basins," 2002.

period[17] (1952 – 1956), the estimated increase in Edwards Recharge in the Nueces Basin is 2,639 acft/yr (or 6.3%).

Weather modification on the Blanco River watershed is estimated to increase recharge in the Blanco Recharge Basin an average of 4,250 acft/yr (or 6.4%). For the 5-year drought (1952 – 1956), the estimated increase in Edwards Recharge in the Blanco Basin is 1,093 acft/yr (or 9.2%).

This recharge enhancement information was then processed by an Edwards Aquifer model (GWSIM4) to quantify potential increases in sustained yield.[18] GWSIM4 Edwards Aquifer groundwater flow model developed by the Texas Water Development Board simulates Edwards Aquifer response in terms of water levels and springflows for specified recharge and pumping rates. Weather modification evaluated with 5 percent precipitation increase in the Nueces Recharge Basin and 6.5 percent precipitation increase in the Blanco Recharge Basin is calculated to increase sustained yield by 1,916 acft/yr and 488 acft/yr, respectively. The Nueces Basin has greater water supply benefits with a weather modification program due to its higher average annual recharge as compared with the Blanco Basin. It is emphasized, however, that these recharge estimates pertain only to the Edwards Aquifer area and are not necessarily applicable to other aquifers.

Although these weather modification projects[24,27] could potentially provide additional water opportunities for Region N, to determine these benefits would require additional studies to translate increased annual flow to Choke Canyon Reservoir and Lake Corpus Christi to firm yield.

4C.16.4 Environmental Issues

Although weather modification is not a new technique, its effectiveness has been difficult to measure. Since Texas has established a permit procedure, administered by TCEQ, data are being collected for a more scientific study of cloud seeding effectiveness and management. Originally conceived as a means to help end droughts, experience shows that cloud seeding may

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[17] The Nueces and Blanco Basins drought of record was from 1952 through 1956, according to NWS precipitation gage data (16.8 inches of rainfall in Nueces Basin and 25.4 inches of rainfall in Blanco Basin, based on 5-year precipitation average from 1934 – 1998).

[18] Sustained yield of the Edwards aquifer is defined as the amount of pumped from the Edwards such that a simulated minimum flow at Comal Springs is protected during the drought of record (in this case, 60 cfs).

work best during periods of normal rainfall. In some areas of the State, weather modification is considered a long-term water augmentation strategy for freshwater supplies.[19]

The amount of silver iodide and calcium chloride used during a seeding event is negligible and too dispersed to have a measurable effect on the environment. Safe handling and storage of these materials prior to dispersal are a larger concern. Both are normally used in industrial applications and printing. Therefore, procedures for handling and storing silver iodide are well documented. There are no known environmental problems associated with this option.

4C.16.5 Engineering and Costing

For 2004, the Edwards Aquifer Authority contracted SWTREA as part of their Precipitation Enhancement Program to perform cloud-seeding over Uvalde County at a cost of $37,951 or $0.04 per acre. The Authority also contracted STWMA to perform cloud seeding in Bandera, Bexar, and Medina Counties at a cost of $86,825 or $0.03 per acre. According to Evergreen UWCD, the full cost of the program for STWMA's 10-county region (6,603,520 acres) was $428,067 in 2003, including $215,387 in initial capital costs and $212,680 Operations and Maintenance costs, or $0.65 per acre.

The 2006 South Central Texas Regional Water Plan estimated unit water costs for weather modification which ranged from $74-$77 per acft.[20] These costs are based on increases in sustained yield from the Edwards Aquifer (1,916 acft/yr and 488 acft/yr attributed to weather modification in the Nueces Basin and Blanco Basin, respectively). For the Nueces Recharge Basin, the total annual cost for a weather modification program for Edwards, Real, Kinney, and Uvalde Counties (3,693,440 acres) is estimated at $147,740, assuming an annual cost of $0.04 per acre. For the Blanco Recharge Basin, the total annual cost for a weather modification program for Blanco and Hays Counties (901,120 acres) is estimated at $36,050, assuming an annual cost of $0.04 per acre. This cost is based on increases in sustained yield from the Edwards Aquifer and is not necessarily applicable to other basins or aquifers. These costs were not updated by the South Central Texas Regional Water Planning Group as part of the 2011 regional water planning process, citing the need for more studies to be completed in order to accurately determine the costs of weather modification.

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[19] Bomar, George, TNRCC Senior Meteorologist, Austin, Texas.

[20] These unit costs were not updated by the South Central Texas Regional Water Planning Group as part of the 2011 planning cycle. However, using the updated Construction Cost Index (CCI) value, these costs would likely be 31 to 32% higher if updated to September 2008 dollars.

4C.16.6 Implementation Issues

Weather modification in the form of cloud seeding is a beneficial, but uncertain, source of usable water. However, data are not adequate to quantify firm yield in terms of a measurable and dependable regional water supply option.

One important potential benefit of cloud seeding is that a part of the agricultural water supply needs (irrigated and dryland crops and rangelands) could be met. For example, higher rainfall would lower the quantities of irrigation water that has to be withdrawn from the aquifers and streams of the Coastal Bend Region, and dryland production would benefit from increased rainfall. This could be a significant water supply option for agricultural uses. Over a sufficient period, agricultural production data could be developed to demonstrate that crop yield, animal production, and other measurable agricultural parameters have increased as compared to the same data prior to beginning the cloud seeding program. For a relatively minor cost, cloud seeding could meet some of the agricultural needs, as well as contribute to aquifer recharge and streamflows of the region.

4C.16.7 Evaluation Summary

An evaluation summary of this strategy is included in Table 4C.16-5.

Table 4C.16-5.
Evaluation Summary of Weather Modification to Enhance Water Supplies

Impact Category	*Comment(s)*
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Variable, indeterminate quantity. 2. Low, uncertain timing. 3. Low cost.
b. Environmental factors 1. Instream flows 2. Bay and Estuary Inflows 3. Wildlife Habitat 4. Wetlands 5. Threatened and Endangered Species 6. Cultural Resources 7. Water Quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	 1. May slightly increase instream flows. 2. May slightly increase bay and estuary flows. 3. None or low impact. 4. None or low impact. 5. None or low impact. 6. None or low impact. 7. Low impact with potential for limited benefits.
c. Impacts to State water resources	• No apparent negative impacts on other water resources • Potential benefit to Gulf Coast and Carrizo Aquifers water resources due to increased water for recharge • Potential benefit to farmers and ranchers through increased rainfall
d. Threats to agriculture and natural resources in region	• Potential threats due to limited potential for increased flooding
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Cost reported in annual unit area cost only
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Improvement over existing conditions
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

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4C.17 Seawater Desalination (N-17)

4C.17.1 Description of Strategy

Desalting seawater from the Gulf of Mexico is a potential source of freshwater supplies for municipal and industrial uses. Significant cost savings may be realized from co-siting a seawater desalination facility with a power plant utilizing once-through cooling water. Therefore, the desalination facility for this option is co-sited with the Barney M. Davis Power Station in Corpus Christi near Laguna Madre, Oso Bay, and Corpus Christi Bay.

This section describes seawater desalination for a large-scale facility producing desalinated water at flows between 25 to 100 MGD (28,000 to 112,000 acft/yr).[1]

In August 2004, the City of Corpus Christi (City) conducted a feasibility study[2] funded by the Texas Water Development Board (TWDB) of a large-scale seawater desalination facility in the Region N area. This report includes a discussion of opportunities for state and/or federal participation in project development.

4C.17.1.1 General Desalination Background

Commercially available processes that are commonly used to desalt seawater to produce potable water are:

- Distillation (thermal) Processes, and
- Membrane (non-thermal) Processes.

The following section describes each of these processes and discusses a number of issues that should be considered before selecting a process for desalination of seawater.

4C.17.1.1.1 Distillation (Thermal) Processes

Distillation processes produce purified water by vaporizing a portion of the saline feedstock to form steam. Since the salts dissolved in the feedstock are nonvolatile, they remain unvaporized and the steam formed is captured as a pure condensate. Distillation processes are normally very energy-intensive, expensive, and are generally used for large-scale desalination of seawater. Heat is usually supplied by steam produced by boilers or from a turbine power cycle

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[1] The 2006 Plan included an evaluation to utilize a combination of brackish groundwater and seawater in a desalination plant to produce a range of finished water supply options from 14 to 25 MGD. For the 2011 Plan, a new study was conducted to optimize brackish groundwater desalination opportunities (Section 4C.20), resulting in a lower unit cost of finished water as compared to previous brackish groundwater and seawater combinations when updated to September 2008 prices.

used for electric power generation. Distillation plants are commonly dual-purpose facilities that produce purified water and electricity.

In general, for a specific plant capacity, the equipment in distillation plants tends to be much larger than membrane desalination equipment. However, distillation plants do not have the stringent feedwater quality requirements of membrane plants. Due to the relatively high temperatures required to evaporate water, distillation plants have high energy requirements, making energy a large factor in their overall water cost. Their high operating temperatures can result in scaling (precipitation of minerals from the feedwater), which reduces the efficiency of the evaporator processes, because once an evaporator system is constructed, the size of the exchange area and the operating profile are fixed, leaving energy transfer as a function of only the heat transfer coefficient. Therefore, any scale that forms on heat exchanger surfaces reduces heat transfer coefficients. Under normal circumstances, scale can be controlled by chemical inhibitors, which inhibit but do not eliminate scale, and by operating at temperatures of less than 200 degrees Fahrenheit.

Distillation product water recoveries normally range from 15 to 45 percent, depending on the process. The product water from these processes is nearly mineral-free, with very low total dissolved solids (TDS) (less than 25 mg/L). However, this product water is extremely aggressive and is too corrosive to meet the Safe Drinking Water Act corrosivity standards without post-treatment. Product water can be stabilized by chemical treatment or by blending with other potable water.

The three main distillation processes in use today are Multistage Flash Evaporation (MSF), Multiple Effect Distillation (MED), and Vapor Compression (VC). All three of these processes utilize an evaporator vessel that vaporizes and condenses the feedstock. The three processes differ in the design of the heat exchangers in the vessels and in the method of heat introduction into the process. Since there are no distillation processes in Texas that can be shown as comparable installations, distillation will not be considered here. However, there are membrane desalination operations in Texas, so the following discussion and analyses are based upon information from the use of membrane technology for desalination.

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[2] City of Corpus Christi, Draft Report “Large Scale Demonstration Desalination Feasibility Study,” August 2004.

4C.17.1.1.2 Membrane (Non-thermal) Processes

The two types of membrane processes use either pressure—as in reverse osmosis (RO)—or electrical charge—as in electrodialysis reversal (EDR)—to reduce the mineral content of water. Both processes use semi-permeable membranes that allow selected ions to pass through while other ions are blocked. EDR uses direct electrical current applied across a vessel to attract the dissolved salt ions to their opposite electrical charges. EDR can desalinate brackish water with TDS up to several thousand milligrams per liter, but energy requirements make it economically uncompetitive for seawater, which contains approximately 35,000 mg/L TDS. As a result, only RO is used for seawater desalination.

RO utilizes a semi-permeable membrane that limits the passage of salts from the saltwater side to the freshwater side of the membrane. Electric motor-driven pumps or steam turbines (in dual-purpose installations) provide the 800 to 1,200 pounds per square inch (psi) pressure to overcome the osmotic pressure and drive the freshwater through the membrane, leaving a waste stream of brine/concentrate. The basic components of an RO plant include pre-treatment, high-pressure pumps, membrane assemblies, and post-treatment. Pretreatment is essential because feedwater must pass through very narrow membrane passages during the process and suspended materials, biological growth, and some minerals can foul the membrane. As a result, virtually all suspended solids must be removed and the feedwater must be pre-treated so precipitation of minerals or growth of microorganisms does not occur on the membranes. This is normally accomplished by using various levels of filtration and the addition of various chemical additives and inhibitors. Post-treatment of product water is usually required prior to distribution to reduce its corrosivity and to improve its aesthetic qualities. Specific treatment is dependent on product water composition.

A "single-pass/stage" seawater RO plant will produce water with a TDS of 300 to 500 mg/L, most of which is sodium and chloride. The product water will be corrosive, but this may be acceptable, if a source of blending water is available. If not, and if post-treatment is required, the various post-treatment additives may cause the product water to exceed the desired TDS levels. In such cases, or when better water quality is desired, a "two-pass/stage" RO system is used to produce water typically in the 200 mg/L TDS range. In a two-pass RO system, the concentrate water from the first RO pass/stage is further desalted in a second RO pass/stage, and the product water from the second pass is blended with product water from the first pass.

Recovery rates up to 45 percent are common for a two-pass/stage seawater RO facility. RO plants, which comprise about 47 percent of the world's desalting capacity, range from a few gallons per day to 35 MGD. The largest RO seawater plant in the United States is the 25-MGD plant in Tampa Bay, Florida. The current domestic and worldwide trend seems to be for the adoption of RO when a single purpose seawater desalting plant is to be constructed. RO membranes have been improved significantly over the past two decades (i.e., the membranes have been improved with respect to efficiency, longer life, and lower prices). Municipal use desalination plants in Texas that use lake water, river, or groundwater are shown in Table 4C.17-1. The plant capacities range from 0.1 MGD (Homestead MUD-El Paso) to 10 MGD (Lake Granbury).

Table 4C.17-1.
Municipal Use Desalt Plants in Texas
(>25,000 gpd and as of June 2004)

Location	Source	Total Capacity (MGD)	Desalt Capacity (MGD)	Membrane Type[1]
Abilene, City of	Lake Water	5	3	RO
Bardwell, City of	Groundwater	0.12	0.12	RO
Bayside, City of	Groundwater	0.15	0.15	RO
Brownsville, City of	Groundwater	7.5	7.5	RO
Burleson County MUD 1	Groundwater	0.43	0.43	RO
Country View Estates	Groundwater	0.18	0.18	RO
Dell City, City of	Groundwater	0.11	0.11	EDR
Electra, City of	Groundwater	2.23	2.23	RO
El Paso County Water Auth.	Groundwater	2.29	2.29	RO
Ft. Stockton, City of	Groundwater	6.5	3.67	RO
Granbury, City of	Lake Water	0.35	0.35	EDR
Haciendas del Norte (El Paso)	Groundwater	0.12	0.12	RO
Homestead MUD (El Paso)	Groundwater	0.1	0.1	RO
Kenedy, City of	Groundwater	2.86	0.72	RO
Lake Granbury	Lake Water	10	10	RO
Lake Granbury	Lake Water	5	5	EDR
Los Ybanez, City of	Groundwater	0.11	0.11	RO
Oak Trail Shores	Lake Water	0.72	0.72	EDR
Robinson, City of	River	2.38	2.38	RO
Seadrift, City of	Groundwater	0.24	0.17	RO
Sherman, City of	Lake Water	5.6	5.6	EDR
Sportsman’s World	Lake Water	0.17	0.17	RO
Tatum, City of	Groundwater	1.14	1.14	RO
Texas Resort Co.	Lake Water	0.144	0.144	EDR

[1] RO = Reverse Osmosis EDR = Electrodialysis Reversal

Source: Partial information obtained from Texas Commission on Environmental Quality, 2003.

4C.17.1.1.3 Examples of Relevant Existing Desalt Projects

Seadrift, Texas: In 1996, Seadrift (retail population 1,890) was dependent on the Gulf Coast Aquifer for its water supply. TDS and chlorides had reached unacceptable levels of 1,592 mg/L and 844 mg/L, respectively. These values exceeded the primary drinking water standard for TDS (1,000 mg/L) and the secondary drinking water standard for chlorides (300 mg/L). Since the community was not located near an adequate quantity of freshwater or a wholesaler of drinking water, the decision was made to install RO to treat this slightly brackish groundwater. The city installed pressure filters, two RO units, antiscalant chemical feed equipment, and a chlorinator. The capital cost for the system was $1.2 million and the annual operation and maintenance (O&M) cost is $56,000, resulting in a total debt service plus O&M cost of about $0.88 per 1,000 gallons treated by RO. The capital cost included the cost of facilities in addition to the RO units and their appurtenant equipment. Product water from the RO units is blended with groundwater to meet an acceptable quality level. About 60 percent of the total is from the desalt units.

Tampa, Florida: The water utility, Tampa Bay Water, selected a 30-year design, build, operate, and own (DBOO) proposal to construct a nominal 25 MGD seawater desalt plant. The plant will use RO as the desalt process. The proposal included total capitalization and operations costs for producing high quality drinking water (chlorides less than 100 mg/L). The total cost to Tampa Bay Water in the original proposal was to be $2.08 per 1,000 gallons on a 30-year average, with first year cost being $1.71 per 1,000 gallons. However, subsequent issues with the original design including significant problems in obtaining adequate pretreatment have increased the projected total cost to Tampa Bay Water by $0.72 per 1,000 gallons for a total projected cost of $2.80 per 1,000 gallons on a 30-year average.[3] The results of Tampa Bay's competition has attracted international interest in the current cost profile of desalting seawater for drinking water supply, since these costs are only about one-half the levels experienced in previous desalination projects.

Tampa Bay Water selected the winning proposal from four DBOO proposals submitted, which ranged from $2.08 to $2.53 per 1,000 gallons. The factors listed below may be all or partially responsible for these seemingly low costs:

1. Salinity at the Tampa Bay sites ranges from 25,000 to 30,000 mg/L, lower than the more common 35,000 mg/L for seawater. RO cost is sensitive to salinity.

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[3] Associated Press, "Tampa Bay Water to Hire Group to Fix Desalination Plant," September 21, 2004.

2. The power cost, which is interruptible, is below $0.04 per kilowatt-hour (kWh).
3. Construction cost savings through using existing power plant canals for intake and concentrate discharge.
4. Economy of scale at 25 MGD.
5. Amortizing over 30 years.
6. Use of tax-exempt bonds for financing.

The Tampa bids contrast with another current large-scale desalination project in which distillation is proposed. The current desalt project of the Singapore Public Utility Board, which proposes a 36 MGD multi-stage flash distillation plant, will cost an estimated $5.76 per 1,000 gallons for the first year operation.[4]

City of Corpus Christi Desalination Study: The TWDB funded several studies to evaluate the feasibility of large-scale desalination in Texas. As part of this initiative, the City was selected as one of three potential locations for large-scale seawater desalination and a feasibility study was conducted. The draft report[5] from this study was completed in August 2004. The study evaluated several options and concluded that the most feasible large-scale desalination project for the City's area was a 25 MGD seawater desalination treatment plant located at the Barney M. Davis Power Station.

4C.17.2 Available Yield

Seawater from the Gulf of Mexico is assumed to be available in an unlimited quantity within the context of a supply for the Coastal Bend Region. Also, it is assumed that the cost of Gulf water is zero prior to extraction from the source. Finished water supplies of 25 MGD, 50 MGD, 75 MGD, and 100 MGD were evaluated.

4C.17.3 Environmental Issues

The project area for the proposed desalination plant is adjacent to the Barney M. Davis Power Station in South Corpus Christi near Laguna Madre, Oso Bay, and Corpus Christi Bay. It is assumed that the seawater desalination plant will utilize the existing cooling water intake for the Davis Power Station. Cooling water for the Davis power station is drawn from Laguna Madre and discharged to Oso Bay. The desalination concentrate is not discharged into the Davis outfall but instead is piped out to the open Gulf of Mexico to be discharged in waters over 30 feet deep.

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[4] Desalination & Water Reuse Quarterly, vol. 7/4, Feb/Mar 1998.

[5] City of Corpus Christi, Draft Report "Large Scale Demonstration Desalination Feasibility Study," August 2004.

If an alternate intake location is considered during project construction, additional environmental analyses including impingement and entrainment will need to be considered.

Estuaries serve as critical habitat and spawning grounds for many marine species and migratory birds. Estuaries are marine environments maintained in a brackish state by the inflow of freshwater from rivers and streams. The high productivity characteristic of estuaries arises from the abundance of terrigenous nutrient input, shallow water, and the ability of a few marine species to exploit environments continually stressed by low, variable salinities, temperature extremes, and, on occasion, low dissolved oxygen concentrations. The potential environmental effects resulting from the construction of a desalination plant in the vicinity of Laguna Madre will be sensitive to the siting of the plant and its appurtenances. The existing intake structure and volume of water taken from the bay would not be impacted because the desalination plant would take its raw water feed from the discharge of the Davis Power Station cooling water. Since the brine concentrate is planned to be located off-shore in the open Gulf of Mexico, there would be no impact of this feature upon the estuary. Also, it is assumed that the outfall will be located and constructed so as to result in little or no effect upon the environment at the discharge location.

The water transmission pipeline between the desalination plant and the City’s O.N. Stevens Water Treatment Plant (Stevens WTP) would be approximately 29 miles long. A construction right-of-way, approximately140 feet wide, would affect a total area of approximately 492 acres. The construction of the pipeline would include the clearing and removal of woody vegetation. A 40-foot-wide right-of-way corridor, free of woody vegetation and maintained for the life of the project, would total 141 acres. Destruction of potential habitat can be avoided by diverting the corridor through previously disturbed areas. A cultural resource survey of the plant and pipeline routes will need to be performed consistent with requirements of the Texas Antiquities Commission.

An alternate option was also evaluated to transport the finished water 5 miles to a distribution facility on the south side of Corpus Christi.

Because of the relatively small areas involved, construction and maintenance of surface facilities are not expected to result in substantial environmental impacts. Where environmental resources (e.g., endangered species habitat and cultural resource sites) could be impacted by infrastructure, changes in facility siting and pipeline alignment would generally be sufficient to avoid or minimize adverse effects.

4C.17.4 Engineering and Costing

A cost estimate was developed for a major desalination water treatment plant on the Texas coast and the infrastructure for transferring potable water from the coast to the City's major municipal demand center. Costs of seawater desalination were based on the 2006 Regional Water Plan, updated to September 2008 dollars based on Engineering News Record Construction Cost Indices.

The estimated seawater desalination facility is located next to the Barney M. Davis Power Station between Laguna Madre and Oso Bay. Davis is a once-through cooling water power plant with an existing reported cooling water flow of 467 MGD (521 MGD maximum capacity). Cooling water is diverted from Laguna Madre and returned to Oso Bay. Figure 4C.17-1 shows the desalination plant location, finished water pipeline route to the Stevens WTP, and concentrate pipeline route. Engineering assumptions for the Davis seawater desalination facility are shown in Table 4C.17-2.

The basis for estimating the seawater desalination plant costs were developed from evaluation of recent experience of other utilities that are involved in similar projects (e.g., technical data from the Tampa Bay Water proposal, referenced in subsection 4C.17.1.1.3) and from information and estimating models developed in a previous desalination study) updated to September 2008 Prices.[6]

Estimates are based on utilizing the existing power plant seawater intake to obtain the RO treatment plant feedwater. Pumps and 1,000 feet of intake pipeline are added to transfer the feedwater from the discharge canal to the desalination plant. Drawing the source water from the power plant discharge eliminates the need to draw additional flow from the bay for cooling water to the power plant and supplies feedwater with an increased temperature that is beneficial for the RO process.

A separate RO concentrate disposal outfall is included to pipe the RO concentrate to the open Gulf of Mexico. The outfall would cross Laguna Madre and Padre Island and extend into the Gulf to be diffused in water over 30 feet deep. Seagrass covers the majority of the bay between the mainland and the barrier island. Therefore, costs for appropriate mitigation are included assuming that half of the concentrate pipeline will be located through seagrass beds.

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[6] HDR Engineering, Inc., "Desalination for Texas Water Supply," Texas Water Development Board, Nueces River Authority, August 2000.

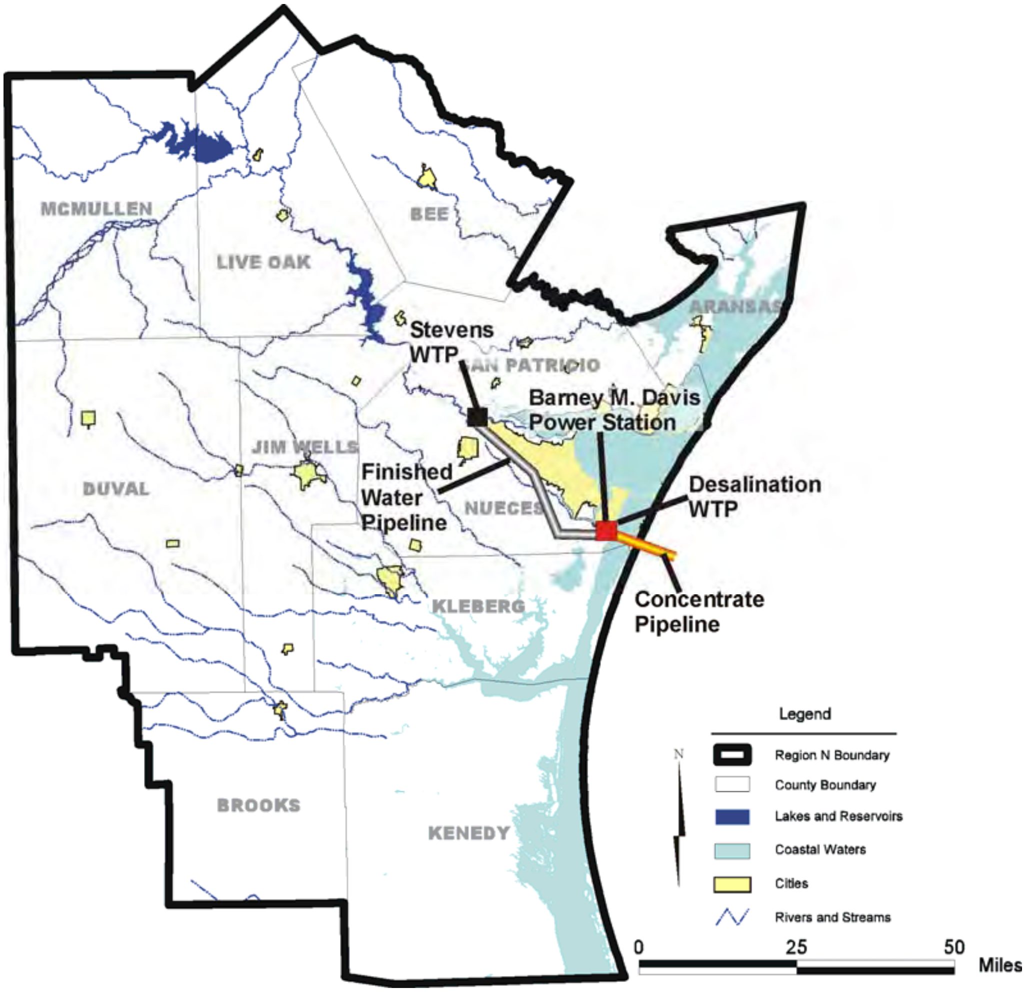

Figure 4C.17-1. Desalination Plant Location and Pipeline Route

A water storage tank with one-half day's finished water capacity and water transmission pumps and pipeline are included to transport the finished water. For the base option the finished water is to be transported 29 miles to either the Stevens WTP to blend into the city system or to distribution lines supplying industries along the ship channel. For the alternate option finished water is transported 5 miles to a distribution facility on the south side of the City. The alternate option is identical to the base option in all other aspects. Post-treatment stabilization and disinfection are included.

Table 4C.17-2.
Seawater Desalination at Barney M. Davis Power Station
Engineering Assumptions for Base Option

Parameter	***Assumption***	***Description***
Raw Water Salinity	33,000 mg/L	Intake from power plant at Laguna Madre
Raw Water Total Suspended Solids	40 mg/L	
Finished Water Chlorides	100 mg/L	Existing median at Stevens WTP is about 120 mg/L
Finished Water Capacity	25, 50, 75, 100 MGD	
Finished Water Pipeline Length	29 Miles	
WTP Storage	one-half day's capacity	
Concentrate Pipeline Length	10 miles	Diffused in open gulf in over 30 ft of water
Treated Water Pipeline Length	29 miles	Distance to Stevens WTP or port industries
Feedwater Pumping Head	900 psi	
Pretreatment	High	Coagulation, media filtration, and chemical addition
Post-treatment	Stabilization & disinfection	Lime and chlorination
Recovery Rate	50 percent	
Flux	8 gpm	Rate product water passes through membrane
Cleaning Frequency	6 months	Membranes cleaned once every 6 months
Membrane Life	5 years	Membrane elements replaced every 5 years
Plant Production Downtime	5 percent	

Water treatment parameters are estimated based on available water quality data for Laguna Madre near the power plant intake. Coagulation and media filtration is included along with other standard pretreatment components (cartridge filtration, antiscalant and acid addition). Included sludge handling consists of mechanical sludge dewatering and disposal to a non-hazardous waste landfill. Capacities for the seawater desalination plant are shown in Table 4C.17-3.

Land acquisition for the base option includes 17 acres for the 25-MGD desalination plant and 145 acres for the desalted water storage tank and transmission pipeline.

Table 4C.17-3.
Capacities for Seawater Desalination Plant Option

Item/Facility	Nominal Water Treatment Plant Capacity			
	25 MGD	**50 MGD**	**75 MGD**	**100 MGD**
Intake Pump Station (MGD)	50	100	150	200
Desalted Product Water (drinking water) (MGD)	25	50	75	100
Concentrate Discharge Pump Station (MGD)	25	50	75	100
Concentrate Discharge Pipeline Diameter (inches)	42	54	64	72
Storage Tank at Plant (million gallons)	25	50	75	100
Finished Water Pump Station at Plant (gpm)	17,361	34,722	52,083	69,444
Finished Water Pipeline Diameter (inches)	42	54	66	78
Total Land Acquisition (acres)	162	171	178	185

Tables 4C.17-4 and 4C.17-5 show the cost estimate summaries for seawater desalination at Barney M. Davis Power Station for the base option and the alternate option, respectively. The estimated total costs assume a 95 percent utilization of the desalination facility.

The base option includes a 29-mile pipeline from the desalination plant to the Stevens WTP. Once the desalted water is pumped to the Stevens WTP, it can be mixed with treated surface water and put into the City's distribution system. The alternative option takes advantage of the City's plans to develop a new water distribution center on the south side of town. If developed, the desalination plant could pump water 5 miles to the proposed distribution center, saving capital and operating costs in transmission of the potable desalt water into the City's system. The costs shown in Tables 4C.17-4 and 4C.17-5 assume that the desalination plant is purchasing power at $0.09 per kWh.

A desalination project could potentially be an opportunity for Federal or State participation. To be consistent with other strategies in this Plan with opportunity for Federal or State participation, it was assumed that 65% of the firm yield would be available for public water supply with 35% dedicated for ecosystem restoration or other Federal or State purposes. The project cost for water supply interests was estimated to be 35% of the total cost, with the remaining 65% contributed by Federal or State participants. Annual operations and maintenance and pumping energy costs would be paid in full by water supply interests. For desalination, over

Table 4C.17-4.
Cost Estimate Summary
Seawater Desalination at Barney M. Davis Power Station
for Base Option (29-mile pipeline)
(September 2008 Prices)

Item	*Estimated Costs 25 MGD*	*Estimated Costs 50 MGD*	*Estimated Costs 75 MGD*	*Estimated Costs 100 MGD*
Capital Costs				
Seawater Supply	$1,131,000	$1,841,000	$2,498,000	$3,024,000
Water Treatment Plant (Pretreatment and Desal)	$108,278,000	$192,977,000	$285,716,000	$360,680,000
Concentrate Disposal	$45,362,000	$68,372,000	$92,039,000	$118,336,000
Transmission Pipeline	$55,163,000	$76,038,000	$106,372,000	$135,986,000
Transmission Pump Station(s)	$3,708,000	$6,421,000	$7,563,000	$7,993,000
Total Capital Cost	**$213,642,000**	**$345,649,000**	**$494,188,000**	**$626,019,000**
Engineering, Legal Costs and Contingencies	$72,291,000	$117,659,000	$168,360,000	$213,230,000
Environmental & Archaeology Studies and Mitigation	$6,606,000	$8,623,000	$10,819,000	$12,902,000
Land Acquisition and Surveying (162 acres)	$2,582,000	$2,711,000	$2,816,000	$2,908,000
Interest During Construction (2.5 years)	$29,513,000	$47,465,000	$67,619,000	$85,506,000
Total Project Cost	**$324,634,000**	**$522,107,000**	**$743,802,000**	**$940,565,000**
Annual Costs				
Debt Service (6 percent, 20 years)	$28,303,000	$45,520,000	$64,848,000	$82,003,000
Operation and Maintenance				
Seawater Supply	$289,000	$427,000	$500,000	$565,000
Water Treatment Plant	$22,376,000	$44,152,000	$65,162,000	$85,632,000
Concentrate Disposal	$1,578,000	$3,024,000	$4,207,000	$5,522,000
Finished Water Transmission	$1,468,000	$2,641,000	$3,442,000	$3,978,000
Total Annual Cost	**$54,014,000**	**$95,764,000**	**$138,159,000**	**$177,700,000**
Available Project Yield (acft/yr)	28,000	56,000	84,000	112,000
Annual Cost of Water ($ per acft)	$1,929	$1,710	$1,645	$1,587
Annual Cost of Water ($ per 1,000 gallons)	$5.92	$5.25	$5.05	$4.87

Table 4C.17-5.
Cost Estimate Summary
Seawater Desalination at Barney M. Davis Power Station
for Alternate Option (5-mile pipeline)
(September 2008 Prices)

Item	***Estimated Costs 25 MGD***	***Estimated Costs 50 MGD***	***Estimated Costs 75 MGD***	***Estimated Costs 100 MGD***
Capital Costs				
Seawater Supply	$1,131,000	$1,841,000	$2,498,000	$3,024,000
Water Treatment Plant (Pretreatment and Desal)	$108,278,000	$192,977,000	$285,716,000	$360,680,000
Concentrate Disposal	$45,362,000	$68,372,000	$92,039,000	$118,336,000
Transmission Pipeline	$13,888,000	$20,911,000	$29,827,000	$38,311,000
Transmission Pump Station(s)	$1,816,000	$3,145,000	$4,030,000	$4,764,000
Total Capital Cost	**$170,475,000**	**$287,246,000**	**$414,110,000**	**$525,115,000**
Engineering, Legal Costs and Contingencies	$59,246,000	$99,975,000	$144,159,000	$182,797,000
Environmental & Archaeology Studies and Mitigation	$6,006,000	$8,023,000	$10,219,000	$12,302,000
Land Acquisition and Surveying (46 acres)	$1,467,000	$1,596,000	$1,701,000	$1,792,000
Interest During Construction (2.5 years)	$23,720,000	$39,685,000	$57,019,000	$72,201,000
Total Project Cost	**$260,914,000**	**$436,525,000**	**$627,208,000**	**$794,207,000**
Annual Costs				
Debt Service (6 percent, 20 years)	$22,748,000	$38,058,000	$54,683,000	$57,698,000
Operation and Maintenance				
Seawater Supply	$289,000	$427,000	$500,000	$565,000
Water Treatment Plant	$22,376,000	$44,152,000	$65,162,000	$85,632,000
Concentrate Disposal	$1,578,000	$3,024,000	$4,207,000	$5,522,000
Finished Water Transmission	$507,000	$727,000	$1,320,000	$1,644,000
Total Annual Cost	**$47,498,000**	**$86,388,000**	**$125,872,000**	**$151,061,000**
Available Project Yield (acft/yr)	28,000	$56,000	$84,000	$112,000
Annual Cost of Water ($ per acft)	$1,696	$1,543	$1,498	$1,349
Annual Cost of Water ($ per 1,000 gallons)	$5.21	$4.73	$4.60	$4.14

half of the annual costs are associated with energy costs and water treatment plant operations and maintenance not considered eligible for discounted costs. Furthermore, with reduced project supply (65% of firm yield) increases the unit water cost. **Using these assumptions, Federal or State participation would not be anticipated to reduce annual unit cost of water.**

4C.17.5 Implementation Issues

Permitting of this facility will require extensive coordination with all applicable regulatory entities. Use of the existing power plant intake should facilitate permitting for the source water because no additional water is to be drawn from the bay. However, permitting the construction of the concentrate pipeline across Laguna Madre and Padre Island and construction of the ocean outfall will be major project issues.

The installation and operation of a seawater desalination water treatment plant may have to address the following issues.

- Disposal of concentrated brine from desalination water treatment plant;
- Permitting and constructing concentrate pipeline through seagrass beds and barrier island;
- Impact on the bays from removing water for consumptive use and altering existing power plant water rights permit;
- Confirming that blending desalted seawater with other water sources in the municipal demand distribution system can be successfully accomplished;
- High power requirements for desalination process dependant on large, reliable power source;
- Skilled operators of desalination water treatment plants;
- Permitting of a pipeline across rivers, highways, and private rural and urban property; and
- Possibility of using a design, build, operate contract for a desalination water treatment plant.

4C.17.6 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Table 4C.17-6.

Table 4C.17-6.
Evaluation Summary of the Seawater Desalination Option

Impact Category	*Comment(s)*
a. Water Supply	
1. Quantity	1. Variable, ranges from 28,000 to 112,000 acft/yr ; actual water supply virtually unlimited.
2. Reliability	2. Highly reliable quantity.
3. Cost of Treated Water	3. Generally high cost; between $1,929 to $1,349/acft. Cost could potentially be reduced with Federal or State participation.
b. Environmental factors	
1. Instream flows	1. None or low impact.
2. Bay and Estuary Inflows	2. Environmental impact to estuary
3. Wildlife Habitat	3. Disposal of concentrated brine created from process may impact fish and wildlife habitats or wetlands.
4. Wetlands	4. Disposal of concentrated brine created from process may impact fish and wildlife habitats or wetlands.
5. Threatened and Endangered Species	5. None identified. Endangered species survey will be needed to identify impacts.
6. Cultural Resources	6. Cultural resource survey will be needed to identify any significant sites
7. Water Quality	7.
a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	7a-b. Total dissolved solids and salinity of water is removed with reverse osmosis treatment. Brine concentrate disposal issues will need to be evaluated.
c. Impacts to State water resources	• No negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• Temporary damage due to construction of pipeline
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Standard analyses and methods used for portions • Seawater desalination cost modeled after bid and manufactures' budgets, but not constructed, comparable project
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• Construction and maintenance of transmission pipeline corridor. Possible impact to wildlife habitat along pipeline route and right-of-way.

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4C.18 Potential Water System Interconnections (N-18)

4C.18.1 Description of Strategy

In addition to providing backup water supplies for emergencies, water system interconnections are another potential source of freshwater supplies for municipal and industrial uses for this region. This section describes additional community water system candidates located in Duval, Jim Wells, Brooks, and San Patricio Counties for interconnection within the Coastal Bend Region. The analyses were evaluated in detail during the 2001 Regional Water Planning Process. Costs were based on the 2006 Regional Water Plan, updated to September 2008 dollars based on Engineering News Record Construction Cost Indices.

There are certain municipal water systems that rely totally on local groundwater. Many of these groundwater systems operate under one or more of the following conditions:

- Insufficient groundwater supply
- Insufficient well capacity
- Unsuitable water quality

The Trans-Texas Water Program Phase II Report[1] listed 24 municipal water systems in the Coastal Bend Area that have converted at least a part of their groundwater supply to the regional surface water system. This list is shown in Table 4C.18-1. Most of the water systems shown on this list have converted totally to the regional surface water system.

One example of an existing interconnection between the regional surface water system and a local groundwater system is the City of Kingsville in Kleberg County. The City maintains its groundwater supply as its primary source but also has an interconnection with the South Texas Water Authority's (STWA) surface water system.

4C.18.2 Available Yield

4C.18.2.1 Duval County

In 1996, TWDB funded a regional water supply study for Duval and Jim Wells Counties.[2] The study evaluated several alternative surface water supply systems from the City

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[1] HDR Engineering, Inc. (HDR), "Trans-Texas Water Program - Corpus Christi Study Area - Phase II Report," City of Corpus Christi, et al, September 1995.

[2] Naismith Engineering, Inc. (NEI), et al., "Regional Water Supply Study, Duval and Jim Wells County, Texas," Nueces River Authority, et al., October 1996.

Table 4C.18-1. Public Water Suppliers That Have Converted Totally or Partially to Surface Water from the Choke Canyon/Lake Corpus Christi/Lake Texana (CCR/LCC/Lake Texana) System

Water Supplier	Conversion Date	Currently Supplied By[1]
Aransas County		
Rockport	1970	Aransas Co. CRD/ San Patricio/Corpus Christi
Copano Cover Water Co.	1972	Rockport
Peninsula Water Co.	1978	Rockport
Bee County		
Beeville	1985	—
Jim Wells County		
Alice	1965	—
Jim Wells Co. FWSD 1	1980	Alice
Kleberg County		
Kingsville	1985	South Texas Water Authority
Ricardo WSC	1985	South Texas Water Authority
U.S. Naval Air Station-Kingsville	1985	South Texas Water Authority
McMullen County		
Choke Canyon Water System	1991	—
Nueces County		
Aqua Dulce	1985	South Texas Water Authority
Bishop	1985	South Texas Water Authority
Corpus Christi	1983-4	—
Driscoll	1985	South Texas Water Authority
Nueces Co. WCID #3-Robstown	1985	Nueces River[1]
Nueces Co. WCID #4-Port Aransas	1958	Corpus Christi & San Patricio MWD
Nueces Co. WCID #5-Banquette Area	1985	South Texas Water Authority
San Patricio County		
Odem	1954	San Patricio MWD
Aransas Pass	1962	San Patricio MWD
Ingleside	1955	San Patricio MWD
Gregory	1954	San Patricio MWD
Mathis	1980	—
Portland	1954	San Patricio MWD
Taft	1965	San Patricio MWD

[1] All surface water is supplied from the CCR/LCC/Lake Texana System under water rights held by the City of Corpus Christi except for Robstown, which has their own water rights from the Nueces River at Calallen.

of Alice to various combinations of cities in Duval County. Those cities included San Diego, Freer, Benavides, Realitos, and Concepcion. The alternatives evaluated are:

Alternative 1 - Alice to San Diego, Benavides, Realitos, Concepcion, and Freer (Figure 4C.18-1)
Alternative 2 - Alice to San Diego, Benavides and Freer (Figure 4C.18-2)
Alternative 3 - Alice to San Diego and Benavides (Figure 4C.18-3)
Alternative 4 - Alice to San Diego and Freer (Figure 4C.18-4)
Alternative 5 - Alice to San Diego (Figure 4C.18-5)

An interconnection to the CCR/LCC/Lake Texana System to serve community water systems in Duval County via the City of Alice is feasible because the City of Alice has existing raw water pump capacity, treatment capacity, and high service pump capacity to meet the projected peak day demands for all cities in the study area through the near-term (2030) and long-term (2060) planning horizon.

Required regional facilities would include transmission lines ranging in size from 6-inch to 16-inch diameters, and intermediate storage and booster pump stations. Total capital costs and annual costs (debt service, power cost, operation and maintenance (O&M) cost, and treated water cost) were estimated for each alternative and are included in Tables 4C.18-2 through 4C.18-6.

The 1996 Regional Water Supply Study recommended that surface water projects in Duval County be initiated, constructed, financed, operated and maintained by the Duval County Conservation and Reclamation District (DCCRD).

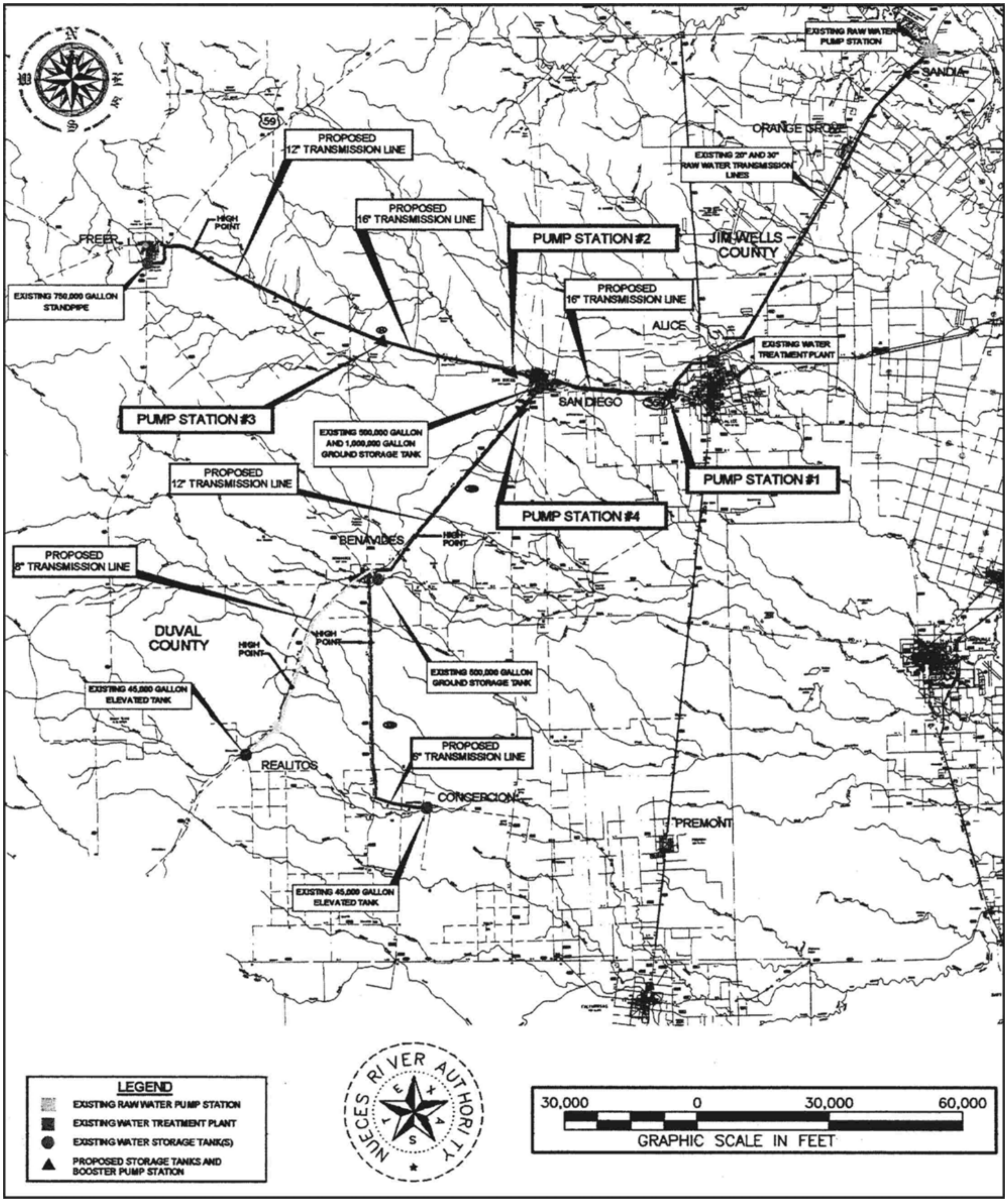

Figure 4C.18-1. Duval County Interconnection Alternative 1

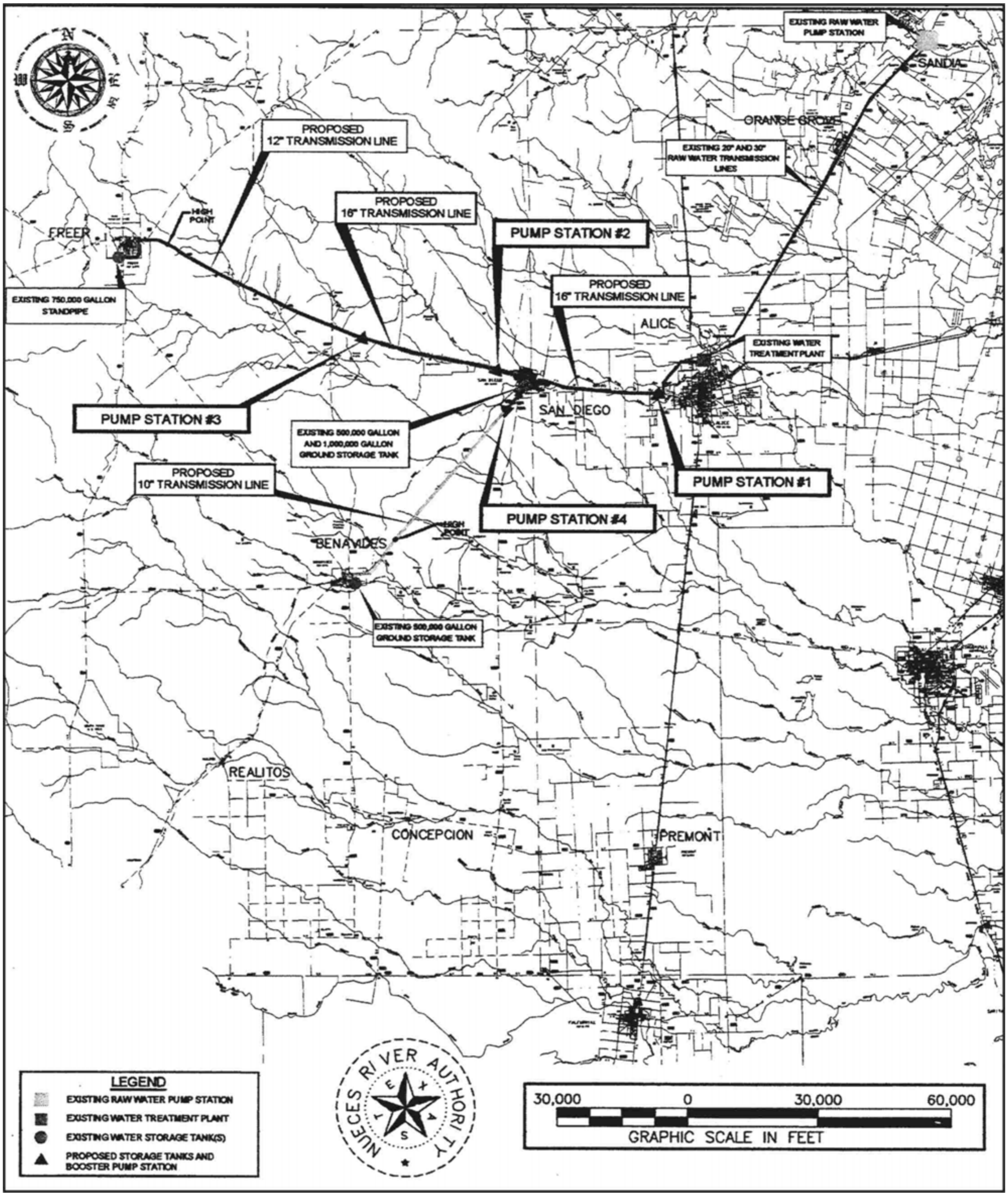

Figure 4C.18-2. Duval County Interconnection Alternative 2

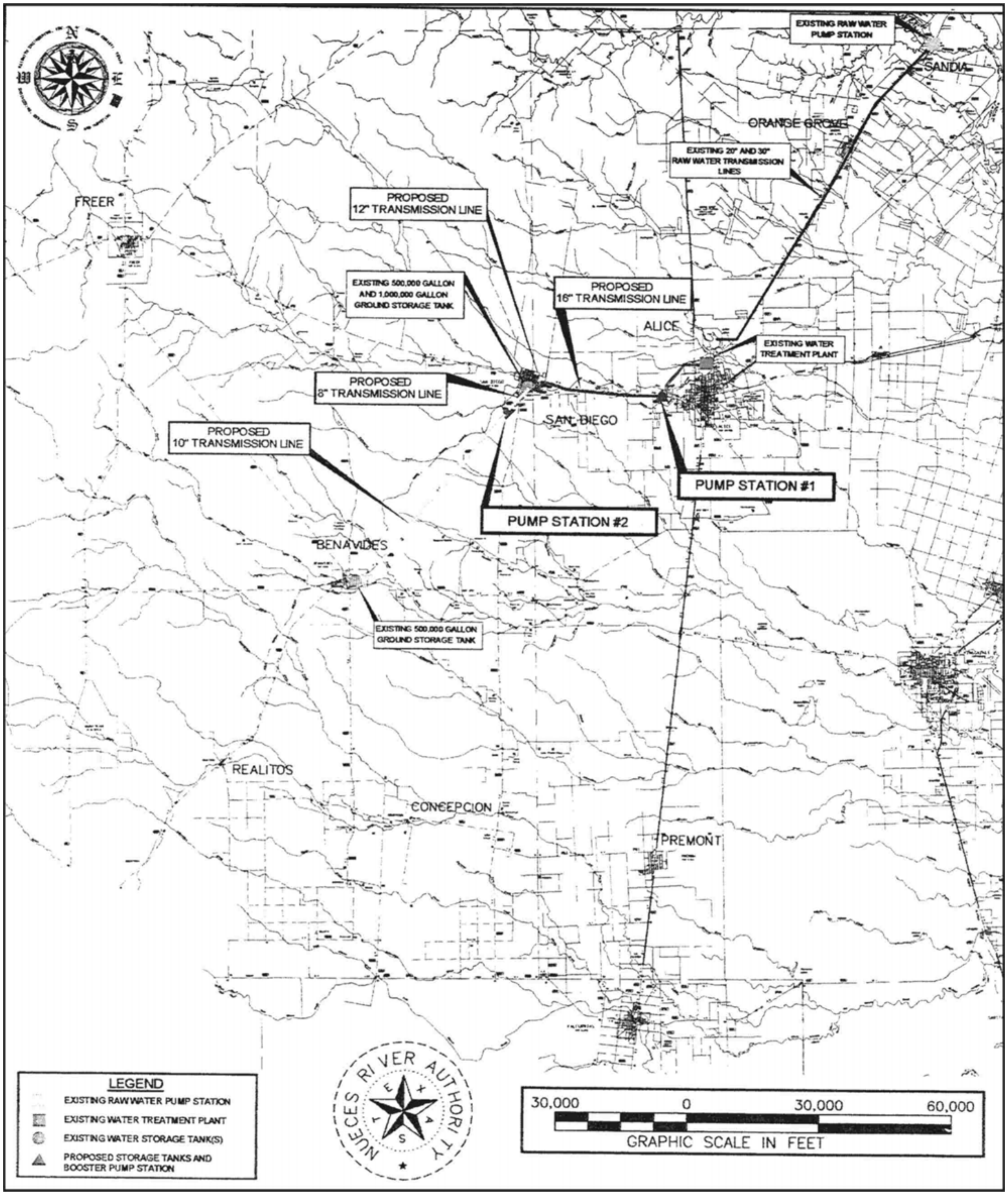

Figure 4C.18-3. Duval County Interconnection Alternative 3

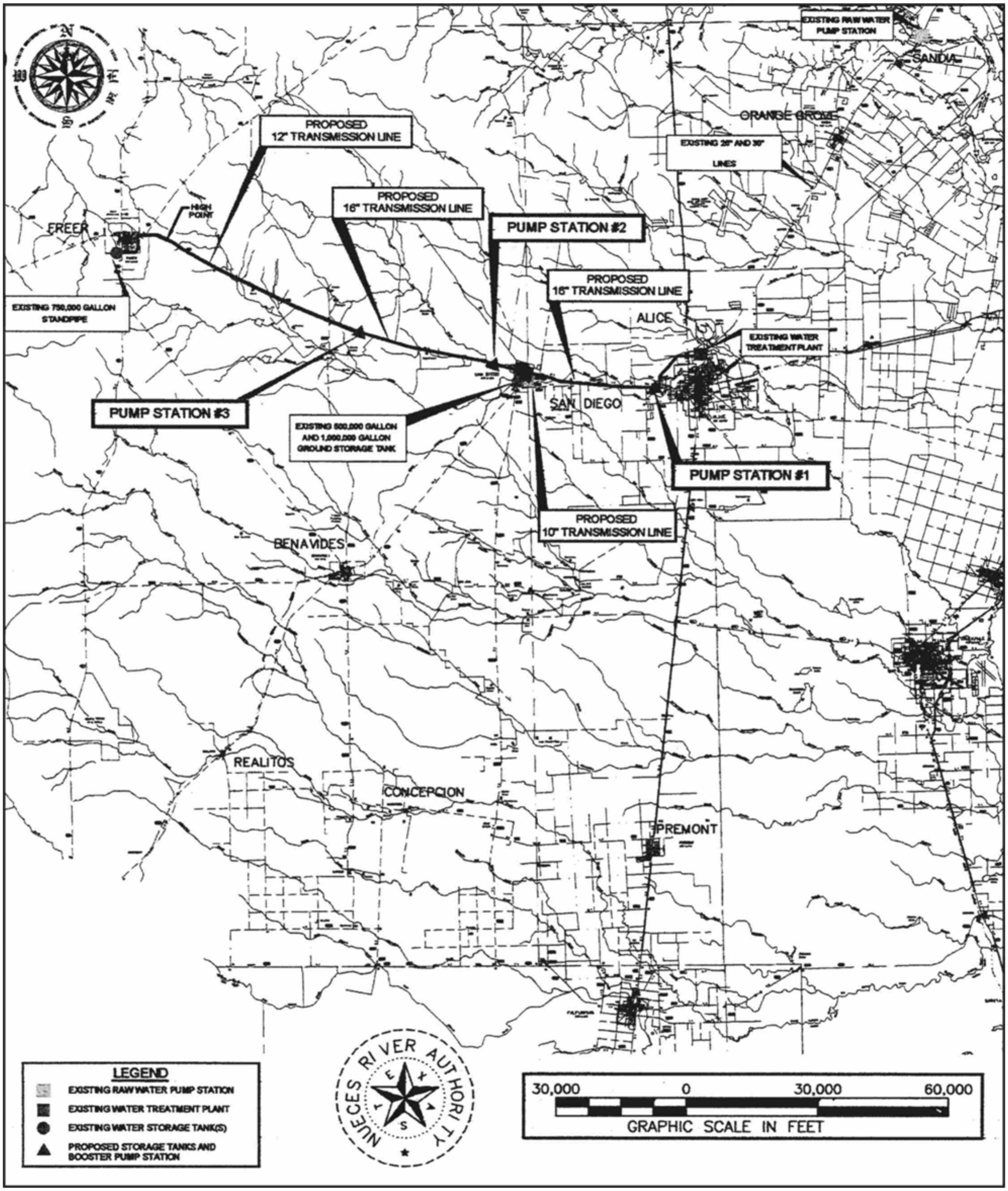

Figure 4C.18-4. Duval County Interconnection Alternative 4

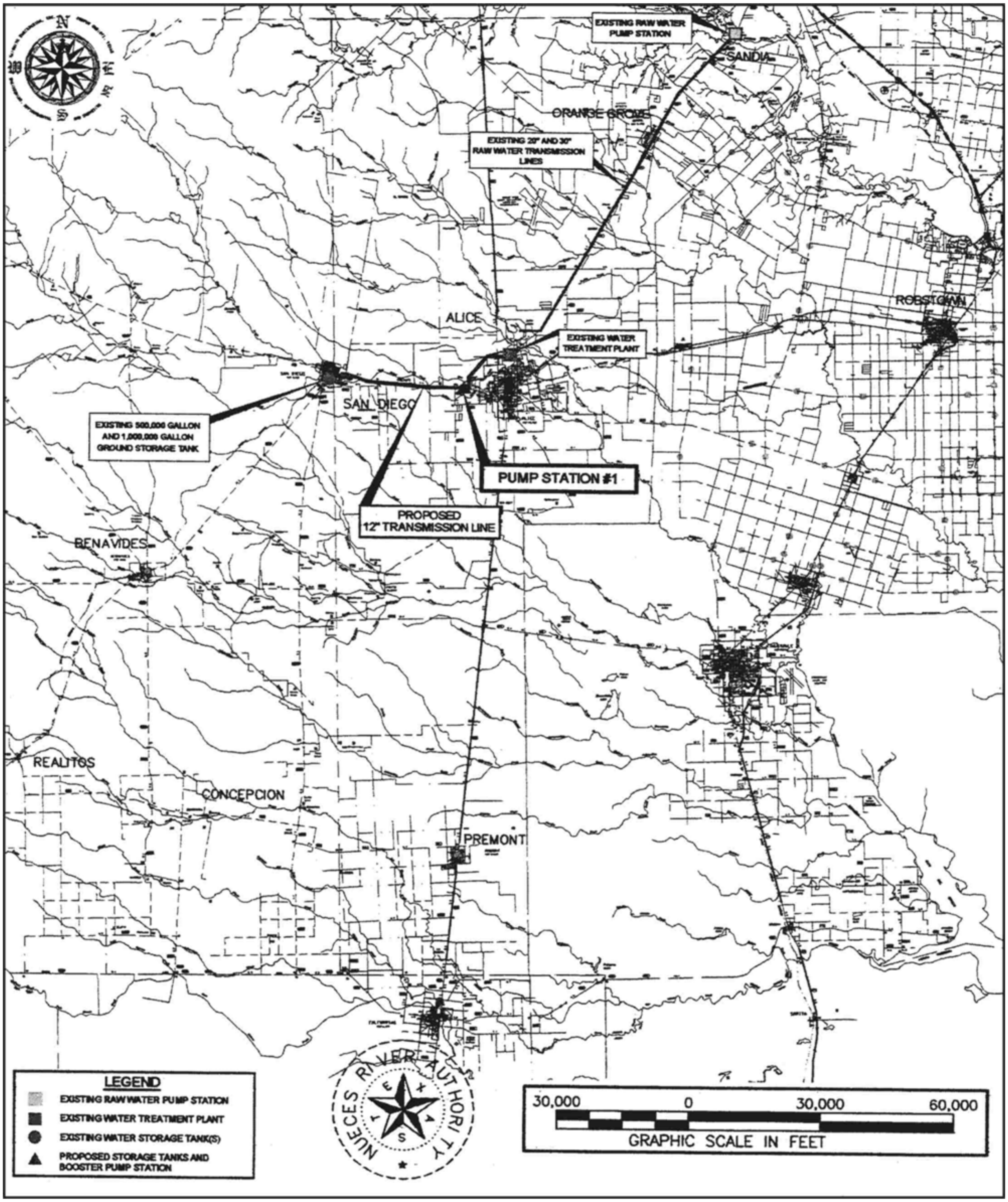

Figure 4C.18-5. Duval County Interconnection Alternative 5

Table 4C.18-2.
Cost Estimate Summary
Regional Surface Water Supply
Duval County Interconnection Alternative 1[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (85.4 miles)	$12,500,000
Storage and Pump Stations	3,707,000
Total Capital Costs	**$16,207,000**
Engineering, Legal Costs and Contingencies	$5,048,000
Environmental & Archaeology Studies and Mitigation	2,807,000
Land Acquisition and Surveying	3,820,000
Interest During Construction (2 years)	2,231,000
Total Project Cost	**$30,113,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$2,625,000
Operation and Maintenance:	
Pipelines and Pump Stations	218,000
Pumping Energy Costs ($.09 per kWh)	356,000
Treated Water Cost	1,624,000
Total Annual Cost	**$4,823,000**
Available Project Yield[2] (acft/yr)	**2,520**
Annual Cost of Water ($ per ac ft)	**$1,914**
Annual Cost of Water ($ per 1,000 gallons)	**$5.87**

[1] Interconnection between Alice Water Authority Water Treatment Plant, and San Diego, Freer, Benavides, Realitos and Concepcion.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

Table 4C.18-3.
Cost Estimate Summary
Regional Surface Water Supply
Duval County Interconnection Alternative 2[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (54.6 miles)	$8,798,000
Storage and Pump Stations	3,603,000
Total Capital Costs	**$12,401,000**
Engineering, Legal Costs and Contingencies	$3,901,000
Environmental & Archaeology Studies and Mitigation	1,795,000
Land Acquisition and Surveying	2,443,000
Interest During Construction (2 years)	1,644,000
Total Project Cost	**$22,184,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$1,934,000
Operation and Maintenance:	
Pipelines and Pump Stations	178,000
Pumping Energy Costs ($.09 per kWh)	306,000
Treated Water Cost	1,566,000
Total Annual Cost	**$3,984,000**
Available Project Yield[2] (acft/yr)	**2,430**
Annual Cost of Water ($ per ac ft)	**$1,640**
Annual Cost of water ($ per 1,000 gallons)	**$5.03**

[1] Interconnection between Alice Water Authority Water Treatment Plant and San Diego, Freer, and Benavides.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

Table 4C.18-4.
Cost Estimate Summary
Regional Surface Water Supply
Duval County Interconnection Alternative 3[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (28 miles)	$4,168,000
Storage and Pump Stations	1,866,000
Total Capital Costs	**$6,034,000**
Engineering, Legal Costs and Contingencies	1,903,000
Environmental & Archaeology Studies and Mitigation	920,000
Land Acquisition and Surveying	1,253,000
Interest During Construction (2 years)	809,000
Total Project Cost	**$10,919,000**
Annual Costs	
Debt Service (6 percent for 20 years)	952,000
Operation and Maintenance:	
Pipelines and Pump Stations	88,000
Pumping Energy Costs ($.09 per kWh)	108,000
Treated Water Cost	989,000
Total Annual Cost	**$2,137,000**
Available Project Yield[2] (acft/yr)	**1,534**
Annual Cost of Water ($ per ac ft)	**$1,393**
Annual Cost of Water ($ per 1,000 gallons)	**$4.27**

[1] Interconnection between Alice Water Authority Water Treatment Plant and San Diego and Benavides.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

Table 4C.18-5.
Cost Estimate Summary
Regional Surface Water Supply
Duval County Interconnection Alternative 4[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (38.8 miles)	$6,792,000
Storage and Pump Stations	2,573,000
Total Capital Costs	**$3,365,000**
Engineering, Legal Costs and Contingencies	2,938,000
Environmental & Archaeology Studies and Mitigation	1,275,000
Land Acquisition and Surveying	1,736,000
Interest During Construction (2 years)	1,226,000
Total Project Cost	**$16,540,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$1,442,000
Operation and Maintenance:	
Pipelines and Pump Stations	132,000
Pumping Energy Costs ($.09 per kWh)	198,000
Treated Water Cost	1,205,000
Total Annual Cost	**$2,977,000**
Available Project Yield[2] (acft/yr)	**1,870**
Annual Cost of Water ($ per ac ft)	**$1,592**
Annual Cost of Water ($ per 1,000 gallons)	**$4,88**

[1] Interconnection between Alice Water Authority Water Treatment Plant, San Diego and Freer.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

Table 4C.18-6.
Cost Estimate Summary
Regional Surface Water Supply
Duval County Interconnection Alternative 5[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (12.2 miles)	$1,996,000
Storage and Pump Stations	836,000
Total Capital Costs	**$2,832,000**
Engineering, Legal Costs and Contingencies	$891,000
Environmental & Archaeology Studies and Mitigation	401,000
Land Acquisition and Surveying	545,000
Interest During Construction (1 year)	187,000
Total Project Cost	**$4,856,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$423,000
Operation and Maintenance:	
Pipelines and Pump Stations	41,000
Pumping Energy Costs ($.09 per kWh)	39,000
Treated Water Cost	628,000
Total Annual Cost	**$1,131,000**
Available Project Yield[2] (acft/yr)	**974**
Annual Cost of Water ($ per ac ft)	**$1,161**
Annual Cost of Water ($ per 1,000 gallons)	**$3.56**

[1] Interconnection between Alice Water Authority Water Treatment Plant and San Diego.
[2] Average Day Demand in 2030.

4C.18.2.2 Jim Wells County

The 1996 Regional Water Supply Study[3] also included two alternative surface water supply systems to deliver water from the CCR/LCC System, via the City of Alice, to Orange Grove (Figure 4C.18-6) and Premont (Figure 4C.18-7) in Jim Wells County.

Required regional facilities for Jim Wells County options would include new transmission lines ranging in size from 8-inches to 18-inches in diameter. Associated total capital costs and annual costs (debt service, O&M cost, and treated water cost) were estimated for each alternative and are included in Tables 4C.18-7 and 4C.18-8.

Although not evaluated, it could be feasible to connect the City of Premont to STWA's system in Kleberg County. Before pursuing an interconnection between the cities of Alice and Premont, a STWA to Premont interconnection should be evaluated.

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[3] Ibid.

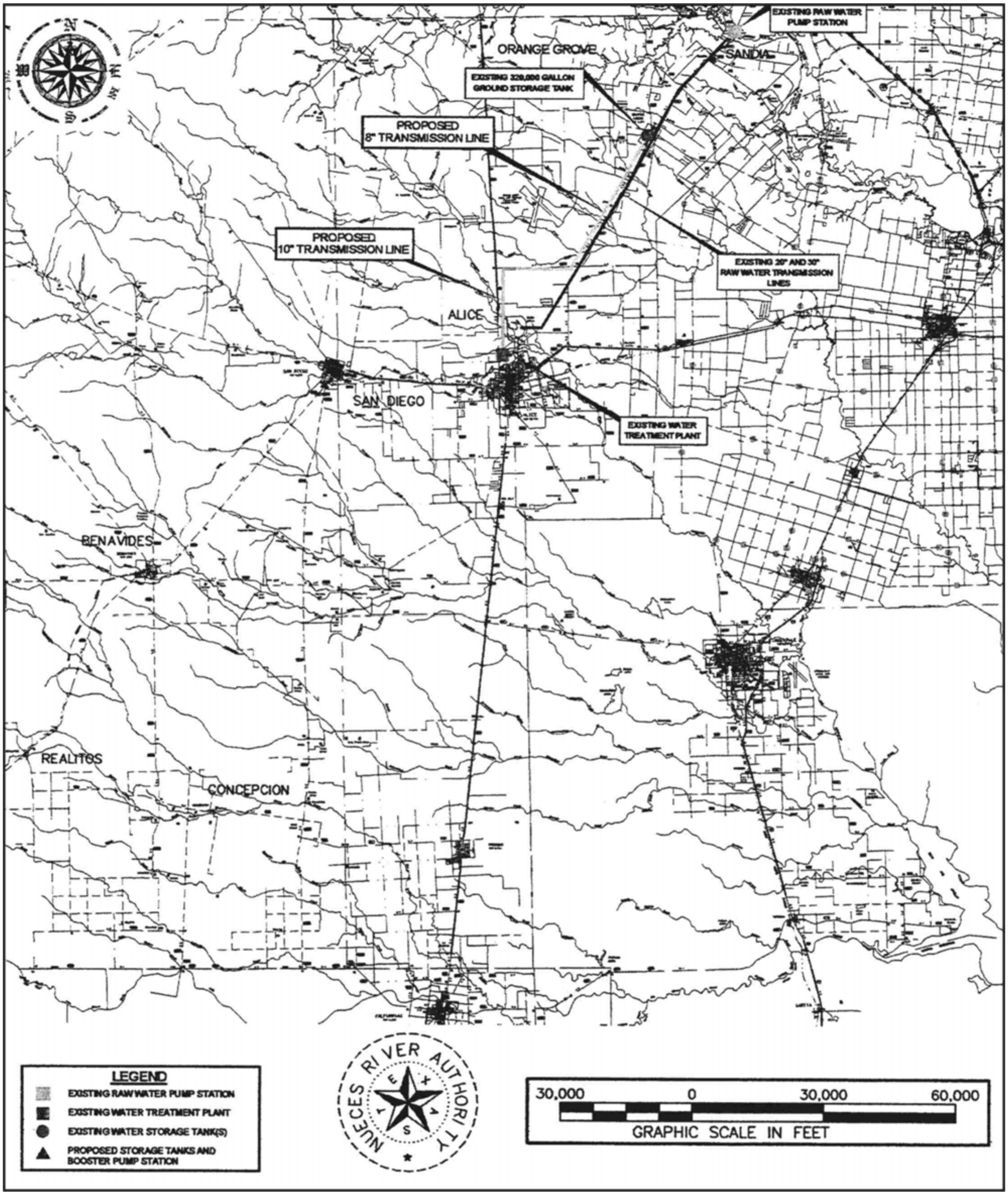

Figure 4C.18-6. Jim Wells County Interconnection Alternative 1

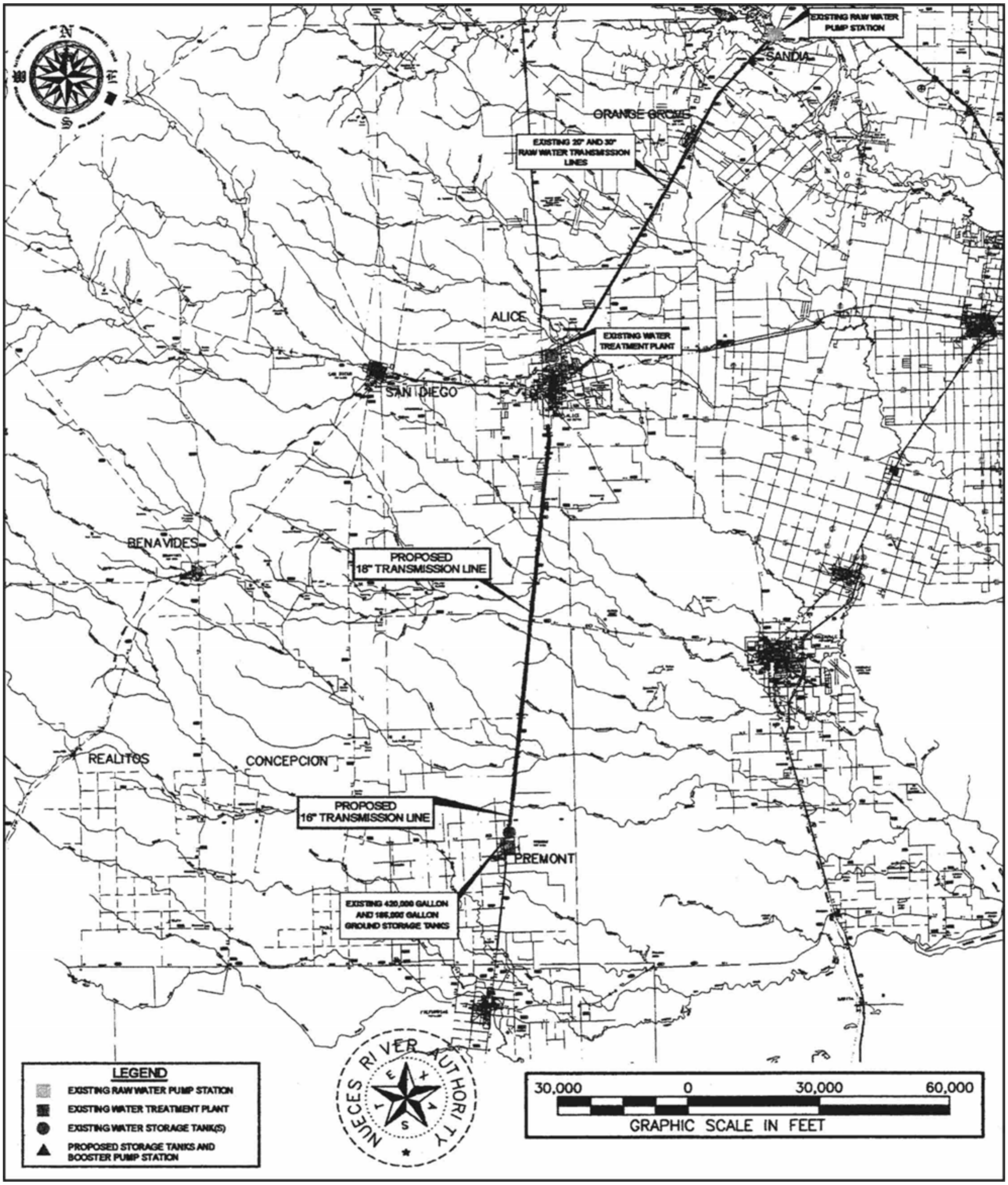

Figure 4C.18-7. Jim Wells County Interconnection Alternative 2

Table 4C.18-7.
Cost Estimate Summary
Regional Surface Water Supply
Jim Wells County Interconnection Alternative 1[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (19.1 miles)	$2,037,000
Total Capital Costs	**$2,037,000**
Engineering, Legal Costs and Contingencies	$611,000
Environmental & Archaeology Studies and Mitigation	628,000
Land Acquisition and Surveying	854,000
Interest During Construction (1 year)	166,000
Total Project Cost	**$4,296,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$375,000
Operation and Maintenance:	
Pipelines and Pump Stations	20,000
Treated Water Cost	158,000
Total Annual Cost	**$553,000**
Available Project Yield[2] **(acft/yr)**	**246**
Annual Cost of Water ($ per ac ft)	**$2,248**
Annual Cost of Water ($ per 1,000 gallons)	**$6.90**

[1] Interconnection between Alice Water Authority Water Treatment Plant and Orange Grove.
[2] Average Day Demand in Year 2030, based on 2001 Plan.

Table 4C.18-8. Cost Estimate Summary Regional Surface Water Supply Jim Wells County Interconnection Alternative 2[1] (September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (26.9 miles)	$6,104,000
Total Capital Costs	**$6,104,000**
Engineering, Legal Costs and Contingencies	$1,831,000
Environmental & Archaeology Studies and Mitigation	884,000
Land Acquisition and Surveying	1,203,000
Interest During Construction (2 years)	802,000
Total Project Cost	**$10,824,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$944,000
Operation and Maintenance**:**	
Pipelines	61,000
Treated Water Cost	924,000
Total Annual Cost	**$1,929,000**
Available Project Yield[2] (acft/yr)	**1,434**
Annual Cost of Water ($ per ac ft)	**$1,345**
Annual Cost of Water ($ per 1,000 gallons)	**$4,13**

[1] Interconnection between Alice Water Authority Water Treatment Plant and Premont.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

4C.18.2.3 Brooks County

The TWDB water demand projections show an increase in water demand for Falfurrias from 2000 to 2060. If future regional surface water supply facilities are constructed from Alice to Premont, it may be feasible to extend the system an additional 10.5 miles to Falfurrias (Figure 4C.18-8). Total capital costs and annual costs for regional surface water supply facilities to serve Premont and Falfurrias are shown in Table 4C.18-9.

Although not evaluated, it could be feasible to connect the cities of Premont and Falfurrias to the STWA system in Kleberg County. Before pursuing an interconnection between Alice and Premont and/or Falfurrias, a STWA interconnection to one or both cities should be evaluated.

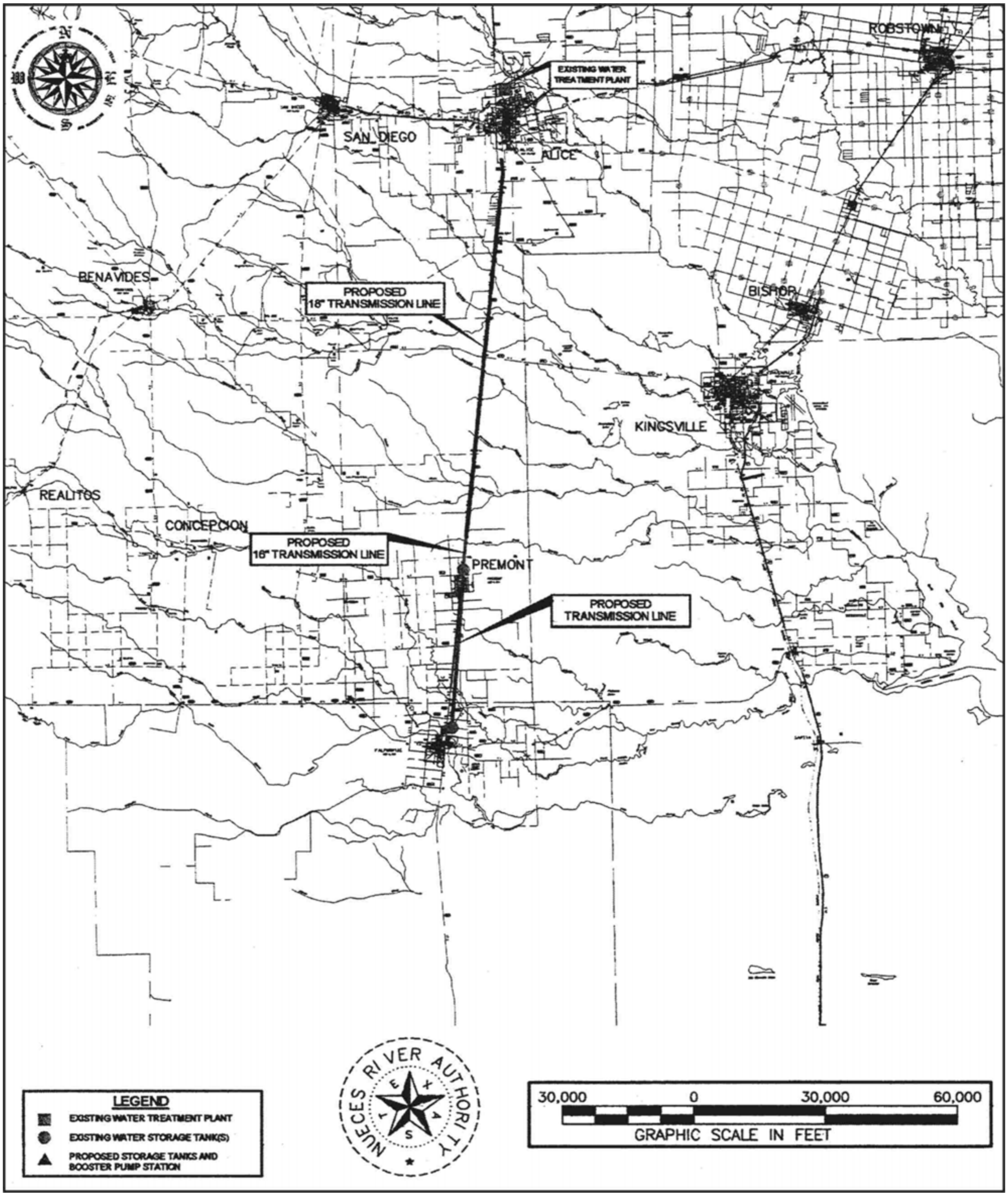

Figure 4C.18-8. Brooks County Interconnection Alternative 1

Table 4C.18-9.
Cost Estimate Summary
Regional Surface Water Supply
Jim Wells and Brooks County Interconnection Alternative 1[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (37.4 miles)	$8,495,000
Storage and Pump Station	777,000
Total Capital Costs	**$9,272,000**
Engineering, Legal Costs and Contingencies	$2,820,000
Environmental & Archaeology Studies and Mitigation	1,229,000
Land Acquisition and Surveying	1,674,000
Interest During Construction (2 years)	1,200,000
Total Project Cost	**$16,195,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$1,412,000
Operation and Maintenance:	
Pipelines and Pump Stations	104,000
Pumping Energy Costs ($.09 per kWh)	116,000
Treated Water Cost	1,891,000
Total Annual Cost	**$3,523,000**
Available Project Yield[2] (acft/yr)	**2,554**
Annual Cost of Water ($ per ac ft)	**$1,379**
Annual Cost of Water ($ per 1,000 gallons)	**$4.23**

[1] Interconnection between Alice Water Authority Water Treatment Plant and Premont and Falfurrias.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

4C.18.2.4 San Patricio County

In San Patricio County, the City of Sinton, along with water supply corporations located in the communities of Edroy and St. Paul, and several residential communities located along Lake Mathis, still rely on groundwater supplies.

Water supply for the City of Sinton is located in two well fields located along US 181 in the vicinity of the Rob and Bessie Welder Park. In the early 1980s, the City of Sinton recognized that its municipal water supply, which was originally developed in the 1940s and 50s, was rapidly deteriorating and affecting its ability to reliably serve potable water to its customers. The corrosive nature of the groundwater supplies from the well fields located approximately 3 miles northwest of the city was causing severe deterioration of the well field casings, screens, and pumping units.

In 1983, the first of three 12-inch diameter stainless steel wells were constructed for the City of Sinton. The well design included under reaming and gravel packing of the water bearing zones which produced adequate water from depths of approximately 300 to 700 feet. While water quality in the Sinton municipal well field area meets established published secondary drinking water standards, the chemical constituents of total dissolved solids and chlorides only marginally meets these standards.

When developing the final replacement well in the Sinton west field constructed in 1993, careful review of well field logs still could not predict the water quality which would be produced from the final constructed well. When the well was turned on, water quality parameters exceeded secondary drinking water standards for chlorides. Chloride levels for this well fell in the range of 300 to 325 ppm. Permission was sought from the Texas Water Commission (now the Texas Commission on Environmental Quality (TCEQ)) to allow the City of Sinton to blend its water with its other water well resources in order that water supply delivered to its customers would fall within the recommended secondary drinking water standards. To this date, the City of Sinton is still mandated by the TCEQ to operate this water blending plan.

Water well capacity for the City of Sinton is expected to be sufficient to meet the population demands through the year 2060. However, if groundwater quality continues to degrade, the City of Sinton could either construct a water treatment facility or connect directly to the San Patricio Municipal Water District's (SPMWD) treated surface water system. The SPMWD could either provide raw water through its 36-inch Nueces River transmission line or its connection to the Mary Rhodes pipeline. Treatment for potable use purposes would be required.

A direct connection to the SPMWD's 24-inch treated water transmission line would require approximately 8 miles of 12-inch waterline (Figure 4C.18-9). Connections and modifications to the City of Sinton's ground storage and pump stations would also be required. Total costs to establish an interconnection for Sinton to the regional surface water system are shown in Table 4C.18-10.

Water service for the community of Edroy, Texas located along US 77 west of Odem, Texas is provided by the San Patricio Municipal Water District Number 1 (District #1). In 1985, District #1 constructed a community water system complete with two wells, storage facilities and distribution lines. Approximately 200 connections are served through this system. Although the groundwater supply marginally meets secondary drinking water standards, the water is high in hydrogen sulfide (H_2S) making it extremely corrosive. From its initial operations, District #1 has utilized an aeration tower and the addition of chlorine to oxidize the hydrogen sulfide to acceptable odor levels. Corrosion to pump station equipment has been a continual problem. Original construction of the wells for the water supply for the community was based on an economic decision at the time and was limited to available grant funding. It has been anticipated that a conversion to treated surface water via the SPMWD may be required in the future.

During the mid 1990s, the TWDB Economic Development Assistance Program (EDAP) for San Patricio County identified a project which would have extended an 8-inch water line from the SPMWD 24-inch treated water line to the community of Edroy. This plan included an expansion to the District #1 service area, a new elevated storage tank, pumping facilities, and an interconnection to the existing Edroy system. Figure 4C.18-10 outlines the recommended EDAP plan. The cost of construction for these facilities is shown in Table 4C.18-11.

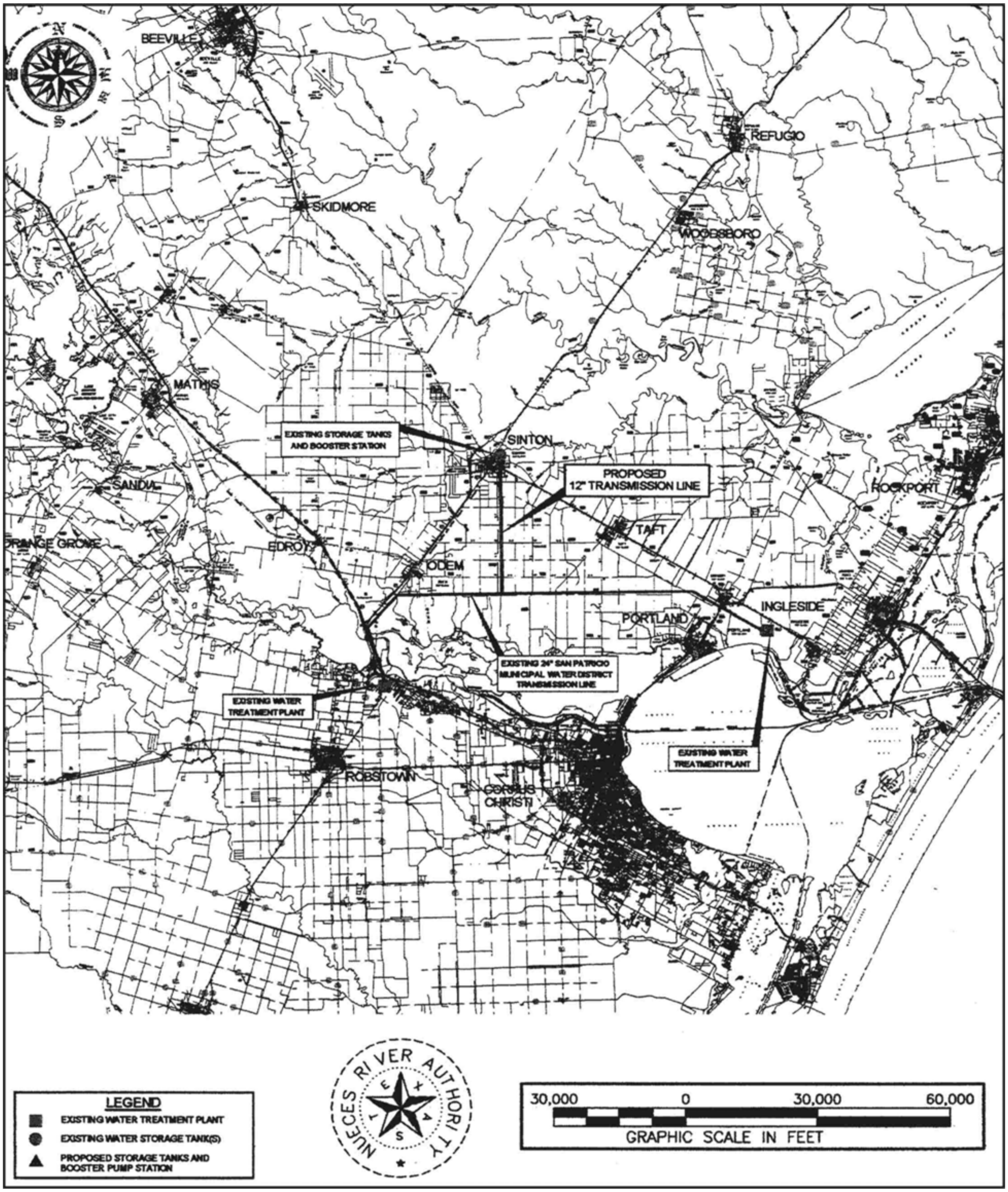

Figure 4C.18-9. San Patricio County Interconnection Alternative 1

Table 4C.18-10.
Cost Estimate Summary
Regional Surface Water Supply
San Patricio County Interconnection Alternative 1[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (8.1miles)	$1,087,000
Storage and Pump Station Modifications	282,000
Total Capital Costs	**$1,369,000**
Engineering, Legal Costs and Contingencies	425,000
Environmental & Archaeology Studies and Mitigation	266,000
Land Acquisition and Surveying	314,000
Interest During Construction (1.5 years)	143,000
Total Project Cost	**$2,517,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$220,000
Operation and Maintenance:	
Pipelines and Pump Stations	18,000
Pumping Energy Costs ($.09 per kWh)	58,000
Treated Water Cost	722,000
Total Annual Cost	**$1,018,000**
Available Project Yield[2] (acft/yr)	**1,120**
Annual Cost of Water ($ per ac ft)	**$909**
Annual Cost of Water ($ per 1,000 gallons)	**$2.79**

[1] Interconnection between San Patricio Municipal Water District transmission main and Sinton.
[2] Average Day Demand in Year 2030, based on 2001 Plan.

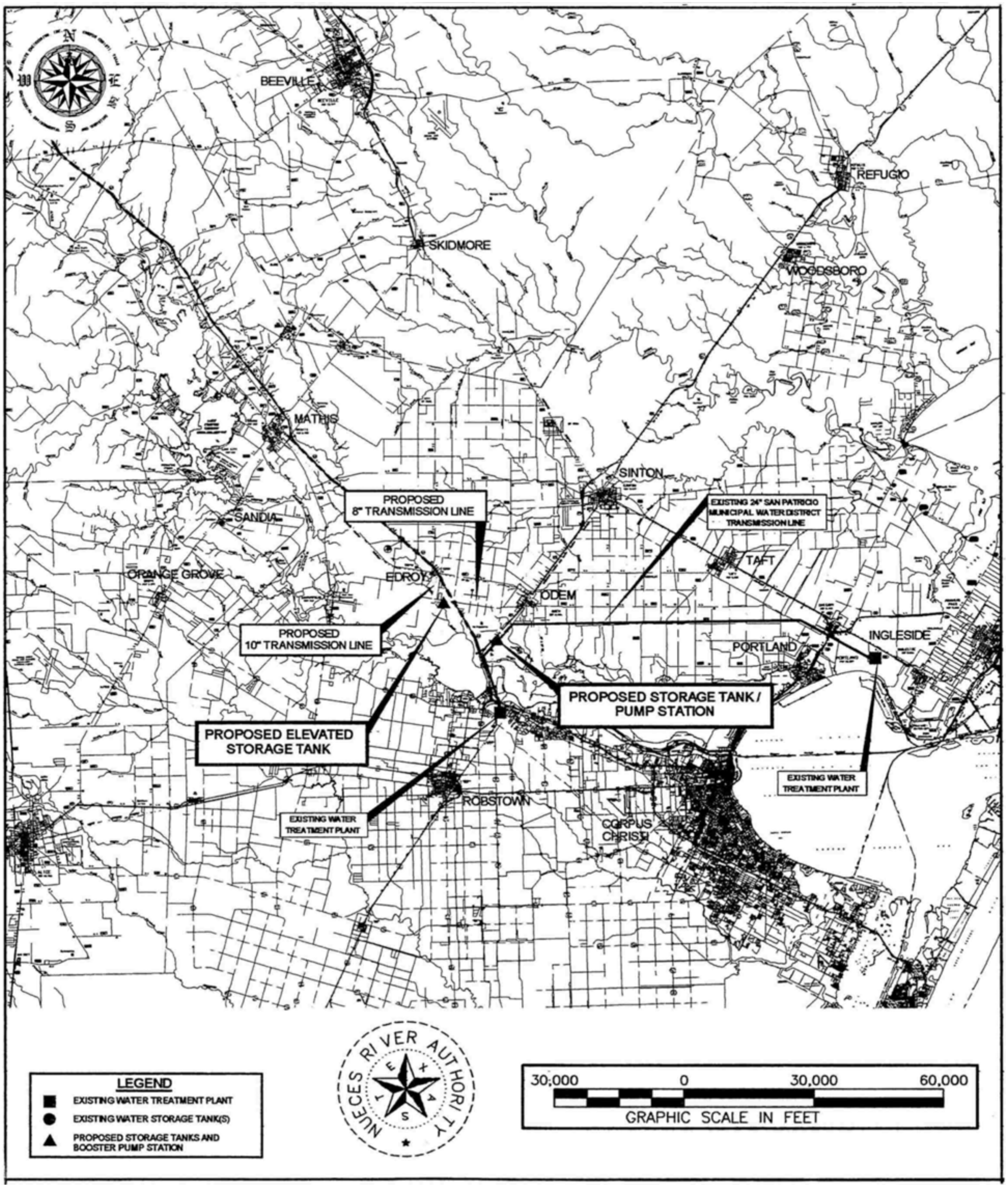

Figure 4C.18-10. San Patricio County Interconnection Alternative 2

Table 4C.18-11.
Cost Estimate Summary
Regional Surface Water Supply
San Patricio County Interconnection Alternative 2[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Transmission Pipelines (8.5 miles)	$939,000
Storage and Pump Station	898,000
Total Capital Costs	**$1,837,000**
Engineering, Legal Costs and Contingencies	$596,000
Environmental & Archaeology Studies and Mitigation	279,000
Land Acquisition and Surveying	191,000
Interest During Construction (2 years)	233,000
Total Project Cost	**$3,136,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$273,000
Operation and Maintenance:	
Pipelines and Pump Stations	32,000
Pumping Energy Costs ($.09 per kWh)	16,000
Treated Water Cost	80,000
Total Annual Cost	**$401,000**
Available Project Yield[2] (acft/yr)	**125**
Annual Cost of Water ($ per ac ft)	**$3,208**
Annual Cost of Water ($ per 1,000 gallons)	**$9.84**

[1] Interconnection between San Patricio Municipal Water District transmission main and Edroy.

[2] Average Day Demand in Year 2030, based on 2001 Plan.

4C.18.3 Environmental Issues

Environmental issues related to the potential water system interconnections in the Coastal Bend Region can be categorized as follows:

- Effects related to pipeline construction and maintenance; and
- Effects resulting from changes in Nueces River flows, including inflows to the Nueces Estuary.

The various proposed pipelines required for the water system interconnections are within Duval, Jim Wells, Brooks, and San Patricio Counties. The pipelines are intended to transfer water between the municipal and industrial demands of these counties. The construction of these pipelines would result in soil and vegetation disturbance within the pipeline construction corridor. Longer-term impacts would be confined to the maintained right-of-way. Several studies are required before the proposed pipelines are constructed. The studies include, but are not limited to, environmental, habitat, and cultural resources studies.

Implementation of the water system interconnections would place an increased demand on the CCR/LCC/Lake Texana System. This will impact reservoir levels, streamflows, and inflows to the Nueces Estuary. An evaluation of these impacts may be required before the water system interconnections are implemented, although the anticipated impacts are negligible.

Implementation of water system interconnections in San Patricio County are expected to reduce chlorides for Sinton and hydrogen sulfide for Edroy and help to ensure Safe Drinking Water Act standards.

4C.18.4 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Table 4C.18-12.

Table 4C.18-12.
Evaluation Summary of the Potential Water System Interconnections

Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Firm yield: Range from 2,554 acft/yr to 125 acft/yr depending on interconnection project
2. Reliability	2. Good reliability.
3. Cost of Treated Water	3. Generally high project cost; between $3,208 to $909 per acft.
b. Environmental factors	
1. Instream flows	1. Possible low impact.
2. Bay and Estuary Inflows	2. Possible low impact.
3. Wildlife Habitat	3. Construction and maintenance of transmission pipeline corridor(s) may impact wildlife species.
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. Endangered species survey will be needed to avoid significant sites.
6. Cultural Resources	6. Cultural resource survey will be needed to avoid significant sites.
7. Water Quality a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	7. May potentially enhance water quality for rural communities. 7d. May improve water quality issues associated with chlorides for Sinton. 7f. May improve water quality issues associated with high hydrogen sulfide for Edroy.
c. Impacts to state water resources	• No negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• Temporary damage due to construction of pipeline(s)
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Standard analyses and methods used for portions
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities
j. Effect on navigation	• None

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4C.19 O.N. Stevens Water Treatment Plant Improvements (N-19)

4C.19.1 Description of Strategy

The O.N. Stevens Water Treatment Plant (Stevens WTP) provides treated water supplies to the City of Corpus Christi (City) and its customers. The City expects to experience increasing municipal and industrial water demands due to a growing population, enterprise, and commerce. Despite the successful water conservation efforts of the City's industrial customers, raw and treated water demand is increasing due to increased manufacturing. Not only have manufacturers indicated that they will need increasing amounts of water in the coming years, other water users have approached the City about various efforts slated to come online in the next several years with increasing rates of water consumption over a 10-year period. The projected growth in manufacturing and steam-electric demand, in combination with municipal demand, requires that the City develop additional treated water supply over the next few years.

Although the Stevens WTP is currently rated at 167 MGD by the TCEQ, the City currently can produce only 159 MGD (or less) of treated water through the Stevens WTP (the sole source of treated water for the City municipal supply, various large industrial users, and the South Texas Water Authority)[1] due to a hydraulic bottleneck at the front end of the Stevens WTP. SPMWD receives treated water supplies from the Stevens WTP and treats some raw water supplies from the CCR/LCC/Lake Texana system with their own water treatment plant. Re-designing the influent end of the plant will allow the plant, operating under acceptable TCEQ detention rates, to produce up to 200 MGD which would increase the amount of treated water supplies needed to meet increasing water demands for City customers and improve supply reliability. Additional system improvements to the water treatment plant will provide operational cost savings from increased reliability and functionality. The proposed O.N. Stevens Water Treatment Plant Improvements are as follows:

- **Raw Water Influent Improvements –** these improvements will address the current hydraulic bottleneck at the Stevens WTP front end that limits total plant capacity to 159 MGD (or less) in order to increase plant capacity to 200 MGD.
- **Nueces River Raw Water Intake Pump Station Improvements** – these improvements will increase the reliability of water delivery to O.N. Stevens from the Calallen Pool.

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[1] The City of Corpus Christi, STWA, and some industrial users rely solely on the Stevens WTP for treated water supplies, and do not have backup treatment plants or treated water furnished from other sources.

- **Stevens WTP Solids Handling Facilities** – these improvements will allow thickening and dewatering of alum sludge from the sedimentation basins which would also employ vacuum recovery for the associated water which would be recovered and returned to the treatment train as a new raw water supply. Current practice is to evaporate the water from the sludge in holding ponds.

The Raw Influent Improvements would allow for blending and pre-sedimentation of 100% of the source water which would increase finished water quality, as well as allow for a more uniform treatment regimen which would save operational costs. Full blending and full pre-sedimentation will also accomplish the goal of increasing the quality of the partially treated water that is provided to local industry. Raw Influent Improvements will also increase security at the Stevens WTP as currently the influent pipelines emerge in an open top meter vault only a few feet from a major road, which is a security concern.

The Nueces River Raw Water Intake Pump Station Improvements will upgrade the pump station in order to increase the reliability of water delivery to Stevens WTP. The upgrades will also increase the operational capability of the pump station and provide operational cost savings from the increased reliability and capabilities of the improved pump station, including new pump motors and motor starters to be installed.[2]

The Stevens WTP Solids Handling Facility will employ vacuum recovery of water that is currently evaporated. With these improvements, water would be recovered and returned to the treatment train as a new raw water supply.

In addition to the projects detailed above, the City anticipates the need for additional water treatment plant improvements to the chemical feed system, electrical distribution system, and process monitoring instrumentation and automation system. Such improvements are not fully discussed in this water management strategy and are not included in the cost estimate.

4C.19.2 Available Yield

Should Region N or the City develop additional raw water supplies in the next few years such as the Garwood Pipeline project (Section 4C.14) or the Nueces Off-Channel Reservoir (Section 4C.11), the industrial customers downstream of the Stevens WTP may face a supply deficit without the proposed Stevens WTP improvements as they depend on partially and/or fully treated supplies from Stevens WTP which currently has a hydraulic bottleneck at the front end of

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[2] The Stevens WTP currently contains emergency generators. Proposed water treatment improvements would be added to the existing electrical distribution system.

their treatment train that limits water treatment plant production. With raw water influent improvements, the Stevens WTP capacity will increase to 200 MGD (peak day).

The City has plans to re-use treated supplies that are currently being evaporated from their sludge handling ponds. With the Stevens WTP improvements in place, the new sludge handling facilities will provide a new reuse supply of water to the head of the treatment train of approximately 14.3 MGD[3] = 16,000 ac-ft/yr. As this water is currently being evaporated, capturing it through this reuse strategy provides an additional 16,000 ac-ft/yr of supply.

Table 4C.19-1 shows the additional yield assumed from both the Stevens WTP expansion and from the solids handing facilities improvements.

Table 4C.19-1.
Additional Yield from Stevens WTP Improvements[1]

Improvement	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Raw Water Influent Improvements[2]	26,329	24,048	22,102	20,366	18,817	16,996
Solids Handling Improvements	16,000	16,000	16,000	16,000	16,000	16,000
Total Increase (acft/yr)	42,329	40,048	38,102	36,366	34,817	32,996

[1] The additional yield is based on an improved Stevens WTP capacity of 200 MGD. Based on the City's most recent 5-year water use data, the Stevens WTP provides treated water supplies at a peak to average day ratio of 1.4:1. Using this peaking ratio, the 200 MGD peak capacity WTP would have an average day capacity of 143 MGD. The sludge handling facilities are anticipated to recover 10%, or 14.3 MGD (16,000 acft/yr).

[2] The yield associated with raw water influent improvements was calculated based on information shown in Table 4A-24 and limited by existing raw water supplies. It is assumed that the improvements will provide additional treated water supplies of 2,156 acft/yr for SPMWD and its customers. The City has a contract with SPMWD to provide up to 40,000 acft/yr, including 30,000 acft/yr raw water supplies and 10,000 acft/yr treated water supplies.

4C.19.3 Environmental Issues

A summary of environmental issues by water treatment plant improvement component is included in Table 4C.19-2. There is little to no environmental impact from the proposed Stevens WTP projects. The majority of the work will be on existing facilities and structures.

4C.19.4 Engineering and Costing

Figure 4C.19-1 show the facilities required to develop the Raw Influent Improvements. The improved headworks piping at O.N. Stevens will also allow for 100% blending and pre-sedimentation of source waters which will effect water quality improvements and chemical cost savings per unit. Table 4C.19-3 summarizes the capital and annual costs for the City's Stevens

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[3] The additional yield is based on an improved Stevens WTP capacity of 200 MGD. Based on the City's most recent 5-year water use data, the Stevens WTP provides treated water supplies at a peak to average day ratio of 1.4:1. Using this peaking ratio, the 200 MGD peak capacity WTP would have an average day capacity of 143 MGD. The sludge handling facilities are anticipated to recover 10%, or 14.3 MGD (16,000 acft/yr).

Table 4C.19-2.
Environmental Issues
City of Corpus Christi Water Supply Improvements

Water Management Strategy/Component	***Environmental Impact***
Raw Influent Improvements	Negligible impact. Possibility of processing more water daily by the WTP could allow for increased consumption if the demand manifests itself, but also increased B&E inflows possible as well.
Nueces River Raw Water Pump Station Improvements	Negligible impact. Upgrades to existing facility will <u>not</u> involve construction in river or alteration of flows, excavation, or dredging.
Stevens WTP Solids Handling Facilities	Negligible impact. Minimum flows to Audubon Society Rookery will be preserved.

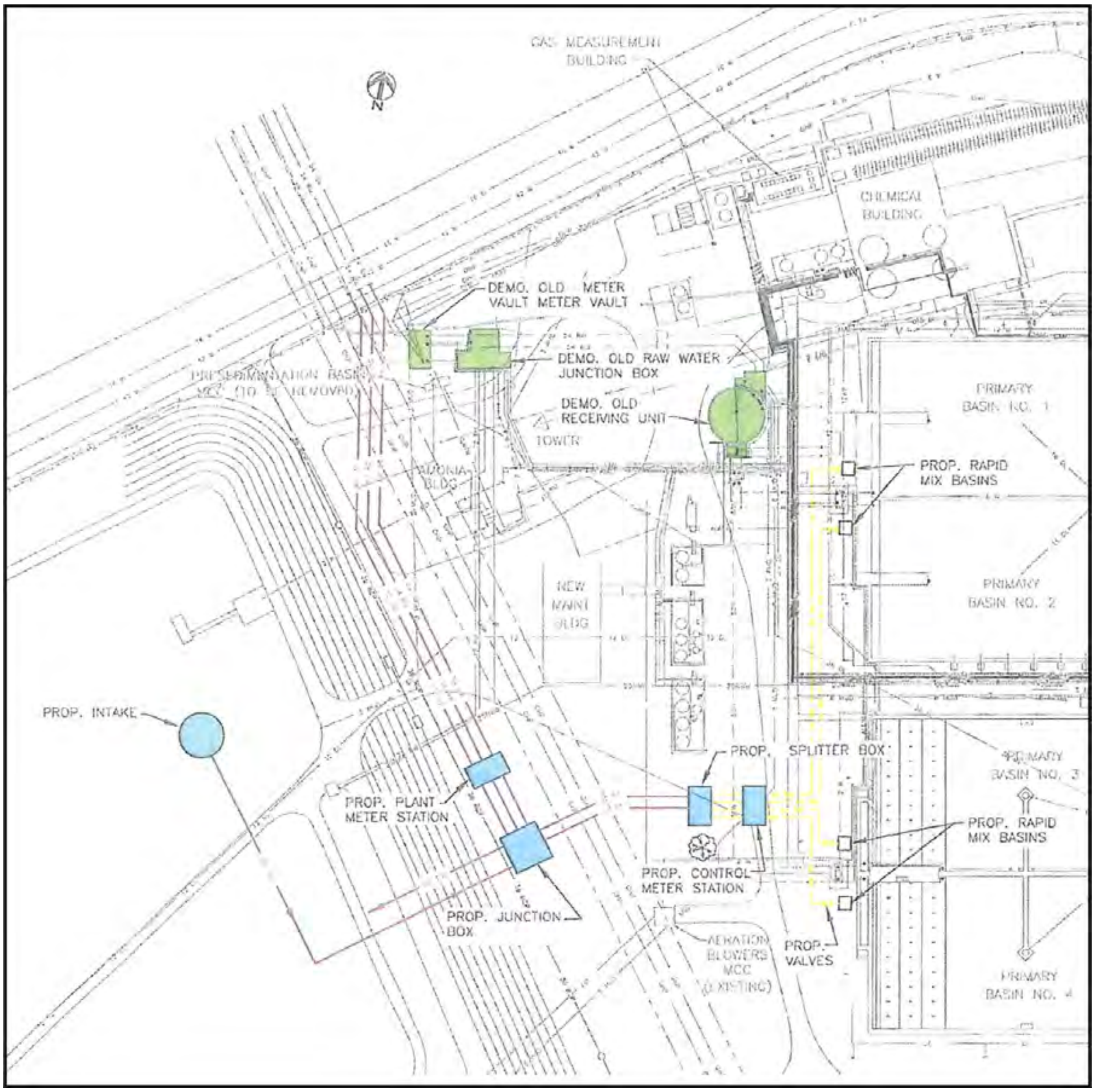

Figure 4C.19-1. O.N. Stevens Water Treatment Plant Raw Water Influent Improvements

Table 4C.19-3.
Cost Estimate Summary for Stevens WTP Improvements

Item Description	*Amount*
O.N. Stevens Water Treatment Plant Improvements — Construction	
Raw Influent Improvements	$12,107,000
Nueces River Raw Water Intake Pump Station Improvements	$3,125,000
O.N. Stevens Solids Handling Facilities	$7,590,000
Total Capital Costs	**$22,822,000**
Engineering, Administrative, Legal Costs, and Contingencies	$7,988,000
Loan Origination Fee	$514,000
Total Project Cost	**$31,324,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$2,731,000
Operations and Maintenance (for 41 MGD conventional treatment added)	$3,564,000
Energy Costs	$1,259,000
Total Annual Cost	**$7,554,000**

WTP Improvements, while Table 4C19-4 summarizes the available project yield and the annual cost of water for each decadal point during the planning period, including treated water costs with assumption of $326 per acft used for other water management strategies. It is important to note that the large decrease in annual cost between 2030 and 2040 is due to the debt service being retired.

Table 4C.19-4.
Unit Cost of Water Summary

	Year					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
Available Project Yield (acft/yr)	42,329	40,048	38,102	36,366	34,817	32,996
Annual Cost of Raw Water ($ per acft)	$178	$189	$198	$133	$139	$146
Annual Cost of Treated Water ($ per acft)	$504	$515	$524	$459	$465	$472

4C.19.5 Implementation Issues

Implementation of these water management strategies will require a National Pollutant Discharge Elimination System (NPDES) Stormwater Pollution Prevention Plan Permit.

There are limited chances for participation by partners. To the extent these improvements will provide improvements in water quality or supply for wholesale finished or wholesale partially treated or wholesale raw water customers, there may be partnership opportunities with the wholesale customers.

The sequencing of construction will have to take into account the fact that the Stevens WTP is the City's only water treatment plant, so it has to keep operating throughout the construction process. There is detention time of only a few hours in the clearwells to allow for switching over to the new hydraulic structures near the end of construction. The Raw Influent Improvements Component is the only portion of the proposed improvements that will require special sequencing consideration.

4C.19.6 Evaluation Summary

An evaluation summary of this water management option is provided in Table 4C.19-5.

Table 4C.19-5.
Evaluation Summary of O.N. Stevens Water Treatment Plant Improvements

Impact Category	*Comment(s)*
a. Water Supply	
1 Quantity	1. Ranges from 32,996 acft/yr to 42,329 acft/yr.
2. Reliability	2. High reliability.
3. Cost of Treated Water	3. Ranges from $133 to $198 per acft.
b. Environmental factors	
1. Instream flows	1. Negligible impact. The Stevens WTP Solids Handling Facilities will reduce demand on river water.
2. Bay and Estuary Inflows	2. Negligible impact. The Stevens WTP Solids Handling Facilities may have minor reduction in inflows to tidal portion of the Nueces River.
3. Wildlife Habitat	3. Negligible impact. The Stevens WTP Solids Handling Facilities will preserve minimum water levels in the Audubon Society Rookery.
4. Wetlands	4. Low or no impact.
5. Threatened and Endangered Species	5. Negligible impact. The Stevens WTP Solids Handling Facilities will preserve minimum water levels in the Audubon Society Rookery.
6. Cultural Resources	6. Negligible impact. All work on Stevens WTP property- should be no impact.
7. Water Quality	7. Low or no impact.
a. dissolved solids b. salinity c. bacteria d. chlorides e. bromide f. sulfate g. uranium h. arsenic i. other water quality constituents	The Stevens WTP Solids Handling Facilities will likely produce water of higher quality than the original source water (including lowered TDS), as the facility would remove solids.
c. Impacts to State water resources	• No apparent negative impacts on water resources
d. Threats to agriculture and natural resources in region	• None
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Standard analyses and methods used
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies	• Improvement over current conditions
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

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4C.20 Brackish Groundwater Desalination (N-20)

4C.20.1 Description of Strategy

Several water management strategies using brackish groundwater have been developed in the vicinity of Corpus Christi. This strategy could help meet the future water supply needs for the City of Corpus Christi (City), San Patricio Municipal Water District (SPMWD), South Texas Water Authority (STWA), and other customers in the region. The supplies are to be developed from the Gulf Coast Aquifer. This strategy identified include three independent well fields, as shown in Figure 4C.20-1, for brackish groundwater supplies, including treatment and delivery, to one or more of the water utilities. Although three well fields were considered, it is unlikely that more than one well field would be developed. The Bee-San Patricio (Bee-SanPat) well field and water facilities are designed to produce an average supply of 21.4 MGD (24,000 acft/yr) at a uniform rate for either the City or SPMWD. Concentrate disposal options include deep-injection wells or a pipeline to Copano Bay. The Nueces Northwest (Nueces-NW) well field is located south of the Nueces River and near the Nueces-Jim Wells County line. It is designed to produce an average supply of 16.1 MGD (18,000 acft/yr) at a uniform rate. The treated water is to be delivered to Corpus Christi’s O.N. Stevens Water Treatment Plant (Stevens WTP). Concentrate disposal is to deep-injection wells. The Nueces South-Central (Nueces S-C) well field is located just north of the Nueces-Kleberg County line and about mid way between the town of Bishop and Laguna Madre. The project is designed to produce an average annual water supply of 10.7 MGD (12,000 acft/yr). One option is to deliver the water to the City’s distribution system in the southern part of the city; and the other option is to deliver the water to STWA’s distribution pipeline for delivery to STWA customers and/or Stevens WTP. Concentrate disposal is designed to either be blended in with return flows from the Barney Davis Power Station with discharge to Oso Bay or to deep-injection wells.

4C.20.2 Available Yield

In the Coastal Bend region, the Gulf Coast Aquifer System is the primary source of substantial groundwater supplies. The most productive water-bearing zone is the Goliad Sand, which is also known as the Evangeline Aquifer. The outcrop of the Goliad Sand is about 50 to 75 miles inland. The formation dips toward the coast at about 20 feet per mile. Near the coast, the shallower Chicot Aquifer provides some groundwater supplies. West of the outcrop of the

Goliad Sands, the deeper Jasper Aquifer can supply a moderate amount of groundwater in some areas.

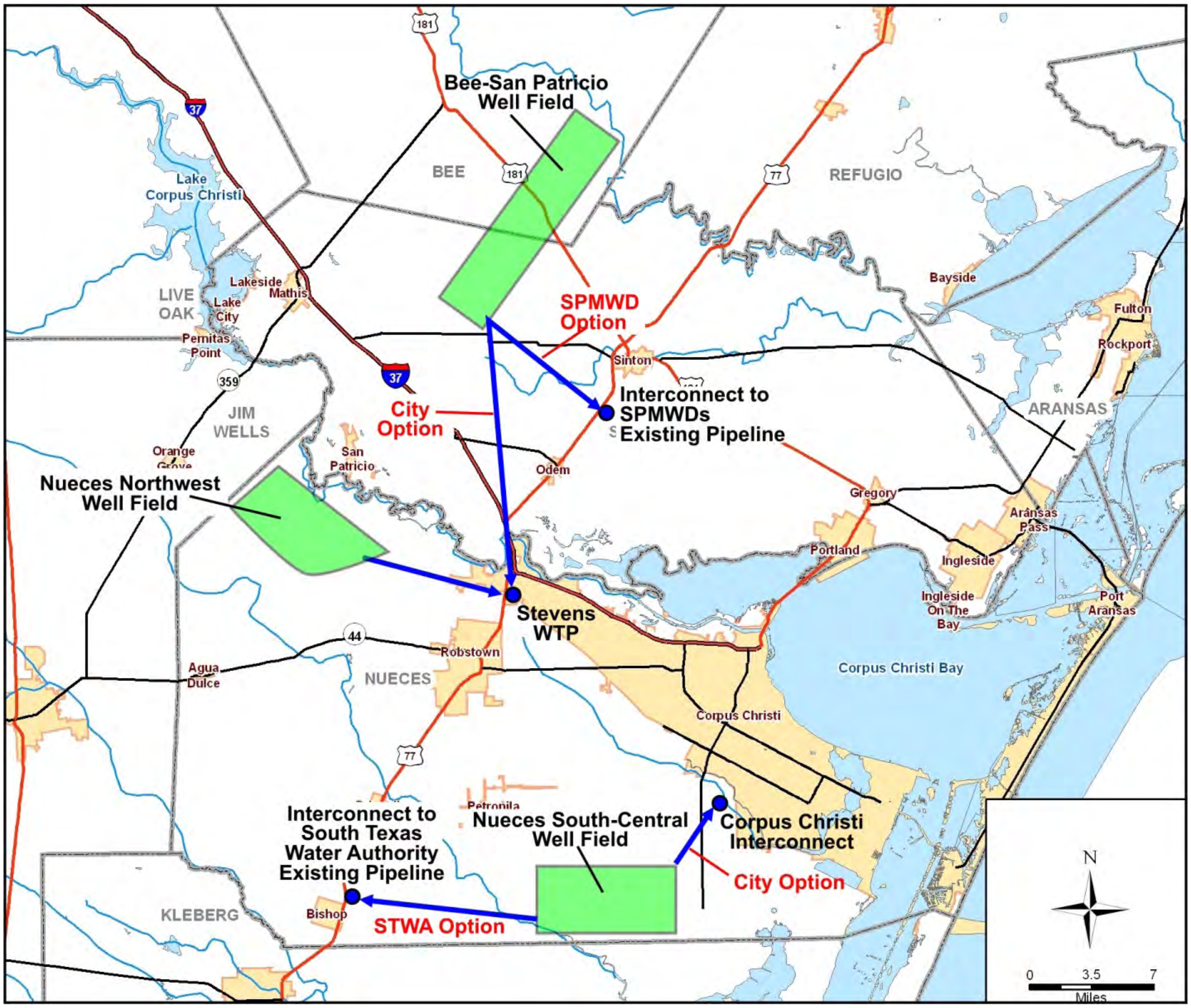

Figure 4C.20-1. Location of Brackish Groundwater Well Fields

Each of the three well fields are designed to produce water from the Evangeline Aquifer. High capacity wells in these areas typically yield about 500 gallons per minute (gpm), but some can yield up to 750 gpm. Well depths increase toward the coast. In the Bee-SanPat, Nueces NW, and Nueces S-C well fields, typical wells depths are about 800, 800 and 1,300 ft[1], respectively. A study of groundwater salinity in the vicinity of these three well field shows total dissolved solid concentrations (TDS) to be about 1,050, 1,750, and 1,900 mg/L, respectively.

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[1] Deeper wells in Nueces S-C well fields closer to the Coast are needed to access most productive water bearing layers in the Evangeline Aquifer without encountering water with higher salinity.

An analysis of the impact of developing the three well fields separately was conducted with the Central Gulf Coast Aquifer Groundwater Availability Model (CGCGAM)[2]. This model application required three steps. The first step included developing separate pumping files for the projects, conducting a simulation with the original (fully penetrating model) of the CGCGAM for brackish project wells through 2060 for each of the projects, and calculating the drawdown from 2000 to 2060. The second step included developing pumping files of background pumping, conducting a simulation from year 2000 to 2060 with the TWDB recalibrated (partial penetrating model) CGCGAM, and calculating the drawdown since predevelopment[3]. The third step included adding the drawdowns from the background and project pumping together to get the cumulative drawdown. Figures 4C.20-2, 4C.20-3, and 4C.20-4 show the cumulative drawdown for background pumping and project pumping from Bee-SanPat, Nueces NW, and Nueces S-C projects, respectively. As shown in these figures, the greatest drawdown is in the vicinity of the City of Kingsville. In all cases, the maximum drawdown is less than a threshold of 250 ft, which was the drawdown criterion for confined aquifers that was adopted by the Coastal Bend Regional Water Planning Group established for estimating groundwater availability in the regional planning process. This threshold is likely to change when the Desired Future Conditions (DFC) are established by Groundwater Management Area 16.

4C.20.3 Potential Groundwater-Surface Water Interaction

The impact of groundwater pumping on streamflow gains or losses is not an element considered in groundwater availability. However, it is of interest. Using mass balance results from the groundwater model simulations, the impact of streamflow is estimated for each of the projects. The impact can either: (1) reduce the amount of baseflow discharging from the aquifer to the streams, (2) increase the baseflow losses from the stream to the aquifer, or (3) change a stream from gaining flow to losing flow. The streams in the area that are likely to be affected and included in the analysis are between the San Antonio River to the northeast and San Fernando Creek to the southwest. Major streams include the Nueces, Aransas, and Mission Rivers. The net streamflow losses attributed to the project, as calculated by the CGCGAM, average 12,600, 13,600, and 0 acft/yr from 2000 to 2060 for the Bee-SanPat, Nueces NW and Nueces S-C,

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[2] Chowdhury, A.H., and others, Sept 27, 2004, Groundwater Availability Model of the Central Gulf Coast Aquifer System: Numerical Simulations through 1999, Texas Water Development Board Model Report.

[3] Predevelopment is representative of conditions prior to the development of a significant number of wells, which is generally considered to be about 1940.

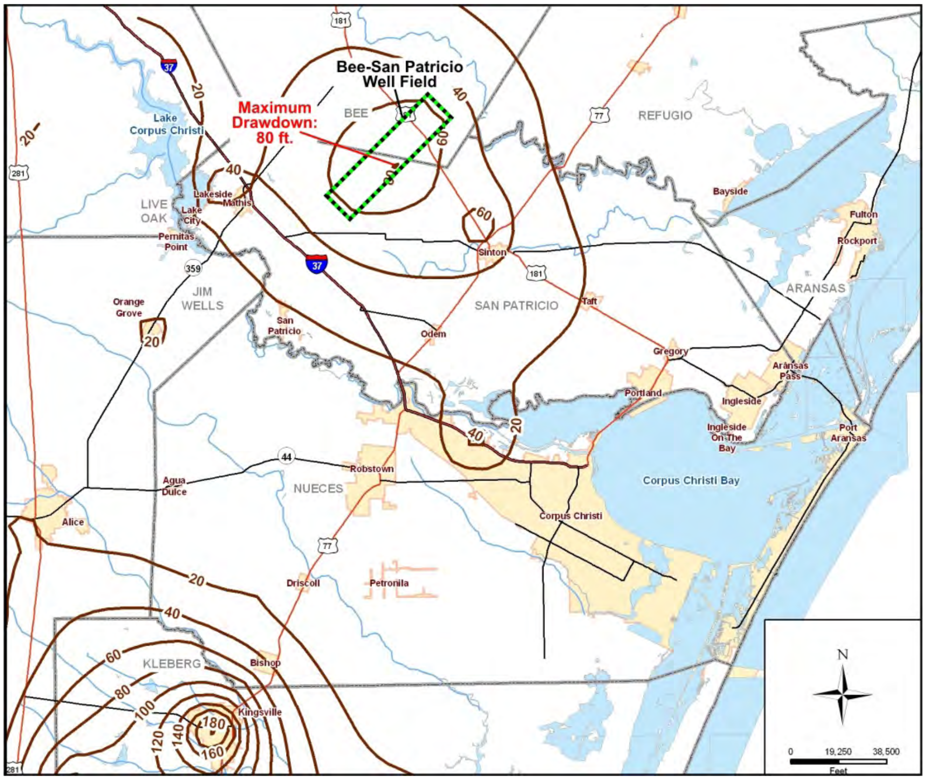


Figure 4C.20-2. Cumulative Drawdown Attributed to Background and Bee-San Patricio Project Pumping, Predevelopment to 2060

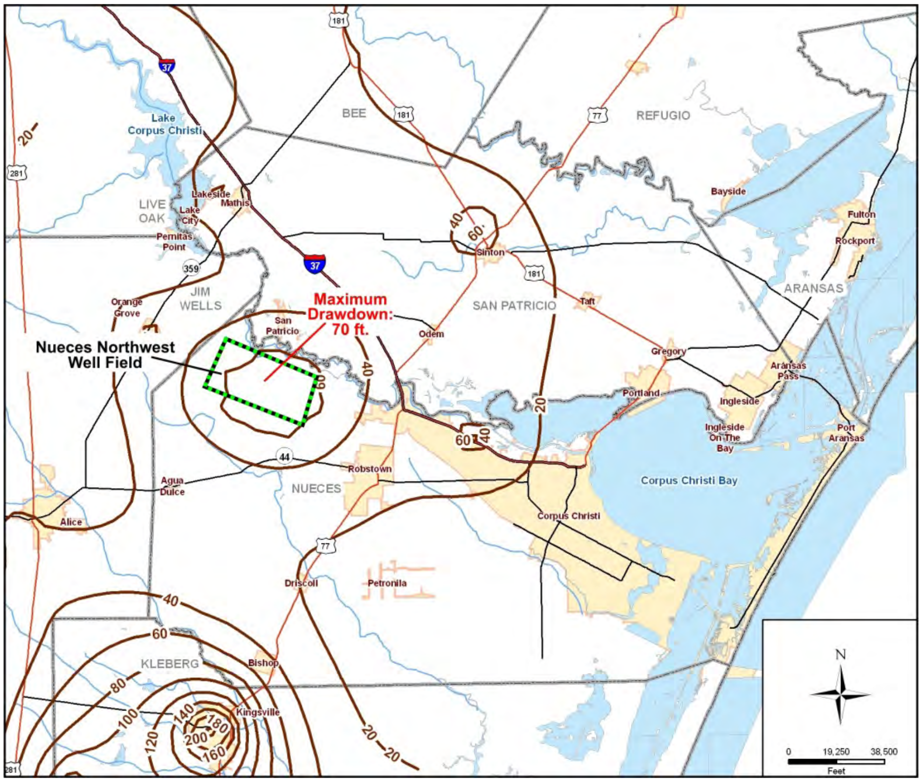


Figure 4C.20-3. Cumulative Drawdown Attributed to Background and Nueces Northwest Project Pumping, Predevelopment to 2060

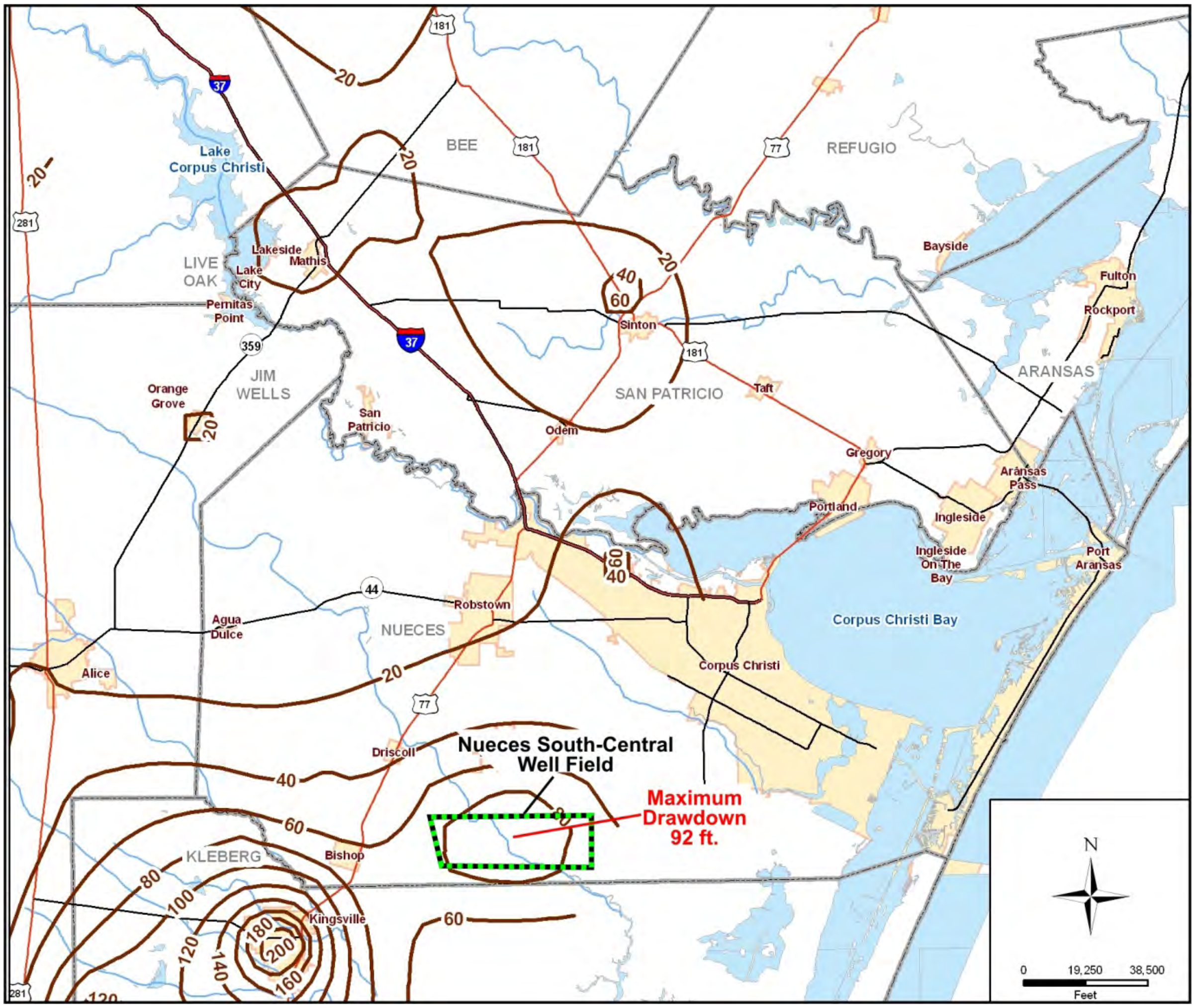


Figure 4C.20-4. Cumulative Drawdown Attributed to Background and Nueces South-Central Project Pumping, Predevelopment to 2060

respectively. This is about 47, 64, and 0 percent, respectively, of the total amount of water pumped by the brackish water wells in these well fields. For the Bee-SanPat well field, about 22 percent of the streamflow losses are occurring in the Nueces River basin and about 25 percent in the Aransas and Mission River basins. For the NW Nueces well field, essentially all the streamflow losses attributed to the well field are occurring in the Nueces River Basin.

4C.20.4 Environmental Issues

Plans for the proposed water management strategies include three different project areas: Bee-SanPat (two delivery options with two concentrate disposal options), Nueces NW and Nueces S-C (two options). The primary environmental issues related to the development of brackish groundwater desalination of water from the Evangeline Aquifer in Nueces, San Patricio, and/or Bee Counties are the development of the well fields and associated pipelines, development of brackish water treatment facilities, integration into the existing pipeline system, discharge of brine concentrate into bay areas, and the deep well injection of brine concentrate.

All of the proposed project areas are located in the Gulf Coastal Plains of Texas Physiographic Province, specifically in the subprovince of the Coastal Prairies. This area is locally characterized as a nearly flat prairie composed of deltaic sands and muds which terminates at the Gulf of Mexico and includes topography changes of less than one foot per mile. Elevation levels in the Coastal Prairies range from 0 to 300 feet above mean sea level.

4C.20.4.1 Environmental Considerations Associated with Bee-SanPat Project

The Bee-San Patricio project area includes a large well field of 36 brackish water wells located along the shared county lines of Bee and San Patricio Counties. This project also includes a treated water pump station and a desalination water treatment plant located adjacent to the well field. Concentrate disposal for this project has two options, deep-injection wells or an approximately 32 mile concentrate disposal pipeline which discharges into Copano Bay in Aransas County.

The concentrate disposal pipeline crosses areas which are primarily used for pasture and crops. Vegetation types found along the pipeline route also include areas of Mesquite-Live Oak-Bluewood Parks. The concentrate disposal pipeline would cross possible wetland areas associated with Chiltipin Creek and the marshy areas near Copano Bay. Planning of the pipeline route should include avoidance of impacts to these wetland areas where possible. The potential environmental effects resulting from the disposal of brine concentrate from the Bee-SanPat project will be sensitive to the siting of the project and its associated pipeline. Although the construction of portions of both the concentrate disposal and treated water pipelines may include the clearing and removal of woody vegetation, destruction of potential habitat can generally be avoided by diverting the corridor through previously disturbed areas.

Estuaries such as those found near Copano Bay serve as critical habitat and spawning grounds for many marine species and migratory birds. Estuaries are marine environments maintained in a brackish state by the inflow of freshwater from rivers and streams. The high productivity characteristic of estuaries arises from their large nutrient input, shallow water, and the ability of a few marine species to thrive in environments continually stressed by low, variable salinities, temperature extremes, and, on occasion, low dissolved oxygen concentrations. The potential environmental effects resulting from the disposal of brine concentrate from the Bee-

SanPat project will be sensitive to the siting of the project and its appurtenances. The salinity level of the discharged concentrate is lower than that of the water found within the Copano Bay system, which should minimize its impact on the associated aquatic habitat. Prior to implementation, additional water quality studies of discharge impacts to the Bay system would need to be performed.

The Bee-SanPat well field area is primarily located within an area used for crops; however it also contains smaller portions of Mesquite-Live Oak-Bluewood Parks vegetation areas. Mesquite-Live Oak-Bluewood Parks areas commonly contain plants such as huisache, grajeno, lotebush, pricklypear, agarita, purple threeawn, and Mexican persimmon. Distribution of this vegetation type is found primarily within the South Texas Plains. Because the well field is located near Papalote Creek, site selection for the wells should include the avoidance of impacts to wetland areas. A preliminary assessment of the impact of operating this well field on groundwater discharge to the Aransas and Nueces Rivers, Lake Corpus Christi and nearby streams suggest that the discharge will be reduced by about 17 cfs (or 12,310 acft) in 2060.

In addition, there are two treated water pipeline options associated with this project. One treated water pipeline runs in a southeast direction for approximately twelve miles before reaching its delivery point at a SPMWD connection site. The second treated water pipeline option travels southeast for approximately twenty miles before terminating at the Stevens WTP. The SPMWD pipeline potentially crosses marshy and wetland areas associated with Chilitipin Creek, while the Stevens WTP pipeline route crosses both Chilitipin Creek and the Nueces River. Appropriate pipeline route selection, construction methods and right-of-way selection should avoid or minimize any anticipated impacts to these potential wetland areas.

4C.20.4.2 Environmental Considerations Associated Nueces NW Project

The Nueces NW project includes a brackish water well field of 29 wells located in the upper northwest part of Nueces County, a desalination water treatment plant, treated water pump station, and treated water pipeline. Concentrate disposal for this option includes deep well injection. Brackish water received from the well field would be processed at the desalination water treatment plant, then moved southeast by the treated water pump station through an approximately 5 mile pipeline to its delivery point at the Stevens WTP.

Vegetation found within the project area is primarily crops, with a small portion of Mesquite-Blackbrush Brush vegetation located within the northern portion of the well field area. Mesquite-Blackbrush Brush vegetation commonly includes species such as lotebush, guajillo, whitebrush, pricklypear, kidneywood, yucca, and purple three-awn. This type of vegetation is found principally on shallow, gravelly or loamy soils in the South Texas Plains. Wetland areas and sand and gravel pits found near the Nueces River may necessitate careful selection of well locations within the well field area to avoid impact to wetlands. A preliminary assessment of the impact of operating this well field on groundwater discharge to the Nueces River, Lake Corpus Christi and nearby streams suggest that the discharge will be reduced by about 18 cfs (or 13,030 acft) in 2060.

4C.20.4.3 Environmental Considerations Associated Nueces S-C Project

The Nueces S-C project includes two delivery options: to the City's storage facility in their south service area (City option) or to STWA treated water pipeline for delivery to STWA customers and/or Stevens WTP (STWA option). The City option includes 20 brackish water wells located in southeast Nueces County approximately 13 miles southwest of the City of Corpus Christi. Treated water would then be transported through an approximately 6 mile pipeline to its delivery point, which is located in the southern part of the City's distribution system. Concentrate disposal would pass through a nearby concentrate disposal pump station and along an approximately 9 mile pipeline which would then discharge into the Barney M. Davis Power Station outfall to Oso Bay. Although the construction of portions of both the concentrate disposal and treated water pipelines may include the clearing and removal of woody vegetation, destruction of potential habitat can generally be avoided by diverting the corridor through previously disturbed areas. Prior to implementation, additional water quality studies of discharge impacts to the Bay system would need to be performed.

Estuaries such as those found near Oso Bay serve as critical habitat and spawning grounds for many marine species and migratory birds. Estuaries are marine environments maintained in a brackish state by the inflow of freshwater from rivers and streams. The high productivity characteristic of estuaries arises from their large nutrient input, shallow water, and the ability of a few marine species to thrive in environments continually stressed by low, variable salinities, temperature extremes, and, on occasion, low dissolved oxygen concentrations. The potential environmental effects resulting from the disposal of brine concentrate from the Nueces S-C project will be sensitive to the siting of the project and its appurtenances. The salinity level of the discharged concentrate is lower than that of the water found within the bay system, which should minimize its impact on the associated aquatic habitat.

Vegetation types found within the City Option include primarily crop areas within the well field area and treated water pipeline locations, with the concentrate disposal pipeline located within a Mesquite-Granjeno Park vegetation area. Vegetation in the Mesquite-Granjeno Park areas commonly include bluewood, lotebush, Texas prickly-pear, hooded windmillgrass, croton, silver-leaf nightshade and fireweed. This vegetation type is found principally on sandy or loamy upland soils in the South Texas Plains.

The STWA option includes a brackish well field of 20 wells located in the lower southwest portion of Nueces County, a desalination water treatment plant, treated water pump station, and treated water pipeline. Concentrate disposal for this option includes deep well injection. Treated water from the well field will flow through a 15 mile pipeline to its delivery point which consists of a connection with the existing STWA system. This option is located within an area of vegetation that contains primarily existing croplands. Wetland impacts possibly associated with pipeline crossings at Petronila Creek or its tributaries should be avoided where possible by careful siting and construction.

A preliminary assessment of the impact of operating this well field on groundwater discharge to nearby streams suggest that there will be little or no impact by 2060.

4C.20.4.4 Area Vegetation and Wildlife Habitat

The brackish water desalination project area is located within the Gulf Prairies and Marshes Vegetational Area. Gulf Prairies have slow surface drainage and elevations that range from sea level to 250 feet. These areas include nearly level and virtually undissected plains. Originally the Gulf Prairies were composed of tallgrass prairie and post oak savannah. However tree species such as honey mesquite, and acacia, along with other trees and shrubs have increased in this area forming dense thickets in many places. Typical oak species found in this area include live oak (*Quercus virginiana*) and post oak (*Q. stellata*), in addition to huisache (*Acacia smallii*), black-brush (*A. rigidula*), and a dwarf shrub; bushy sea-ox-eye (*Borrichia frutescens*). Principal climax grasses of the Gulf Prairies include gulf cordgrass (*Spartina spartinae*), indiangrass (*Sorghastrum nutans*), and big bluestem (*Andropogon gerardii* var. *gerardii*). Prickleypear (*Opunita* sp.) are common within this area along with forbs including asters (*Aster* sp.), poppy mallows (*Callirhoe* sp.), bluebonnets (*Lupinus* sp.), and evening primroses (*Oenothera* sp.). Gulf Marshes range from sea level to a few feet in elevation, and include low, wet marshy coast areas commonly covered with saline water. These salty areas support numerous species of sedges (*Carex* and *Cyperus* sp.), bulrushes (*Scirpus* sp.), rushes (*Juncus* sp.), and grasses. Aquatic forbs found in these areas generally include pepperweeds (*Lepidium* sp.), smartweeds (*Polygonum* sp.), cattails (*Typha domingensis*) and spiderworts (Tradescantia sp.) among others. Game and waterfowl find these low marshy areas to be excellent natural wildlife habitat.

4C.20.4.5 Threatened and Endangered Species (ES)

The Federal Endangered Species Act of 1973, as amended, prohibits the “take” of any threatened or endangered species. The term “take” under the ESA means “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct.” The term “harm” was further defined to include “significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering.” Designation of critical habitat areas has been established for the public knowledge where the publishing of such information would not cause harm to the species. Additional federal protection is extended to migratory birds, and bald and golden eagles under the Migratory Bird Treaty Act (MBTA) as amended, and the Bald and Golden Eagle Protection Act. Protection is also afforded to Texas state-listed species. The Texas Parks and Wildlife Department (TPWD) enforces the state regulations.

The MBTA protects most bird species, including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds. Migratory bird pathways, stopover habitats, wintering areas, and breeding areas may occur within and adjacent to the pipeline area, and may be associated with wetlands, ponds, shorelines, riparian corridors, fallow fields and grasslands, and woodland and forested areas. Pipeline construction activities could disturb migratory bird habitats and/or species’ activities.

Reasonable and prudent measures should be taken to avoid and minimize the potential effects of the proposed project’s activities on threatened and endangered species as well as bald eagles. Species’ locations, activities, and habitat requirements should be considered based on U.S. Fish and Wildlife Service and TPWD recommendations.

In Nueces, San Patricio, Aransas, and Bee Counties there may occur 40 state-listed endangered or threatened species and 19 federally-listed endangered or threatened wildlife species, according to the county lists of rare species published by the TPWD. A list of these species, their preferred habitat and potential occurrence in the four county areas is provided in Table 4C.20-1.

Table 4C.20-1.
Federal- and State-Listed Threatened, Endangered, and Species of Concern Listed for Nueces, San Patricio, Aransas, and Bee Counties

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Potential Occurrence in Project Area***	***Federal Status***	***State Status***
Peregrine falcon	*Falco peregrinus anatum* (American)	Open country; cliffs	Nesting/Migrant	DL	T
	Falco peregrinus tundrius (Arctic)	Open country; cliffs	Nesting/Migrant	DL	—
Brown pelican	*Pelecanus occidentalis*	Coastal inlands for nesting, shallow gulf and bays for foraging.	Resident	LE-PDL	E
Eskimo Curlew	*Numenius borealis*	Nonbreeding in grasslands, pastures and plowed fields.	Historic	LE	E
Henslow's sparrow	*Ammodramus henslowii*	Wintering individuals found in weedy fields	Migrant	—	—
Mountain plover	*Charadrius montanus*	Breeding, nesting on shortgrass prairie.	Resident	—	—
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	Open country, especially savanna and open woodland, and sometimes in very barren areas; grassy plains and valleys with scattered mesquite, yucca, and cactus.	Migrant	LE	E
Piping plover	*Charadrius melodus*	Beaches and flats of coastal Texas	Migrant	LT	T
Reddish egret	*Egretta rufescens*	Coastal inlands for nesting, coastal marshes for foraging	Resident	—	T
Sennett's Hooded Oriole	*Icterus cucullatus sennetti*	Often builds nests in and of Spanish moss feeds on invertebrates, fruit, and nectar.	Resident	—	—
Snowy plover	*Charadrius alexandrinus*	Potential migrant, wintering along the coast	Migrant	—	—
Sooty Tern	*Sterna fuscata*	Catches small fish as it hovers or flies over water	Resident	—	T
Southeastern Snowy Plover	*Charadrius alexandrinus tenuirostris*	Wintering migrant along the Texas Gulf Coast beaches and bayside mud or salt flats.	Migrant	—	—
Texas Botteri's Sparrow	*Aimophila botterii texana*	Grassland and short-grass plains with scattered bushes or shrubs, sagebrush, mesquite, or yucca; nests on ground of low clump of grasses	Resident	—	T
Western burrowing owl	*Athene cunicularia hypugaea*	Open grasslands, especially prairie.	Resident	—	—
Western Snowy Plover	*Charadrius alexandrinus nivosus*	Potential migrant; wintering along the coast.	Potential Migrant	—	—
White-faced ibis	*Plegadis chihi*	Prefers freshwater marshes	Resident	—	T

Table 4C.20-1 (Continued)

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Potential Occurrence in Project Area***	***Federal Status***	***State Status***
White-tailed hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf Coastal Plain	Nesting/Migrant	—	T
Whooping crane	*Grus Americana*	Winters in coastal marshes	Migrant	LE	E
Wood stork	*Mycteria Americana*	Forages in prairie ponds, ditches and shallow standing water; formerly nested in Texas	Migrant	—	T
Aransas short-tailed shrew	*Blarina hylophaga plumbea*	excavates burrows in sandy soils underlying mottes of live oak trees or in areas with little to no ground cover	Resident	—	—
Black bear	*Ursus americanus*	Historic in bottomland hardwoods and large tracts of inaccessible forested areas.	Historic	T/SA;NL	T
Jaguarundi	*Herpailurus yaguarondi*	Thick brushlands, near water favored.	Resident	LE	E
Louisiana black bear	*Ursus americanus luteolus*	Historic as possible transient. Bottomland hardwoods and large tracts of inaccessible forested areas.	Historic	LT	T
Maritime pocket gopher	*Geomys personatus maritimus*	Found in deep sandy soils; feeds mostly from within burrow on roots and other plant parts.	Resident	—	—
Ocelot	*Leopardus pardalis*	Dense chaparral thickets; mesquite-thorn shrub and live oak stands.	Resident	LE	E
Plains spotted skunk	*Spilogale putorius interrupta*	Open fields, and prairies.	Resident	—	—
Red wolf	*Canis rufus*	Extirpated	Historic	LE	E
Southern yellow bat	*Lasiurus ega*	Associated with trees, such as palm trees.	Resident	—	T
West Indian manatee	*Trichechus manatus*	Gulf and bay system; opportunistic, aquatic herbivore	Aquatic Resident	LE	E
White-nosed coati	*Nasua narica*	Woodlands, riparian corridors and canyons	Transient	—	T
Black-spotted newt	*Notophthalmus meridionalis*	Ponds and resacas in south Texas	Resident	—	T
Sheep frog	*Hypopachus variolosus*	Predominantly found in grassland and savannas; moist sites in arid areas	Resident	—	T
South Texas siren	*Siren sp.1*	Wet or sometimes wet areas, such as arroyos, canals, ditches, or even shallow depressions.	Resident	—	T
American eel	*Anguilla rostrata*	Coastal waterways to Gulf.	Resident	—	—
Opossum pipefish	*Microphis brachyurus*	Brooding adults found in fresh or low salinity waters and young in more saline waters; Southern coastal areas	Aquatic Resident	—	T

Table 4C.20-1 (Continued)

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Potential Occurrence in Project Area***	***Federal Status***	***State Status***
Smalltooth sawfish	*Pristis pectinata*	young found very close to shore in muddy and sandy bottoms, in sheltered bays, on shallow banks, and in estuaries or river mouths; adult sawfish are encountered in various habitat types.	Aquatic Resident	LE	E
Texas pipefish	*Syngnathus affinis*	Corpus Christi Bay; seagrass beds	Aquatic Resident	—	—
Manfreda giant-skipper	*Stallingsia maculosus*	most skippers are small and stout-bodied; name derives from fast, erratic flight	Resident	—	—
Golden Orb	*Quadrula aurea*	Sand and gravel areas in river basins.	Resident	—	T
Atlantic hawksbill sea turtle	*Eretmochelys imbricata*	Gulf and bay system, warm shallow waters especially in rocky marine environments.	Aquatic Resident	LE	E
Green sea turtle	*Chelonia mydas*	Gulf and bay systems; shallow water seagrass beds	Aquatic Resident	LT	T
Gulf saltmarsh snake	*Nerodia clarkii*	Saline flats and river mouths	Resident	—	—
Indigo snake	*Drymarchon corais*	South of the Guadalupe River and Balcones Escarpment; mainly in dense riparian corridors	Resident	—	T
Keeled earless lizard	*Holbrookia propinqua*	Coastal dunes, barrier islands, and other sandy areas; eats insects and likely other small invertebrates.	Resident	—	—
Kemp's Ridley sea turtle	*Lepidochelys kempii*	Gulf and bay systems; shallow waters of the Gulf of Mexico	Aquatic Resident	LE	E
Leatherback sea turtle	*Dermochelys coriacea*	Gulf and bay systems; forages in Gulf of Mexico	Aquatic Resident	LE	E
Loggerhead sea turtle	*Caretta caretta*	Gulf and bay systems for juveniles, adults prefer open waters	Aquatic Resident	LT	T
Spot-tailed earless lizard	*Holbrookia lacerate*	Open prairie-brushland.	Resident	—	—
Texas diamondback terrapin	*Malaclemys terrapin littoralis*	Coastal marshes and tidal flats.	Resident	—	—
Texas horned lizard	*Phrynosoma cornutum*	Varied; sparsely vegetated uplands, grass, cactus, brush	Resident	—	T
Texas scarlet snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils	Resident	—	T
Texas tortoise	*Gopherus berlandieri*	Open bush with grass understory; open grass and bare ground avoided	Resident	—	T
Timber/Canebrake rattlesnake	*Crotalus horridus*	Floodplains, riparian zones with dense ground cover	Resident	—	T

Table 4C.20-1 (Continued)

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Potential Occurrence in Project Area***	***Federal Status***	***State Status***
Coastal gay-feather	*Liatris bracteata*	Endemic to black clay soils of prairie.	Resident	—	—
Elmendorf's onion	*Allium elmendorfii*	Endemic to grassland openings in woodlands	Resident	—	—
Lila de los Llanos	*Echeandia chandleri*	Shrubs or in grassy openings in subtropical thorn shrublands along Gulf Coast.	Resident	—	—
Mexican mud-plantain	*Heteranthera mexicana*	Resacas and ephemeral wetlands	Resident	—	—
Plains gumweed	*Grindelia oolepis*	Coastal prairies on heavy clay soils.	Resident	—	—
Slender rushpea	*Hoffmannseggia tenella*	Texas endemic; coastal prairie grasslands.	Resident	LE	E
South Texas ambrosia	*Ambrosia cheiranthifolia*	Found on grasslands and mesquite-dominated shrublands.	Resident	LE	E
Texas windmill-grass	*Chloris texensis*	Texas endemic; sandy to sandy loam soils in bare areas in coastal prairie grassland remnants.	Resident	—	—
Tharp's rhododon	*Rhododon angulatus*	Texas endemic; deep, loose sands in sparsely vegetated areas on stabilized dunes of barrier islands.	Resident	—	—
Three-flower broomweed	*Thurovia triflora*	Endemic, remnant grasslands and tidal flats	Resident	—	—
Welder machaeranthera	*Psilactis heterocarpa*	Endemic to grasslands and adjacent scrub flats.	Resident	—	—

Source: TPWD, Annotated County List of Rare Species, Bee County, May 4, 2009, San Patricio County, May 4, 2009, and Nueces County May 4, 2009.

DL Delisted LE Federally listed endangered PDL Proposed for Delisting LT Federally listed threatened

--- Not Listed (Species of Concern) E State Endangered T State Threatened

T/SA Threatened due to Similarity of Appearance

Inclusion in Table 4C.20-1 does not imply that a species will occur within the project area, but only acknowledges the potential for occurrence in the project area counties. A more intensive field reconnaissance would be necessary to confirm and identify specific suitable habitat that may be present in the project area.

The proposed projects occur primarily in areas which have been previously developed and used for farming and pasture for a long period of time. Disturbance within these areas due to construction of the pipeline routes and well fields is anticipated to have minimal effect on the existing environment. Although the use of deep well injection methods for disposal of the brine concentrate is not anticipated to impact existing terrestrial species, impacts from the disposal of saline concentrate into Oso or Copano Bays should be carefully monitored in order to minimize any impacts this may have on aquatic species. After a review of the habitat requirements for each listed species, it is anticipated that it is unlikely that this project will have an adverse effect on any federally listed threatened or endangered species, its habitat, or designated habitat, nor would it adversely affect any state endangered species. Although suitable habitat for some listed species may exist within the project areas, no impact is anticipated due to the abundance of similar habit near the project areas and the ability of most species to relocate to those areas if necessary. The presence or absence of potential habitat within an area does not confirm the presence or absence of a listed species. No species specific surveys were conducted in the project area for this report.

4C.20.4.6 Wetland Areas

Potential wetland impacts are expected to include pipeline and well field areas located near rivers, streams, or marshy areas near bays. The wells, collection system within the well field, and transmission systems should be sited in such a way as to avoid or minimize impacts to these sensitive resources. Potential impacts can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetland would be required where impacts are unavoidable.

4C.20.4.7 Cultural Resources

A review of the Texas Historical Commission Texas Historic Sites Atlas data base indicated that there are no National Register Properties listed near any of the proposed project areas. Three Historical Markers have been identified within two of the project areas, one within the Nueces S-C option, and two in the area of the Nueces NW well field. Impact to any of these markers should be easily avoided through planning associated with the development of the well fields and pipeline routes. In addition there are four cemeteries located near the Nueces S-C and Bee-SanPat project areas which should be avoided by planning and location of the well fields and pipeline routes.

A cultural resource survey of the well field and pipeline routes for each of the proposed project areas will need to be performed consistent with requirements of the Texas Antiquities Commission.

4C.20.4.8 Summary of Overall Possible Environmental Impacts

Because of the relatively small areas involved, construction and maintenance of surface facilities are not expected to result in substantial environmental impacts. Where environmental resources (e.g., endangered species habitat and cultural resource sites) could be impacted by infrastructure, minor adjustments in facility siting and pipeline alignment would generally be sufficient to avoid or minimize adverse effects.

The pumping of groundwater from the Evangeline Aquifer could cause a slight reduction on baseflow in downstream reaches. However, no measurable impact on wildlife along the streams is anticipated from this project. Minor land surface subsidence could potentially occur as a result of lowering of groundwater levels. As a result, drainage patterns and other habitats might change to a small extent.

4C.20.5 Engineering and Costing

4C.20.5.1 Bee-SanPat Projects

This project considers two options for delivery of treated water, which are delivery to the Stevens WTP and to SPMWD's water main near U.S. Hwy 77 and about 2 miles south of Sinton. There are two options for disposal of concentrate, including deep-well injection and discharge to Copano Bay. The project is designed to yield 21.4 MGD (24,000 acft/yr) and provide a treated water supply with a total dissolved solids concentration of about 400 mg/L. Figures 4C.20-5 and 4C.20-6 show the location of the City and SPMWD options, respectively.

The preliminary water treatment design has the facilities located in the vicinity of the well field. The brackish groundwater does not contain a high level of suspended solids; therefore, only the other standard pretreatment components are included. With a source water having relatively low TDS for brackish water, a portion of the raw water can be blended with desalinated, treated water to operate the project more economically while achieving a treated water that is comparable to existing supplies.

With a source water having a TDS of about 1,050 mg/L and a product water of about 400 mg/L, about 62 percent of the raw well water from the Bee-SanPat project will be sent to the desalination plant to remove inorganic and organic water quality constituents; and, the remaining 38 percent will be blended with the desalinated water. Based on a conventional reverse osmosis (RO) desalination process, the desalination plant recovery rate for this raw water is estimated to be 85 percent, meaning that 85 percent of the water entering the desalination plant passes through as purified water and 15 percent of the water remains as brine. The desalinated water is blended back with the brackish water that bypasses the desalination process to produce the finished water. Overall, this process converts about 90 percent of the raw water produced from

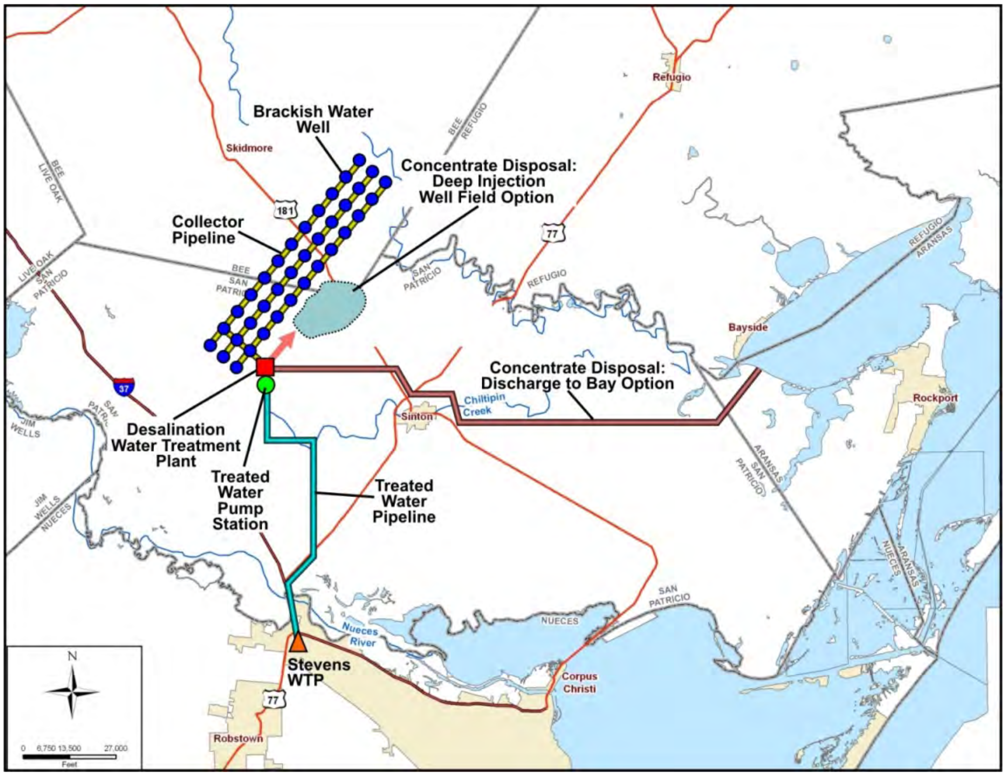


Figure 4C.20-5. Location of Bee-San Patricio Project for City of Corpus Christi

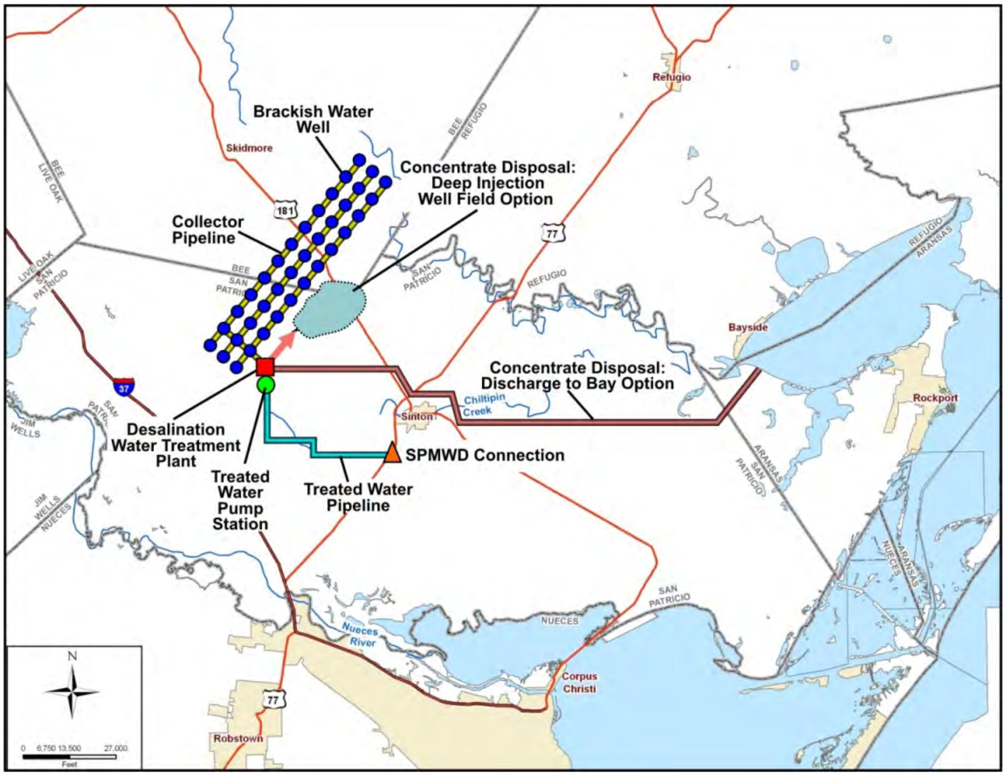
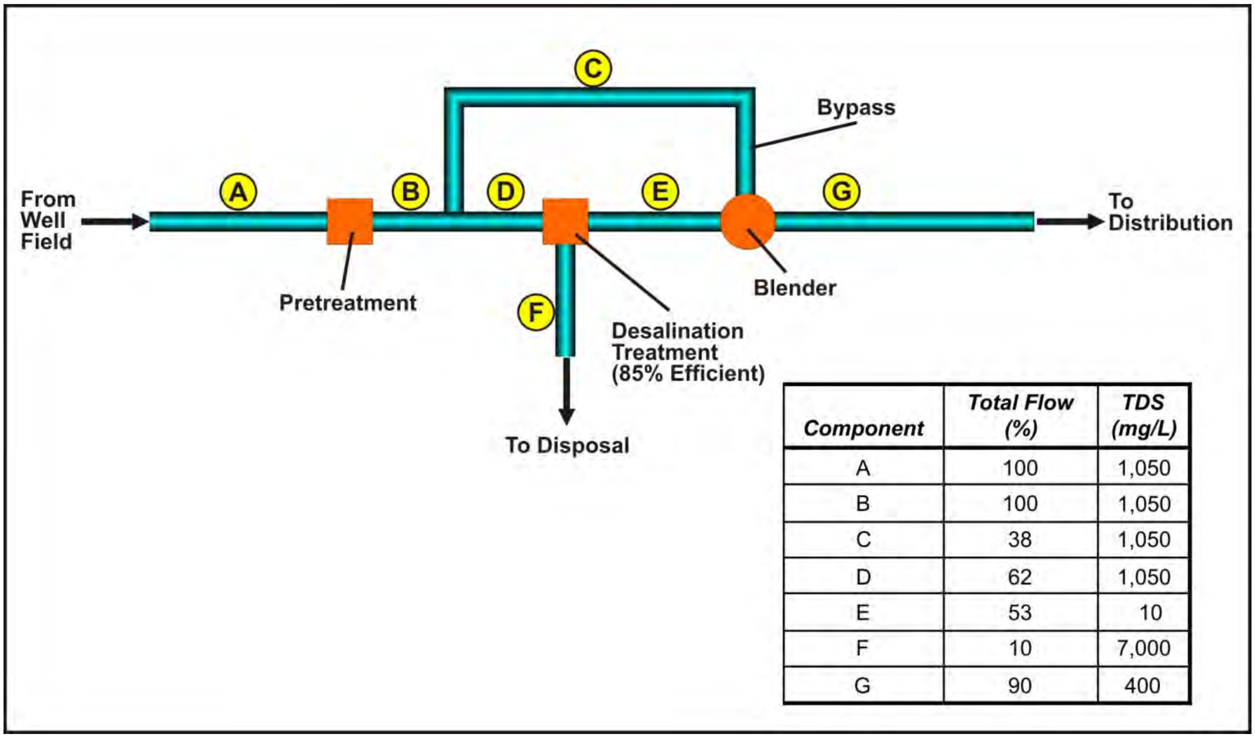


Figure 4C.20-6. Location of Bee-San Patricio Project for SPMWD the well field into potable water. The remaining 10 percent is a concentrate and is discharged either to deep-injection wells or Copano Bay. The concentrate will have a TDS of about 7,000 mg/L.

Figure 4C.20-7 is provided to illustrate the water treatment system for a typical brackish groundwater desalination treatment plant, the percent of water flowing through each component of the system, and the concentration of the TDS.



Component	Total Flow (%)	TDS (mg/L)
A	100	1,050
B	100	1,050
C	38	1,050
D	62	1,050
E	53	10
F	10	7,000
G	90	400

Figure 4C.20-7. Flow Diagram for a Typical Brackish Groundwater Desalination Water Treatment Plant

Based on the loss of raw water to concentrate in the desalination process, the well field capacity will need to be about 23.8 MGD. The well field is located in Bee and San Patricio Counties and consists of 36 wells, which includes a contingency of about 10 percent. The wells have an average yield of 500 gpm, are 800 ft deep, spaced about 1 mile apart, and produce water with a TDS of about 1,050 mg/L. In the well field, the collector pipeline ranges from a diameter of 8 to 36 inches, and includes about 35 miles of pipeline. Well pumps will be sized to deliver the raw water directly to the water treatment plant.

The distribution pipeline for delivery of water to the Stevens WTP is about 19.2 miles long and has a diameter of 36 inches. For the SPMWD option, the distribution pipeline is about

12.5 miles long and also has a diameter of 36 inches. A pump station is required at the desalination water treatment plant for both options.

For the option to discharge the concentrate to Copano Bay, a 32 mile long, 16 inch diameter pipeline is required. At the terminal end and in the bay, a diffuser will be installed to disperse the concentrate over a relatively large area. For the concentrate disposal option using deep-well injection, five disposal wells are needed. Plans are to screen these wells in the Jasper Aquifer where the TDS is about 20,000 mg/L,[4] which is considerably greater than the concentrate. These wells are expected to have a capacity of about 400 gpm and be about 2,800 ft deep.

Cost estimates have been prepared for the two delivery options with two options for concentrate disposal. Tables 4C.20-2 and 4C.20-3 provide cost estimate summaries for delivery to the Stevens WTP with concentrate disposal to Copano Bay and deep-injection wells, respectively. Tables 4C.20-4 and 4C.20-5 provide cost estimate summaries for delivery to the SPMWD distribution system with concentrate disposal to Copano Bay and deep-injection wells, respectively. The costs assume groundwater leases can be obtained for $40 per acft of raw water. The unit costs for the project with delivery of water to Stevens WTP with disposal to Copano Bay and deep-injection are $932/acft and $901/acft, respectively. The unit costs for the delivery of water to SPMWD with disposal to Copano Bay and deep-injection wells are $859/acft and $828/acft, respectively.

4C.20.5.2 Nueces NW Project

This project is designed to deliver treated water to the Stevens WTP. Concentrate disposal is planned for deep-injection wells. The project design is to yield 16.1 MGD (18,000 acft/yr) and provide a treated water supply with a TDS of about 400 mg/L. Figure 4C.20-8 shows the location of the project and facilities.

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[4] Ryder, P.D., and Ardis, A.F, 2002, Hydrology of the Texas Gulf Coast Aquifer Systems, U.S. Geological Survey Professional Paper 1416-E, Plate 2.

Table 4C.20-2.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Bee-San Patricio Well Field with Delivery to Stevens WTP, Concentrate to Bay

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (36 in, 19.2 mi)	$30,279,000
Concentrate Disposal Transmission (16 in, 32.1 mi)	$13,877,000
Brackish Water Well Field (36-500 gpm, 800 ft deep water wells)	$21,064,000
Brackish Well Field Collector Pipelines (8-36 in, 35 mi)	$13,774,000
Water Treatment Plant (Pretreatment and Desalination)	$27,608,000
Total Capital Cost	**$106,602,000**
Engineering, Legal Costs and Contingencies	$35,490,000
Environmental & Archaeology Studies and Mitigation	$2,181,000
Land Acquisition and Surveying (222 acres)	$2,037,000
Interest During Construction (1 years)	$5,853,000
Total Project Cost	**$152,163,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$13,266,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$872,000
Water Treatment Plant	$5,743,000
Pumping Energy Costs (14565223 kW-hr @ 0.09 $/kW-hr)	$1,311,000
Purchase of Water (26,518 acft/yr @ $40/acft)	$1,064,000
Groundwater District Fees	$108,000
Total Annual Cost	**$22,364,000**
Available Project Yield (acft/yr)	24,000
Annual Cost of Water ($ per acft)	$932
Annual Cost of Water ($ per 1,000 gallons)	$2.86

Table 4C.20-3.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Bee-San Patricio Well Field with Delivery to Stevens WTP, Concentrate to Wells

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (36 in, 19.2 mi)	$30,279,000
Brackish Water Well Field (36-500 gpm, 800 ft deep water wells)	$21,064,000
Brackish Well Field Collector Pipelines (8-36 in, 35 mi)	$13,774,000
Concentrate Disposal Well Field (5-400 gpm, 2,800 ft deep injection wells)	$6,204,000
Concentrate Disposal Transmission (12 in, 4 mi)	$2,900,000
Water Treatment Plant (Pretreatment and Desalination)	$27,608,000
Total Capital Cost	**$101,829,000**
Engineering, Legal Costs and Contingencies	$34,404,000
Environmental & Archaeology Studies and Mitigation	$1,528,000
Land Acquisition and Surveying (144 acres)	$1,111,000
Interest During Construction (1 years)	$5,555,000
Total Project Cost	**$144,427,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$12,592,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$819,000
Water Treatment Plant	$5,743,000
Pumping Energy Costs (14505813 kW-hr @ 0.09 $/kW-hr)	$1,306,000
Purchase of Water (26,518 acft/yr @ $40/acft)	$1,064,000
Groundwater District Fees	$108,000
Total Annual Cost	**$21,632,000**
Available Project Yield (acft/yr)	24,000
Annual Cost of Water ($ per acft)	$901
Annual Cost of Water ($ per 1,000 gallons)	$2.77

Table 4C.20-4.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Bee-San Patricio Well Field with Delivery to US Hwy 77, Concentrate to Bay

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (36 in, 12.5 mi)	$19,238,000
Concentrate Disposal Transmission (16 in, 32.1 mi)	$13,877,000
Brackish Water Well Field (36-500 gpm, 800 ft deep water wells)	$21,064,000
Brackish Well Field Collector Pipelines (8-36 in, 35 mi)	$13,774,000
Water Treatment Plant (Pretreatment and Desalination)	$27,608,000
Total Capital Cost	**$95,561,000**
Engineering, Legal Costs and Contingencies	$32,116,000
Environmental & Archaeology Studies and Mitigation	$2,063,000
Land Acquisition and Surveying (214 acres)	$1,779,000
Interest During Construction (1 years)	$5,261,000
Total Project Cost	**$136,780,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$11,925,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$743,000
Water Treatment Plant	$5,743,000
Pumping Energy Costs (11458377 kW-hr @ 0.09 $/kW-hr)	$1,031,000
Purchase of Water (26,518 acft/yr @ $40/acft)	$1,064,000
Groundwater District Fees	$108,000
Total Annual Cost	**$20,614,000**
Available Project Yield (acft/yr)	24,000
Annual Cost of Water ($ per acft)	$859
Annual Cost of Water ($ per 1,000 gallons)	$2.64

Table 4C.20-5.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Bee-San Patricio Well Field with Delivery to US Hwy 77, Concentrate to Wells

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (36 in, 12.5 mi)	$19,238,000
Brackish Water Well Field (36-500 gpm, 800 ft deep water wells)	$21,064,000
Brackish Well Field Collector Pipelines (8-36 in, 35 mi)	$13,774,000
Concentrate Disposal Well Field (5-400 gpm, 2,800 ft deep injection wells)	$6,204,000
Concentrate Disposal Transmission (12 in, 4 mi)	$2,900,000
Water Treatment Plant (Pretreatment and Desalination)	$27,608,000
Total Capital Cost	**$90,788,000**
Engineering, Legal Costs and Contingencies	$31,030,000
Environmental & Archaeology Studies and Mitigation	$1,360,000
Land Acquisition and Surveying (112 acres)	$799,000
Interest During Construction (1 years)	$4,960,000
Total Project Cost	**$128,937,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$11,241,000
Operation and Maintenance	
Wells, Pipeline, Pump Station	$690,000
Water Treatment Plant	$5,743,000
Pumping Energy Costs (11458377 kW-hr @ 0.09 $/kW-hr)	$1,031,000
Purchase of Water (26,518 acft/yr @ $40/acft)	$1,064,000
Groundwater District Fees	$108,000
Total Annual Cost	**$19,877,000**
Available Project Yield (acft/yr)	24,000
Annual Cost of Water ($ per acft)	$828
Annual Cost of Water ($ per 1,000 gallons)	$2.54

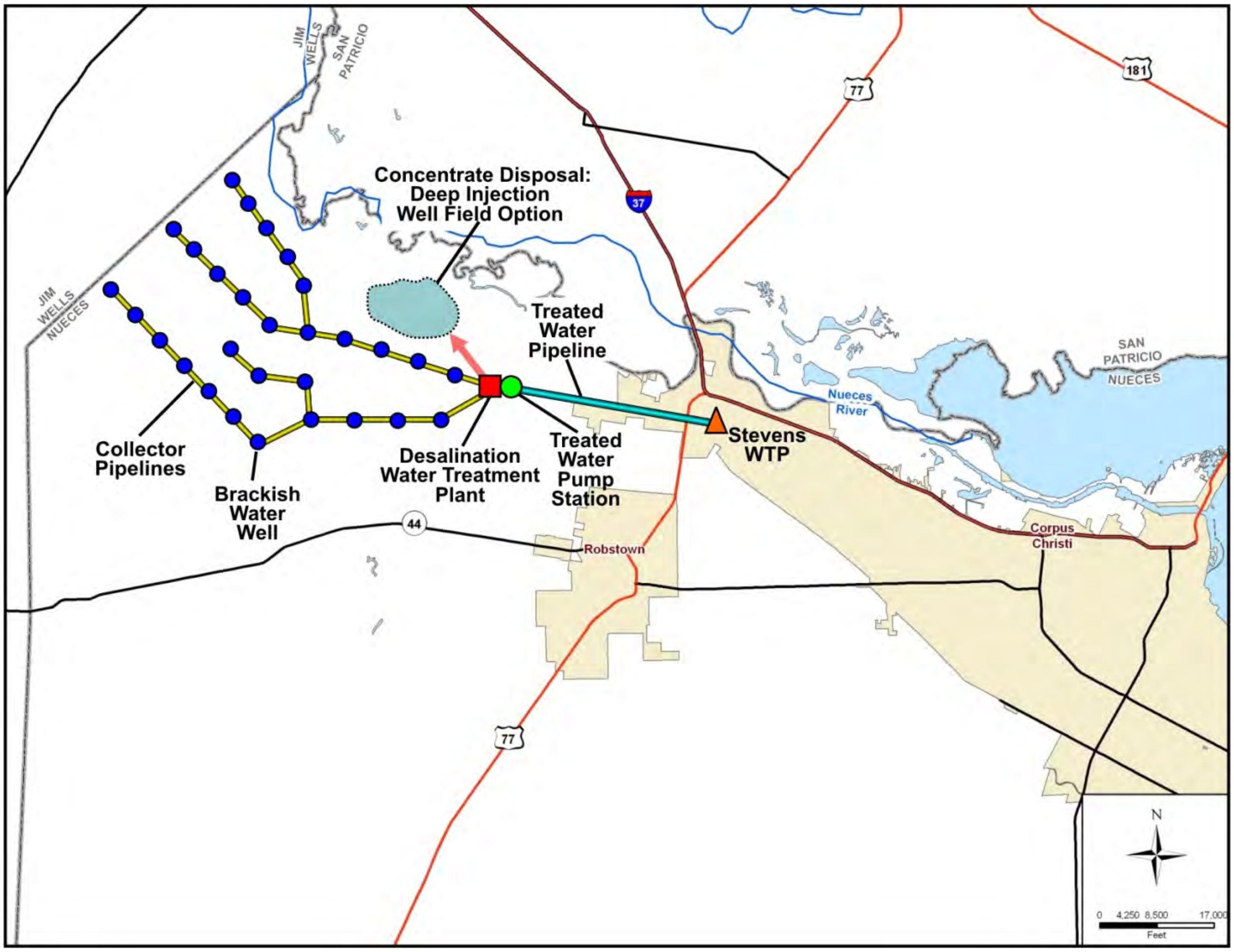

Figure 4C.20-8. Location of Nueces Northwest Project

The preliminary water treatment design has the facilities located in the vicinity of the well field, and has a similar design to the facilities for the Bee-SanPat project. In this part of the Gulf Coast Aquifer, the water in the Evangeline Aquifer has a TDS of about 1,750 mg/L. With a goal of product water having about 400 mg/L of TDS, about 77 percent of the raw well water will be sent to the desalination plant to remove inorganic and organic water quality constituents; and, the remaining 23 percent will be blended with the desalinated water. The desalination plant recovery rate is estimated to be 80 percent. Overall, this process converts about 84 percent of the raw water produced from the well field into potable water. The remaining 16 percent is a concentrate that requires disposal. This concentrate will have a TDS of about 8,750 mg/L.

Based on the loss of raw water to concentrate in the desalination process, the well field capacity will need to be about 19.1 MGD. The planned well field is located south of the Nueces River, and between the Nueces-Jim Wells county line and U.S. Hwy 77. There are 29 wells, which includes a contingency of about 10 percent. The wells have an average yield of 500 gpm, are 800 ft deep, spaced about 1 mile apart, and produce water with a TDS of about 1,750 mg/L. In the well field, the collector pipeline ranges from a diameter of 8 to 24 inches and includes about 28 miles of pipeline. Well pumps will be sized to deliver the raw water directly to the water treatment plant.

The delivery pipeline to the Stevens WTP is about 5.4 miles long and has a diameter of 30 inches. It will require a pump station at the desalination water treatment plant.

Concentrate disposal will be to deep-injection wells. Plans are for 7 injection wells that will be screened in the Jasper Aquifer where the TDS is about 60,000 mg/L (Ryder and Ardis, 2002), which is considerably greater than the concentrate. These wells are expected to have a capacity of about 400 gpm and be about 3,100 ft deep.

Cost estimates have been prepared and are provided in Table 4C.20-6. As shown in the table the unit cost for the delivery of water to Stevens WTP is $977/acft.

4C.20.5.3 Nueces S-C Project

This project is designed with two options. One is to deliver treated water to the City of Corpus Christi's distribution system near the intersection of TX Hwys 286 and 2444 and to dispose the concentrate to Oso Bay through the Barney Davis Power Station. The other option is to delivery treated water to the STWA pipeline near Bishop and dispose of the concentrate to deep-injection wells. This strategy is to make water available for STWA customers and to supplement the supplies at the Stevens WTP. The projects are designed to yield 10.7 MGD (12,000 acft/yr) at a uniform rate. The project is to provide a treated water supply with TDS of about 400 mg/L. Figure 4C.20-9 shows the location of the facilities.

The preliminary water treatment design has the facilities located in the vicinity of the well field and near the pump station for the delivery pipelines. In this part of the Gulf Coast Aquifer, the water in the Evangeline Aquifer has a TDS of about 1,900 mg/L at depths considered in this analysis to sustain long-term pumping. With a goal of product water having about 400 mg/L of TDS, about 79 percent of the raw well water will be sent to the desalination plant to remove inorganic and organic water quality constituents; and, the remaining 21 percent will be blended with the desalinated water. The desalination plant recovery rate is estimated to be 80 percent. Overall, this process converts about 83 percent of the raw water produced from the well field into potable water. The remaining 17 percent is a concentrate and is discharged to deep-injection wells or Barney Davis Power Station. This concentrate will have a TDS of about 9,500 mg/L.

Table 4C.20-6.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Nueces Northwest Well Field with Delivery to Stevens WTP, Concentrate to Wells

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (30 in, 5.4 mi)	$9,593,000
Brackish Water Well Field (29-500 gpm, 800 ft deep water wells)	$15,363,000
Brackish Well Field Collector Pipelines (8-24 in, 28 mi)	$10,581,000
Concentrate Disposal Well Field (7-400 gpm, 3,100 ft deep injection wells)	$9,450,000
Concentrate Disposal Transmission (12 in, 4 mi)	$4,473,000
Water Treatment Plants (Pretreatment & Desalination)	$26,699,000
Total Capital Cost	**$76,159,000**
Engineering, Legal Costs and Contingencies	$26,359,000
Environmental & Archaeology Studies and Mitigation	$1,084,000
Land Acquisition and Surveying (94 acres)	$562,000
Interest During Construction (1 years)	$4,167,000
Total Project Cost	**$108,331,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$9,445,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$550,000
Water Treatment Plant	$5,420,000
Pumping Energy Costs (14569034 kW-hr @ 0.09 $/kW-hr)	$1,311,000
Purchase of Water (21,356 acft/yr @ $40/acft)	$858,000
Groundwater District Fees	$0
Total Annual Cost	**$17,584,000**
Available Project Yield (acft/yr)	18,000
Annual Cost of Water ($ per acft)	$977
Annual Cost of Water ($ per 1,000 gallons)	$3.00

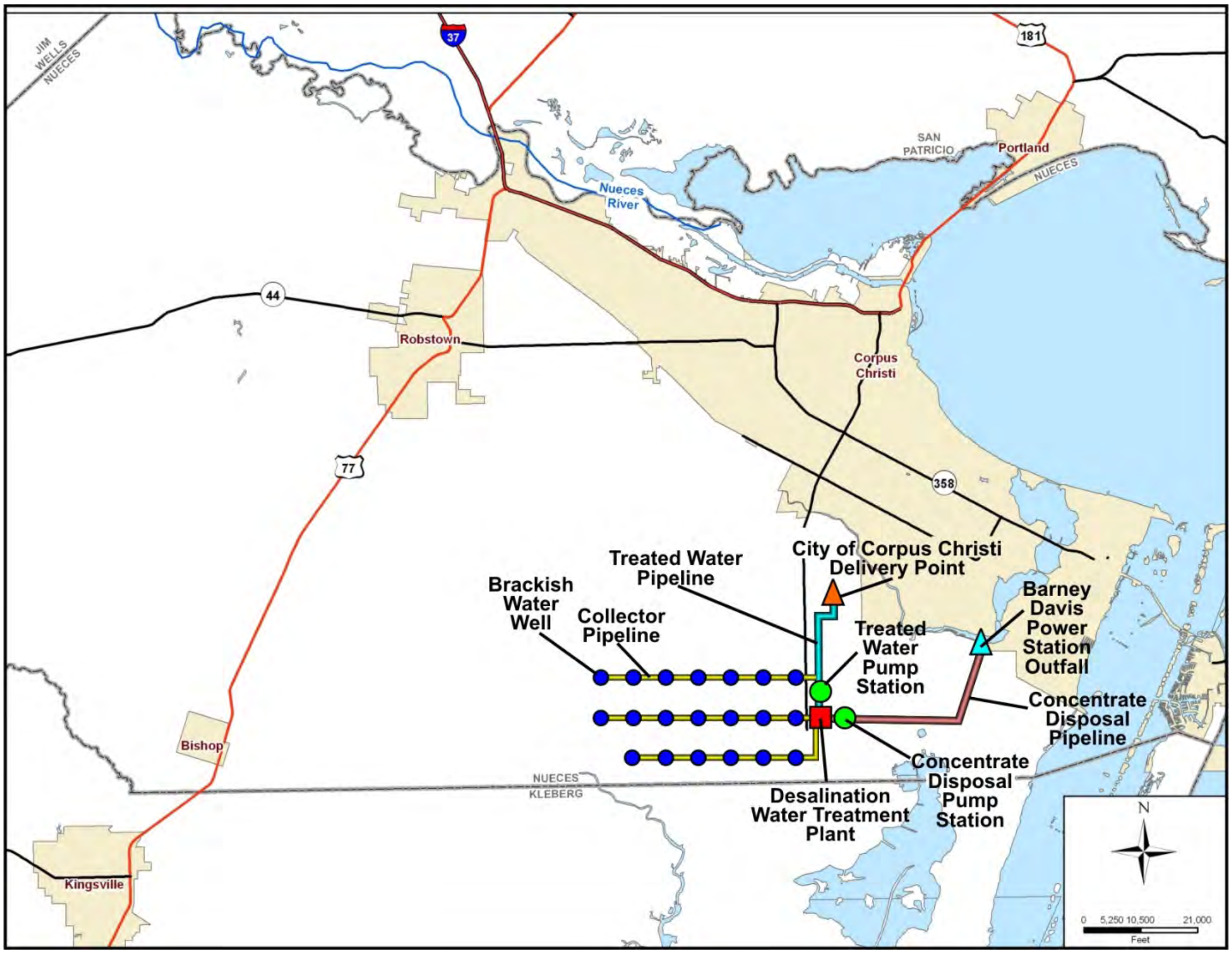

Figure 4C.20-9. Location of Nueces South-Central Project for Corpus Christi

The well field is planned to be along TX Hwy 70 and about midway between Laguna Madre and Bishop. Based on the loss of raw water to concentrate in the desalination process, the well field capacity will need to be about 12.8 MGD. The wells are expected to have an average yield of 500 gpm, are 1,300 ft deep, spaced about 1 mile apart, and produce water with a TDS of about 1,900 mg/L. There are 20 wells planned, which includes a contingency of about 10 percent. The collector pipeline ranges from a diameter of 8 to 30 inches and includes about 20 miles of pipeline. Well pumps will be sized to deliver the raw water directly to the water treatment plant.

The treated water delivery pipeline to the City distribution system will be about 5.5 miles long and be 24 inches in diameter. For the STWA option, the delivery pipeline will about 15.0

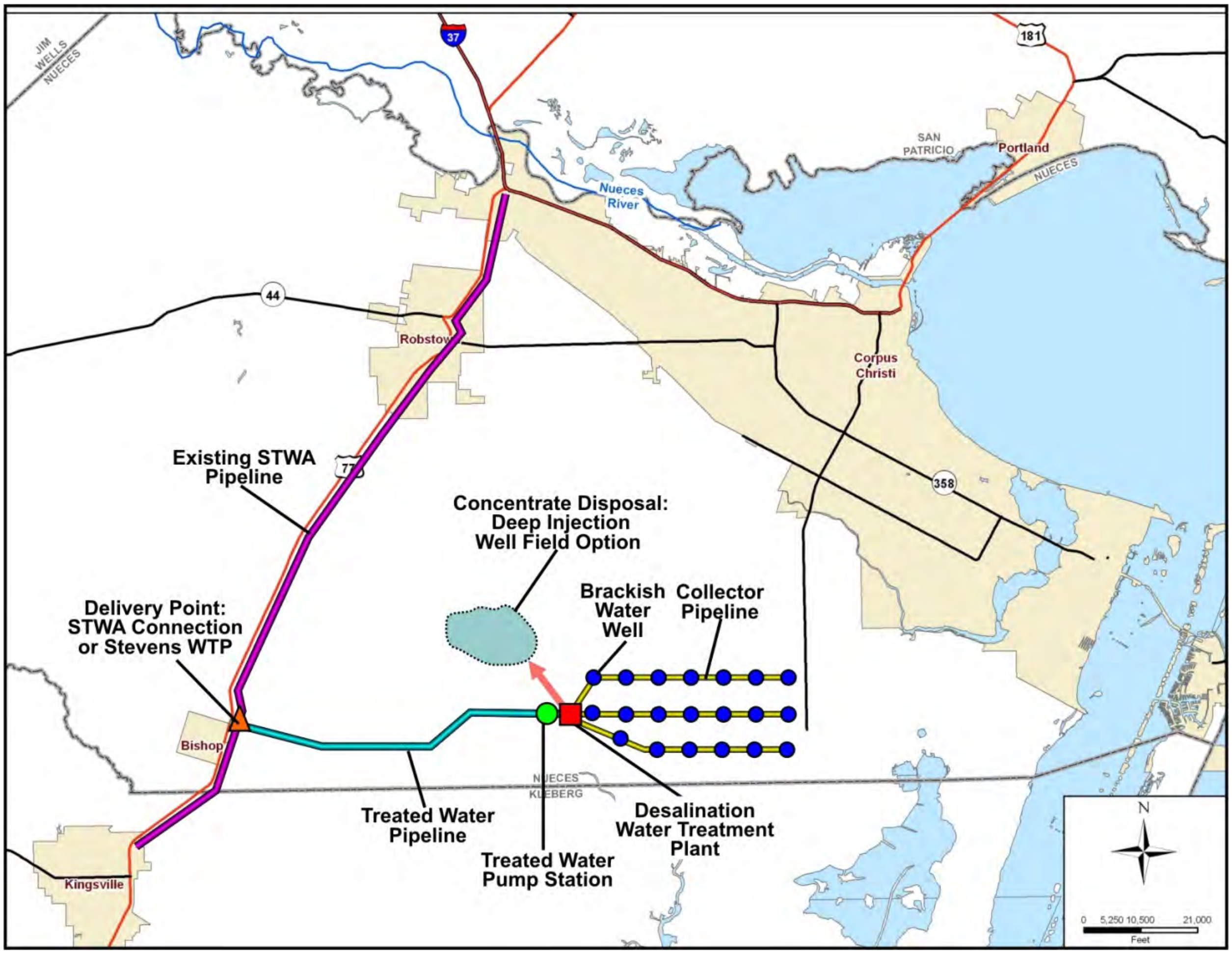

Figure 4C.20-10. Location of Nueces South-Central Project for South Texas Water Authority and Corpus Christi

miles long and be 30 inches in diameter. Both options require a pump station at the desalination water treatment plant.

For the concentrate disposal options with discharge at the Barney Davis Power Station, the pipeline will be 9.3 miles long and 16 inches in diameter. For the option with concentrate disposal to deep-injection wells, five wells will be required, with a capacity of about 400 gpm, and a depth of about 3,900 ft. Plans are for injection wells that will be screened in the Jasper Aquifer where the TDS is about 140,000 mg/L (Ryder and Ardis, 2002).

Cost estimates are provided in Table 4C.20-7 for the City option and in Table 4C.20-8 for the STWA option. The unit cost for the City option is $1,023/acft; and, the unit costs for the STWA option is $1,151/acft. If the STWA option is downsized to provide a uniform supply of 4,000 acft/yr of treated water to the STWA pipeline, the unit cost would be about $1,450/acft.

4C.20.5.4 Summary of Cost

A comparison of the unit water cost of delivered treated water for the three projects with various delivery and concentrate disposal options shows the large projects produce water at a lower cost than the small projects. For an example with concentrate being injected to deep wells, the largest (Bee-SanPat, SPMWD option), medium (Nueces NW) and smallest (Nueces S-C, STWA option) costs are $828, $977, and $1,151 per acft, respectively. These costs are not directly comparable because of differences in water delivery, but the project cost comparisons suggest reducing a large project by a third increases the unit water cost by 15-20 percent; and, reducing the project by half increases the unit cost by 35-45 percent.

4C.20.6 Implementation Issues

The brackish groundwater supply analyses considered for this water management strategy were based on drawdown criteria adopted by the Coastal Bend Regional Water Planning Group. For future planning efforts, water availability estimates provided by Groundwater Management Area 16 and local groundwater conservation districts will need to be considered when determining available groundwater supplies.

Implementation of the Brackish Groundwater Desalination Projects includes the following issues:

- Permitting desalination concentrate discharge to Copano and Oso Bays for some options;
- Verification of the Gulf Coast Aquifer water quality for concentrations of the dissolved constituents such as TDS, chloride, sulfate, iron, manganese, radium, uranium, and arsenic;
- Deep-injection well permits concentrate disposal from TCEQ;
- Purchase or lease of property for well field, and coordination with landowners;
- Skilled operators of desalination water treatment plants;
- Impact of water levels in the aquifer, potential intrusion of saline groundwater, land surface subsidence, and streamflow;
- USCOE Section 10 and 404 dredge and fill permits for pipelines;
- General Land Office Sand and Gravel Removal permit for pipeline and crossings of streams and roads;
- General Land Office Easement for use of State-owned lands, if any;
- Texas Parks and Wildlife Department Sand, Gravel, and Marl permit; and
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 4C.20-7.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Nueces South-Central Well Field with Delivery to City and Barney Davis PS

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (24 in, 5.5 mi)	$7,307,000
Concentrate Disposal Transmission (16 in, 9.3 mi)	$5,219,000
Brackish Water Well Field (20-500 gpm, 1,300 ft deep water wells)	$15,554,000
Brackish Well Field Collector Pipelines (8-30 in, 20 mi)	$6,926,000
Water Treatment Plants (Pretreatment & Desalination)	$20,433,000
Total Capital Cost	**$55,439,000**
Engineering, Legal Costs and Contingencies	$19,050,000
Environmental & Archaeology Studies and Mitigation	$888,000
Land Acquisition and Surveying (63 acres)	$536,000
Interest During Construction (1 years)	$3,037,000
Total Project Cost	**$78,950,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$6,883,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$402,000
Water Treatment Plant	$3,846,000
Pumping Energy Costs (6371376 kW-hr @ 0.09 $/kW-hr)	$573,000
Purchase of Water (14,387 acft/yr @ $40/acft)	$574,000
Groundwater District Fees	$0
Total Annual Cost	**$12,278,000**
Available Project Yield (acft/yr)	12,000
Annual Cost of Water ($ per acft)	$1,023
Annual Cost of Water ($ per 1,000 gallons)	$3.14

Table 4C.20-8.
Cost Estimate Summary
Water Supply Project Option (Sept 2008 Prices)
Nueces South-Central Well Field with Delivery to STWA and Concentrate to Wells

Item	*Estimated Costs for Facilities*
Capital Costs	
Treated Water Transmission (30 in, 15.0 mi)	$17,239,000
Brackish Water Well Field (20-500 gpm, 1,300 ft deep water wells)	$15,554,000
Brackish Well Field Collector Pipelines (8-30 in, 20 mi)	$6,926,000
Concentrate Disposal Wells (5-400 gpm, 3,900 ft deep)	$5,251,000
Concentrate Disposal Transmission (12 in, 4 mi)	$1,295,000
Water Treatment Plants (Pretreatment & Desalination)	$20,433,000
Distribution	$0
Relocations & Other	$0
Total Capital Cost	**$66,698,000**
Engineering, Legal Costs and Contingencies	$22,662,000
Environmental & Archaeology Studies and Mitigation	$1,193,000
Land Acquisition and Surveying (163 acres)	$763,000
Interest During Construction (1 years)	$3,653,000
Total Project Cost	**$94,969,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$8,280,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$514,000
Water Treatment Plant	$3,846,000
Pumping Energy Costs (6615647 kW-hr @ 0.09 $/kW-hr)	$595,000
Purchase of Water (14,387 acft/yr @ $40/acft)	$574,000
Groundwater District Fees	$0
Total Annual Cost	**$13,809,000**
Available Project Yield (acft/yr)	12,000
Annual Cost of Water ($ per acft)	$1,151
Annual Cost of Water ($ per 1,000 gallons)	$3.53

4C.20.7 Evaluation Summary

An evaluation summary of this regional water management strategy is provided in Tables 4C.20-9.

Table 4C.20-9.
Evaluation Summary of the Brackish Groundwater Desalination Option

Impact Category	*Comment(s)*
a. Water Supply	
1. Quantity	1. Variable, well field capacities ranges from up to about 24,000 acft/yr
2. Reliability	2. High.
3. Cost of Treated Water	3. Generally moderate to high cost; between $828 to $1,151/acft for projects ranging from 12,000 to 24,000 acft/yr.
b. Environmental factors	
1. Instream flows	1. Moderate impact.
2. Bay and Estuary Inflows	2. None to Low. However, greatest impact is during low-flow conditions.
3. Wildlife Habitat	3. Disposal of concentrated brine with bay option may impact fish and wildlife habitats or wetlands.
4. Wetlands	4. None to Low.
5. Threatened and Endangered Species	5. None identified. Project can be adjusted to bypass sensitive areas. Endangered species survey will be needed to identify impacts.
6. Cultural Resources	6. Cultural resource survey will be needed to identify any significant sites
7. Water Quality	7.
a. dissolved solids	7a-b. Total dissolved solids and salinity of water is removed with reverse osmosis treatment. Brine concentrate disposal issues will need to be evaluated.
b. salinity	
c. bacteria	
d. chlorides	
e. bromide	7d-i. Chloride, sulfate, uranium, and arsenic concentrations in groundwater will need to be considered prior to implementation of project.
f. sulfate	
g. uranium	
h. arsenic	
i. other water quality constituents	
c. Impacts to State water resources	• Little to minor negative impacts on surface water resources
d. Threats to agriculture and natural resources in region	• Temporary damage due to construction of pipeline
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Standard analyses and methods used for portions • Brackish groundwater desalination cost modeled after bid and manufactures' budgets, but not constructed, comparable project
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities for water that otherwise be unused.
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• Construction and maintenance of transmission pipeline corridor. Possible impact to wildlife habitat along pipeline route and right-of-way.