Coastal Bend Regional Water Planning Area Region N

Regional Water Plan Volume II Water Management Strategies

Prepared for:

Texas Water Development Board

Prepared by:

Coastal Bend Regional Water Planning Group

With Administration by:

Nueces River Authority

With Technical Assistance by:

HDR Engineering, Inc.

In Association with:

The Rodman Company

September 2010

List of Acronyms

acft	acre-feet
acft/yr	acre-feet per year
ASR	Aquifer Storage and Recovery
BEG	Bureau of Economic Geology
BMPs	Best Management Practices
CA	Certificate of Adjudication
CaCO3	Calcium Carbonate
CBBEP	Coastal Bend Bays and Estuaries Program
CBRWP	Coastal Bend Regional Water Plan
CBRWPG	Coastal Bend Regional Water Planning Group
CCR/LCC	Choke Canyon Reservoir/Lake Corpus Christi
cfs	cubic feet per second
CGCGAM	Central Gulf Coast Groundwater Availability Model
DFCs	Desired Future Conditions
EPA	U.S. Environmental Protection Agency
IPP	Initially Prepared Plan
GAM	Groundwater Availability Model
GCD	Groundwater Conservation District
GLO	General Land Office
GMA	Groundwater Management Area
gpcd	gallons per capita per day
GPM or gpm	gallons per minute
kW-hr	kilowatts hours
LCC	Lake Corpus Christi
LEPA	Low Energy Precision Application
LESA	Low Elevation Spray Application
LNRA	Lavaca-Navidad River Authority
LOUWCD	Live Oak Underground Water Conservation District
MAG	Managed Available Groundwater
MGD or mgd	million gallons per day
mg/L	milligrams per liter
MSA	Metropolitan Statistical Area
msl	mean sea level
MUD	Municipal Utility District
N/A	not available <u>or</u> not applicable
NEAC	Nueces Estuary Advisory Council
NPDES	National Pollutant Discharge Elimination System
NRA	Nueces River Authority
NTU	Nephelometric Turbidity Units
NUBAY	Lower Nueces River Basin and Estuary Model
NWF	National Wildlife Federation
O&M	Operation and Maintenance
PPD	Pounds per day
psi	pounds per square inch

List of Acronyms (Concluded)

REIS	Regional Economic Information System
RWP	Regional Water Plan
RWPG	Regional Water Planning Group
SB1	Senate Bill 1
SPMWD	San Patricio Municipal Water District
STWA	South Texas Water Authority
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TOES	Texas Organization for Endangered Species
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
UWCD	Underground Water Conservation District
WAM	Water Availability Model
WCID	Water Control and Improvement District
WMS	Water Management Strategies
WRAC	Water Resources Advisory Committee
WRAP	Water Rights Analysis Package
WSC	Water Supply Corporation
WTP	Water Treatment Plant
WUG	Water User Group
WWP	Wholesale Water Provider
WWTP	Wastewater Treatment Plant

Table of Contents

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Continued)

Table of Contents (Concluded)

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List of Figures

Figure **Page**

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Continued)

List of Figures (Concluded)

List of Tables

List of Tables (Continued)

List of Tables (Continued)

Table **Page**

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Concluded)

4C.1 Municipal Water Conservation (N-1)

4C.1.1 Description of Strategy

Water conservation refers to those methods and practices that either reduce the demand for water supply or increase the efficiency of the supply or use facilities so that available supply is conserved and made available for future use. Water conservation is typically a low-capital intensive alternative that water supply entities can pursue. All water supply entities and some major water right holders are required by Senate Bill 1 regulations to submit a Drought Contingency and Water Conservation Plan to the TCEQ for approval. These plans must detail the water supply entities' plans to reduce water demand at times when the demand threatens the total capacity of the water supply delivery system or overall supplies are low. Information regarding water supply entities that have provided Drought Contingency and Water Conservation Plans to TCEQ is summarized in Section 1.

In 2001, the Texas Legislature amended the Texas Water Code to require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). The Water Conservation Implementation Task Force (Task Force) was created by Senate Bill 1094 to identify and describe Water Conservation Best Management Practices (BMPs) and provide a BMP Guide for use by Regional Water Planning groups in the development of the 2006 Regional Water Plans. Additional water conservation guidance reports include a TWDB report entitled, "Quantifying Effectiveness of Various Water Conservation Techniques in Texas," and a document entitled, "Strategies to Enhance Water Conservation in the Coastal Bend," specifically prepared to assist communities with water conservation in the Coastal Bend Area.

For regional water planning purposes, municipal water use is defined as residential and commercial water use. Municipal water is primarily for drinking, sanitation, cleaning, cooling, fire protection, and landscape watering for residential, commercial, and institutional establishments. A key parameter of municipal water use within a typical city or water service area is the number of gallons used per person per day (per capita water use). The objective of water conservation is to decrease the amount of water – measured in gallons per person per day (gpcd) – that a typical person uses.

As part of the first phase of this round of regional water planning, the Coastal Bend Regional Water Planning Group (CBRWPG) developed and distributed a water conservation survey to municipal water user groups in the Coastal Bend Region (summarized in Appendix B). The purpose of the survey was to gather information regarding the success of their water conservation practices and to determine their interest in participating in voluntary water conservation BMPs identified by the CBRWPG.[1] The survey was also intended to gather information about the challenges that water user groups in the region experience with respect to implementing water conservation programs. Based on survey responses, most local water conservation programs in the Coastal Bend Region have shown at least a 1-5% annual reduction in water use which exceeds the Task Force target of a "minimum annual reduction of 1 percent in total gpcd."[2] According to survey responses, the primary objectives of water conservation programs in the Coastal Bend Region are to reduce (1) water loss, (2) per capita consumption, and/or (3) seasonal and peak demands. Not surprisingly, the main reasons cited for lack of interest in adding new BMPs to existing water conservation programs are cost and a lack of staff.

The Task Force recommends that a standardized methodology be used for determining per capita per day (gpcd) municipal water use so as to allow consistent evaluations of effectiveness of water conservation measures among Texas cities that are located in the different climates and parts of Texas. The Task Force further recommends gpcd targets and goals that should be considered by retail public water suppliers when developing water conservation plans required by the state, as follows:

- All public water suppliers that are required to prepare and submit water conservation plans should establish targets for water conservation, including specific goals for per capita water use and for water loss programs using appropriate water conservation BMPs.
- Municipal Water Conservation Plans required by the state shall include per capita water-use goals, with targets and goals established by an entity giving consideration to a minimum annual reduction of 1 percent in total gpcd, based upon a 5-year moving average, until such time as the entity achieves a total gpcd of 140 gpcd or less, or
- Municipal water use (gpcd) goals approved by regional water planning groups.

Per capita water use was calculated using TWDB-approved population and water demand estimates based on water user surveys for each decade from 2000 to 2060. For this round of regional water planning, new census numbers were not available and the TWDB did not provide

[1] Coastal Bend Regional Water Planning Group, 2011 Regional Water Plan, Study 1 – Region-Specific Water Conservation Best Management Practices (BMPs), April 2009.
[2] TWDB Special Report, "Water Conservation Implementation Task Force Report to the 79th Legislature," November 2004.

updates to population or demand projections. The population and municipal water demand projections used in this plan for the Coastal Bend Region are the same as those used in the 2006 Regional Water Plan. The per capita water use in 2000 and projected per capita water use in 2010, 2020, 2030, 2040, 2050, and 2060 include expected effects of low flow plumbing fixtures upon per capita water use and are shown for each municipal entity located in the Coastal Bend Region in Table 4C.1-1. The projected municipal water demands assume a 100 percent replacement of existing plumbing fixtures to water efficient fixtures by 2045 (assumed 2 percent per year replacement).[3] The 51 municipal entities of Region N are listed in Table 4C.1-1, in the order of low to high per capita water use, in year 2000 in four groupings as follows:

- Less than 140 gpcd,
- 140 to 164 gpcd,
- 165 to 199 gpcd, and
- 200 and greater gpcd.

The projected municipal water needs (shortages) were calculated for each municipal entity by subtracting projected municipal water demands, with plumbing fixture water conservation taken into account, from existing municipal water supplies. The purpose of the municipal water conservation water management strategy is to evaluate the potential of additional municipal water conservation for inclusion in the Regional Water Plan to meet a part of the projected water needs (shortages) of each municipal entity.

The City of Corpus Christi, the largest municipal water user in the Coastal Bend Region, has demonstrated significant water savings attributable to water conservation efforts over the last decade. The City's municipal water use was nearly 220 gpcd in 1990[4] and was reduced to 179 gpcd by 2000, a decrease of 41 gpcd (or 19 percent). According to TWDB water use projections, the City of Corpus Christi water use is anticipated to decline to 165 gpcd by 2060 (Table 4C.1-1).

Based on the success of the City's water conservation program, the Coastal Bend Regional Water Planning Group recommends that water user groups, with and without shortages, exceeding 165 gpcd should reduce consumption by 15 percent by 2060. For entities with projected water use equal or less than 165 gpcd in 2060, TWDB projections are recommended.

[3] Correspondence with Kevin Kluge, TWDB, September 2004.
[4] City of Corpus Christi Water Conservation Plan, 1999.

Table 4C.1-1.
Municipal Water User Groups Projected Per Capita Water Use
(TWDB Projections)

No.	Water User	County	Per Capita Water Use with Low Flow Plumbing Fixtures						
			2000	2010	2020	2030	2040	2050	2060
1	County-Other	Bee	77	74	72	70	68	67	67
2	Ingleside	San Patricio	83	77	75	73	72	72	72
3	Gregory	San Patricio	96	92	89	86	83	81	81
4	County-Other	Kenedy	100	96	94	91	89	88	88
5	Ingleside On The Bay	San Patricio	100	96	93	91	90	89	89
6	McCoy WSC	Live Oak	101	98	95	93	93	92	92
7	River Acres WSC	Nueces	102	97	94	92	91	90	90
8	County-Other	Brooks	103	99	96	93	90	89	89
9	Driscoll	Nueces	105	100	97	95	94	93	93
10	County-Other	San Patricio	105	101	98	95	92	91	91
11/12	San Diego[1]	Duval/Jim Wells	107	103	99	96	93	92	92
13	County-Other	Aransas	109	104	101	98	96	95	95
14	Odem	San Patricio	114	109	106	103	100	99	99
15	Ricardo WSC	Kleberg	115	107	105	104	103	103	103
16	County-Other	Jim Wells	117	114	111	108	105	104	104
17	Lake City	San Patricio	119	114	111	108	106	105	105
18	Portland	San Patricio	119	114	111	108	107	106	106
19	Mathis	San Patricio	119	115	112	109	106	104	104
20	Bishop	Nueces	124	120	117	114	111	109	109
21	Agua Dulce	Nueces	139	136	133	130	127	125	125
1	Choke Canyon WSC	McMullen	143	141	139	138	137	136	136
2	Choke Canyon WSC	Live Oak	143	141	139	138	137	136	136
3	County-Other	Live Oak	145	142	139	137	135	134	134
4	Taft	San Patricio	147	143	140	137	134	133	133
5	Aransas Pass	San Patricio	150	145	141	139	137	136	136
6	Fulton	Aransas	150	148	146	145	144	143	143
7	Aransas Pass	Aransas	150	145	141	139	137	136	136
8	Robstown	Nueces	151	148	145	142	139	137	137
9	Aransas Pass	Nueces	153	142	141	138	137	135	135
10	County-Other	Nueces	155	152	149	146	143	141	141
11	Kingsville	Kleberg	155	152	148	145	142	141	141
12	Sinton	San Patricio	163	160	156	153	150	149	149
13	Rockport	Aransas	164	161	158	156	154	153	153

Table 4C.1-1 (Concluded)

No.	Water User	County	Per Capita Water Use with Low Flow Plumbing Fixtures 2000	2010	2020	2030	2040	2050	2060
1	County-Other	Kleberg	165	161	158	156	154	153	153
2	Benavides	Duval	167	163	159	156	153	152	152
3	El Oso WSC	Bee	169	165	162	159	157	156	156
4	Live Oak El Oso WSC	Live Oak	169	165	162	159	157	156	156
5	Freer	Duval	172	168	164	161	158	157	157
6	Beeville	Bee	172	168	164	161	158	157	157
7	Corpus Christi	Nueces	179	175	171	168	166	165	165
8	Nueces County WCID #4	Nueces	187	181	179	178	177	177	177
9	County-Other	Duval	191	188	185	182	179	178	178
1	County-Other	McMullen	201	196	193	190	188	186	187
2	Three Rivers	Live Oak	202	198	195	192	189	188	188
3	George West	Live Oak	227	223	220	217	214	213	213
4	Orange Grove	Jim Wells	245	240	237	234	231	230	230
5	Alice	Jim Wells	248	244	241	238	235	234	234
6	Premont	Jim Wells	260	256	253	250	247	246	246
7	Falfurrias	Brooks	280	273	270	268	266	265	265
8	Port Aransas	Nueces	424	418	416	414	413	413	413

[1] San Diego is located in both Duval and Jim Wells Counties.

In year 2000, in the Coastal Bend Water Planning Region, 34 municipal water users had per capita water use of less than 165 gpcd (Table 4C.1-1). Water users with less than 165 gpcd represented 36.03 percent of the population of the Region in 2000, and used 27.14 percent of the quantity of municipal water used in the Region in 2000 (Table 4C.1-2). In 2000, in the Region, 17.65 percent of the municipal entities had per capita water use of 165 to 199 gpcd. This group represented 57.18 percent of the region's population in 2000, and accounted for 61.95 percent of the municipal water used in the Region in 2000 (Table 1.1-2). Of the 51 municipal entities located in the region, eight (or 15.69 percent) had per capita water use greater than 200 gpcd, representing 6.79 percent of the Region's year 2000 population, and accounted for 10.91 percent of the municipal water use in the Region in 2000 (Table 4C.1-2).

Table 4C.1-2.
Municipal Water User Groups Number, Population, and Water Use by Per Capita Water Use Levels
Coastal Bend Water Planning Region

Per Capita Water Use in 2000 (gpcd)	Number of Municipal Entities	Percent of Municipal Entities	Population		Water Use	
			2000	Percent of Total	2000 (acft)	Percent of Total
Less than 140	21	41.18%	116,105	21.45%	13,527	13.53%
140 to 164	13	25.49%	78,912	14.58%	13,603	13.61%
165 to 199	9	17.65%	309,427	57.18%	61,915	61.95%
200 and above	8	15.69%	36,740	6.79%	10,905	10.91%
Totals	51	100.00%	541,184	100.00%	99,950	100.00%

4C.1.2 Available Yield

Of the 51 municipal entities in Region N, 17 had per capita water use rates in year 2000 equal to or higher than 165 gpcd. Of these 17 municipal entities, ten had per capita water use rates higher than the 165 gpcd goal established by the CBRWPG in 2060. All municipal entities in the Coastal Bend Region are encouraged to conserve water, regardless of per capita consumption. Consistent with the approach used in the 2006 Plan, a 15 percent reduction in per capita water use was recommended by the CBRWPG for those municipal entities with per capita use in 2060 greater than 165 gpcd. This conservation can be achieved in a variety of ways, including using these BMPs identified by the Task Force:

1. System Water Audit and Water Loss,
2. Water Conservation Pricing,
3. Prohibition on Wasting Water,
4. Showerhead, Aerator, and Toilet Flapper Retrofit,
5. Residential Toilet Replacement Programs with Ultra-Low-Flow toilets,
6. Residential Clothes Washer Incentive Program,
7. School Education,
8. Water Survey for Single-Family and Multi-Family Customers,
9. Landscape Irrigation Conservation and Incentives,
10. Water-Wise Landscape Design and Conversion Programs,
11. Athletic Field Conservation,
12. Golf Course Conservation,
13. Metering of all New Connections and Retrofitting of Existing Connections,
14. Wholesale Agency Assistance Programs,

15. Conservation Coordinator,
16. Reuse of Reclaimed Water,
17. Public Information,
18. Rainwater Harvesting and Condensate Reuse,
19. New Construction Greywater,
20. Park Conservation, and
21. Conservation Programs for Industrial, Commercial, and Institutional Accounts.

The water conservation water management strategy for municipal entities of the Coastal Bend Region is based upon BMPs listed above, quantities and costs of water conservation measures as reported in TWDB and TCEQ guidance documents,[5,6] and the Task Force guidelines for water-use targets and goals listed previously. Since costs and savings presented in the Task Force Draft Report are general and have limited applicability, the list of specific BMPs is significantly reduced, as presented in Table 4C.1-3. Specific conservation measures are not assigned to each municipal entity to provide flexibility for entities to identify practical conservation strategies that fit their individual situation the best. It is also important to note that the list in Table 4C.1-3 has been identified primarily to estimate costs and water savings. A city may choose other BMPs not included in Table 4C.1-3 to reduce their per capita water use.

A description of water conservation BMPs listed in Table 4C.1-3 to assist municipal entities exceeding 165 gpcd in 2060 achieve a 15 percent reduction in water use or 165 gpcd by 2060 is presented below, and includes indoor, landscape irrigation, and general water conservation methods.

4C.1.2.1 Indoor Water Conservation

An average demand reduction of 13 gpcd for Coastal Bend municipal entities is included in the TWDB per capita water use projections associated with replacing plumbing fixtures. The TWDB water use projections have a maximum built-in per capita reduction of 16 gpcd from 2000 to 2060, which assumes 100 percent participation in low flow plumbing fixture programs. The amount of additional indoor water conservation is calculated based upon the potential typical water conservation of 11 gpcd, which assumes 50 percent participation in toilet

[5] TWDB, GDS Associates, "Quantifying the Effectiveness of Various Water Conservation Techniques in Texas," July 2003.
[6] TCEQ Water Audit, August 26, 2002.

Table 4C.1-3.
Possible Water Conservation Techniques (BMPs)

	Rural		Suburban		Urban	
	Water Savings (gpcd)		Water Savings (gpcd)		Water Savings (gpcd)	
	Maximum	Typical*	Maximum	Typical*	Maximum	Typical*
Indoor Conservation						
Toilet Retrofit[1]	10.5	4.2	10.5	4.3	10.5	4.4
Showerheads and Aerators[1]	5.5	2.2	5.5	2.2	5.5	2.3
Clothes Washer Rebate[1]	5.4	4.8	5.3	4.8	4.7	4.2
Outdoor Conservation						
Irrigation Audit-High User[1]	19.4	0.8	19.1	0.8	14.9	0.7
Rainwater Harvesting[1]	12.0	0.6	11.7	0.6	10.4	0.5
Rain Barrels[1]	1.3	0.4	1.3	0.4	1.3	0.4
Landscape Irrigation & Incentives[2]	62.3	12.4	105.5	12.4	32.0	12.4
Seasonal water use reduction[3]	5.0	1.8	5.0	1.8	5.0	1.8
General Conservation						
Unaccounted for losses[3]	7.8	—	7.8	—	7.8	—
Public Education Programs[3]	7.8	3.1	7.8	3.1	7.8	3.1
Total	**136.9**	**30.3**	**179.4**	**30.3**	**99.8**	**29.8**

1 GDS Associates, July 2003.
2 Water Conservation Implementation Task Force, typical based on 15 percent reduction of outdoor water use and maximum based on 30 percent reduction of outdoor water use. Outdoor water use = Total Water Use - 72.5 gpcd (indoor).
3 TCEQ Water Audit, August 2002.
* Typical water savings calculated based on potential savings identified by GDS Associates divided by number of people potentially affected as reported in “Quantifying the Effectiveness of Various Water Conservation Techniques in Texas,” TWDB, GDS Associates, Austin, TX, July 2003.

retrofit/showerhead programs and 45 percent participation in clothes washer rebate. The potential amount of “additional” indoor conservation beyond the savings included in the TWDB projections was determined for the projected population at the respective projection dates, by subtracting the plumbing fixtures effects already in the water demand projections. For municipal entities that already have a built-in reduction exceeding 11 gpcd in TWDB per capita water use projections, no additional savings would be expected from indoor water conservation.

4C.1.2.2 Landscape Irrigation Water Conservation

In addition to the indoor water conservation measures described above, the water conservation water management strategy for municipal entities for the Coastal Bend Region includes landscape irrigation. The estimated potentials are based upon the following conditions and assumptions:

1. For those municipal entities having year 2060 water use of 165 to 200 gpcd, landscape irrigation potential can be 15 percent of water use above 75 gpcd.
2. For those WUGs having year 2060 water use greater than 200 gpcd, landscape irrigation potential can be as much as 30 percent of water use greater than 75 gpcd.

4C.1.2.3 General Water Conservation

A municipality can determine unaccounted for water losses by performing a water audit, which includes collecting information that can then be used to calculate unaccounted for water loss using the following equation:

Unaccounted for water = Water production/purchased (gallons) – Water Sales (gallons)

To maximize the benefits of this conservation strategy, the utility uses this audit information to revise meter testing and repairs, reduce unmetered use, improve accuracy of the utility's metering system, and implement effective water loss management strategies. Factors that affect the amount of unaccounted for water include density of the system, age of the system, construction quality of the system, and accuracy of the water metering.[7]

In December 2004 in response to House Bill 3338, the TWDB adopted rules to require retail public utilities, as defined by Texas Water Code §13.002, to perform a water loss audit and submit water loss audit forms to the TWDB every five years.[8] Pursuant to TWDB Rules[9] for regional water planning, regional water planning groups are required to include information compiled by the TWDB from water loss audits performed by retail public utilities and consider strategies to address any issues identified in the water loss audit information compiled by the TWDB. A discussion of the water loss audit information provided by the TWDB for Coastal Bend Retail Public Utilities is included in Section 1- Planning Area Description.

To assist communities and water supply entities with their conservation planning, the TWDB prepared two publications: the first in January 2007 entitled *An Analysis of Water Loss as Reported by Public Water Suppliers in Texas (Final Report)* and one in March 2008 entitled *Water Loss Audit Manual for Texas Utilities*. Additionally a document entitled *Strategies to*

[7] Naismith Engineering, Inc., "Strategies to Enhance Water Conservation in the Coastal Bend," April 1999.
[8] In accordance with Texas Administrative Code §358.6.
[9] In accordance with Texas Administrative Code §357.7(a)(1)(M) and Texas Administrative Code §357.7(a)(7)(a)(iv)

Enhance Water Conservation in the Coastal Bend was specifically prepared to assist communities in the Coastal Bend Area with water conservation. Both the TWDB and Coastal Bend Area documents include a water audit to assist each community in assessing their system. It is anticipated that efforts to assess water losses will improve with future water audits filed on a five year basis, as retail public utilities become more familiar with reporting methodologies and the TWDB provides additional guidance and support.

The TCEQ reports that unaccounted for water losses of 15 percent or less are acceptable for communities greater than 5,000 people. Losses above 15 percent may be an area of concern and provide conservation potentials. Rural communities in the Coastal Bend may experience as high as 20 percent unaccounted for losses,[10] which presents an opportunity to conserve at least 5 percent of per capita water use by taking measures to reduce unaccounted for losses.

In addition to unaccounted for water losses, public information programs can be an important and key element to having water users save water inside homes and commercial structures, in landscaping and lawn watering, and in recreation uses. Public information and education can work in two ways to accomplish water conservation. One way is to inform and convince water users to obtain and use water-efficient plumbing fixtures and appliances, to adopt low water use landscaping plans and plants, to find and repair plumbing leaks, to use gray water for permissible uses (e.g., lawn and shrubbery watering where regulations allow), and to take advantage of water conservation incentives where available.

A second way public information and education can work to conserve water is to inform water users of ways to manage and operate existing and new fixtures and appliances so that less water is used. This includes ideas and practices such as washing full loads of clothes and dishes; using a pail of water instead of a flowing hose to wash automobiles; turning the water off while brushing one's teeth, washing one's hands, or shaving; and watering lawns, gardens, and shrubs during evening—as opposed to daytime—hours.

After subtracting demand reductions already incorporated into the TWDB demand projections, a 15 percent reduction in per capita water use for those cities and county-others using greater than 165 gpcd in 2060 would result in savings—less water used—of 721 acft in 2030 and 2,415 acft in 2060, as seen in Table 4C.1-4. Note: Water savings are only included for 10 of the 17 municipal entities, since seven of the entities have a projected water use equal or

[10] Conversation with Carl Crull, HDR, January 2005.

Table 4C.1-4.
Potential Additional Water Conservation Savings for Water User Groups having 2060 Per Capita Water Use Greater than 165 gpcd

Water User	County	Housing Area	Water Demand Reduction via Additional Water Conservation											
			2010		2020		2030		2040		2050		2060	
			gpcd	acft/yr	gpcd	acft/yr	gpcd	acft/yr	gpcd	acft/yr	gpcd	acft/yr	gpcd	acft/yr
Nueces County WCID #4	Nueces	Suburban	0	0	0	0	3	56	5	135	9	261	12	384
County-Other	Duval	Rural	1	6	3	13	4	21	5	27	8	44	12	63
County-Other	McMullen	Rural	1	1	2	2	5	3	8	5	10	7	16	10
Three Rivers	Live Oak	Rural	1	3	3	8	5	14	7	18	11	27	16	34
George West	Live Oak	Rural	1	5	4	14	7	25	10	33	14	45	20	57
Orange Grove	Jim Wells	Rural	2	3	5	8	8	14	11	18	16	28	22	38
Alice	Jim Wells	Rural	2	50	5	133	9	219	12	306	17	438	23	585
Premont	Jim Wells	Rural	3	9	6	22	10	36	13	49	19	70	25	92
Falfurrias	Brooks	Rural	0	1	4	38	9	95	14	156	20	228	27	309
Port Aransas	Nueces	Suburban	5	28	13	115	22	238	31	406	42	615	52	843
Total			—	**104**	—	**353**	—	**721**	—	**1,155**	—	**1,764**	—	**2,415**

less than 165 gpcd in 2060. As can be seen in Table 4C.1-5, the average per capita water use for cities exceeding 165 gpcd in 2000 with additional conservation is approximately 7 percent lower than without additional conservation.

Table 4C.1-5.
Coastal Bend Region Average Per Capita Water Use for Expected and Advanced Conservation (gpcd)

Type of Conservation	Region Average		Average for Water Users >165 gpcd in 2000	
	2030	2060	2030	2060
TWDB projections	145	142	205	202
TWDB plus additional conservation	143	137	200	188

4C.1.3 Environmental Issues

Environmental impacts from water conservation measures in the Coastal Bend Region are not associated with direct physical impacts to the natural environment. Some of the indoor conservation measures recommended could reduce the amount of treated wastewater available to send to the Nueces Bay and Estuary during low flow times, which could be offset by possible positive impact resulting from higher reservoir levels.

Under a 2001 Agreed Order from the TCEQ,[11] the City is required to pass specified volumes of inflows to the reservoirs in accordance with a monthly schedule to mitigate the impacts of Choke Canyon Reservoir and maintain the health of the Nueces Estuary. In any month when the System storage is less than 40 percent but greater than 30 percent, the target Nueces Bay inflow requirement may be reduced to 1,200 acft/mo when the City and its customers implement Condition II of the City's Water Conservation and Drought Contingency Plan (Plan). If System storage drops below 30 percent, bay and estuary releases (except for return flows) may be suspended when the City and its customers implement Condition III of the Plan. The City's water conservation and drought contingency plan is included in Appendix E.

4C.1.4 Engineering and Costing

Municipal water conservation costs were based on the 2006 Regional Water Plan, updated to September 2008 dollars based on Engineering News Record Construction Cost

[11] Texas Commission on Environmental Quality (TCEQ), Agreed Order Establishing Operational Procedures Pertaining to Special Condition B, Certificate of Adjudication No. 21-3214, Held by City of Corpus Christ, et al., April 28, 1995.

Indices. Of all the indoor water conservation activities, clothes washer rebates are the most costly, ranging in cost from $887/acft to $951/acft, as seen in Table 4C.1-6. For outdoor conservation activities, rain barrels are the most costly program. Costs varied significantly for reducing seasonal water use, unaccounted for loss, and public education programs, and therefore were not presented. For example, a city's cost of a meter replacement and leak detection program, generally part of the utilities' operation and maintenance budget, would vary based on size and age of utility operation and will increase the cost per acft of water conservation activities.

The costs for various water conservation strategies are presented in Table 4C.1-6. Those strategies with costs less than $600/acft were averaged to calculate program costs. The average

Table 4C.1-6.
Costs of Possible Water Conservation Techniques (BMPs)
Updated to September 2008 Dollars

	Rural Water Costs (per acft supply realized) Typical	*Suburban[1] Water Costs (per acft supply realized) Typical*	*Urban Water Costs (per acft supply realized) Typical*
Indoor Conservation			
Toilet Retrofit[2]	$511	$599	$481
Showerheads and Aerators[2]	$90	$102	$84
Clothes Washer Rebate[2]	$950	$951	$887
Outdoor Conservation			
Irrigation Audit-High User[2]	$569	$569	$569
Rainwater Harvesting[2]	$838	$838	$774
Rain Barrels[2]	$1,635	$1,635	$1,510
Landscape Irrigation & Incentives[3]	$524	$524	$524
Seasonal water use reduction[3]	N/A	N/A	N/A
General Conservation			
Unaccounted for losses[4]	N/A	N/A	N/A
Public Education Programs[4]	N/A	N/A	N/A

[1] Suburban costs typically higher than rural costs since more multi-family dwellings are in suburban communities and have higher costs to implement indoor conservation programs.
[2] GDS Associates, July 2003 updated to September 2008 cost.
[3] Water Conservation Implementation Task Force, typical based on 15 percent reduction of outdoor water use and maximum based on 30 percent reduction of outdoor water use. Outdoor water use= Total Water Use- 72.5 gpcd (indoor).
[4] TCEQ Water Audit, August 2002.

cost of municipal water conservation for suburban entities is $448/acft of water saved and $423/acft of water saved for rural entities and includes toilet retrofit, installation of low flow showerhead and aerators, irrigation audits, and landscape incentives. The total program costs for municipal entities having per capita use greater than 165 gpcd in 2060 are presented in Table 4C.1-7. Total conservation potential costs for Region N are estimated at $44,837 in 2010 and increasing to $1,052,529 by 2060. The CBRWPG has expressed a desire to offer BMPs to encourage conservation while maintaining flexibility for municipal users to adopt strategies that suit them the best.

4C.1.5 Implementation Issues

There are several issues that may slow down the efforts of water conservation activities. The most crucial is to get water customers to change their water use habits. Effective public outreach and education can go a long way to reducing water use, but in the end the effectiveness of any program is dependent upon the individual. A key element to the Drought Contingency and Water Conservation Plan that each city has been required to submit to the TCEQ is the curtailment of water use during drought. Enforcement of these restrictions—usually ones that limit lawn watering—is often difficult. Lastly, capital costs for retrofit programs can be large depending on system, and may be difficult for cities or rural entities to initially finance.

The CBRWPG encourages voluntary water conservation throughout the region. Regional water planning guidelines require each region to consider water conservation to meet projected shortages, although funding to implement such water conservation programs is limited. In the future, the Texas Legislature should continue to provide funding to the TWDB and other state agencies for water conservation initiatives, including providing technical support and assistance to water user groups regarding public information programs; leak detection, repair, and monitoring; meter testing and replacement; or other BMPs included in their water conservation programs. Based on the results from the survey conducted by the CBRWPG as part of the first phase of this round of regional water planning, the Texas Legislature should consider providing water conservation grants or low-interest loans to implement the following BMPs in the Coastal Bend Region: (1) water conservation pricing, (2) prohibition on wasting water, (3) school education, (4) landscape irrigation conservation, (5) metering connections and retrofits, (4) plumbing retrofits and replacements, and (5) other BMPs identified by water user groups.

4C.1.6 Evaluation Summary

An evaluation summary of this water management option is provided in Table 4C.1-8.

Table 4C.1-7.
Cost of Water Conservation for Selected Water Conservation Techniques for Water User Groups Having 2060 per Capita Water Use Greater than 165 gpcd

Water User	County	Housing Area	Cost per acft	Cost of Water Savings via Additional Water Conservation					
				2010 (dollars)	2020 (dollars)	2030 (dollars)	2040 (dollars)	2050 (dollars)	2060 (dollars)
Nueces County WCID #4	Nueces	Suburban	$448	$0	$0	$25,130	$60,508	$117,026	$171,880
County-Other	Duval	Rural	$423	$2,431	$5,680	$8,837	$11,518	$18,466	$26,467
County-Other	McMullen	Rural	$423	$272	$739	$1,421	$2,232	$2,894	$4,264
Three Rivers	Live Oak	Rural	$423	$1,068	$3,492	$5,797	$7,779	$11,332	$14,508
George West	Live Oak	Rural	$423	$1,961	$6,068	$10,446	$14,026	$19,008	$24,166
Orange Grove	Jim Wells	Rural	$423	$1,087	$3,224	$5,744	$7,826	$11,905	$15,869
Alice	Jim Wells	Rural	$423	$21,240	$56,111	$92,762	$129,589	$185,382	$247,695
Premont	Jim Wells	Rural	$423	$3,813	$9,272	$15,294	$20,901	$29,665	$39,077
Falfurrias	Brooks	Rural	$423	$283	$15,955	$40,021	$66,129	$96,639	$130,882
Port Aransas	Nueces	Suburban	$448	$12,682	$51,653	$106,749	$181,858	$275,709	$377,721
Total				**$44,837**	**$152,194**	**$312,201**	**$502,366**	**$768,026**	**$1,052,529**

Table 4C.1-8.
Evaluation Summary of Municipal Water Conservation

Impact Category	***Comment(s)***
a. Water Supply 1 Quantity 2. Reliability	 1. Firm Yield: 2,415 acft/yr in Year 2060 2. Cost: Ranges from $90 to $1,635 per acft water saved (based on BMP selected.)
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. Some impact due to decreased return flows, which could be offset by possible positive impact resulting from higher reservoir levels. 2. Some impact due to decreased return flows, which could be offset by possible positive impact resulting from higher reservoir levels. 3. Some impact due to decreased return flows, which could be offset by possible positive impact resulting from higher reservoir levels. 4. Some impact due to decreased return flows, which could be offset by possible positive impact resulting from higher reservoir levels. 5. None. 6. No cultural resources affected. 7. None or low impact.
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	• None
h. Third party social and economic impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

4C.2 Irrigation Water Conservation (N-2)

4C.2.1 Description of Strategy

Irrigation water use is the use of freshwater that is pumped from aquifers and/or diverted from streams and reservoirs of the planning area and applied directly to grow crops, orchards, and hay and pasture in the study area. Irrigated agriculture accounted for around 60 percent of approximately 15 million acft of water used in the state in 2007.[1] Approximately 9 million acft of water were used in Texas to grow a variety of crops ranging from food and feed grains to fruits and vegetables to cotton. Of these 9 million acft, groundwater resources provide approximately 80 percent of the water used for irrigation purposes, with surface water supplies accounting for the remaining 20 percent.[2] Although irrigated agriculture accounts for only 29 percent of all harvested cropland acres in Texas, the value of irrigated crops account for nearly 50 percent of the total value of crop production in the State.[3]

In Texas, irrigated acreage development peaked in 1974 with 8.6 million acres of irrigated cropland. By 2007, irrigated acreage had declined statewide by approximately 3.6 million acres, with a corresponding decline in on-farm water use of more than 4.2 million acft, a reduction of 32 percent.[4,5] There are a number of factors associated with this declining trend, including more acreage being set aside for compliance with federal farm programs, poor economic conditions in the agricultural sector, a decline in the number and size of farms, technological advancements in crop production, advancement and implementation of more water efficient irrigation systems, and better irrigation management practices.

Irrigation water is supplied by groundwater and surface water and is typically applied to land by: (1) flowing or flooding water down the furrows; and (2) with the use of sprinklers. When groundwater is used, irrigation wells are usually located within the fields to be irrigated. For surface water supplies, typically water is diverted from the source and conveyed by canals and pipelines to the fields. In both the use of groundwater and surface water, the conservation objective is to reduce the quantity of water that is lost to deep percolation and evaporation between the originating points (wells in the case of groundwater, and stream diversion points in the case of surface water), and the irrigated crops in the fields. Thus, the focus is upon

[1] Texas Water Development Board (TWDB) Historical Water Use Database, 2007.
[2] TWDB, Historical Groundwater Pumpage Database.
[3] 2007 Census of Agriculture.
[4] 2007 Census of Agriculture.
[5] TWDB, Historical Water Use Database, 2007.

investments in irrigation application equipment, instruments, and conveyance facility improvements (canal lining and pipelines) to reduce seepage losses, deep percolation, and evaporation of water between the originating points of the water and the destination locations within the irrigated fields, and management of the irrigation processes to improve efficiencies of irrigation water use and reduce the quantities of water needed to accomplish irrigation.

Although the statewide trend in irrigated acreage is downward, irrigated acreage in the Coastal Bend Region does not reflect this trend. Crops grown on irrigated acres in the Coastal Bend Region included cotton, grain sorghum, corn, forage crops, peanuts, pecans, hay-pasture, Irish potatoes, vegetables, and other crops. Year 2000 data indicates that irrigated acreage totaled about 25,810 acres, with over 60 percent of the acreage planted for cotton, corn, and hay-pasture.[6] In 2007, of the 7,015 farms in the region, 238 had 34,666 acres of irrigated farmland.[7] Table 4C.2-1 summarizes the variety of crops grown in the Coastal Bend Region and number of irrigated crops for each county in 2007.

Table 4C.2-1.
Irrigated Acres by Crop (2007)
Coastal Bend Region

	Corn	Cotton	Forage Crops	Sorghum	Vegetables	Orchards	Other[1]	Total
Aransas	0	0	0	0	0	0	14	14
Bee	1,638	1,683	447	1,469	0	19	482	5,738
Brooks	0	0	254	0	242	0	1,027	1,523
Duval	0	0	0	0	0	0	4,596	4,596
Jim Wells	0	0	878	0	0	4	875	1,757
Kenedy	0	0	407	0	0	0	0	407
Kleberg	0	0	0	0	0	0	13	13
Live Oak	0	0	1,250	0	9	0	804	2,063
McMullen	0	0	0	0	0	0	0	0
Nueces	0	1,560	47	1,259	0	0	1,456	4,322
San Patricio	3,556	7,257	157	2,613	38	0	612	14,233
Total	***5,194***	***10,500***	***3,440***	***5,341***	***289***	***23***	***9,879***	***34,666***
Percent	***15.0%***	***30.3%***	***9.9%***	***15.4%***	***0.8%***	***0.1%***	***28.5%***	***100%***

Source: 2007 Census of Agriculture.
[1] "Other" represents the balance between reported irrigated acres and the acreage listed for the selected crops above. This may represent other types of irrigated crops or data that was withheld for the selected crops above for certain counties.

[6] TWDB, "Surveys of Irrigation in Texas," Report 347, August 2001.
[7] U.S Department of Agriculture, 2007 Census of Agriculture.

In 2000, the irrigators in the Coastal Bend Region used 21,971 acft of water, of which nearly 90 percent was from groundwater sources. In 2007, the TWDB estimated that the irrigators used 16,782 acft. Due, in part, to increased water application efficiencies, the irrigation use rate decreased from 0.85 acft/acre in 2000 to 0.49 acft/acre in 2007. A portion of this decline is also likely due to 2007 being a wet year with less water being pumped for irrigation purposes.

In the Coastal Bend Region, 10 of the 11 counties (except Nueces County) received a majority of their supply, in many cases full water supply, from groundwater sources. Nueces County irrigators receive most of their water supply from run-of-river water rights from the Nueces River, with water rights exceeding projected water demands.

For this round of regional water planning, the TWDB did not provide updated irrigation water demand projections. Generally, the irrigation water demand projections used in this plan for the Coastal Bend Region are the same as those used in the 2006 Regional Water Plan, except for San Patricio and Bee Counties. Early in the second phase of this round of regional water planning, the Coastal Bend Regional Water Planning Group (CBRWPG) considered historical and current irrigation water use in San Patricio and Bee Counties and determined that the 2007 State Water Plan irrigation water demand projections were too low. Current estimates for Bee County irrigated lands, according to the Bee Groundwater Conservation District, is 7,593 irrigated acres and use of about 3,796 acft/yr (using 0.5 acft per year per acre).[8] On August 12, 2009, the TWDB approved use of the CBRWPG's revised San Patricio and Bee County irrigation water demands for the 2011 Plan.

The irrigation water demand projections for the Coastal Bend Region show significant increases in irrigation usage in the future, primarily attributable to projected increases in irrigation water demands in Bee and San Patricio Counties. For example, San Patricio County irrigation water demand is estimated to increase from 8,631 acft/yr in 2010 to 14,195 acft/yr in 2060 (an increase of 64%). Similarly, Bee County irrigation water demand is estimated to increase by 64% during the planning period from 3,796 acft/yr in 2010 to 6,243 acft/yr in 2060. For the Coastal Bend Region, the TWDB estimate of irrigation water use is projected to increase to 26,671 acft by 2030 and 29,726 acft by 2060, representing an increase of approximately 35 percent from 2000; however, most counties show projected decreases in water demand over time. For counties with projected irrigation water demand declines, the declines are likely due to

[8] Correspondence between HDR and Lonnie Stewart (Bee GCD), March 10, 2009.

expected reductions in irrigated land in the future, however this would imply a reversal of the trend observed in reported irrigated acreage from 2000 to 2007.

In the Coastal Bend Region, Bee, Live Oak, and San Patricio Counties are projected to have irrigation needs (shortages) during the 2000 to 2060 planning period, as shown in Table 4C.2-2. All three counties are projected to use both surface water and groundwater supplies to meet demands. For Bee and San Patricio Counties which both show increases in water demands, the supply was estimated to be equal to the maximum pumpage during the 2000 to 2006 time period. The current groundwater supplies for Bee and San Patricio Counties were set equal to 5,311 acft/yr and 9,698 acft/yr, respectively, as discussed further in Section 4A.2. Live Oak County irrigation water supply was based on TWDB water use data for 2000, consisting of 75 percent groundwater and 25 percent surface water. This ratio was maintained through 2060, according to the groundwater supply procedure presented in Section 3.4.

The projected shortage in Bee County begins in Year 2050 and increases over time from 299 acft in 2050 to 890 acft in 2060. The shortage in Live Oak County declines over time from 627 acft in 2010 to 373 acft in 2060. The projected shortage in San Patricio County begins in Year 2030 and increases over time from 750 acft/yr in 2030 to 4,414 acft in 2060. For all three counties combined, the projected shortage increases over time from 627 acft in 2010 to 5,677 acft in 2060.

The predominant irrigated crop in Bee County is cotton, constituting 29 percent of the irrigated acres. In Live Oak County the predominant irrigated crop are forage crops, constituting 61 percent of the irrigated acres. In San Patricio County the predominant irrigated crop is cotton, constituting 51 percent of the irrigation acres (Table 4C.2-1).

TWDB Rules for regional water planning require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). In addition, the Rules direct water conservation BMPs, as identified by the Water Conservation Implementation Task Force (Task Force), be considered in the development of the water conservation water management strategy.

Table 4C.2-2.
Projected Water Demands, Supplies, and
Water Needs (Shortages) for Irrigation Users
Bee, Live Oak, and San Patricio Counties

	Water Projections						
	2000 (acft)	***2010 (acft)***	***2020 (acft)***	***2030 (acft)***	***2040 (acft)***	***2050 (acft)***	***2060 (acft)***
Bee							
Irrigation Demand	2,798	3,796	4,193	4,632	5,116	5,652	6,243
Irrigation Existing Supply							
Groundwater	2,756	3,754	4,151	4,590	5,074	5,311	5,311
Surface water	42	42	42	42	42	42	42
Total Irrigation Supply	2,798	3,796	4,193	4,632	5,116	5,353	5,353
Irrigation Balance	—	—	—	—	—	(299)	(890)
Live Oak							
Irrigation Demand	3,539	3,289	3,056	2,840	2,639	2,451	2,277
Irrigation Existing Supply							
Groundwater	2,649	2,462	2,287	2,126	1,975	1,835	1,704
Surface water	200	200	200	200	200	200	200
Total Irrigation Supply	2,849	2,662	2,487	2,326	2,175	2,035	1,904
Irrigation Balance	(690)	(627)	(569)	(514)	(464)	(416)	(373)
San Patricio							
Irrigation Demand	4,565	8,631	9,534	10,531	11,633	12,850	14,195
Irrigation Existing Supply							
Groundwater	4,565	8,631	9,534	9,698	9,698	9,698	9,698
Surface water	83	83	83	83	83	83	83
Total Irrigation Supply	4,648	8,714	9,617	9,781	9,781	9,781	9,781
Irrigation Balance	83	83	83	(750)	(1,852)	(3,069)	(4,414)

4C.2.2 Available Yield

As part of the 2006 regional water planning process, the CBRWPG recommended that counties with projected irrigation needs (shortages) reduce their irrigation water demands by 15 percent by 2060 using BMPs identified by the Task Force. However, according to data developed by the TWDB and local GCD data[9] the irrigation water application efficiency in Bee and San Patricio Counties already exceeds 80%, equal to the maximum efficiency achieved with this strategy; therefore, no additional conservation is recommended for these two counties.[10] A 15 percent reduction in irrigation water demand by 2060, results in a new demand of 1,935 acft for 2060 (for Live Oak County) and maximum savings of 342 acft as shown in Table 4C.2-3.

Table 4C.2-3.
Projected Water Demands and Needs (Shortages) for
Irrigation Users after Recommended Irrigation Water Conservation
Live Oak County

	Water Projections					
	2010 (acft)	2020 (acft)	2030 (acft)	2040 (acft)	2050 (acft)	2060 (acft)
Live Oak						
New Demand	3,272	3,004	2,737	2,470	2,203	1,935
Expected Savings	17	52	103	169	248	342
New Shortage	(610)	(517)	(411)	(295)	(168)	(31)
Shortage Reduction	3%	9%	20%	36%	60%	92%

The Task Force report lists the following irrigation BMPs that may be used to achieve the recommended water savings:[11]

1. Irrigation Scheduling;
2. Volumetric Measurement of Irrigation Water Use;
3. Crop Residue Management and Conservation Tillage;
4. On-farm Irrigation audit;
5. Furrow Dikes;

[9] Letter provided by the CBRWPG to TWDB on June 26, 2009.
[10] Low-energy precision application systems (LEPA) analysis as an irrigation BMP is assumed to have the highest application efficiency rate of 80% (See Table 4C.2-4).
[11] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

6. Land Leveling;
7. Contour Farming;
8. Conservation of Supplemental Irrigated Farmland to Dry-Land Farmland;
9. Brush Control/Management;
10. Lining of On-Farm Irrigation ditches;
11. Replacement of On-/farm Irrigation Ditches with Pipelines;
12. Low Pressure Center Pivot Sprinkler Irrigation Systems;
13. Drip/Micro-Irrigation System;
14. Gated and Flexible Pipe for Field Water Distribution Systems;
15. Surge Flow Irrigation for Field Water Distribution Systems;
16. Linear Move Sprinkler Irrigation Systems;
17. Lining of District Irrigation Canals;
18. Replacement of District Irrigation canals and Lateral canals with Pipelines;
19. Tailwater Recovery and Use System; and
20. Nursery Production Systems.

The Task Force report describes the above BMP methods and how they reduce irrigation water use, however information regarding specific water savings and costs to install irrigation water saving systems is generally unavailable. The Task Force report does include water savings and costs for three irrigation water conservation BMPs: (1) furrow dikes; (2) low-pressure sprinklers (LESA); and (3) low-energy precision application systems (LEPA). These major irrigation water conservation techniques applicable in the Coastal Bend Region are described briefly below.

Furrow dikes are small mounds of soil mechanically installed a few feet apart in the furrow. These mounds of soil create small reservoirs that capture precipitation and hold it until it soaks into the soil instead of running down the furrow and out the end of the field. This practice can conserve (capture) as much as 100 percent of rainfall runoff, and furrow dikes are used to prevent irrigation runoff under sprinkler systems. This maintains high irrigation uniformity and increases irrigation application efficiencies. Capturing and holding precipitation that would have drained from the fields replaces required irrigation water on irrigated fields; and furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland. Use of furrow dikes can have water savings up to 12 percent gross quantity of water applied using sprinkler irrigation. According to TWDB estimates of acreage equipped with sprinkler irrigation systems, if Live Oak County irrigators install furrow dikes, the expected water savings could be up to 422 acft/yr, assuming 100 percent participation of irrigated lands with sprinkler systems. Furrow dikes require special tillage equipment and costs $7 to $39 per acre to install (for September 2008 dollars).

Low-pressure sprinklers (LESA) with 75 percent application efficiency improve irrigation application efficiency in comparison to conventional furrow irrigation by reducing water requirements per acre by 15 percent. According to the latest irrigation survey conducted by the TWDB, the application efficiency of sprinkler systems in Live Oak County is estimated at 60 percent.[12] Low-pressure sprinklers spray water into the atmosphere above the crops as the sprinkler systems are moved across the fields. In Live Oak County, conversion to LESA systems would save about 0.34 acft/acre converted and result in a total savings of 704 acft/yr.

LEPA systems involve a sprinkler system that has been modified to discharge water directly into furrows at low pressure, thus reducing evaporation losses. When used in conjunction with furrow dikes, which hold both precipitation and sprinkler applied water behind small mounds of earth within the furrows, LEPA systems can accomplish the irrigation objective with less water than is required for the furrow irrigation and pressurized sprinkler methods. If LEPA is used with furrow dike systems the expected water savings would be approximately 0.62 acft/acre (a total reduction in water use of approximately 37 percent). Use of LEPA and furrow dikes allows irrigation farmers to produce equivalent yields per acre at lower energy and labor costs of irrigation. It has been demonstrated that LEPA systems improve production and profitability of irrigation farming. The barriers to installation are high capital costs; with no assurance (at the present time) that the water saved would be available to the irrigation farmer who incurred the costs.

A comparison of irrigation rates for furrow dikes, LESA, and LEPA systems to irrigation rates before irrigation water conservation are shown in Table 4C.2-4.

4C.2.3 Environmental Issues

The irrigation water conservation methods described above have been developed and tested through public and private sector research, and have been adopted and applied within the Region. Hundreds of LEPA systems have been installed, and are in operation today, and experience has shown that there are not any significant environmental issues associated with this water management strategy. For example, this method improves water use efficiency without making changes to wildlife habitat. This method of application, when coupled with furrow dikes

[12] TWDB, Op. Cit., August 2001.

reduces runoff of both applied irrigation water and rainfall. The results are reduced transport of sediment and any fertilizers or other chemicals that have been applied to the crops. Thus, the proposed conservation practices do not have potential adverse effects, and in fact have potentially beneficial environmental effects.

Table 4C.2-4.
Region N Irrigated Acreages and Effects of Water Conservation on Irrigation Water Use and Application Rates
Live Oak County

	Acreage Irrigated with Sprinklers (2000)	*Irrigation Water Use (acft)*	*Irrigation Rate (acft/acre)*	*Estimated water savings (acft)*
Before Conservation				
	2,091	3,518	1.68	—
With Conservation				
Furrow Dikes[1]	2,091	3,096	1.48	422
LESA[2]	2,091	2,814	1.35	704
LEPA[3]	2,091	2,638	1.26	879

[1] 12% savings of water applied using sprinkler irrigation.
[2] Assumes application efficiency of 75 percent.
[3] Assumes application efficiency of 80 percent.

4C.2.4 Engineering and Costing

Municipal water conservation costs were based on the 2006 Regional Water Plan, updated to September 2008 dollars based on Engineering News Record Construction Cost Indices. Consistent with the approach used in the 2006 Plan, the CBRWPG recommended irrigation water conservation strategy for irrigation users results in a potential water savings of 342 acft. This savings can be accomplished by using any one or a combination of three strategies: furrow diking, LESA or LEPA. Furrow dikes can save up to 422 acft at an average unit cost of $228 per acft (Table 4C.2-5). Installing LESA or LEPA systems would incur a greater capital cost, and therefore higher annual costs, however both achieve a substantially higher water savings potential and therefore have more economical unit cost ($/acft) when compared to furrow dikes. The maximum water conservation potential can be realized by using the LEPA system, as shown in Table 4C.2-4. The capital cost to install LEPA irrigation is approximately $524 per acre.[13] It is estimated that it would take a total investment of $1,095,700 to equip the estimated 2,091 irrigated acres currently served by sprinkler systems in Live Oak County. This investment, at an annual cost of $95,527 (20 years at 6 percent), would save an estimated 879 acft/yr at an average unit cost of $109 per acft of water saved.

Each of the three irrigation water conservation strategies described (furrow dikes, LESA, and LEPA) have the potential to increase water savings beyond the recommendations of the CBRWPG. For example, installing LEPA or LESA for acreage currently equipped with sprinkler systems could potentially eliminate all shortages. The largest shortage for Live Oak County is 627 acft in 2010. If LEPA was installed on approximately 1,490 acres of 2,091 acres currently irrigated with sprinkler systems, the shortage would be eliminated. In 2060, only 890 acres would need to be equipped with LEPA to eliminate the shortage.

Table 4C.2-5.
Potential Water Savings and Costs
(Total Project, Annual Average, and Unit Costs)
to Implement Irrigation Water Conservation BMPs
Live Oak County
Updated to September 2008 Dollars

	Maximum Reasonable Water Savings (acft)	Maximum Savings for Strategy (acft)	Total Project Cost (average)	Average Annual Cost	Average Cost per acft
Furrow Dikes	342	422	—	$48,093	$228
LESA (90% efficiency)	342	704	$1,095,700	$95,527	$136
LEPA (95% efficiency)	342	879	$1,095,700	$95,527	$109

It may not be economically feasible for some agricultural producers to pay for additional water supplies to meet projected irrigation water needs (shortages), even if such supplies were available. For example, in 2004, for irrigated cotton, the estimated income remaining after other production expenses had been paid was about $158 per acre. For cotton farming, although limited in the Coastal Bend Region, it may be practical to install furrow, LESA, or LEPA

[13] Costs based on the Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004 were updated to September 2008 dollars.

systems. For other crops, if the cost of water exceeds the estimated income, then it would not be practical to pay for additional water.

4C.2.5 Implementation Issues

The rate of adoption of efficient water-using practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing. There is widespread public support for irrigation water conservation and it is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach its maximum potential. A major barrier to implementation of water conservation is financing. The TWDB has irrigation conservation programs that may provide funding to irrigators to implement irrigation BMPs that increase water use efficiency. Future planning efforts should consider the use of detailed studies to fully determine the maximum potential benefits of additional irrigation conservation.

4C.2.6 Evaluation Summary

An evaluation summary of this water management option is provided in Table 4C.2-6.

Table 4C.2-6.
Evaluation Summary of Irrigation Water Conservation

Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Firm yield: Variable according to BMP selected. Ranges up to 879 acft, depending on BMP and extent of participation.
2. Reliability	2. Highly reliable quantity.
3. Cost of Treated Water	3. Cost: Ranges from $109 to $228 per acft water saved based on BMP selected.
b. Environmental factors	
1. Instream flows	1. None or low impact.
2. Bay and Estuary Inflows	2. None or low impact..
3. Wildlife Habitat	3. No apparent negative impact.
4. Wetlands	4. None.
5. Threatened and Endangered Species	5. None.
6. Cultural Resources	6. No cultural resources affected.
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 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	• None.
h. Third party social and economic impacts from voluntary redistribution of water	• None.
i. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions by reducing rate of decline of local groundwater levels.
j. Effect on navigation	• None.

4C.3 Manufacturing Water Conservation and Nueces River Water Quality Issues (N-3)

4C.3.1 Description of Strategy

Manufacturing is an integral part of the Texas economy, and for many industries, water plays a key role in the manufacturing process. Some of these processes require direct consumption of water as part of the products; others consume very little water but use a large quantity for cleaning and cooling. In 2000, Nueces and San Patricio Counties accounted for 96 percent of the total manufacturing water use in Coastal Bend Region of 54,481 acft. Manufacturing use for the entire planning region is projected to increase to 73,861 acft in 2030 and 88,122 acft by 2060. In 2060, Nueces and San Patricio Counties will account for 97 percent of the total manufacturing water use in the region.

In the manufacturing sector, water quality impacts the quantity of water needed for cooling purposes. Cooling water accounts for 60 to 75 percent of the industrial demand in the region.[1] Assuming 60 percent demand, the industrial demand for cooling water in Nueces and San Patricio Counties is expected to grow from about 31,490 acft/yr in 2000 to 51,360 acft/yr in 2060. The quantity of water needed by industry for cooling is substantial and could potentially be reduced by providing water with lower mineral content. High levels of dissolved minerals result in an increase in manufacturing water demands, due to accelerated build-up of mineral deposits in industrial cooling facilities. Additional water savings can also be achieved by stabilizing the water quality and thereby minimizing the variation in water quality. Manufacturing water conservation would benefit the entire Coastal Bend Region by preventing the need to obtain, treat, and distribute the amount of water that is conserved. Alternatively, the amount of water that is conserved could be used for other beneficial purposes.

Devising water management strategies using water from the Lower Nueces River Basin has been a challenge, especially with regard to water losses and water quality. Figure 4C.3-1 shows that median chloride concentrations at the Calallen Pool near the City of Corpus Christi's O.N. Stevens Water Treatment Plant intake (155 mg/L) are 2 times the level of chlorides in water released from Lake Corpus Christi (80 mg/L). Previous studies by the U.S. Geological Survey

[1] City of Corpus Christi, "Effluent Reuse Study," February 2002.

(USGS) and others have also indicated a significant increase in the concentration of dissolved minerals in the Lower Nueces River between Mathis and the Calallen Saltwater Barrier Dam.[2]

Figure 4C.3-1 also shows the change in chloride concentrations occurring between Lake Corpus Christi (Hwy 359 site) and the Calallen Dam. The results indicate that on average about 60 percent of the increase in chlorides occurs upstream of the Calallen Pool and about 40 percent of the increase within the pool. Despite similar conclusions from the various previous studies, the source(s) of this increase in mineral concentrations has not previously been conclusively established. Potential sources of minerals to the Calallen Pool include saltwater intrusion, groundwater seepage, and upstream sources of contamination from abandoned wells in adjacent oil fields and gravel washing operations.

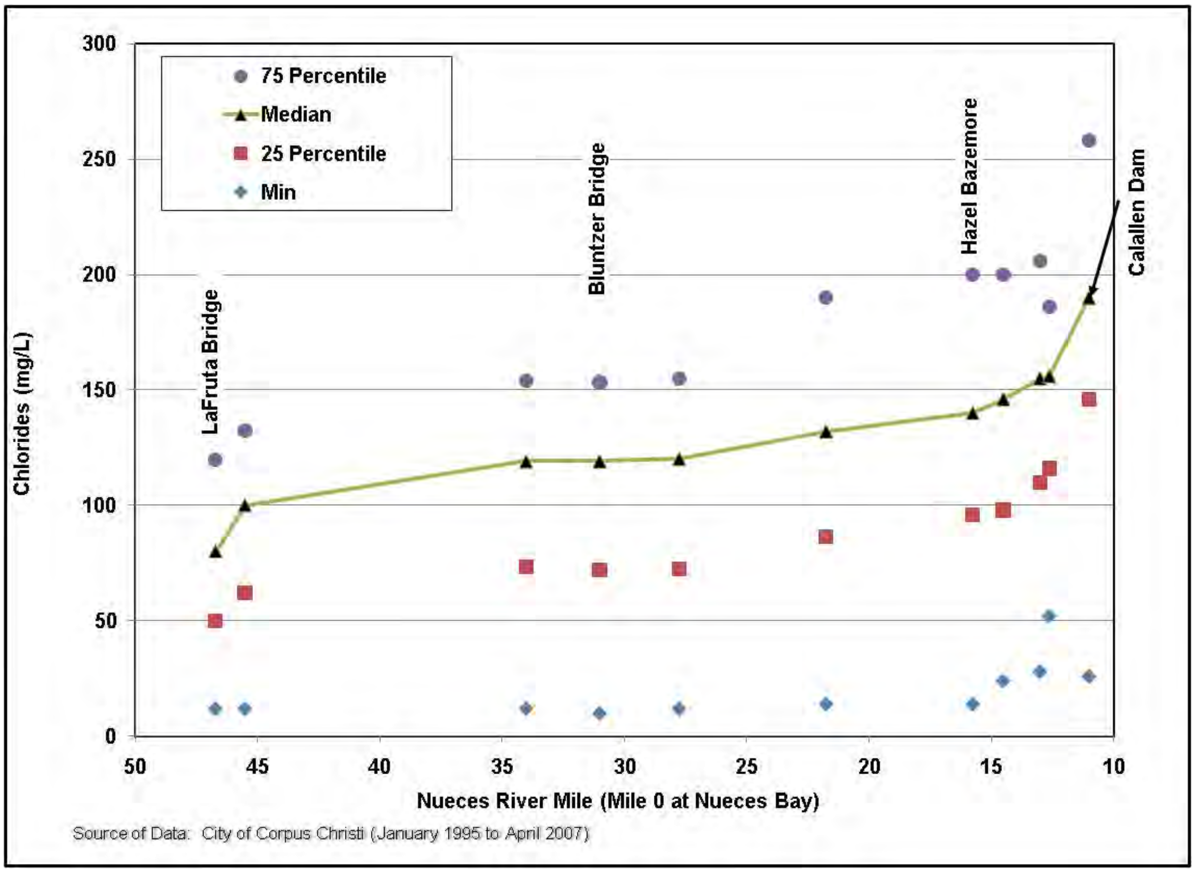


Figure 4C.3-1. Summary of Historical Data — Chloride Content of the Lower Nueces River, Segment 2102

[2] USGS studies report average chloride concentrations in the Calallen Pool are 2.5 times the level of chlorides in water released from Lake Corpus Christi.

This strategy includes discussion of previous studies and recent Lower Nueces River water quality assessment conducted by the Coastal Bend Regional Water Planning Group (CBRWPG). For the 2011 Plan, the CBRWPG conducted assessments of a water budget of LCC and water quality of the Lower Nueces River from Lake Corpus Christi to the Calallen Pool. Following results from the water quality study, the report discusses manufacturing water demands and specific water management strategies that may address water supply issues to promote manufacturing water conservation.

4C.3.2 Previous Water Quality Analyses

For the 2001 Regional Water Plan, a surface water and groundwater evaluation was conducted for the Nueces River downstream of Lake Corpus Christi. The results of the Lower Nueces River Dissolved Minerals Study surface water sampling program are included in Appendix I-1. The study showed the most significant concentration increase in chlorides (and dissolved minerals in general) occurs with increasing depth within the channel. Sampling results showed stratification within the Calallen Pool, with large mineral concentration increases occurring within the bottom 2 feet near the water intake locations. The stratification of the channel was found to be the most significant when no water was spilling over Calallen Dam and the least detectable during periods of high flow. The largest increase in dissolved mineral concentrations was found 100 yards downstream of the O.N. Stevens intake. The study also showed that the surface water sample taken at the Stevens intake is geochemically more similar to the groundwater sample taken at Hazel Bazemore Park, than to any of the other surface water samples (including samples taken at the same location, just three feet higher in the water column). This suggests that groundwater intrusion is taking place in the Calallen Pool.

A second phase of this investigation was initiated as part of the 2001 Regional Water Plan in an effort to identify the possible sources of elevated levels of dissolved solids in the Nueces River water in addition to the surface water sampling effort just described. This effort included monitor well installation, groundwater and surface water sampling, obtaining and interpreting aerial/satellite imagery of the area between Wesley Seale Dam and Calallen Pool, to identify possible point source contributions (specifically, abandoned oil and gas wells and sand/gravel washing operations), and groundwater intrusion. The results of the surface water and groundwater interaction study are included in Appendix I-2.

In August 2003, the NRA conducted a surface water and bathymetric study for the Nueces Tidal Segment of the Nueces River (Segment 2101). Surface water samples were collected periodically from August 2002 to August 2003 at several locations along the segment and monitored at various water depths during various flow conditions to determine stratification of water quality parameters.

The following parameters were measured:

1. Depth;
2. Temperature;
3. Dissolved oxygen;
4. pH;
5. Specific conductance; and
6. Salinity.

Salinity results were used to calculate chloride levels (i.e., salinity (ppt) = chloride (ppt) * 1.80655). The chloride results for various depths and flow conditions for the sample location near Calallen Pool at IH37 is presented in Figure 4C.3-2.

As streamflow rates decreased and during periods of low flow, vertical profiles were high stratified, especially with respect to salinity and dissolved oxygen.[3] Similar trends were apparent for all other parameters to a lesser extent.

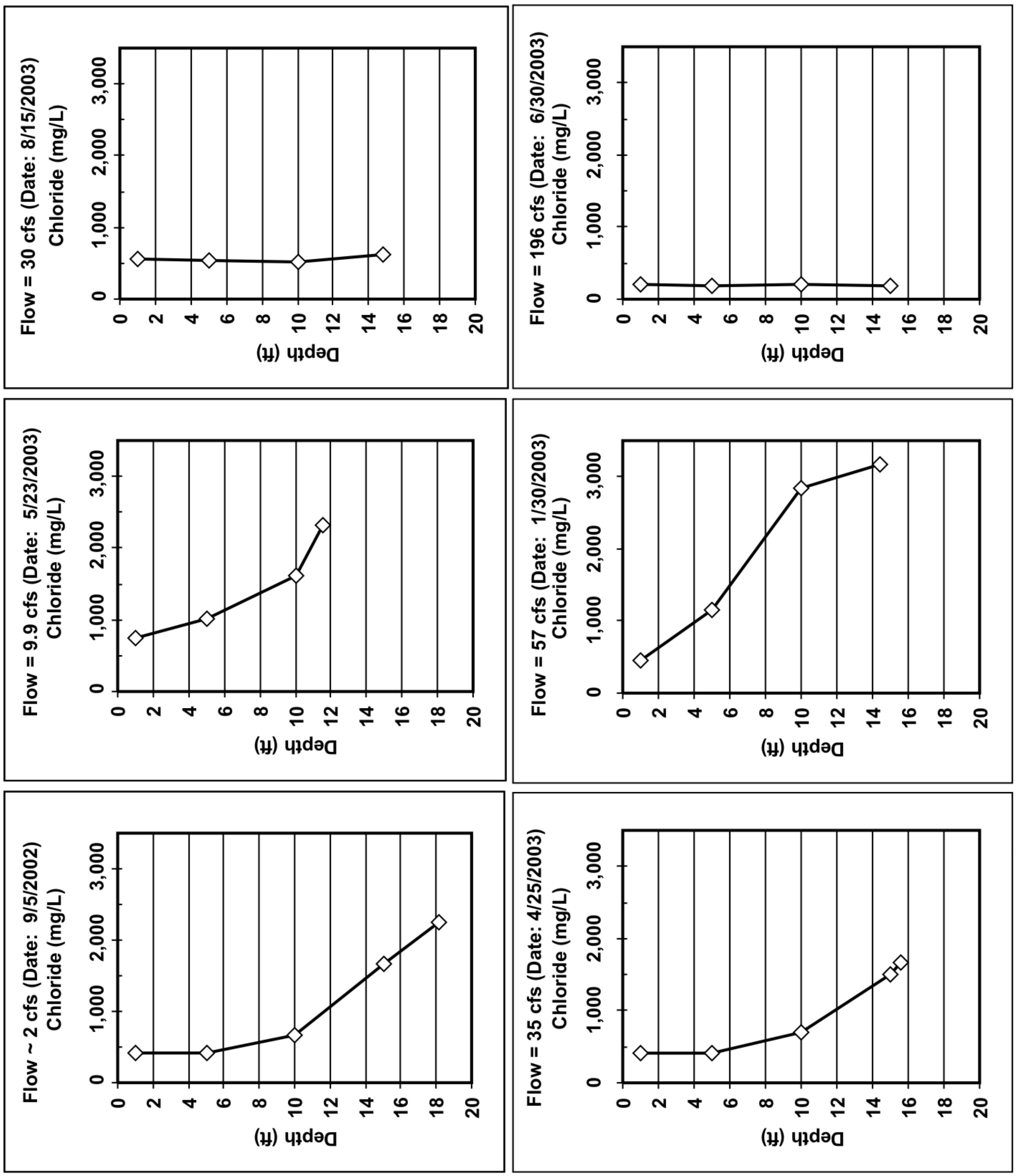
The opportunity exists with permanent monitor wells in place around the Calallen Pool to conduct a comprehensive sampling program to evaluate the gaining and losing nature of the surface/groundwater system and then relate this information to surface water and groundwater sample results acquired within a time period during which the Calallen Pool experiences low and high flow conditions. Based upon the results of the sampling program, best management practices and mitigation can then be suggested.

4C.3.3 Assessment of Water Budget and Salinity in the Lower Nueces River Basin

4C.3.3.1 Introduction

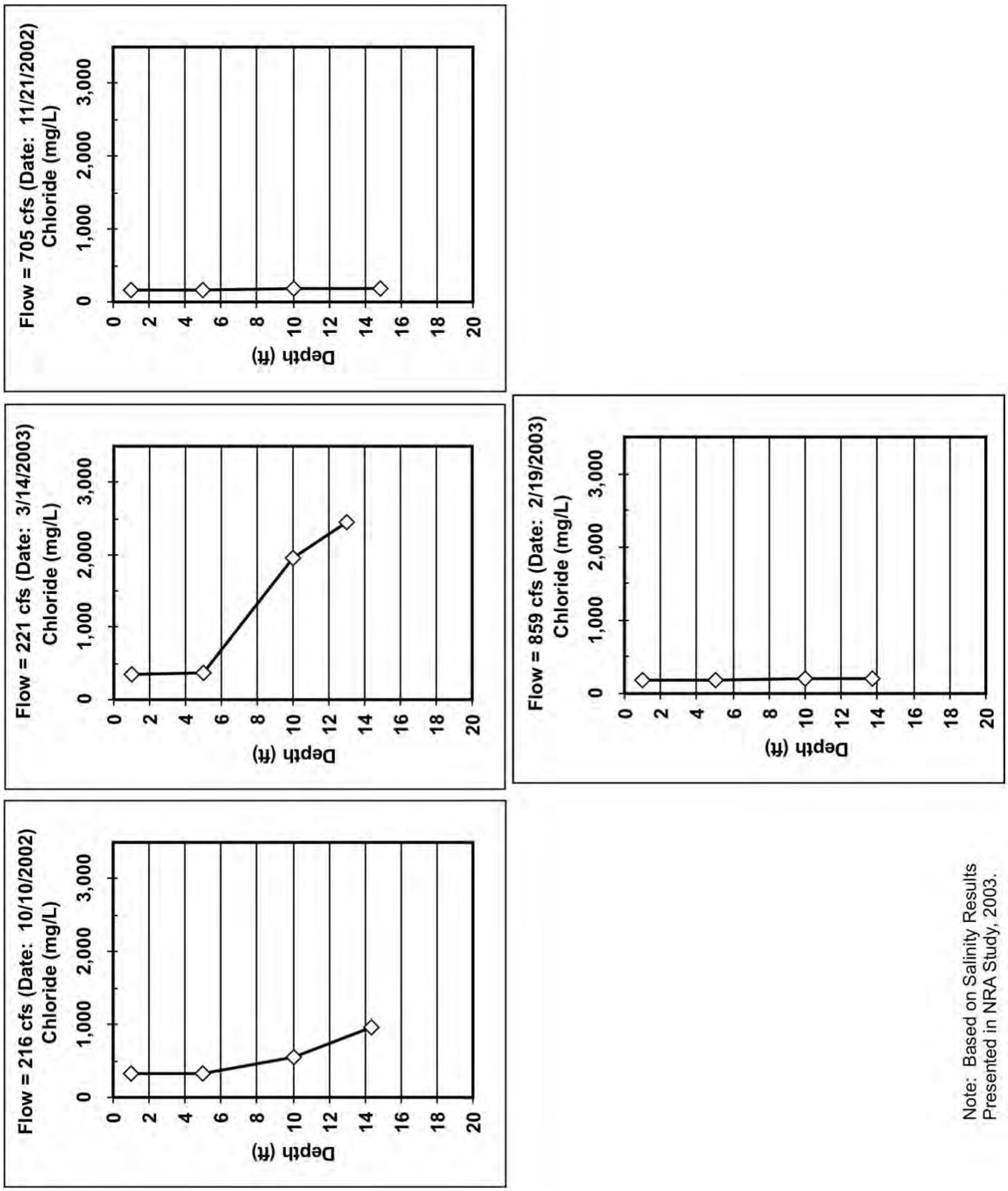
The major purpose of this assessment for the 2011 Plan is to improve our understanding of: (1) surface water/groundwater interactions and (2) influences on water quality conditions. The areas of interest are Lake Corpus Christi (LCC) and the Nueces River between LCC and

[3] Nueces River Authority, "A Final Report on the Surface Water Monitoring and Bathymetric Data Collection Study for the Nueces Tidal Special Study," August 2003.



Note: Based on Salinity Results Presented in NRA Study, 2003.

Figure 4C.3-2. Chloride Concentrations near Calallen Pool at IH-37 (Page 1 of 2)



Note: Based on Salinity Results Presented in NRA Study, 2003.

Figure 4C.3-2. Chloride Concentrations near Calallen Pool at IH-37 (Page 2 of 2)

Calallen. For purposes of this report, the Lower Nueces River Basin is considered to be between the U.S. Geological Survey (USGS) station 08210000 Nueces River near Three Rivers, Texas and station 08211500 Nueces River at Calallen.

The location of the study area and the stream gaging stations is shown in Figure 4C.3-3. Data used for the study included:

- Streamflow—USGS;
- Groundwater levels, groundwater quality, precipitation and lake evaporation—Texas Water Development Board (TWDB);
- LCC stage and volume and direct lake diversions—Nueces River Authority (NRA); and
- Stream water quality and Calallen diversions—City of Corpus Christi.

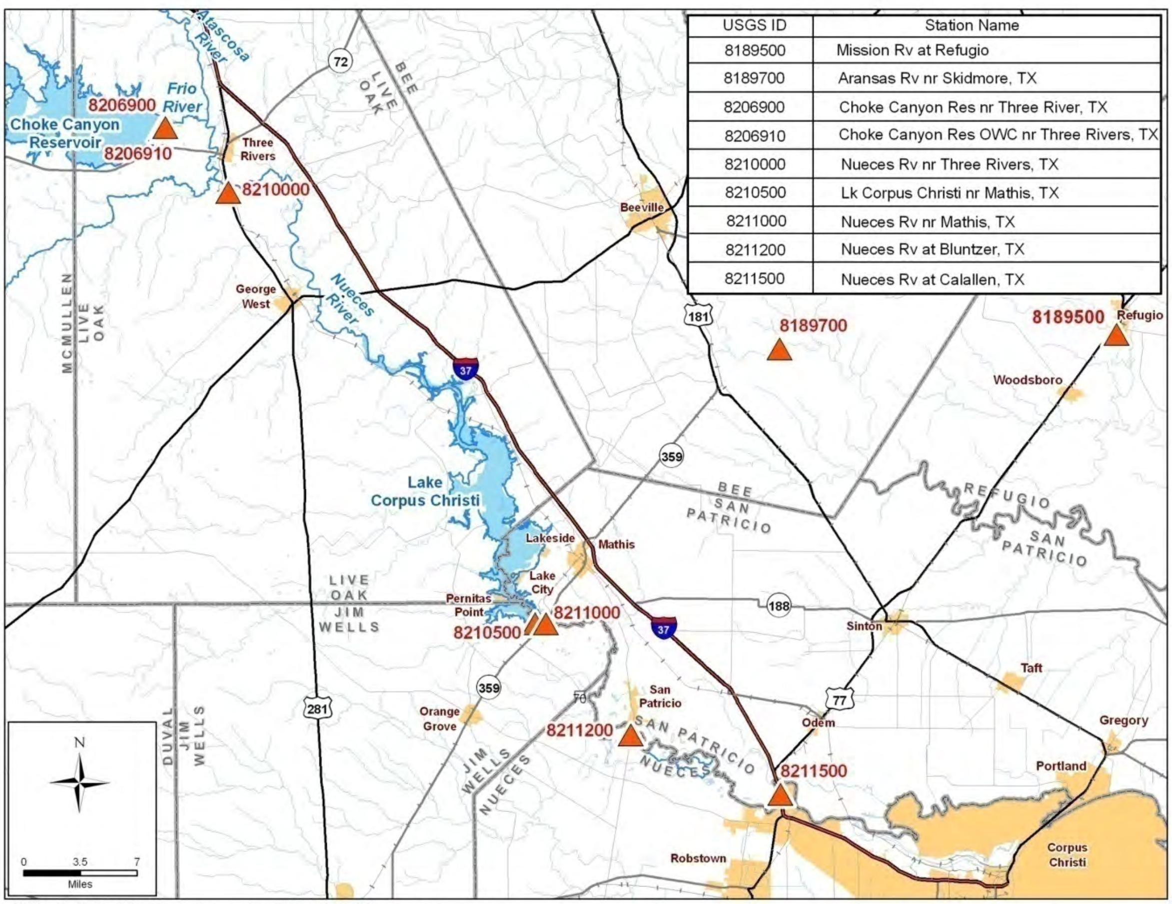


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Figure 4C.3-3. Location of Study Area and Streamflow Gaging Stations

4C.3.3.2 Surface Water/Groundwater Interactions

The interaction (movement) of water between the Nueces River and LCC (surface water) and major aquifers (groundwater) is studied for LCC and in the Nueces River reach between Mathis and Calallen. For LCC, the interaction is studied by calculating the seepage into and out of the lake from a water budget model. For the Lower Nueces River, the interaction is studied by calculating the streamflow gains and losses between streamflow USGS gaging stations.

4C.3.3.2.1 Seepage into and out of Lake Corpus Christi

The selected approach in calculating the seepage into and out of LCC is to develop a water balance model that accounts for all the major inflows and outflows and estimates seepage from the lake as the amount of water needed to balance the other inflow and outflow components. The hydrologic connection of LCC with the Gulf Coast Aquifer, primarily the Goliad Sands (Evangeline Aquifer), is assessed by compiling, plotting and studying groundwater level data in the vicinity of the lake.

4C.3.3.2.1.1 Water Balance Model

A schematic of the water balance model is shown in Figure 4C.3-4. As shown, the major components of inflow to LCC are the Nueces River, runoff from intervening drainage area around the lake, precipitation and seepage; and, the major components of outflow are reservoir releases, lake diversions, evaporation and seepage. The period of study is from January 1959, which is shortly after the enlargement of the current reservoir was completed, to 2008. Because of the length of the study period, data constraints, and ‘noise’ in the daily data, the selected time interval for the water balance model is a month. This minimizes, not eliminates, the potential for outliers in trying to balance the inflow and outflow components.

Inflow from the Nueces River is estimated from the USGS station 08210000 Nueces River near Three Rivers. The intervening area between the Nueces River below the Three Rivers gage and above the LCC Wesley Seale Dam is paired with the USGS station 08189700 Aransas River near Skidmore which is about 20 miles northeast of the lake (Figure 4C.3-3). The streamflow records for the Aransas station were adjusted to the intervening area by: (1) subtracting an estimate of the City of Beeville’s wastewater from data, (2) calculating the unit runoff of the gaged watershed, (3) assuming the unit runoff in the intervening area is the same as for the Aransas River near Skidmore watershed, and (4) multiplying the intervening area times the unit runoff of the Aransas River. The USGS station 08189700 Aransas River near Skidmore station was started in 1964. From 1959-1964, the Aransas River near Skidmore streamflow was estimated by using the USGS station 08189500 Mission River at Refugio streamflow and making an adjustment based on watershed size. The precipitation on the lake was obtained from the Texas Water Development Board (TWDB) data base. An average of precipitation for grids 909 and 910 was considered to be representative.

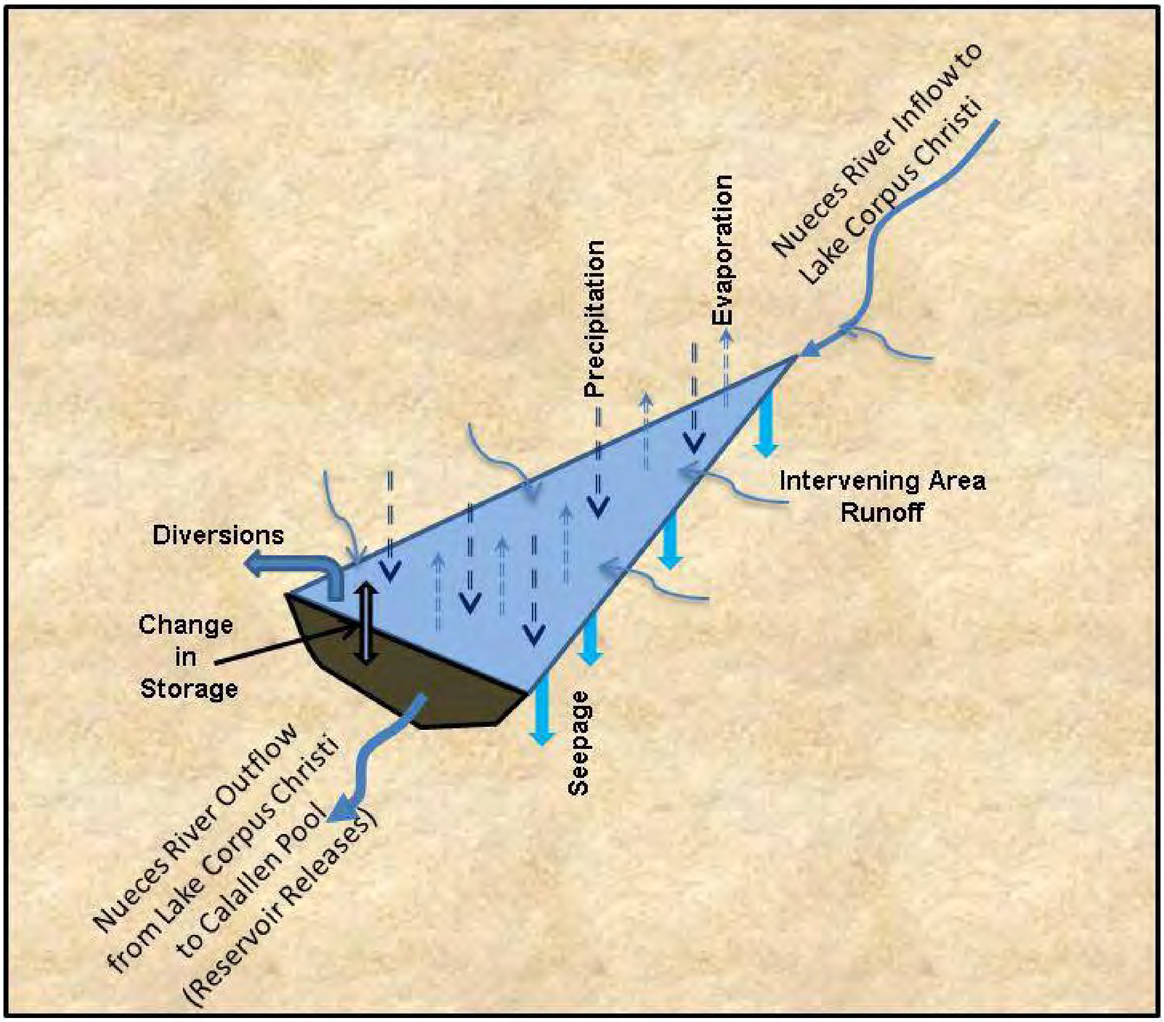

Figure 4C.3-4. Schematic of Lake Corpus Christi Water Balance Components

Outflow from LCC releases is estimated from the USGS station 08211000 Nueces River near Mathis. Major direct diversions from LCC are made by the Cities of Alice, Beeville and Mathis. Diversion data were provided by the Nueces River Authority (NRA). The evaporation from the lake was obtained from the Texas Water Development Board (TWDB) data base. An average of evaporation for grids 909 and 910 was considered to be representative. LCC records on stage and volume were obtained from the NRA.

Charts showing the annual water budget components are shown in:

- Figure 4C.3-5: Amount of inflow and outflow from precipitation and evaporation, respectively;
- Figure 4C.3-6: Inflow and outflow for LCC;
- Figure 4C.3-7: Inflow to LCC from intervening area and Outflow from direct lake diversions;
- Figure 4C.3-8: Net change in lake storage; and
- Figure 4C.3-9: Seepage into and out of lake.

The seepage in the water balance model is considered to be an unknown and is the amount of water needed each month for the water budget to balance.

A water budget summary of the lake's water budget is presented in Table 4C.3-1. The results of this analysis shows seepage out of the lake represents about 17 percent of the outflow and about 1 percent of the inflow. The largest component of inflow is from the Nueces River near Three Rivers, which is about 68 percent. Releases from LCC's Wesley Seale Dam are about 64 percent of the outflow. Evaporation accounts for about 10 percent of the outflow.

Table 4C.3-1.
Annual Average of Lake Corpus Christi's Major Water Budget Components

Component	Units (acft/yr)		Percentage	
	Inflow	Outflow	Inflow	Outflow
Nueces River-Three Rivers	509,100		68	
Nueces River-Mathis		480,500		64
Precipitation	43,600		6	
Evaporation		73,900		10
Intervening Runoff	125,300		17	
Lake Diversions		2,300		0
Net Change in Storage	64,100	64,600	8	9
Seepage	6,700	127,500	1	17
TOTAL	748,800	748,800	100	100

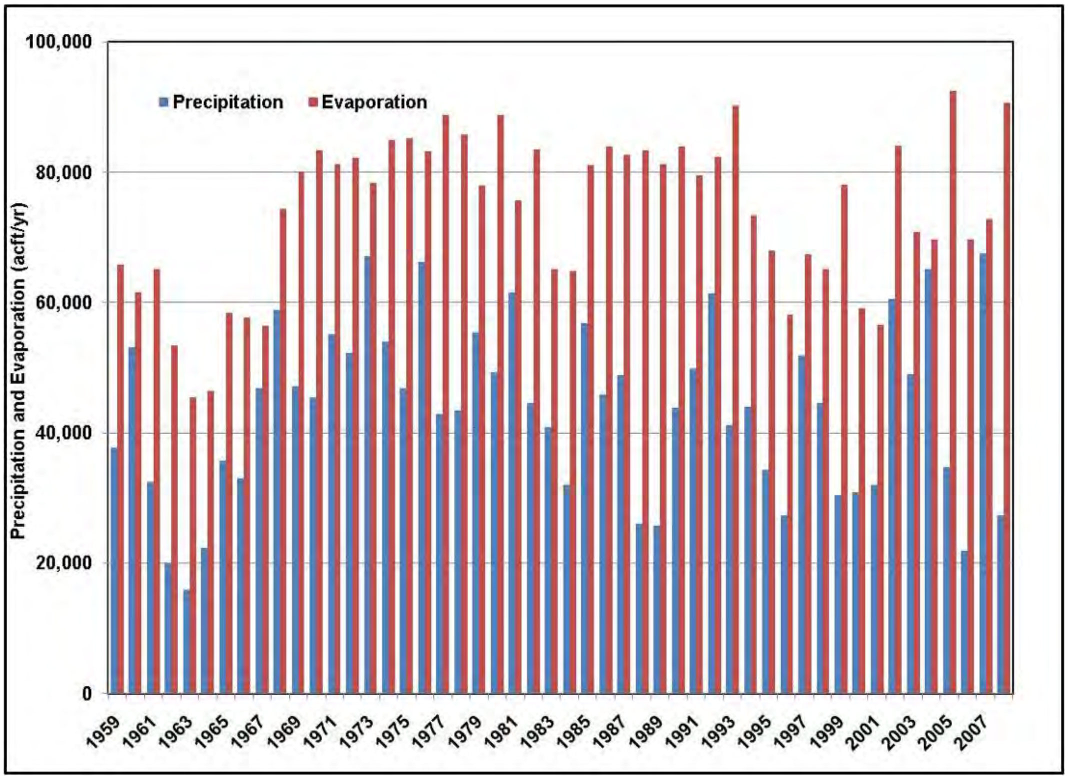

Figure 4C.3-5. Precipitation and Evaporation

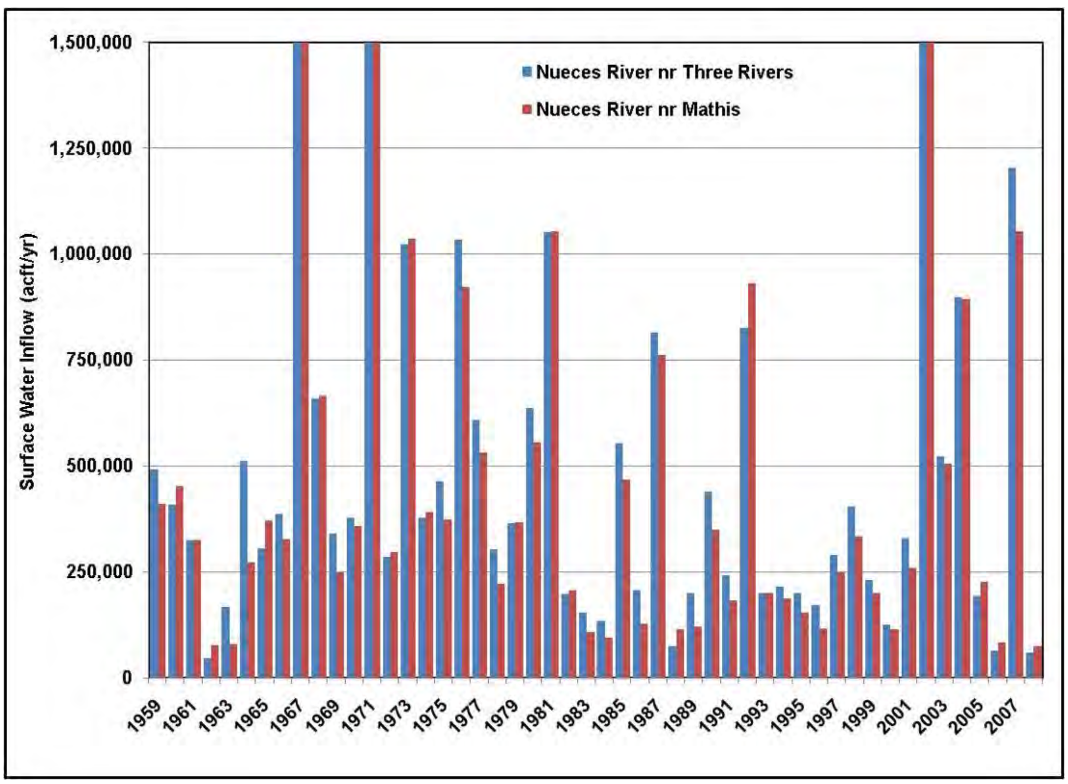

Figure 4C.3-6. Streamflow at Nueces River Inflow and Outflow Stations

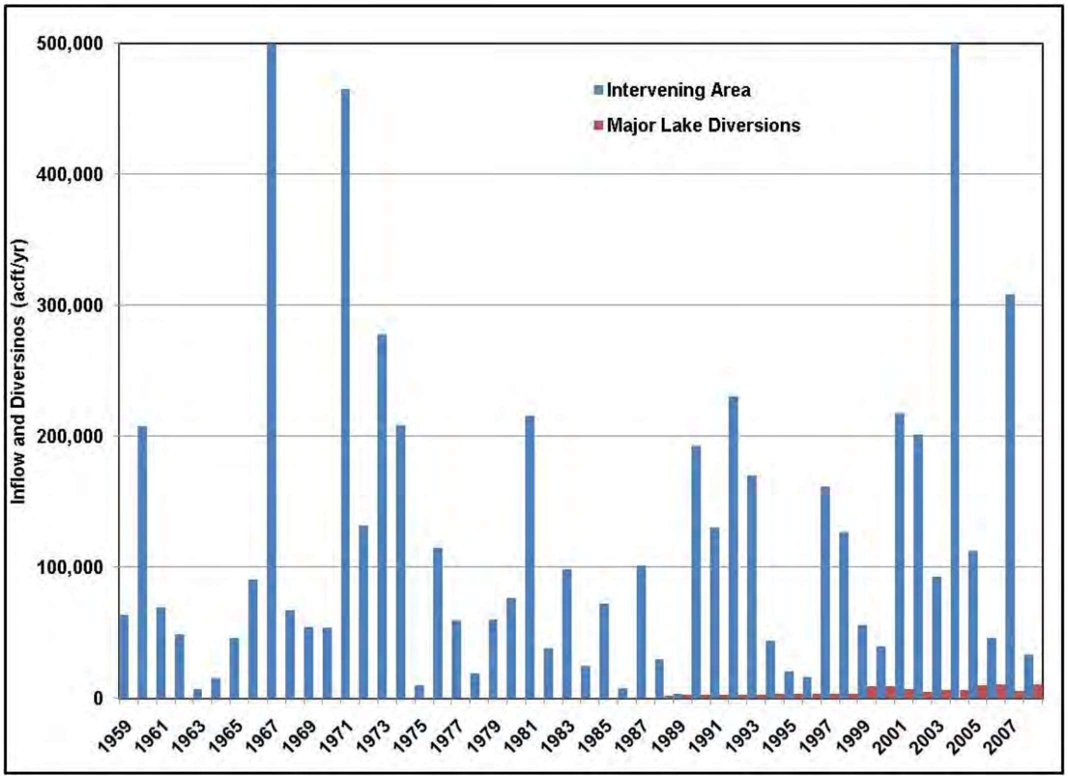

Figure 4C.3-7. Intervening Area Inflow and Major Water Supply from Lake Corpus Christi

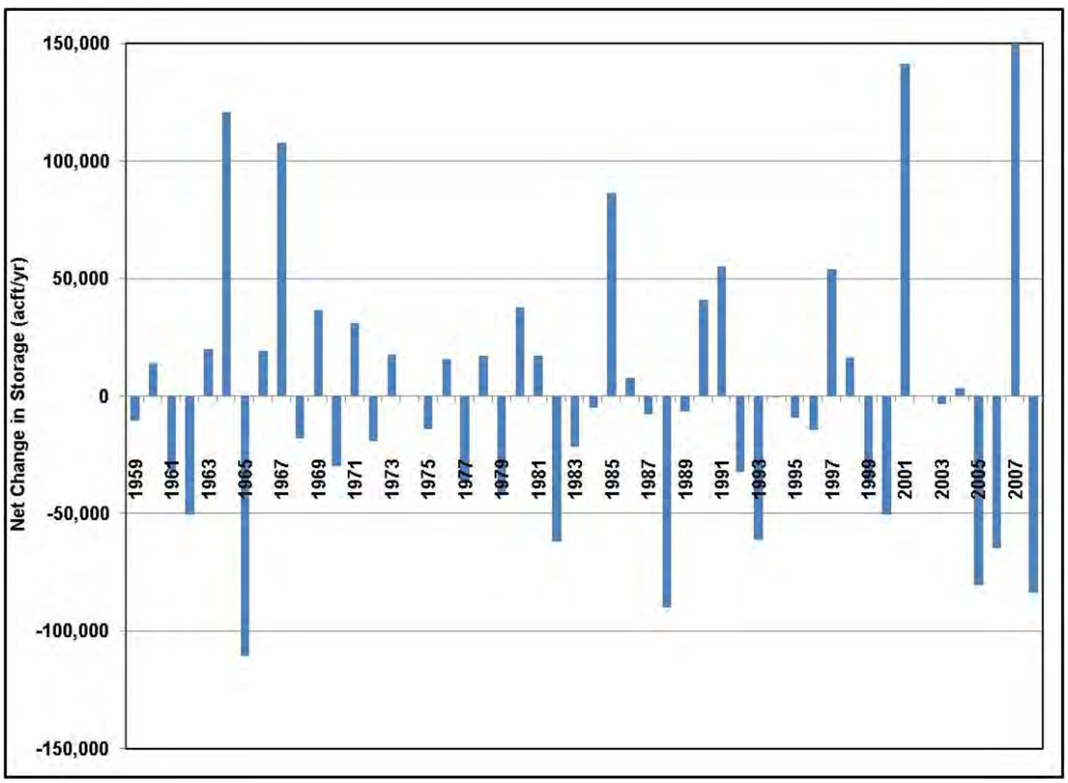

Figure 4C.3-8. Net Change in Lake Storage

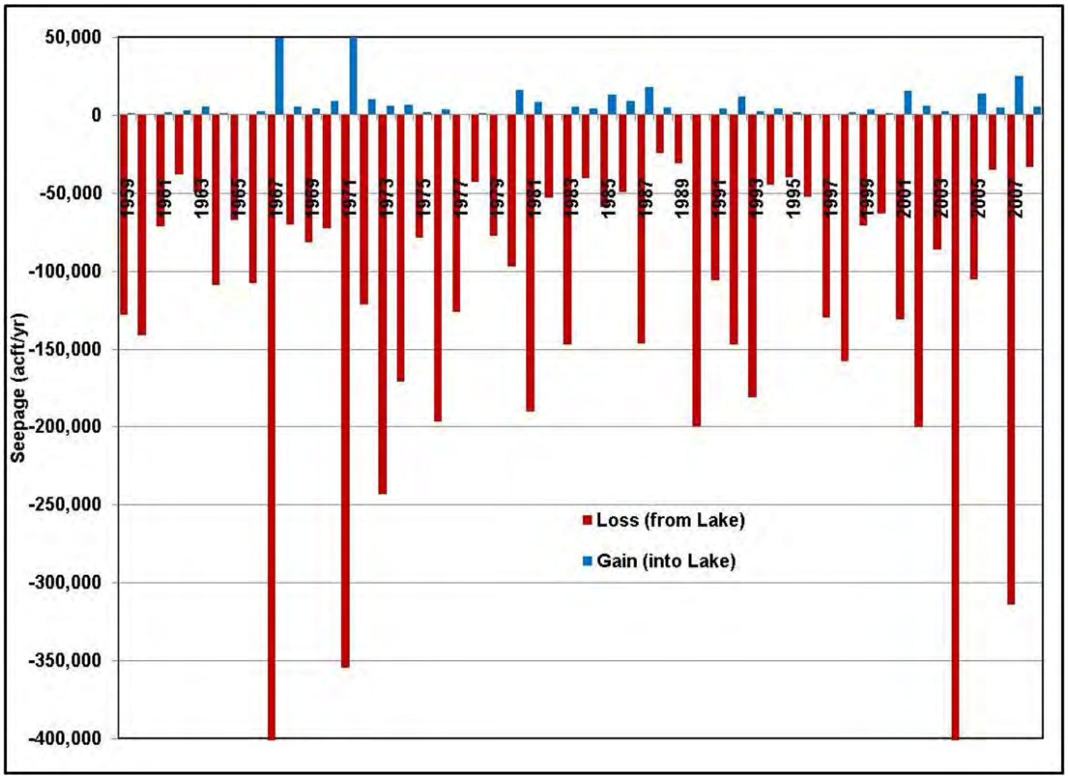

Figure 4C.3-9. Seepage Into and Out of Lake

A detailed chart that illustrates the seepage and lake stage is provided in Figure 4C.3-10. As shown, there is considerable ‘noise’ in the seepage calculation, which is attributed to the accuracy of the records, especially streamflow during high flow conditions, precipitation, evaporation, lake’s stage record as being representative the lake volume during flooding conditions, and the method used to estimate intervening runoff. Included on this chart is a curve that is intended to represent a smoothed and more realistic pattern of the seepage. It is the median value of 12-month period. A median statistic was selected to omit outliers.

A study of Figure 4C.3-10 suggests that 50 % of the time the seepage tends to be between 15 and 115 cfs (900 to 5,600 acft/yr) out of the lake. A trendline suggests slightly increasing trend in seepage out of the lake (about 0.4 cfs (300 acft/yr) over the 50 year period).

There is also an interest in estimating the seepage during several lake conditions, including low conditions (stage less than 90 ft-msl), high conditions (stage greater than 90 ft-msl), falling stage over extended periods and rising stage over extended periods.

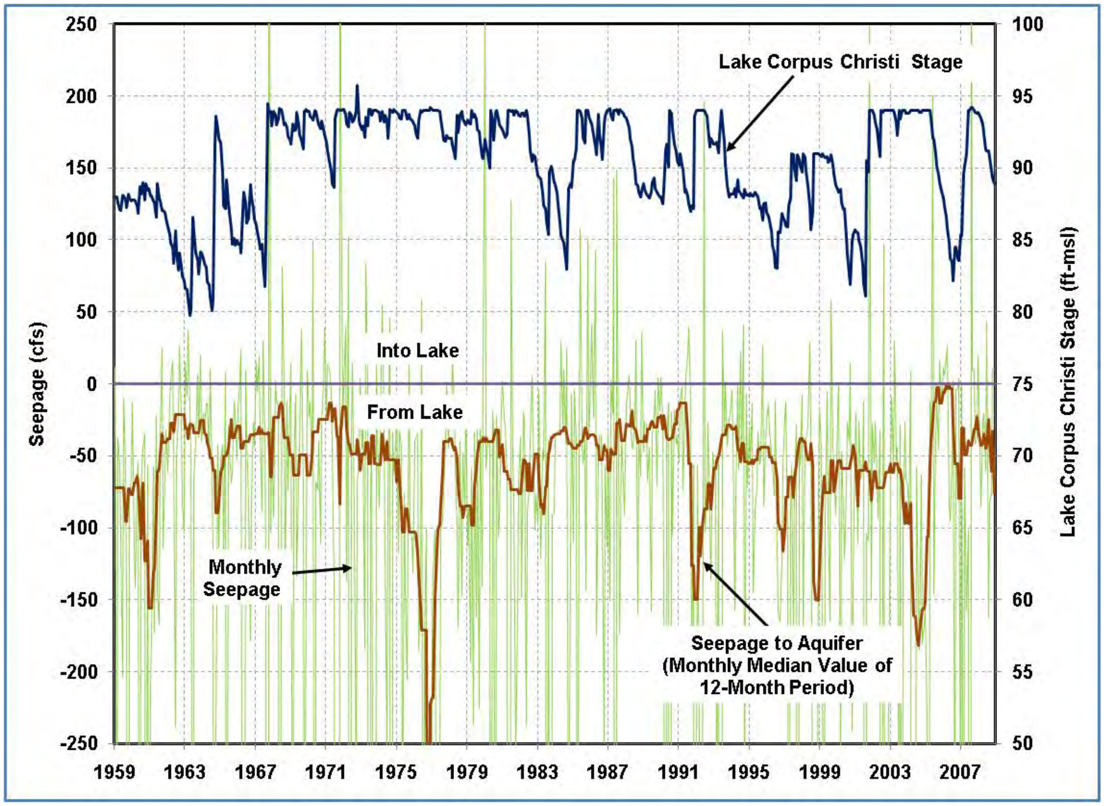

Figure 4C.3-10. Seepage and Lake Stages

Table 4C.3-2 provides a summary of these results for the smoothed seepage values. These results suggest that the lowest seepage rate occurs when the lake stage is in a prolonged decline. The greatest seepage rate occurs at high stages. Seepage during rising stage conditions is slightly greater than low seepage rates. These results support the conceptual understanding that: (1) higher lake stages increases the hydraulic gradient between the lake and the aquifer, which would cause higher seepage rates, (2) higher seepage rates during a rising stage are greater than during a falling stage because of filling and emptying of pore space as well as flow into the aquifer and (3) seepage rates during low conditions are relatively small because of a lower hydraulic gradient between the lake and the aquifer. The overall average seepage is closer to the seepage during high conditions than low conditions because the lake's stage is much longer for high conditions than low conditions.

A USGS study[4] for the period since filling of the lake (1958 thru 1965 estimated an average seepage loss of about 62,000 acft/yr, or 86 cfs. These higher losses than the ones calculated from this study may be partly attributed to the initial filling of the lake.

Table 4C.3-2.
Estimated Seepage from Lake Corpus Christi for Various Lake Conditions

Lake Condition	Seepage Rate from Lake, Smoothed Graph (acft/yr)	
	Average	Median
Low (Stage lower than 90 ft-msl)	35,200	30,200
High (Stage higher than 90 ft-msl)	44,900	35,800
Falling (Stage Declining over Extended Period)	31,800	29,100
Rising (Stage Rising over Extended Period)	36,700	30,900
All	41,100	35,200

4C.3.3.2.1.2 *Hydrogeology*

LCC is formed in the Nueces River valley and is underlain almost entirely by the Goliad Sand, which is the main water-bearing zone of the Evangeline Aquifer. Figure 4C.3-11 is a generalized map of the surface geology in the study area. In the vicinity of the lake, these formations dip toward the Gulf of Mexico about 40-50 ft per mile. Thus, as one moves toward the coast the Evangeline Aquifer becomes deeper and deeper and is eventually overlain by younger sediments, which become thicker and thicker toward the coast. The geologic units and a general description of the lithology are listed in Table 4C.3-3.

Table 4C.3-3.
Stratigraphic Units and Lithology of Gulf Coast Sediments
(Units are from Youngest to Oldest)

Stratigraphic Unit	Lithology
Alluvium and Terrace Deposits	Clay, silt, sand and gravel
Beaumont Clay	Clay interbedded with sand
Lissie	Clay, sandy clay, sand, and gravel
Goliad Sand	Sand or sandstone interbedded with clay and gravel
Fleming and Oakville	Clay and sandstone
Catahoula	Clay, mudstone and sandstone
Jackson Group	Clay, shale and sandstone

[4] Gilbert, C.R., 1975, Water-Loss studies of Lake Corpus Christi Nueces River Basin, Texas, 1949-1965: Texas Water Development Board Report 104.

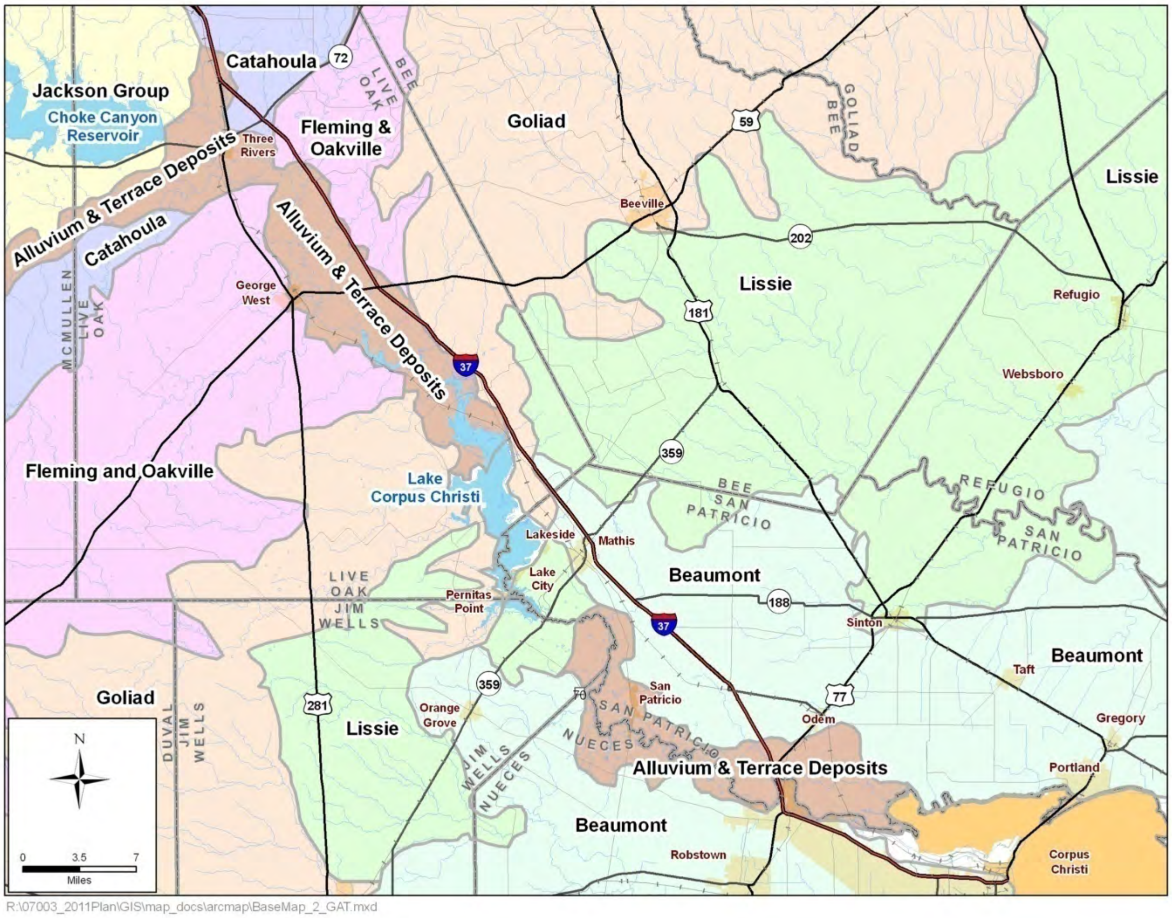

Figure 4C.3-11. Generalized Land Surface Geology

The hydraulic potential for the movement of water between LCC and the Evangeline Aquifer is assessed by studying maps of the outcrop of the Goliad Sand and mapping groundwater levels of the Evangeline Aquifer in the vicinity of the lake. The approach in mapping the general direction of groundwater movement as they relate to LCC was to plot the water levels of Evangeline wells for a period prior to the enlargement of the lake and a relatively recent period. These data are intended to show the groundwater conditions before and after the lake was enlarged. Figure 4C.3-12 is a posting of water level data collected at wells screened in the Evangeline Aquifer that were collected thru 1958. If multiple data values were available, the most recent one was selected. As expected, the data show considerable scatter and irregularities

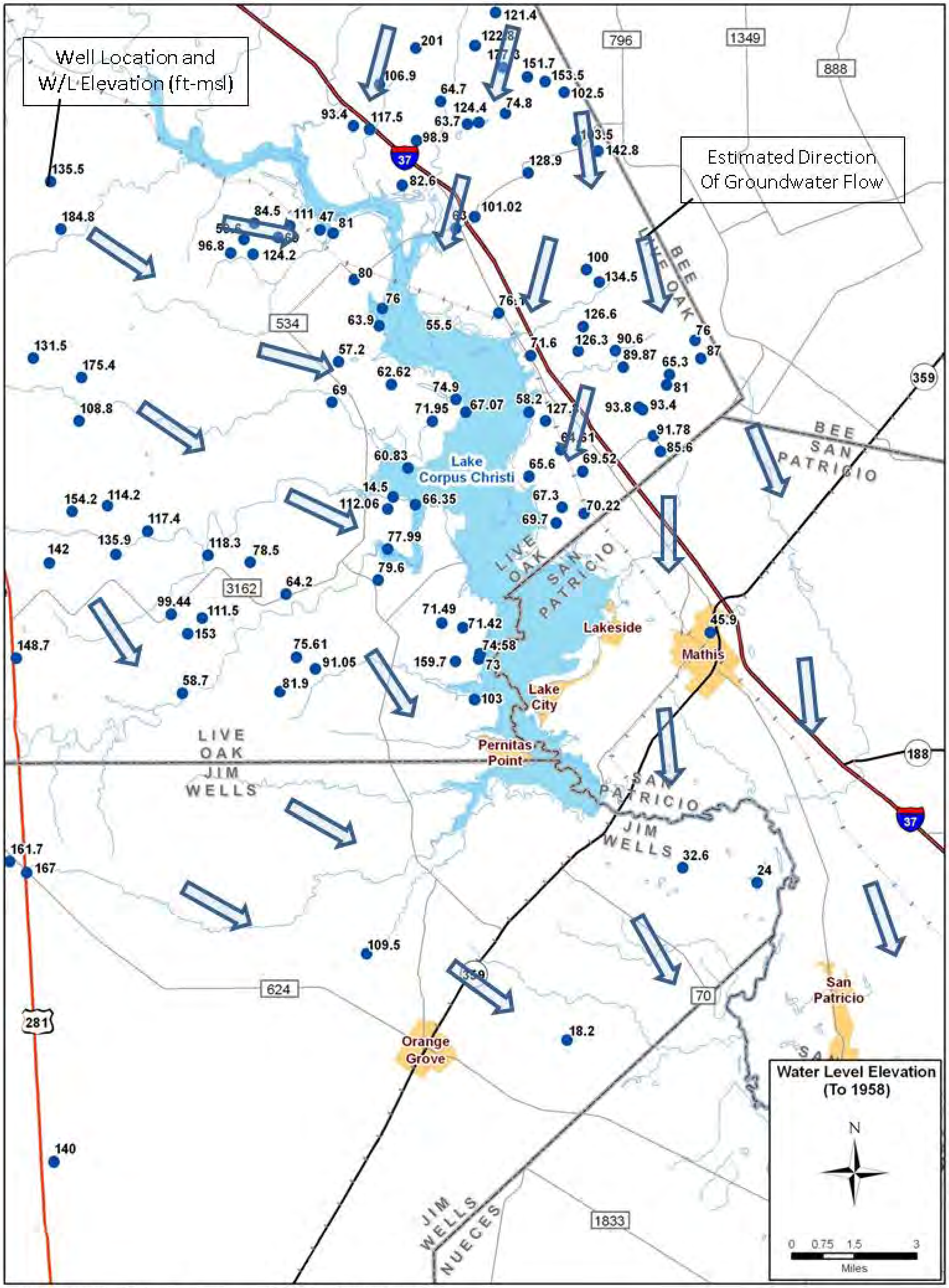

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Figure 4C.3-12. Groundwater Levels in the Evangeline Aquifer Prior to 1958 with Generalized Groundwater Flow Patterns

in some local areas, which is attributed to data collected over a long period of time and wells with widely varying depths and construction. A mapping of the generalized groundwater flow pattern, as illustrated in Figure 4C.3-12, is generally toward the Nueces River and the coast. Figure 4C.3-13 is a posting of water level data collected at wells screened in the Evangeline Aquifer collected after 1970. If multiple data values were available, the earliest one was selected. As with the other water level map, the data also show considerable scatter and irregularities in some local areas. For a lake stage of about 90 ft, a mapping of the generalized groundwater flow pattern, as illustrated in Figure 4C.3-13, is generally away from the lake and toward the coast. A line is shown on the map to generally indicate a divide along the lake that separates the gaining and losing sections for average lake conditions, which is considered to be 90 ft-msl. The flow pattern is generally in a southeast direction towards the coast. The data suggest that the seepage fans out over a large area rather than largely being returned to the Nueces River downstream of the lake. Inspection of the generalized land surface geology map (Figure 4C.3-11) shows the Beaumont Clay occurs along or underneath the lower Nueces River valley. This formation is above the Goliad Sands (Evangeline Aquifer) and below the alluvium and appears to greatly retard the migration of water from the Evangeline Aquifer to the Nueces River downstream of the lake. Of great significance, this map suggests that water from the lake does not generally go into bank storage during a rise in the stage for return to the lake during a lowering of the lake's stage. The concept of bank storage applies in many cases where a stream is incised in an alluvial fill valley. However, this concept does not appear to be applicable for LCC, which is supported by the seepage analysis in the previous section.

To better understand the impact of the filling of LCC and the periodic lowering and rising of the lake stage on groundwater levels, water level hydrographs were drawn for several wells in the surrounding area (Figure 4C.3-14). All of these water level hydrographs except for the well 7933501, which is about 10 miles west of Beeville and 15 miles north of the lake and considered to be upgradient of the lake, show some rise in water levels since 1958. In many of the wells, the water levels have risen 25-40 ft from about 1958 to the mid-1980s. Some of the rise, especially at the well 7958201 at Mathis, probably is attributed to a reduction in groundwater pumping. The rise in groundwater levels in the upper watershed areas suggest a partial hydrologic blockage of groundwater flow by the lake's relatively high water level, which has caused the historic flow

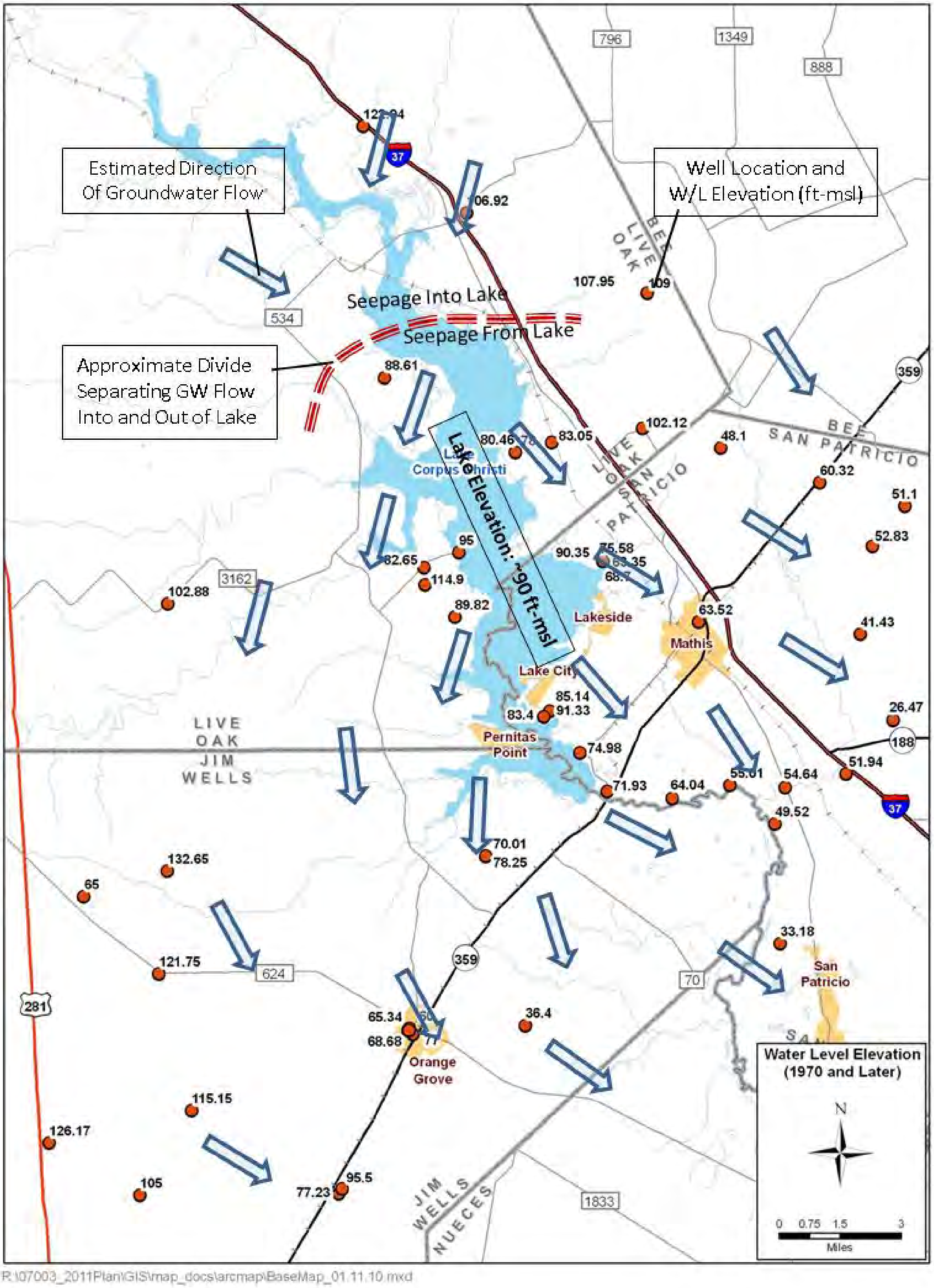

Figure 4C.3-13. Groundwater Levels in the Evangeline Aquifer Since 1970 with Generalized Groundwater Flow Patterns

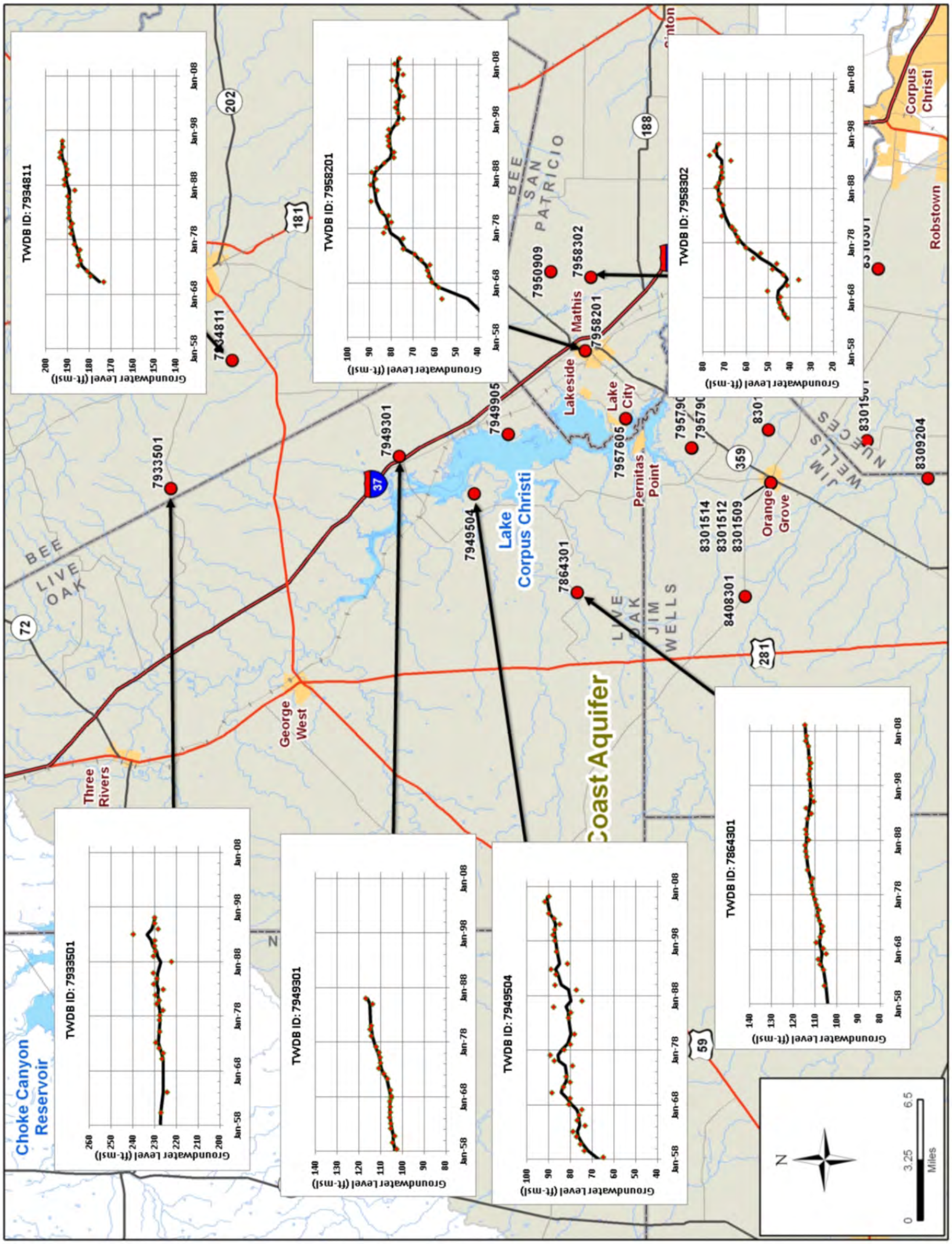

Figure 4C.3-14. Groundwater Hydrographs for Selected Wells

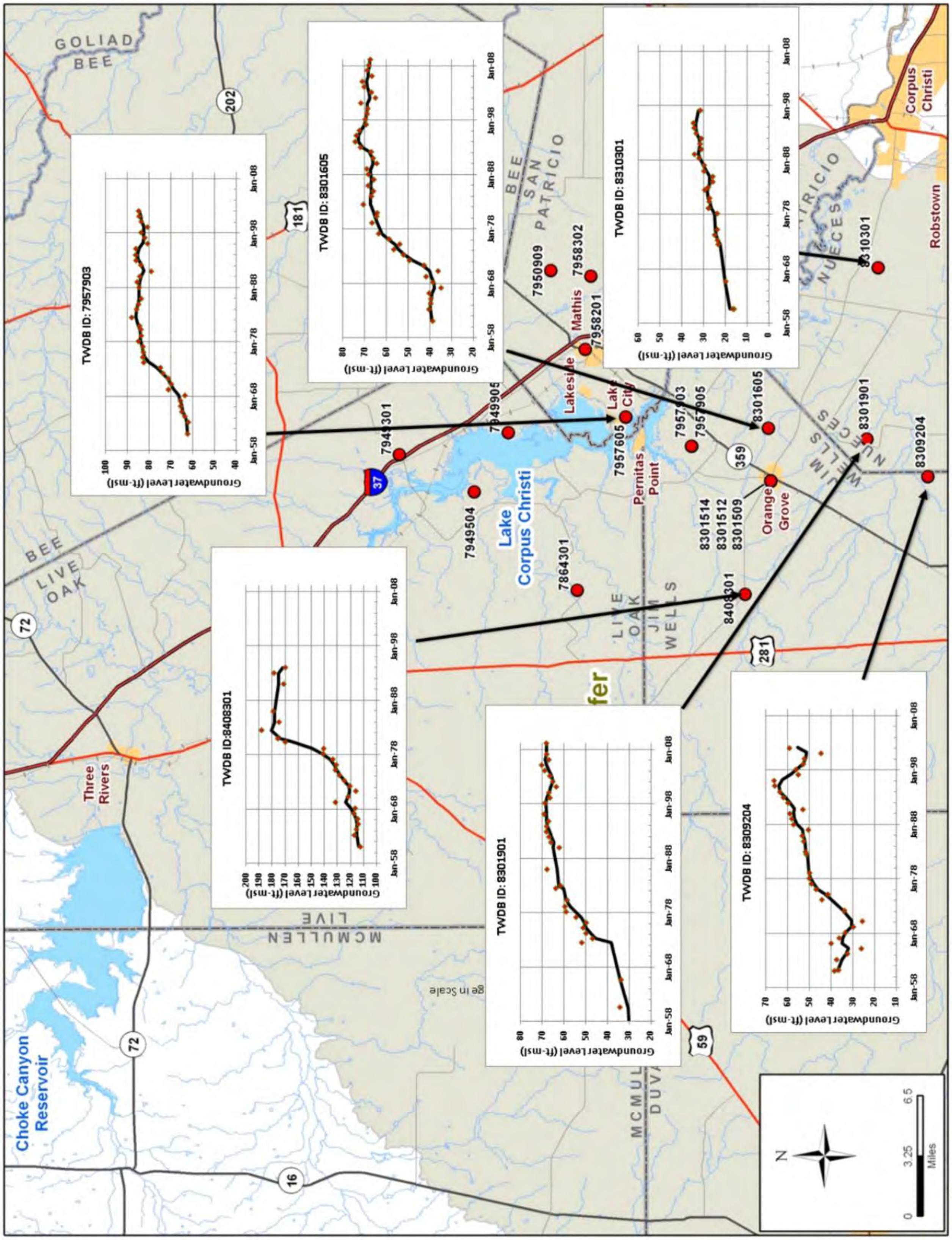

Figure 4C.3-14. Groundwater Hydrographs for Selected Wells (Concluded) pattern to be diverted toward the coast instead of toward the Nueces River where the lake now exists. It's of interest that wells (8408301, 8301605, 8301901, and 8309204, which are 10-20 miles south of the lake, show a strong recovery that appears to be attributed to the filling of LCC. The influences of other factors, such as increases in recharge and reduction in historic pumpage, are not known. Thus, one can't conclusively attribute the rise of these water levels to the filling of LCC.

4C.3.3.2.2 Streamflow Gains and Losses in the Nueces River downstream of Lake Corpus Christi

A study of the steamflow gains and losses was conducted between the USGS gages 08211000 Nueces River near Mathis and 08211200 Nueces River at Bluntzer and between the Bluntzer station and 08211500 Nueces River at Calallen (Figure 4C.3-3). A summary of streamflow and water quality data compiled during this study is presented in Table 4C.3-4. Water supply intakes are located in the Calallen Pool area, just upstream of the 08211500 Nueces River at Calallen gage as shown in Figure 4C.3-15. Although continuous water quality data from the Calallen Pool was provided from December 2003 to June 2009, daily water supply diversion data was provided for the period from January 2005 to July 2009. Suitable data for analysis for the upper subreach was from June 1992 through July 2009. For the lower subreach, the period was from January 2005 through July 2009. For this analysis, water supply diversions from the Calallen Pool were added to the USGS gaged record at the Calallen station. Other diversions, return flows and tributary inflows are assumed to be small and are not account for in the analysis.

The approach in calculating the streamflow gains and losses included: (1) advancing the flow record at the downstream station by one day to better match the timing of changes in streamflow between the two stations, (2) subtracting the upstream station's discharge from the downstream station's discharge (a positive values is a gain to the stream and a negative value is a loss from the stream), (3) filtering the outliers in the gain/loss results by removing the bottom and top ten percent, and (4) preparing a hydrograph of the gain/loss values and a scatter plot of the upstream station's discharge and the gains/losses.

Table 4C.3-4.
Summary of Available, Historical Water Quality Data from Lake Corpus Christi to Calallen

Data Collection Program	Measurement Frequency	Period of Record	Constituents Measured							Comments
			Flow	Cond.	Turbidity	Ca	Cl-	Hardness	Others	
City of Corpus Christi										
O.N. Stevens Intake	Monthly	1/1998- 10/2006; 8/2008- 3/2009		✓	✓	✓	✓	✓	✓	Fluoride & others
La Fruta to Calallen Dam (11 locations)	Bi-weekly	1/1995- 4/2007					✓		✓	Rainfall, DO
Lake Texana	Monthly	1/1999- 3/2009		✓	✓	✓	✓	✓	✓	
San Patricio Municipal Water District	Generally Bi-monthly; Weekly from 1/2007-3/2009	1/2001- 3/2009		✓		✓	✓	✓		Magnesium & others. Limited data in 2003-2005.
Celanese- Bishop Facility	Weekly	1/2006- 12/2008		✓	✓	✓	✓		✓	pH
Flint Hills Resources	Daily	12/2003- 6/2009		✓	✓			✓	✓	Alkalinity
TCEQ/ NRA Clean Rivers Program (Lower Nueces Basin)										
Nueces River at La Fruta Bridge (12965)	Quarterly	9/1977-Current		✓	✓		✓	✓	✓	
Nueces River at Bluntzer Bridge (12964)	Quarterly	9/1977-Current		✓	✓		✓	✓	✓	
Nueces River at Corpus Christi WTP (12963)	Quarterly	5/1977-12/1992		✓	✓		✓	✓	✓	
USGS/ City of Corpus Christi Gages (Lower Nueces Basin)										
Nueces River nr Mathis (8211000)	Real-time	9/1938- Current	✓							
Nueces River at Bluntzer (8211200)	Real-time	1/1966- Current (flow) 11/2008-Current (WQ)	✓	✓					✓	temp, pH, DO
Nueces River bl Hazel Bazemore Pk (08211450)	Real-time	11/2008- Current		✓					✓	temp, pH, DO
Nueces River at Calallen (8211500)	Real-time	10/1989- Current	✓							

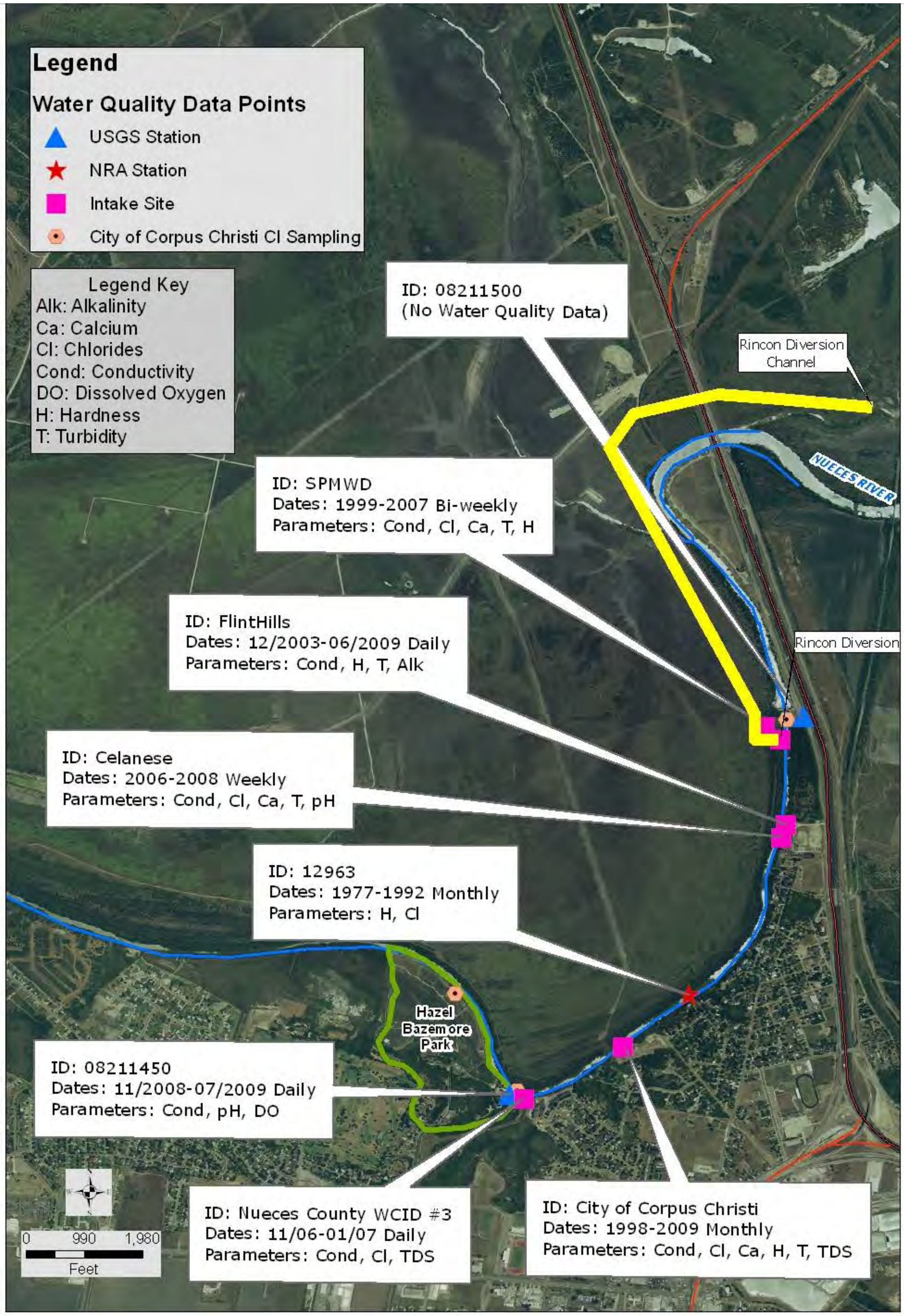

Figure 4C.3-15. Water Quality Locations near Calallen Pool

4C.3.3.2.2.1 Subreach from Mathis to Bluntzer

Hydrographs illustrating results of the streamflow gains and losses analysis are presented in Figure 4C.3-16. Overall, the chart shows the reach is occasionally gaining as much of 55 cfs and losing as much as 15 cfs. A statistical trendline analysis did not indicate any time trends during this period. A frequency distribution shows the subreach is gaining water slightly less than 80 percent of the time, with median gains of about 10 cfs. The average of the daily gains and losses show the average about a 11 cfs gain.

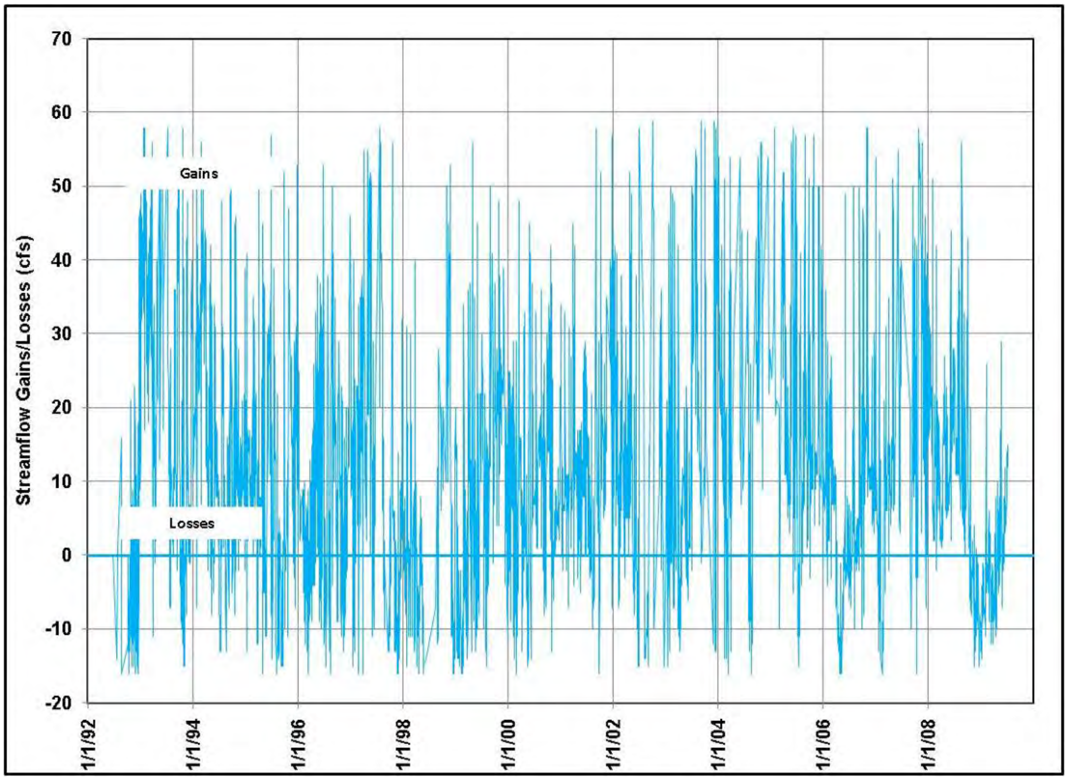

Figure 4C.3-16. Streamflow Gains/Losses along Nueces River: Mathis to Bluntzer

A scatter plot of the daily gain/loss results and the daily streamflow at the Mathis gage is presented in Figure 4C.3-17. From the major cluster of points, the chart indicates a greater gain at lower flows, and losses tending to occur at higher flows. This is conceptually consistent with the stream having a baseflow component during low flows (stream stage is low) and discharging water to the alluvial when the streamflows are high (stream stage is high).

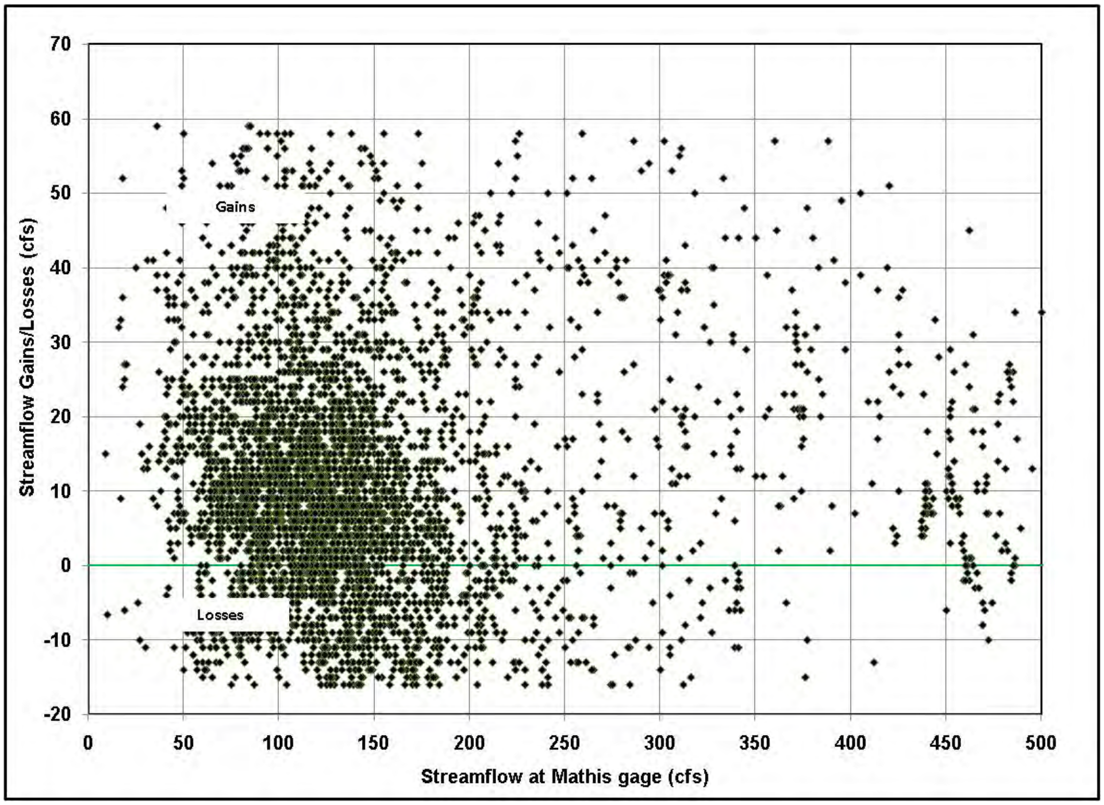

Figure 4C.3-17. Correlation of Streamflow Gains/Losses along Nueces River between Mathis and Bluntzer with Streamflow at Mathis

4C.3.3.2.2.2 *<u>Subreach from Bluntzer to Calallen</u>*

Hydrographs illustrating results of the streamflow gains and losses analysis for the subreach between Bluntzer and Calallen are presented in Figure 4C.3-18. Overall, the chart shows the reach is occasionally gaining as much of 40 cfs and losing as much as 75 cfs. A statistical trendline analysis indicated a slight trend of decreasing losses, however, results in 2009 suggest otherwise. This is a very short period for a trend analysis and probably is indicative of short-term rather than long-term hydrologic conditions. A frequency distribution shows the reach is losing water about 60 percent of the time, with the median being about a 5 cfs loss. The average of the gains and losses show the average to be about a 10 cfs loss.

A scatter plot showing the correlation of the daily gain/loss results and the daily streamflow at the Bluntzer gage is presented in Figure 4C.3-19. From the major cluster of points, the chart indicates a noticeable gain at lower flows and losses at higher flows. Again, this is

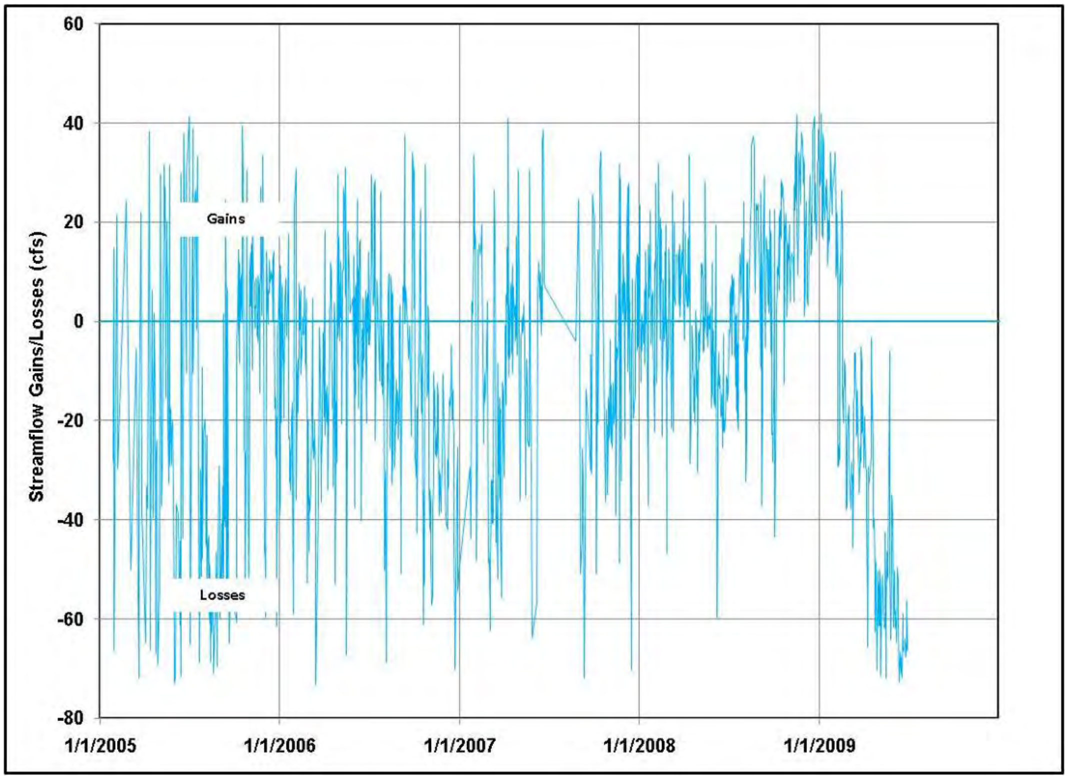

Figure 4C.3-18. Streamflow Gains/Losses along Nueces River: Bluntzer to Calallen

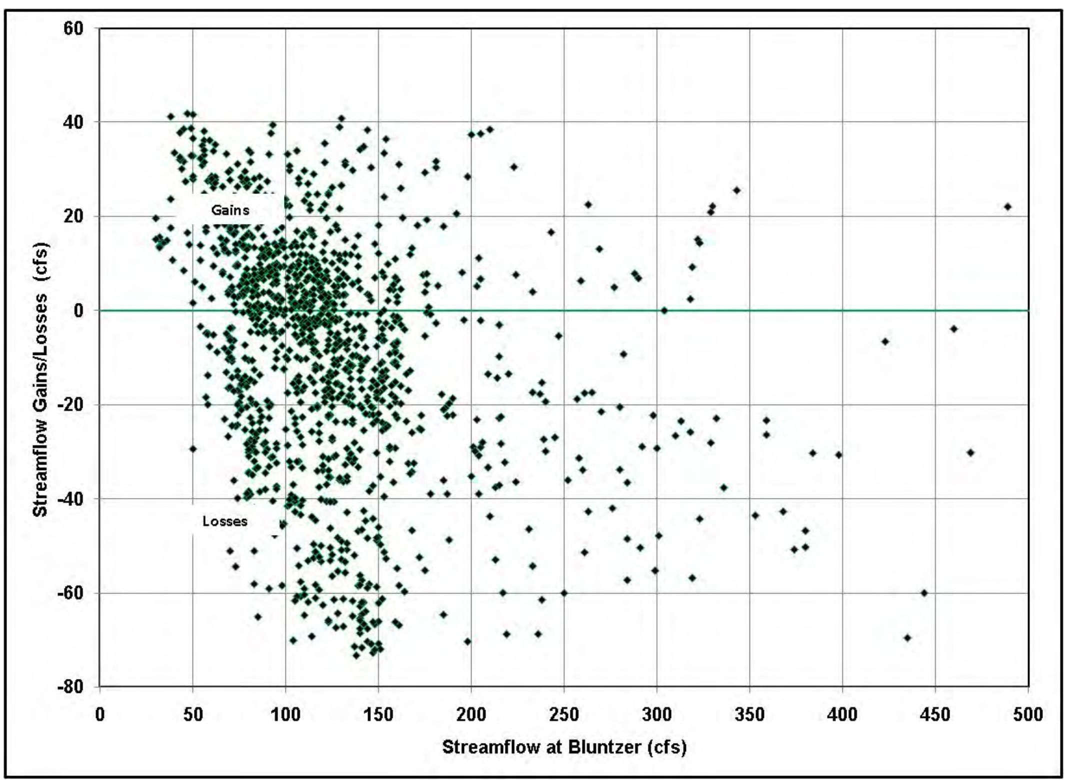

Figure 4C.3-19. Correlation of Streamflow Gains/Losses along Nueces River between Bluntzer and Calallen with Streamflow at Bluntzer

conceptually consistent with the stream having a baseflow component during low flows (stream stage is low) and discharging water to the alluvial when the streamflows are high (stream stage is high). The greater losses in this reach than in the Mathis to Bluntzer reach may be partly attributed to Calallen Dam, which causes the stage of the Nueces River in the lower reach to be higher than native conditions. The cluster of points indicates stream gains tend to be about 30 cfs when the streamflow at Bluntzer is about 60 cfs. Thus, a substantial portion of the streamflow at Calallen is from the alluvium during low flow conditions.

Caution is warranted in considering the reliability and accuracy of this findings. USGS rates the accuracy of the stream discharge at Calallen to be 'poor' and records at Bluntzer as being 'good'. For this analysis, the multiple diversions from the Calallen Pool are added to the discharge at the Calallen station. This amplifies the question of overall accuracy of the streamflow data used in this analysis. The overall results are believed to be suitable for generalized analyses; however, individual values and conditions are questionable.

4C.3.3.3 Hydrologic Influences on Water Quality

A major use of the water from LCC and the Lower Nueces River is for municipal and industrial purposes. As a result, there is a great interest in not only having a sufficient supply during all times but to have water quality meet drinking water standards and be consistent over time. One of the long-term issues with water from the Calallen Pool is variable water quality, especially with regard to salinity (chloride concentrations) during the summer and periods of drought.

For LCC, the hydrologic influences on water quality are studied with regard to the inflow from the Nueces River and surface water/groundwater interaction. Other potential significant influences are stratification of the lake, especially in the deep section near the dam, and evaporation.

For the Nueces River downstream of LCC, the influences are a study of increasing and decreasing salinity between streamflow gaging stations. For purposes of this study, chloride concentrations are considered to be an index to other water quality parameters such as total dissolved solids.

4C.3.3.3.1 Hydrologic Influences on Lake Corpus Christi

4C.3.3.3.1.1 Inflow from the Nueces River

The approach used to study the influences of the Nueces River on the water quality in LCC is to prepare charts showing streamflow and chloride concentrations at the USGS Nueces River near Three River station (Figure 4C.3-20) over time. A study of the chloride data shows a major decrease in chloride concentrations in about 1988, which coincided with the filling of Choke Canyon Reservoir. An inspection of the Nueces River near Three Rivers hydrograph seems to suggest a reduction in the streamflow; however, a cumulative flow analysis did not indicate a noticeable shift in the long-term trends. A study of the correlation between chloride concentration and streamflow for the periods before the filling of Choke Canyon Reservoir showed a very large percentage of the high chloride concentrations occurred during low flow conditions (about 100 cfs), sometimes ranging up to over 800 mg/L. Overall, the average chloride concentration for all the samples between 1968 and 1987 was about 265 mg/L. Since the filling of the lake, the chloride concentrations during the low flow conditions were much lower and seldom greater than 200 mg/L, and having an average of about 65 mg/L for all samples.

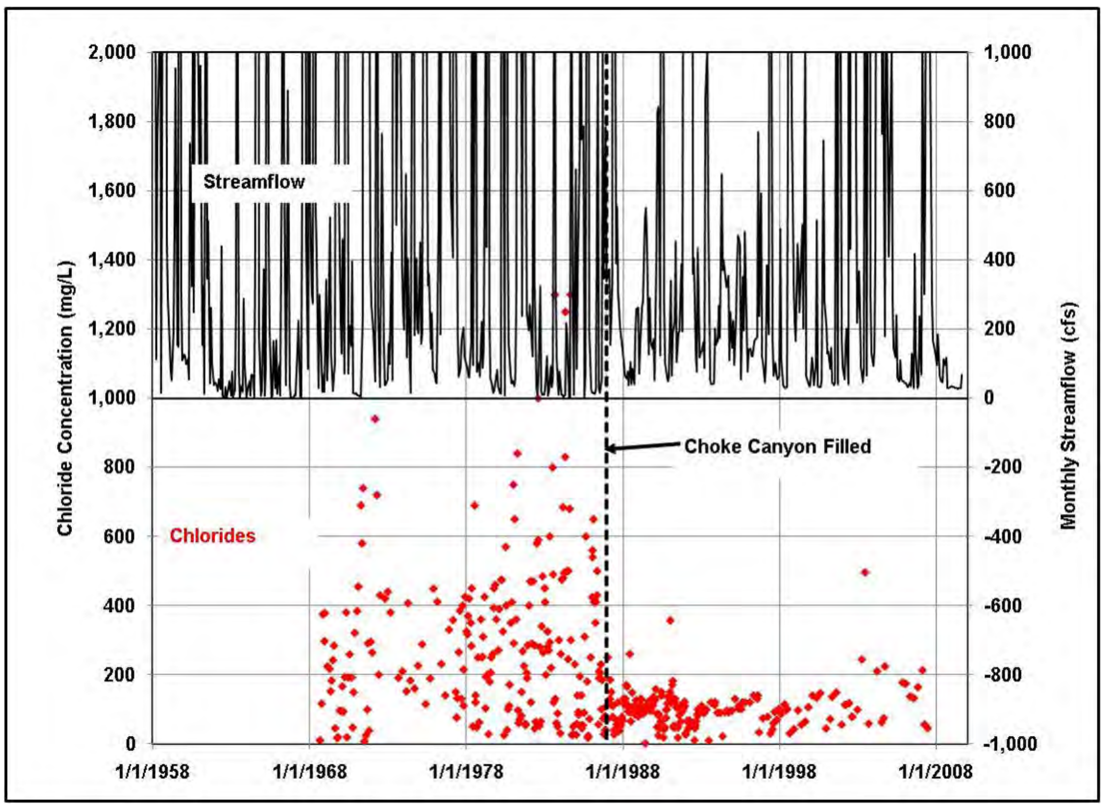

Figure 4C.3-20. Streamflow and Chloride Concentrations at Nueces River near Three Rivers Station

During this time period, chloride and stage data from LCC were compiled and plotted in a manner similar to the Nueces River near Three River gage (Figure 4C.3-21). It's important to note that the chloride data used in this study was from samples that were collected at a TCEQ and Nueces River Authority sampling site near mid-dam (Station 12967).[5] This chart shows a tendency for chloride concentrations to be higher prior to the filling of Canyon Creek Reservoir than afterward, except for the 2005-2007 drought. This is mostly attributed to (1) most all the inflow to Choke Canyon Lake is with flood waters having a very low chloride concentration (2) most all the samples prior to filling the lake were low to medium flow conditions. As a result, the samples from the Nueces River-Three Rivers station is mostly a blending of all flows, instead of the low and medium flows. Overall, these data and analyses show a pattern of gradually increasing chlorides during declining and low lake stages, and an abrupt lowering when the lake rapidly fills.

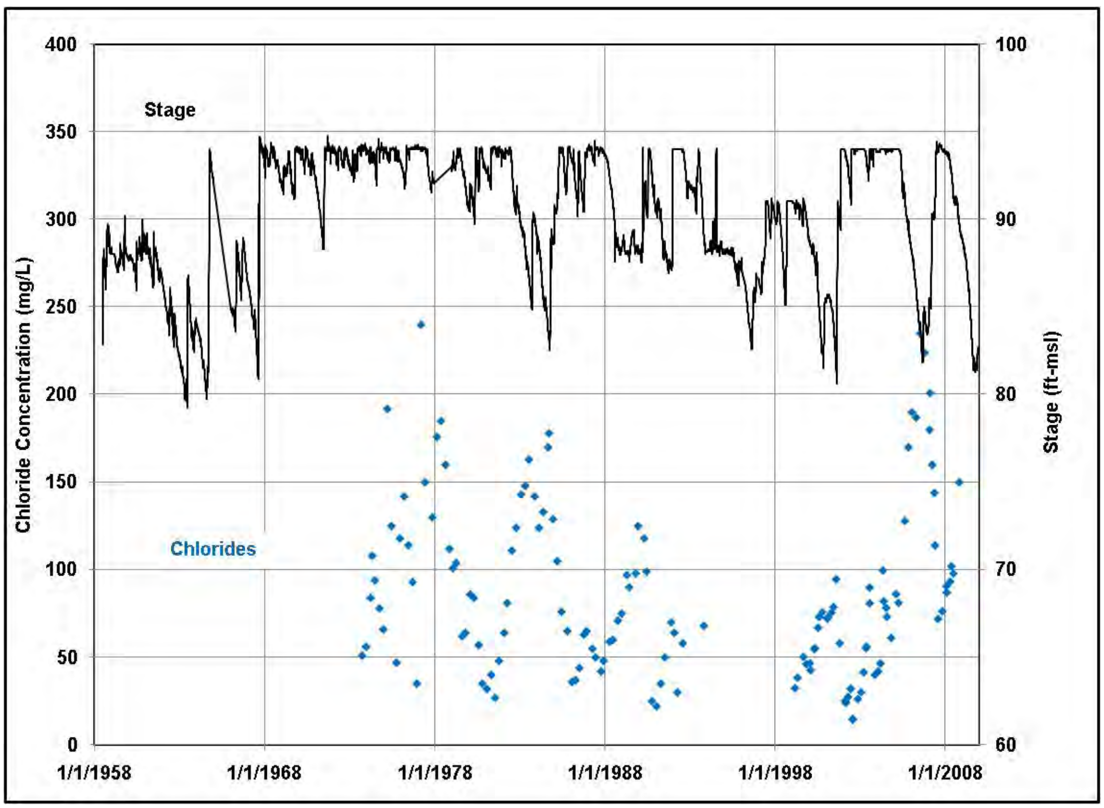

Figure 4C.3-21. Lake Corpus Christi Stage and Chloride Concentrations near Water Surface at a Sampling Site near Dam

[5] Most of the water data is representative of water within the top 10 feet of LCC water level.

A comparison of the chloride concentrations and temporal patterns at the two sampling stations (Nueces River near Three Rivers Gage and TCEQ/NRA LCC near mid-dam station) is shown in Figure 4C.3-22. These data show and as stated earlier, especially since the filling of Choke Canyon Reservoir, that the chloride concentrations in LCC tend to follow the chloride concentrations at the Three Rivers station. This is especially noticeable during the droughts when the chloride concentrations are rising at both sampling stations and following flood conditions when the chloride concentrations are abruptly reduced. These chloride data suggest that the chlorides in the lake stay at or below the concentrations at the Three Rivers station.

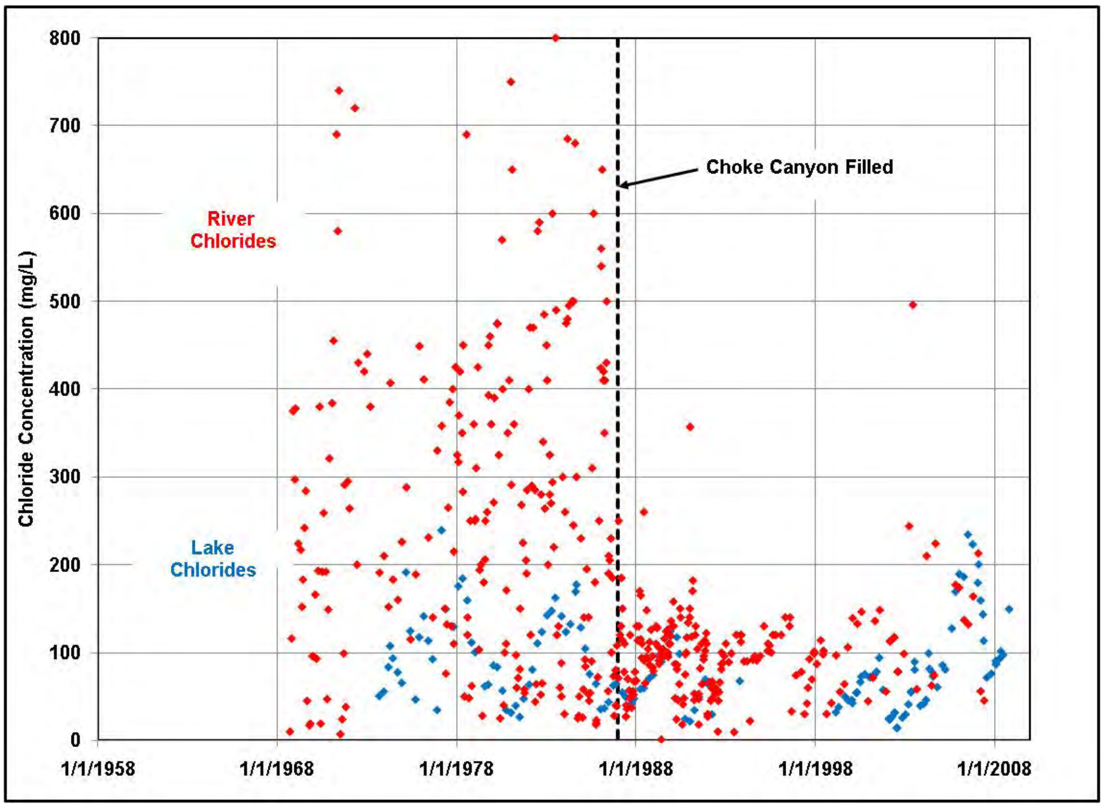

Figure 4C.3-22. Chloride Concentrations at Nueces River: Three Rivers and Lake Corpus Christi

A comparison of chloride concentrations at TCEQ/NRA LCC mid-dam station and USGS Station 08211000 Nueces River at Mathis gage for water quality data collected from 1996 to 2006 shows an increase of chlorides for released water from LCC. As shown in Figure 4C.3-23 based on water quality data from 1996 to 2006, the median chloride levels at USGS Nueces River at Mathis Gage 08211000 during the period was 76 mg/L as compared to median chloride levels of 55 mg/L at the TCEQ/NRA Lake Corpus Christi station near the dam (or 40% increase). This is likely due to stratification of water in LCC, described in further detail in Section 4C.3.3.4.

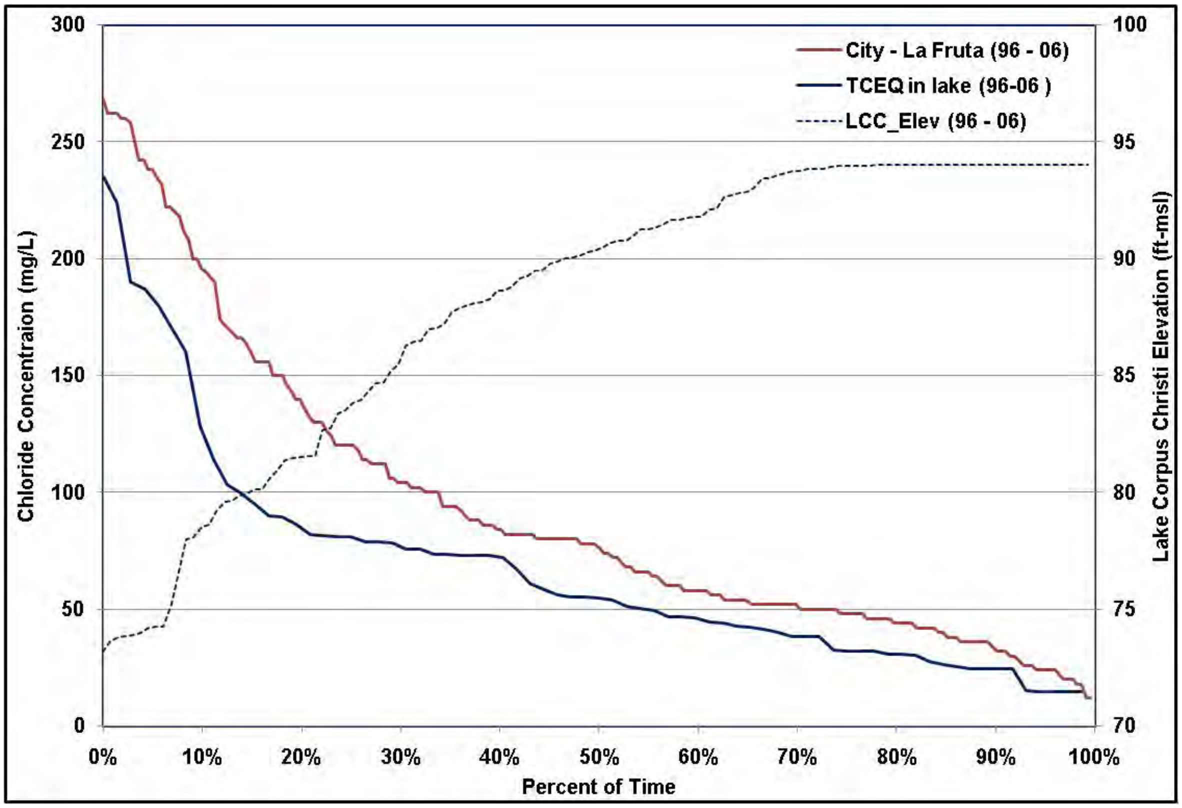

Figure 4C.3-23. Comparison of Chloride Levels in LCC to Lower Nueces River near Mathis Gage Less than ½ Mile Downstream of LCC

4C.3.3.3.1.2 *<u>Groundwater in the Evangeline Aquifer</u>*

A map showing the chloride concentrations of water samples from Evangeline Aquifer wells in the area surrounding LCC is presented in Figure 4C.3-24. In the vicinity of the lake, these data show substantial variations in the water quality. Some of this variation can be attributed to local variations in aquifer characteristics and well depths, and some possibly can be attributed to well construction and leakage from formations with poor quality of water. Overall, the chloride concentrations tend to range between 150 to 300 mg/L. These chloride concentrations are somewhat greater than the typical 25 to 100 mg/L concentrations in the lake since the filling of Choke Canyon Reservoir, except for the 2005-2007 drought. Of great importance, aquifer characteristics and groundwater hydraulics do not appear to be sufficient to cause substantial quantities of groundwater into the lake to substantially change the water quality of LCC.

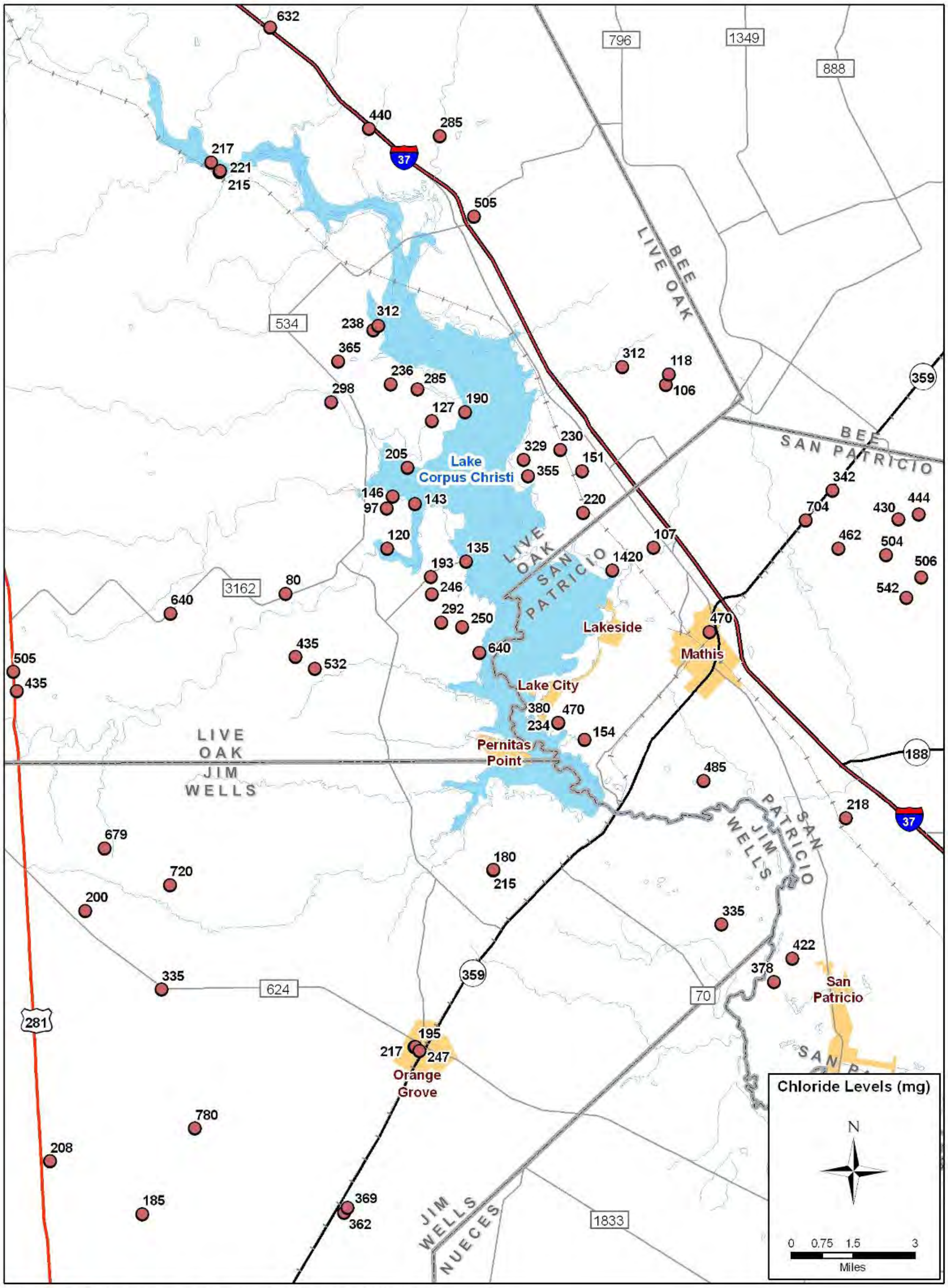

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Figure 4C.3-24. Chloride Concentrations for Evangeline Aquifer Wells

4C.3.3.3.2 Hydrologic Influences in Nueces River downstream of Lake Corpus Christi

The approach used to study the influences contributing to poor water quality water of the Nueces River includes calculating the change in the chloride concentrations for samples collected on the same day (a positive value is a stream gain in chlorides and a negative value is a loss of chlorides from the stream and (1) plotting a timeline of chloride *gains/losses along with the streamflow*, (2) preparing a scatter plot of the correlation of chloride gains/losses against streamflow, (3) plotting a timeline of *chloride gains/losses and streamflow gains/losses*, (4) preparing a scatter plot of the correlation of *chloride gains/losses against streamflow gains/losses*. The scatter plots are particularly useful to attempting to correlate trends in chloride gains/losses with streamflow and streamflow gains/losses.

The data set for the Mathis to Bluntzer and Bluntzer to Calallen Pool reaches are from Jan 1996 to April 2007 and January 2005 to December 2007, respectively, based on readily available water quality data. The USGS Station 08211200 Nueces River at Bluntzer began recording real-time water quality data in November 2008. This analysis uses water sampling data collected by the City of Corpus Christi at Mathis and Bluntzer. Typically, water samples were collected twice a month. The selected sampling site for the Calallen Pool station is Hazel-Bazemore based on data provided by the City of Corpus Christi.

4C.3.3.3.2.1 Subreach from Mathis to Bluntzer

The first analysis considered the relation of *gain/losses of chlorides and streamflow* in the subreach. A timeline of this relation is shown in Figure 4C.3-25. A correlation of the two parameters is shown in Figure 4C.3-26.

The timeline chart indicates a little or no trends over time, however, it does illustrate relatively higher gains in chlorides (greater than 50 mg/L) from 2002-2004. During this period, the streamflow generally appears to be slightly lower than earlier and later periods. Intermediate high flow event during the 2002-2004 period only temporarily lower the gains in chlorides.

The correlation chart shows most of the streamflow is between 50 and 160 cfs and gains in chlorides mostly range from 0 to 100 mg/L. Inspection of the scatter plot suggests that chlorides slightly decreases with higher flow; however, this relationship is weak.

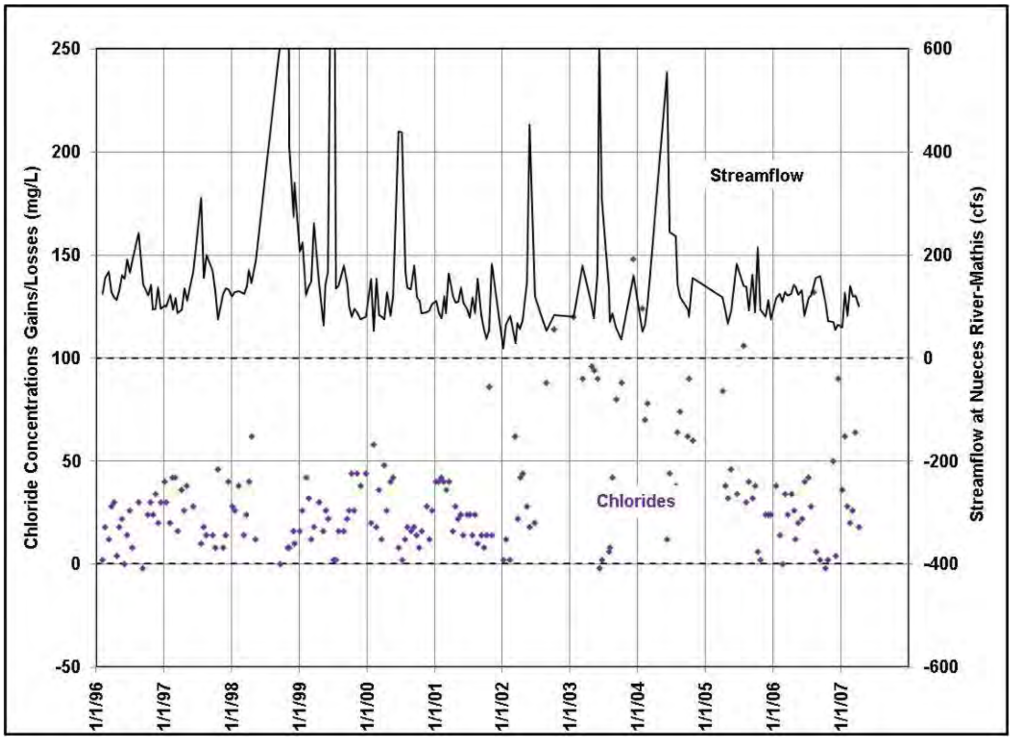


Figure 4C.3-25. Chlorides Gains/Losses and Streamflow along Nueces River: Mathis to Bluntzer

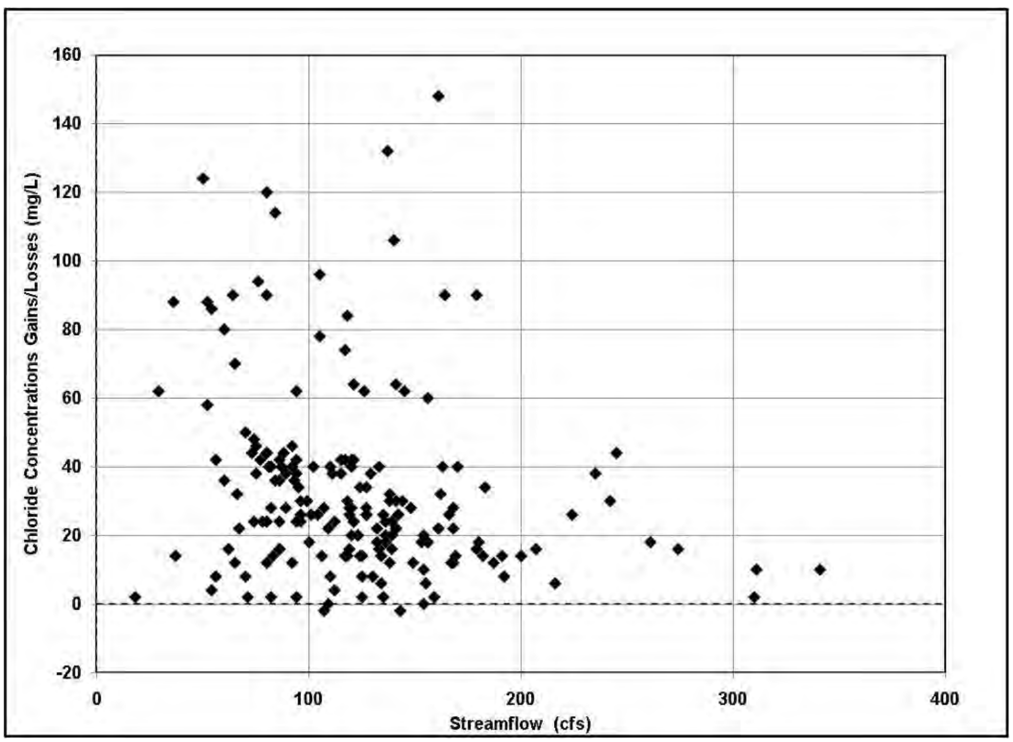


Figure 4C.3-26. Correlation of Gains/Losses of Chlorides and Streamflow along Nueces River: Mathis to Bluntzer

The second analysis considered the relation of *gain/losses of chlorides and streamflow gains/losses* in the reach, which were calculated in a previous section. A timeline of this relation is shown in Figure 4C.3-27. A correlation of the two parameters is shown in Figure 4C.3-28.

As previously noted, the timeline chart of gains/losses of chlorides and gains/losses of streamflow shows an irregular pattern from 2002-2004, when the chloride gains tend to be elevated. During this period, the streamflow gains also seem to be slightly higher than earlier and later periods. Overall from 1996-2007, there does not seem to be a time trend of gaining or losing chlorides or streamflow.

The correlation chart shows most of the streamflow gains/losses from Mathis to Bluntzer tends to range between a 5 cfs loss to a 30 cfs gain and chlorides tend to gain in concentrations up to 50 mg/L. Further study of these results show the stream is gaining about 80 percent of the time. Overall, an inspection of the chart suggests that the gains in chlorides slightly increases with higher streamflow gains; however, the confidence in this relationship is weak. These results support a concept of increasing chlorides in this reach is related to an increase in groundwater inflow into the reach. However, there are some occurrences where there is a gain in chlorides yet the stream is showing a loss of water. A possible explanation is that one subreach is gaining streamflow from groundwater and another subreach is losing streamflow to groundwater at a rate greater than the gains. Another possible explanation is that a tributary is discharging saline water into the river.

4C.3.3.3.2.2 Subreach from Bluntzer to Calallen

The analysis for this reach uses the same approach as the Mathis to Bluntzer reach. The first analysis considered the relation of in the subreach. A timeline of gain/losses of chlorides and streamflow is shown in Figure 4C.3-29. A correlation of the two parameters is shown in Figure 4C.3-30

The timeline chart of *gains/losses of chlorides and of streamflow* shows an irregular pattern of chlorides during the spring and early summer of 2005 and another one in the winter of 2007. During the period of available chloride data, the streamflow at the Bluntzer station was relatively uniform, but included two high flow events in late 2005, which noticeably lowered the gains in chlorides. Overall, the chloride gains/losses are relatively uniform and do not show a time trend for this relatively short period.

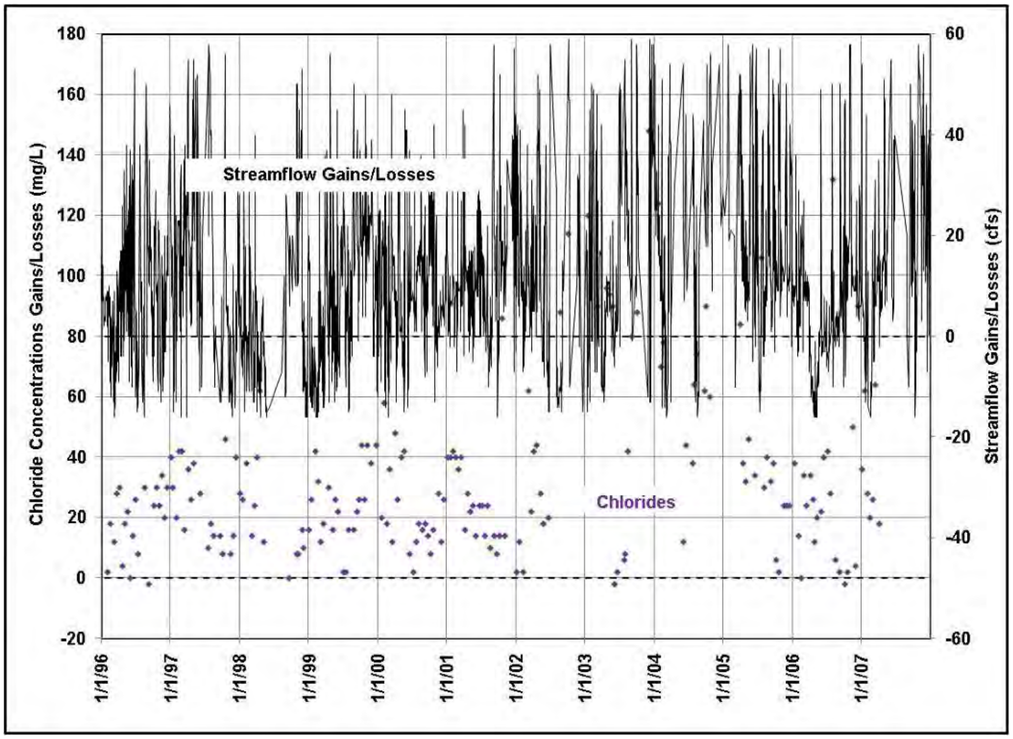


Figure 4C.3-27. Chlorides Gains/Losses and Streamflow Gains/Losses along Nueces River: Mathis to Bluntzer

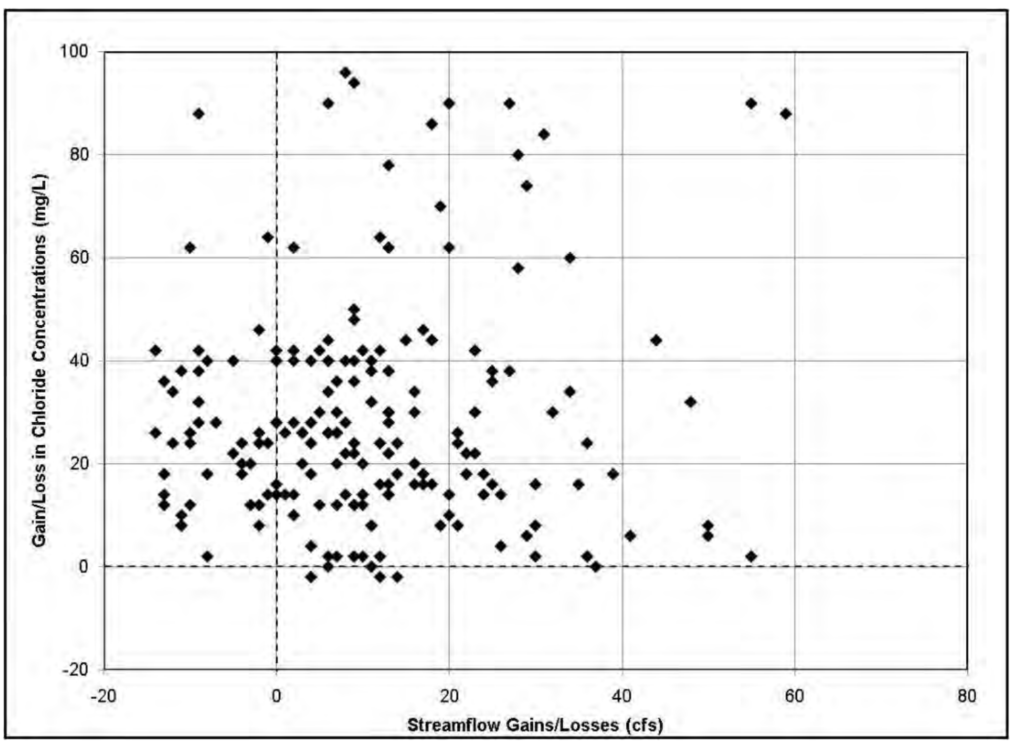


Figure 4C.3-28 Correlation of Chloride Gains/Losses and Streamflow Gains/Losses along Nueces River: Mathis to Bluntzer

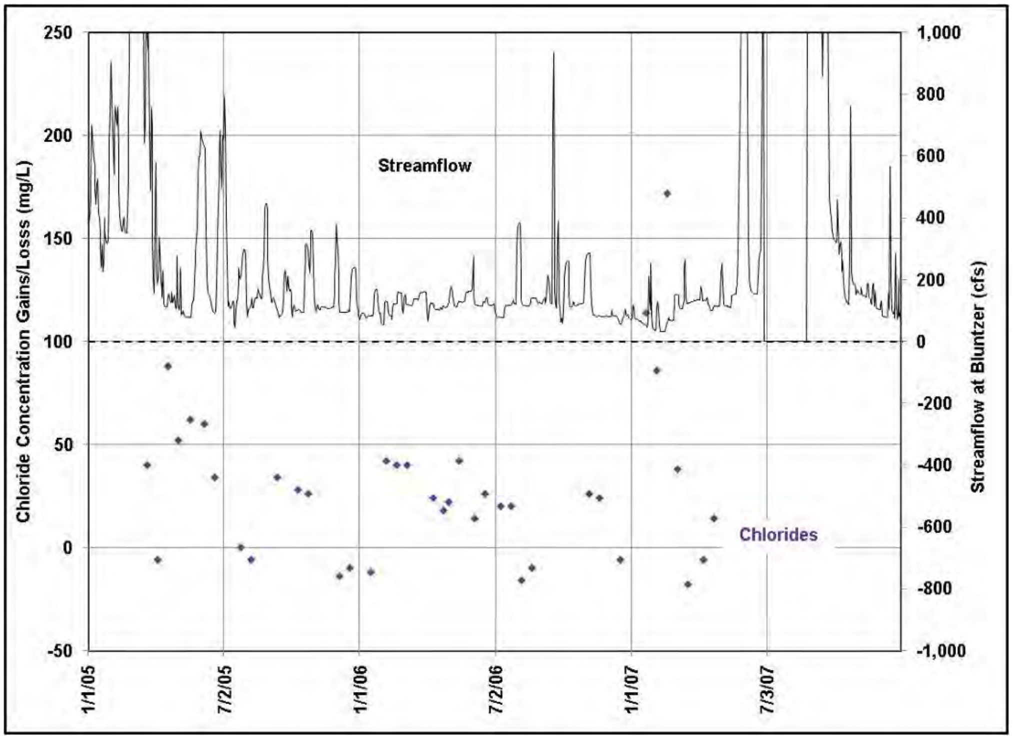


Figure 4C.3-29. Chlorides Gains/Losses and Streamflow along Nueces River: Bluntzer to Calallen

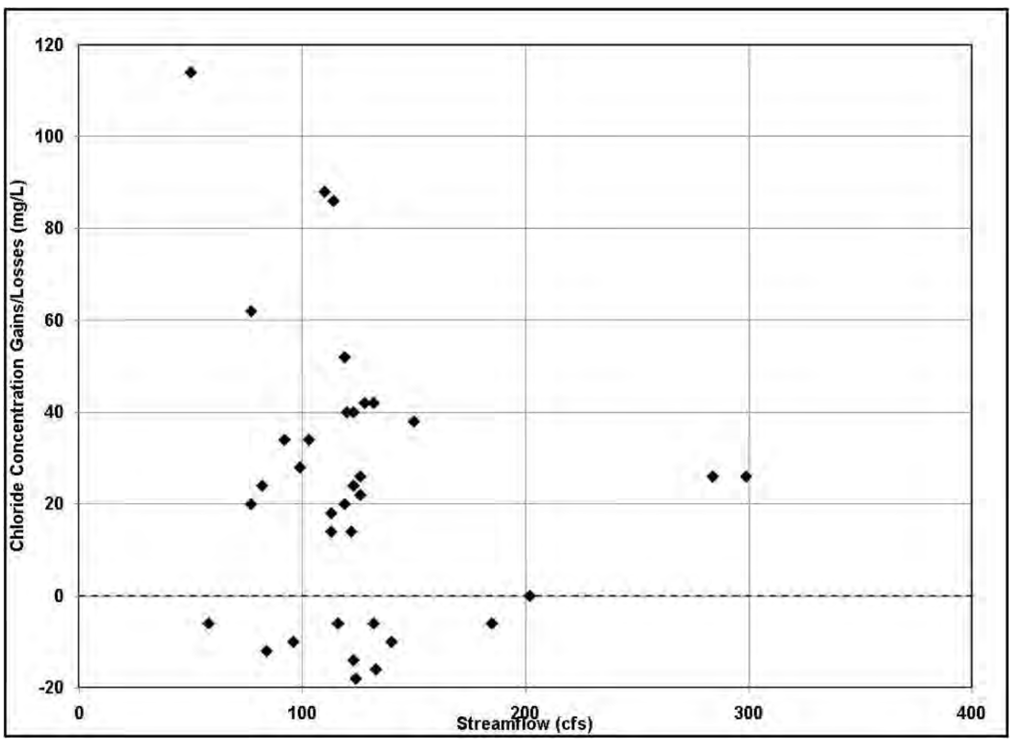


Figure 4C.3-30. Correlation of Gains/Losses of Chlorides and Streamflow along Nueces River: Bluntzer to Calallen

The correlation chart of chloride gains/losses and streamflow shows that most of the water samples were collected when streamflow ranged between 50 and 150 cfs at Bluntzer. During this time the concentration of chlorides tended to range from a loss of 5 mg/L to a gain of about 50 mg/L. This limited data set did not show a noticeable chloride gains/losses relation with streamflow. This correlation may not hold when more data become available with high flow conditions.

The second analysis is the relation between *chloride gains/losses and streamflow gains/ losses.* A timeline of gain/losses of chlorides and streamflow is shown in Figure 4C.3-31. A correlation of the two parameters is shown in Figure 4C.3-32.

The timeline chart of gains/losses of chlorides and gains/losses of streamflow shows essentially no trend, but has a somewhat irregular pattern of chlorides during the spring and early summer of 2005 and another one in the winter of 2007 and a period of unusually high streamflow losses during the late summer of 2005. This was previously noted.

The correlation chart of chloride gains/losses and streamflow gains/losses shows that most of the water samples were collected when streamflow gains/losses usually ranged between losing about 35 cfs to gaining about 18 cfs. The analysis does not show a relationship that would suggest a change in chloride gains/losses in response to changes in streamflow gains/losses. The reasons for the occurrence of increases in chlorides while the stream is losing water are not clear. A possibly explanation is that a subreach is gaining streamflow from groundwater or tributary and another subreach is losing streamflow to groundwater at a rate greater than the gains. Another is the potential inaccuracies of the streamflow data. As stated earlier, the USGS rates the accuracy of the stream discharge at Calallen to be ‘poor’ and records at Bluntzer as being ‘good’. For this analysis, the multiple diversions from the Calallen Pool are added to the discharge at the Calallen station. This amplifies the lack of overall confidence in the accuracy of the streamflow data used in this analysis. The overall results are believed to be suitable for analyses; however, individual values may be questionable. Finally, the analysis did not consider a travel time for the chloride concentrations, which may be several days between the Bluntzer and Calallen stations during low flow conditions.

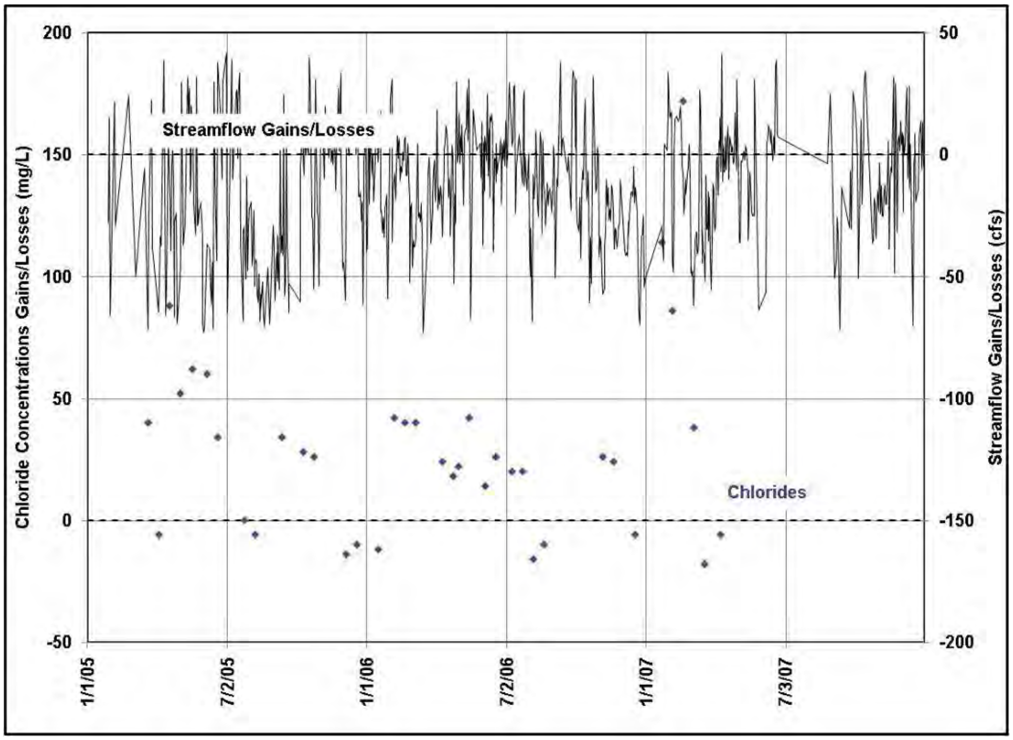


Figure 4C.3-31. Chlorides Gains/Losses and Streamflow Gains/Losses along Nueces River: Bluntzer to Calallen

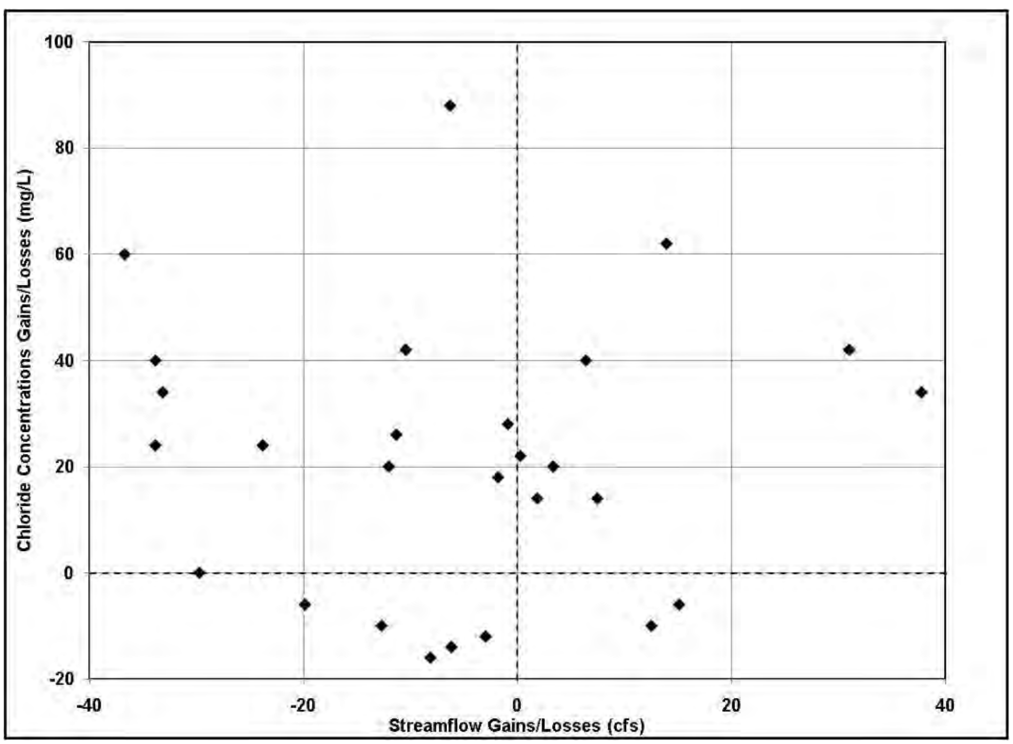


Figure 4C.3-32. Correlation of Chloride Gains/Losses and Streamflow Gains/Losses along Nueces River: Bluntzer to Calallen

4C.3.3.4 Suggested Studies to Refine Water Management Models in the Lower Nueces River Basin

During Phase I development of the 2011 Plan, the Corpus Christi Water Supply Model was updated to include a water quality component as summarized in Appendix B. The calibrated model closely approximated water quality statistics derived from measured values for 25^{th} to 75^{th} percentile conditions, but deviated for less frequent and likely extreme hydrologic conditions (that occurred 10 to 20% of the time). One potential explanation for deviations of calculated salinity in the Lower Nueces River Basin Bay and Estuary Model and the Corpus Christi Water Supply Model from measured results is an assumption of water in LCC being fully blended. In reality, there is a great possibility of water in the lake becoming stratified during certain times. Potential stratification could cause water released from LCC's Wesley Seale Dam to have different chloride levels than measured chloride levels in stored water in LCC near the water level surface (Figure 4C.3-23).

The most likely times are when the more saline would develop on the surface from evaporation would settle to the bottom of the lake because it is more dense. This is most likely to occur near the dam where the lake is the deepest. A temperature inversion commonly occurs in the fall and winter when the shallow water is cooled and migrates to the bottom due to differences in water density. Possibly the condensing of the shallow water during the summer from evaporation and the cooling of the water could enhance the inversion of shallow water and deep water, which would cause the salinity of water near the bottom of the lake to be higher than the average for the lake. A data collection program is planned for the winter, spring and summer of 2010 to document if does or does not occur. Plans are use a portable water quality monitoring probe (temperature and specific conductivity) to measure these parameters at about 3 ft intervals. The sampling site is near the lake's discharge outlet. Of great interest, the opening for the discharge structure is within a few feet of the bottom of the lake.

Other suggested studies to improve the understanding of the variations in salinity in the Lower Nueces River Basin include:

- Assessment of the influence of evaporation on increasing the salinity in LCC, especially during drought conditions.
- Preparation of a mass balance model (water and salinity) of Lake Corpus for the flux of water and salt. The suggested time periods for the mass balance study are when the lake and hydrologic conditions area rather stable and would include high and low conditions.

- Preparation of a water balance model for the Nueces River downstream of LCC. This would be for the period stable conditions and when suitable streamflow and water quality records are available.
- After the completion of the water balance model for the Nueces River downstream of LCC, prepare a mass balance model to account for the salinity conditions.
- Hydrogeologic studies in the vicinity of the Nueces River downstream of LCC to define the hydraulics for surface water/groundwater interaction and the quality of groundwater near the river.
- Development of a groundwater model in the region from Three Rivers to Calallen and centered along the Nueces River. Its initial application would be to better define the factors that control surface water/groundwater interaction and the movement of seepage from LCC during various lake stages.

4C.3.4 Projected Water Needs (Shortages) for Manufacturing Users During 2000 to 2060 Planning Period

There are four counties in the Coastal Bend Region with projected manufacturing water needs: Aransas, Live Oak, Nueces, and San Patricio Counties. Aransas County manufacturers receive groundwater supplies that are limited by well capacity, resulting in a maximum shortage of 136 acft in 2060. Live Oak County receives both surface water[6] and groundwater supplies, with groundwater limited by CBRWPG drawdown criteria. Their maximum projected shortage is 764 acft in 2060. Nueces and San Patricio County manufacturers receive a small supply of groundwater, both the majority is surface water provided from the CCR/LCC System. Since CCR/LCC System demands exceed supply, non-municipal water users have projected shortages. Nueces County manufacturers see projected shortages beginning in 2040 (11,627 acft) and continuing to 2060 (37,893 acft). San Patricio County has a maximum manufacturing shortage of 4,299 acft in 2060. A maximum shortage of 43,092 acft for manufacturing water users is projected for the entire Coastal Bend Region in 2060.

TWDB Rules for regional water planning require RWPGs to consider water conservation and drought management measures for each water user group with a need (projected water shortage). The Task Force report lists the following industrial BMPs that may be used to achieve water savings:[7]

1. Industrial Water Audit
2. Industrial Water Waste Reduction
3. Industrial Submetering

[6] Surface water firm yield supply of 800 acft/yr from City of Three Rivers run-of-river water right in Nueces River Basin (TCEQ Water Right 3215).
[7] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board,

4. Cooling Towers
5. Cooling Systems (other than Cooling Towers)
6. Industrial Alternative Sources and Reuse and Recirculation of Process Water
7. Rinsing/Cleaning
8. Water Treatment
9. Boiler and Steam Systems
10. Refrigeration (including Chilled Water)
11. Once-Through Cooling
12. Management and Employee Programs
13. Industrial Landscape
14. Industrial Site Specific Conservation

The Task Force report describes the above BMP methods and how they reduce water use, however information regarding specific water savings and costs to implement conservation programs is generally unavailable. Conservation savings and costs are by nature facility specific. Since manufacturing entities are presented on a county basis and are not individually identified, identification of specific water management strategies are not a reasonable expectation.

The CBRWPG recommends enhancing water quality to reduce manufacturing water use.

4C.3.5 Summary of Manufacturing Water Use Savings Alternatives

Water supply intakes in the Calallen Pool receive Lake Corpus Christi water via the 'bed and banks' of the Nueces River. The purpose of this section is to evaluate options to improve the quality of the water entering the water supply intakes. The following control strategies are considered:

- Blending of Lake Texana Water with Nueces River Water
- Outlet Works to Remove High TDS Water from the Calallen Pool
- Modification of Existing Intakes
- Pipeline from Lake Corpus Christi to the O.N. Stevens WTP
- Plugging Leaky and Abandoned Oil Wells

The potential for manufacturing water use savings is based on the reduction in chloride concentration of the water supply achieved by each option. Figure 4C.3-33 shows the estimated industrial cooling water usage savings for various levels of water quality improvement. These estimates are based on correspondence with local industries and other sources.

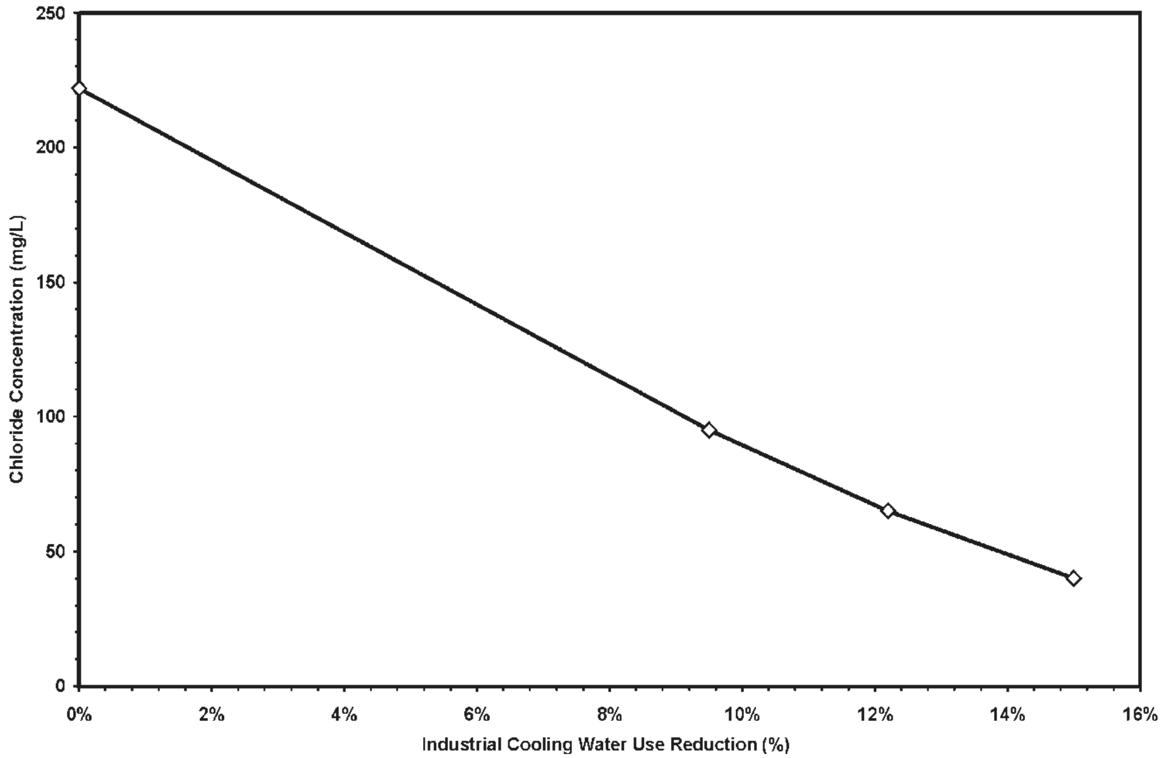


Figure 4C.3-33. Potential for Manufacturing Water Use Savings Based on Reduction in Chlorides

4C.3.6 Available Yield and Water Quality

Cooling towers permit the reuse of cooling water by industry. However, the extent of reuse is limited by water chemistry. Changes in chemistry during cycling of cooling water impact corrosion, scale deposition, and biological fouling of industrial facilities. To control the chemical character of recycled cooling water and prevent these adverse effects, industries discharge (blow down) water from the system. The quantity of makeup water needed is the amount evaporated plus the amount of blow down. Improving makeup water quality would allow industry to reduce their blow down quantity. Other savings include reduced cooling tower chemical costs, and reduced treated water chemical usage and costs. The amount of industrial conservation achieved by improving water quality depends on the current water quality, industrial operations, and amount of water quality improvement effected.

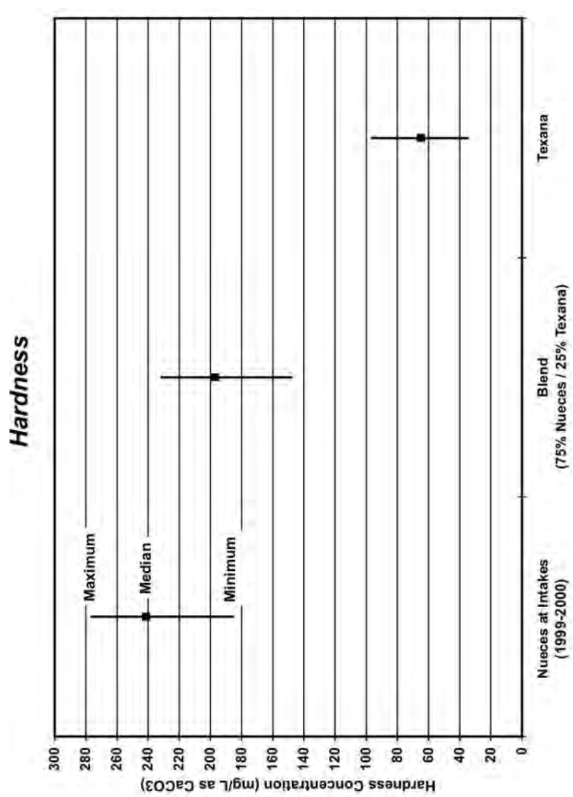
Chloride is an effective indicator of total dissolved solids and is used here as an illustrative example of the savings potential as a result of improving the quality of water entering the manufacturing industry's systems. Another important constituent to cooling water quality is hardness. The concentration of hardness is a critical limitation in the quality of the cooling tower water supply.

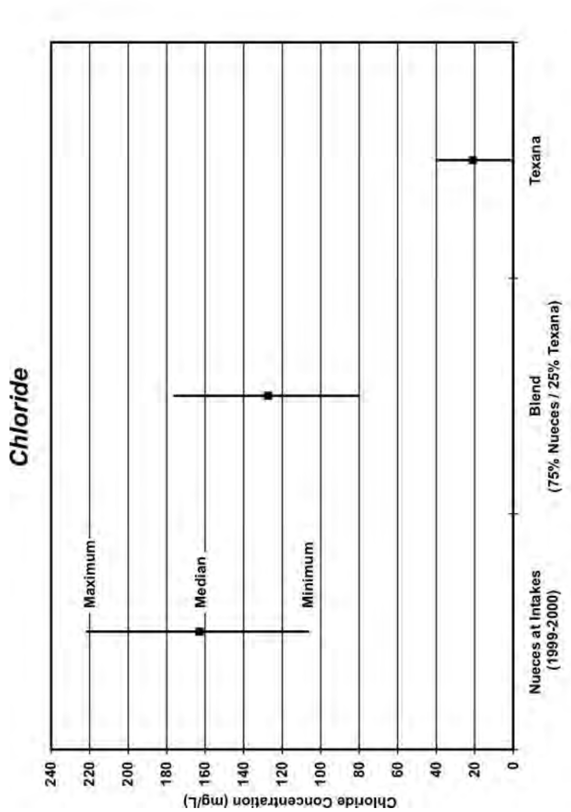
The presence of bromide in drinking water supplies affects the formation of disinfection byproducts (DBPs) such as brominated trihalomethane (THM) and haloacetic acid (HAA) species during treatment. THMs and HAAs have been linked to a number of serious health risks and are regulated by the U.S. Environmental Protection Agency. Reducing the level of bromide in drinking water sources, such as the Nueces River, will reduce the amount of DBPs in the finished drinking water and decrease the cost associated with treatment. The following options were evaluated with respect to the concentration ranges of chloride, hardness and bromide. The potential water savings as a result of each option were based on both the maximum and minimum reductions in chloride levels as indicated in Figure 4C.3-33.

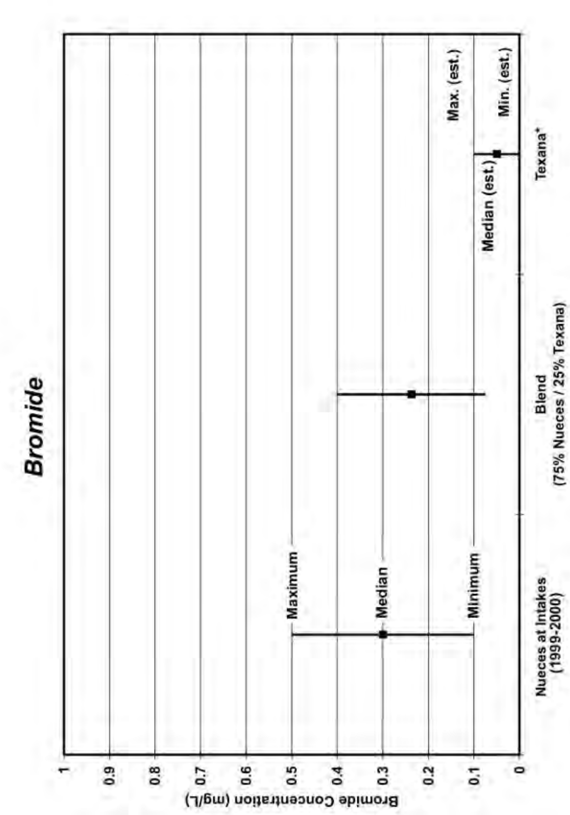
4C.3.6.1 Blending of Texana Water

Corpus Christi currently contracts for a firm amount of 41,840 acft/yr and an interruptible amount of 12,000 acft/yr of water from Lake Texana. Lake Texana supplies constitute about 25 percent of the safe yield supply of 205,000 acft in 2010. The addition of Lake Texana water to the region’s water supply has lowered total dissolved solids and improved water quality for most industrial users. The mean chloride concentration of Nueces River water at Calallen Pool is 163 mg/L and the maximum is about 222 mg/L. Blending 75 percent Nueces River water with 25 percent Lake Texana water would reduce the mean chloride concentration to 127.5 mg/L and the maximum to about 175 mg/L. Figure 4C.3-34 presents the maximum, median, and minimum chloride, hardness and bromide concentrations for the Nueces River at O.N. Stevens WTP, Lake Texana, and the blended supplies. The average hardness concentration is reduced by 18 percent to 197 mg/L from 242 mg/L. The median bromide concentration is reduced by 20 percent as a result of blending.

In order to obtain the maximum potential savings in manufacturing water use this blended water would need to be made available to as many industries as possible. Two significant industries that withdraw raw water from the Calallen Pool that currently do not have access to the Texana water include Flint Hills Resources and Celanese-Bishop. These industries







Note: The detection limit for bromide is 0.1 mg/L. This is the maximum value assigned to Lake Texana water even though it is likely to be lower.

Figure 4C.3-34. Blending Nueces River and Lake Texana Water Decreases Selected Dissolved Mineral Concentration and Variability

have seen a decline in water quality due to reduced water supply releases from Lake Corpus Christi resulting in higher dissolved solids and mineral concentrations in the Calallen Pool.[8] For the 2011 Plan, a study was conducted to evaluate potential pipeline interconnections to the Mary Rhodes Pipeline to provide water supplies to two industries[9] that have intakes in the Calallen Pool. The results of this study are included in Section 4C.3.6.6.

Reductions in chloride levels are expected to result in a 3 to 4 percent savings in cooling water use in the region. Industrial water conservation savings associated with reducing the mean chloride concentration by about 21 percent are as follows:

- Year 2000 – 940 to 1,260 acft/yr
- Year 2060 – 1,540 to 2,050 acft/yr

4C.3.6.2 Outlet Works to Remove High TDS from Calallen Pool

The sampling data has shown that within the Calallen Pool there are sites where saline groundwater entering the system remains at the bottom of the deepest parts of the pool. Removal of the groundwater before the dissolved minerals diffuse into the entire channel could significantly improve the overall quality of the water remaining. This option includes a gravity line to siphon a maximum of 6 MGD from the bottom of the channel at up to eight locations. The alignment of the pipe system is shown in Figure 4C.3-35. The pipe system discharges into an inlet/outlet structure that bypasses the Calallen Dam that will allow for accurate measurement. The line is designed to be flushed by either connecting to San Patricio Municipal Water District's raw water discharge line to backwash the pipeline to remove any buildup of debris or use compressed air to flush the system. Removing the saline groundwater from the channel is estimated to reduce chloride concentrations of the Nueces River water by 15 percent to 138 mg/L based on the median levels, and to 189 mg/L based on the maximum levels as shown in Figure 4C.3-36. The outlet works are estimated to reduce hardness levels by 3.8 percent to an average concentration of 232 mg/L. Figure 4C.3-36 also shows a 39.7 percent reduction in bromide from an average concentration of 0.3 mg/L to 0.18 mg/L.

8 HDR Engineering Inc., "Effluent Reuse Study," February 2002.
9 Flint Hills Resources also receives treated water supplies from the City of Corpus Christi.

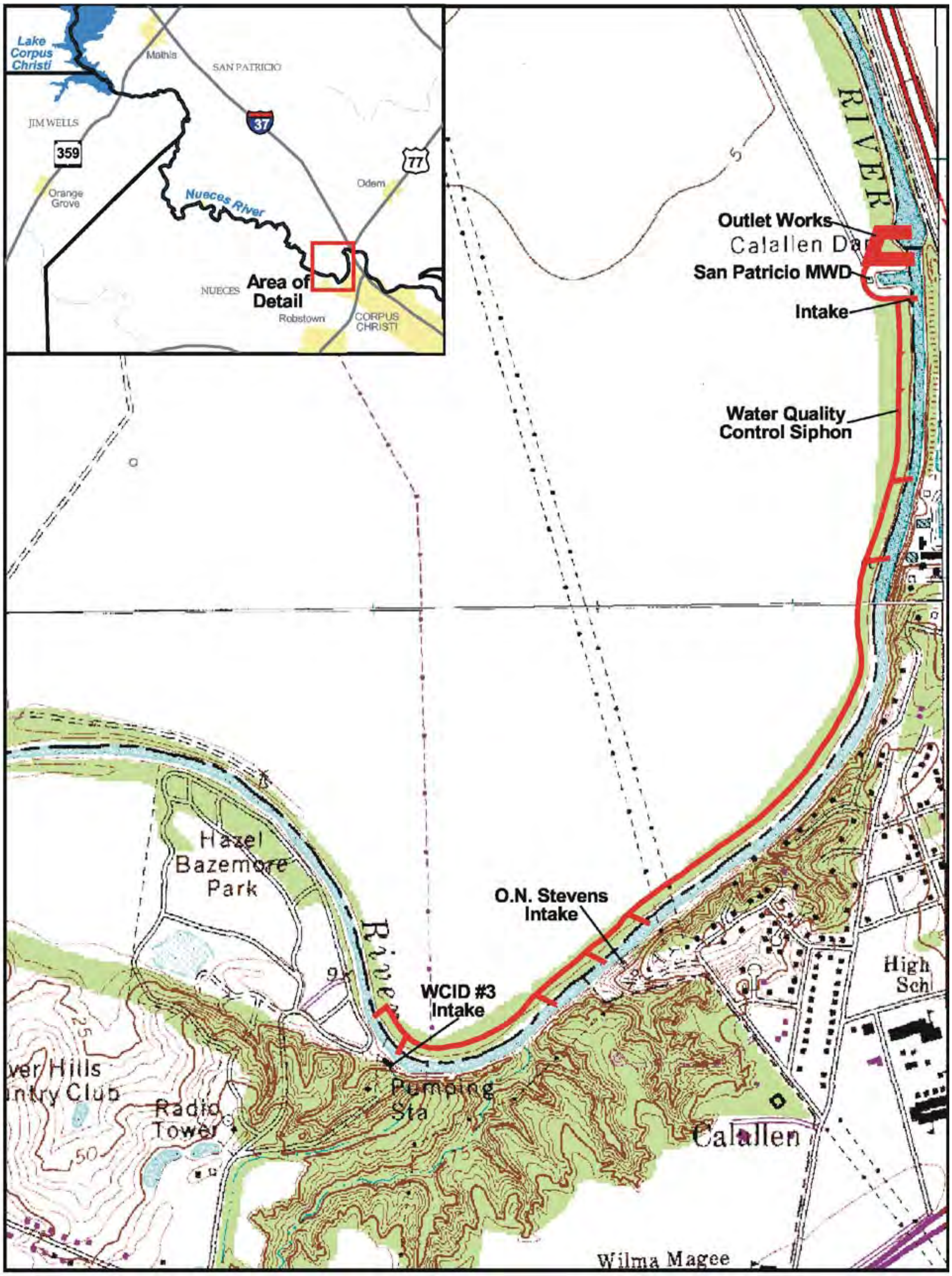
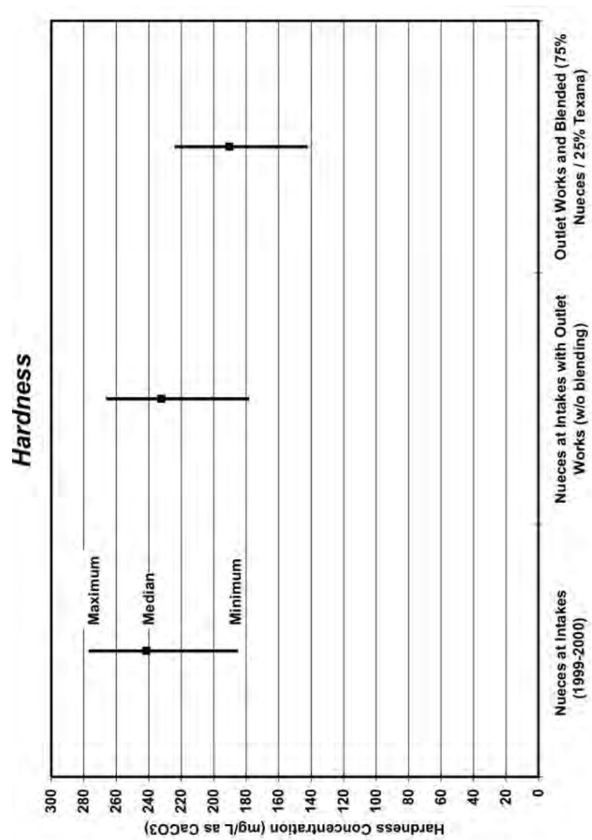
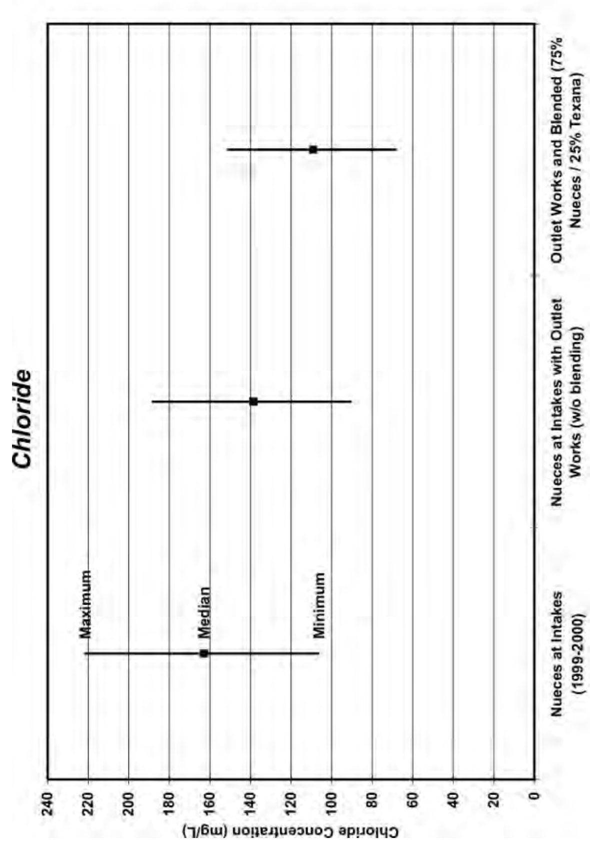


Figure 4C.3-35. Location of Water Quality Control Siphon and Outlet Works





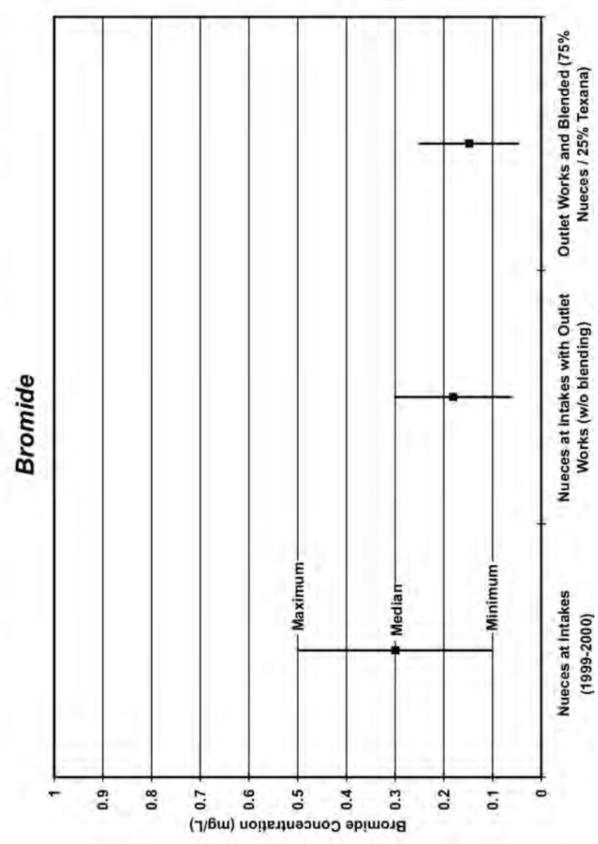


Figure 4C.3-36. Decrease in Selected Dissolved Minerals with Outlet Works and Blending with Lake Texana Water

For determining the estimated benefit of this option, it is assumed that the outlet works are implemented in conjunction with blending Texana water with Nueces River water. After blending with the Texana water, the final median chloride concentration is reduced by an additional 20 percent to 109 mg/L and the maximum to about 152 mg/L. The additional reductions in hardness and bromide concentrations are 18 percent and 17 percent respectively. This option results in an additional savings of manufacturing water consumption by the following amounts:

- Year 2000 – 150 to 470 acft/yr; and
- Year 2060 – 300 to 730 acft/yr.

4C.3.6.3 Intake Modifications

The results of the sampling program show stratification within the Calallen Pool, with large mineral concentration increases occurring within the bottom 2 feet near the water intake locations. A potential option for increasing manufacturing water conservation is modification of the industrial intake structures to prevent withdrawal of water from the deepest part of the channel. Modifications to existing surface water intakes to allow only water from the uppermost portion of the water column to enter the system will differ depending upon the design of the intake. There are two major types of intakes within the channel. The first is a screened pipeline intake and the second is a side stream intake.

The first intake system would require the installation of a pipe with variable level intake screens, which can be opened and closed to allow the optimum quality of water to be withdrawn from the channel. There are multiple modifications possible for the side stream intake. These include the addition of framing, which will allow stop logs to be placed in front of the intake and allow water from selected depths to enter the system. The second is the installation of an exterior sill wall outside of the intake structure. The third option is the construction of an interior baffle wall within the intake structure. The four intakes that would result in the most benefit from modifications include the two side stream intakes operated by the City of Corpus Christi, a single side stream intake operated by the Celanese Corporation Bishop Facility, and a screened pipeline intake operated by Nueces County WCID #3.

The benefit of intake modifications is considered only in conjunction with the outlet works and siphon pipeline, as the siphon would be necessary to prevent the build-up of poor quality groundwater in the bottom of the Calallen Pool. Allowing only water from the uppermost portion of the Nueces River water column to enter the intakes after the most of the saline groundwater has been removed from the channel by the outlet works results in an additional reduction in median and maximum chloride of about 5 percent over the reductions achieved by the outlet works alone. An additional 12 percent reduction in bromide is achieved and hardness is further reduced by 1 percent, as shown in Figure 4C.3-37. It is estimated that the additional water savings due to this option are 150 acft/yr for year 2000 and 300 acft/yr for 2060.

4C.3.6.4 Pipeline from Lake Corpus Christi to the O.N. Stevens Water Treatment Plant

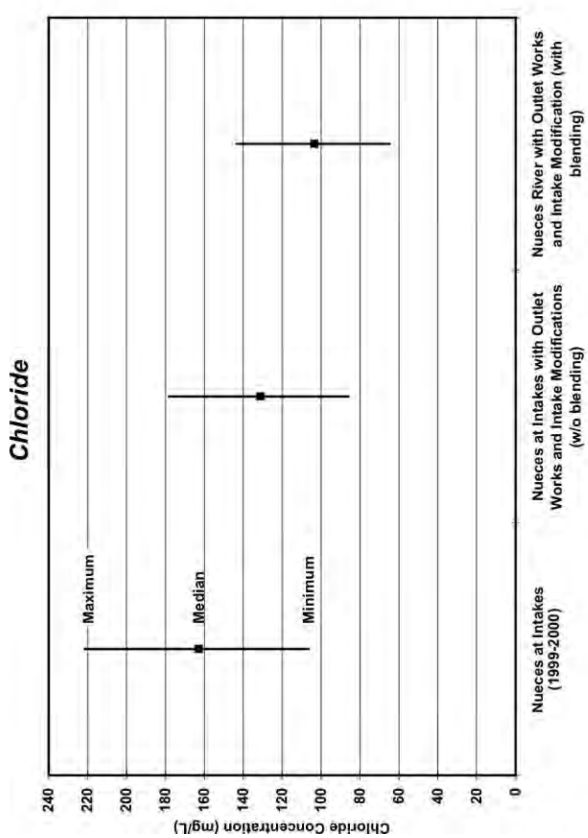
A pipeline to deliver the total system safe yield of 150,000 acft/yr[10] from Lake Corpus Christi to the O.N. Stevens WTP would significantly reduce the chloride concentration of the raw water. Delivering just a portion of the total system yield from the Nueces River system to some users would increase the concentration of dissolved solids of the water remaining within the channel that would be diverted by other industrial and municipal users. Delivering the entire system yield eliminates this problem by supplying water with improved quality to all industrial and municipal users.

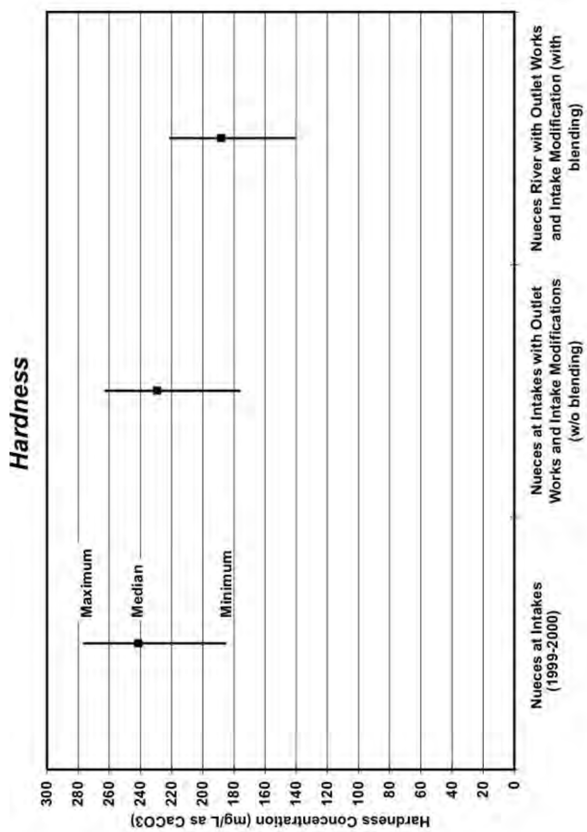
The quality of the water would improve from an average chloride concentration of 163 mg/L to an average chloride concentration of 39 mg/L as shown in Figure 4C.3-38. The hardness levels of Lake Corpus Christi are 27 percent lower than the Nueces River. The average improvement in hardness is from 185 mg/L to 136 mg/L. It is estimated that the manufacturing industry would save about 10 percent to 13 percent of water consumption as a result of the decrease in chloride concentration. This results in a 3,100 acft/yr to 4,000 acft/yr savings in 2000 and 5,100 acft/yr to 6,600 acft/yr savings in 2060. Other benefits to industry include:

- Reduced cooling tower chemical costs
- Reduced demineralized water chemical usage and costs
- Reduced salt loading in the final plant effluent (environmental benefit).

The major facilities needed to deliver raw water from Lake Corpus Christi to the O.N. Stevens WTP include an intake pump station at the lake and a 21-mile transmission pipeline to Calallen. The river habitat downstream of Lake Corpus Christi would be supplied with water from natural inflows and pass-throughs to the Nueces Estuary from Lake Corpus Christi. The total yield for this option includes reduced channel losses and increased

[10] Safe yield for CCR/LCC System in 2010 is 150,000 acft/yr without Lake Texana supplies.





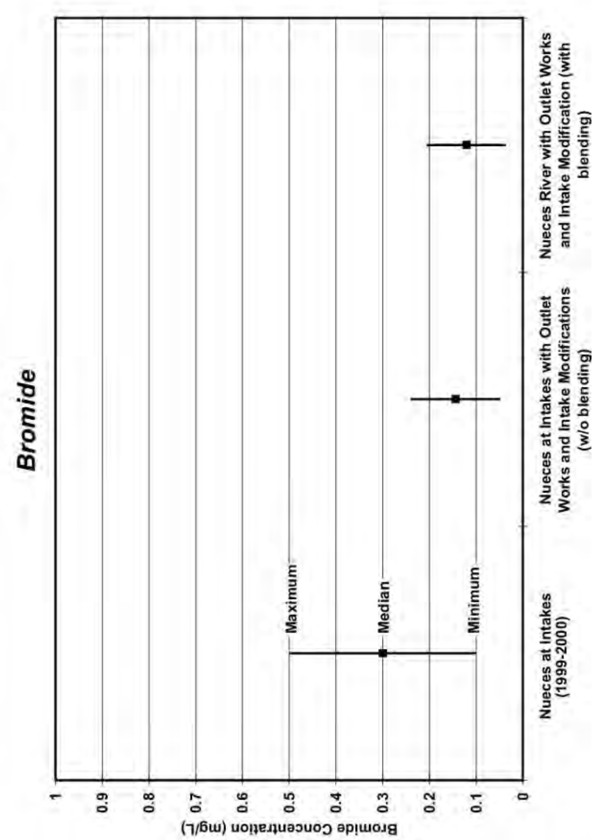


Figure 4C.3-37. Decrease in Selected Dissolved Mineral Concentrations with Intake Modifications, Outlet Works, and Blending with Lake Texana Water

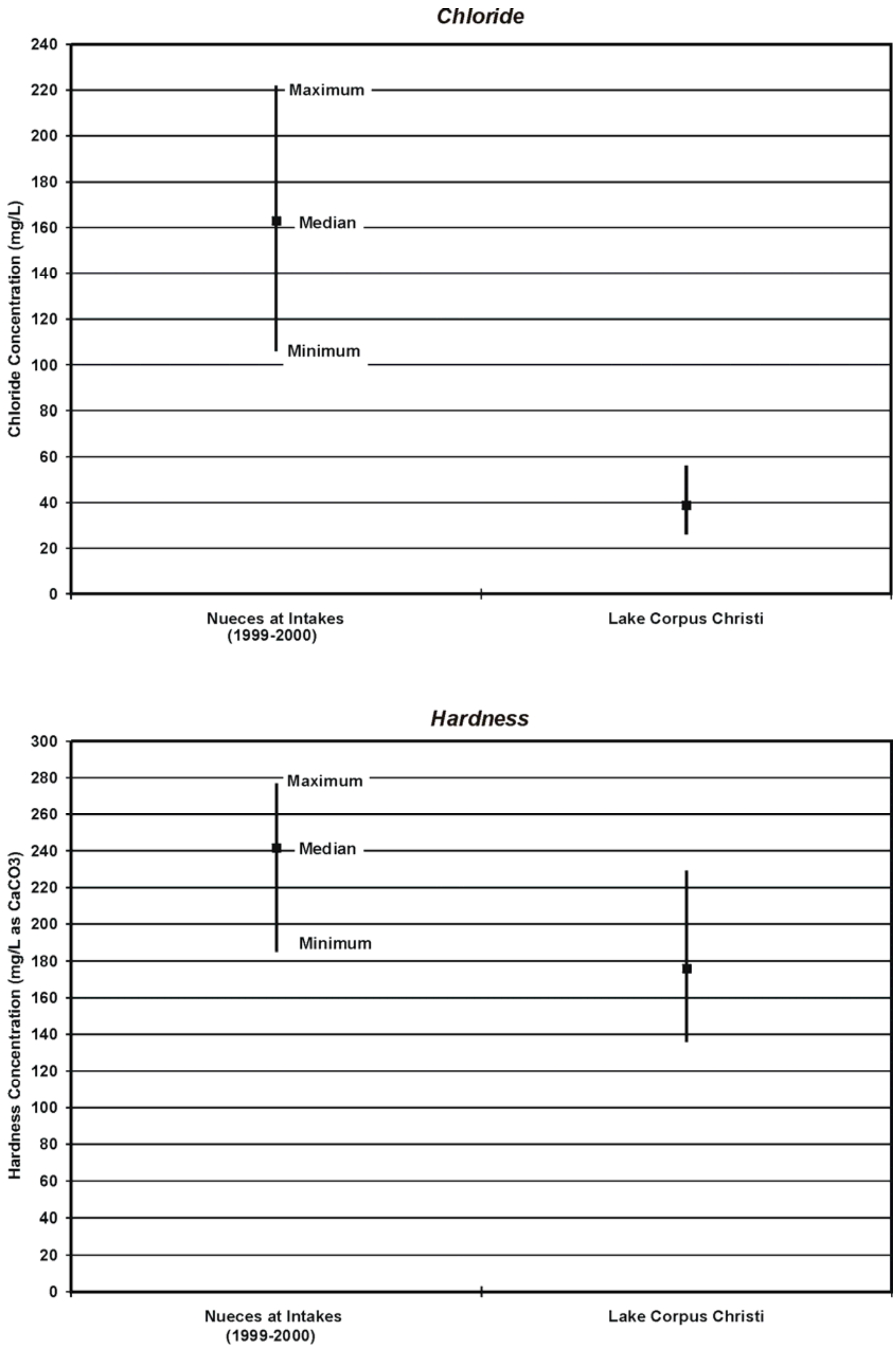


Figure 4C.3-38. Comparison of Chloride and Hardness Concentrations

manufacturing water conservation. Recent studies indicate channel losses average 11 percent between Lake Corpus Christi and the Calallen Pool (or about 16,500 acft/yr on water supply releases of 150,000 acft), depending on flow and seasonal conditions.[11] This project would result in total savings of between 19,600 to 23,100 acft/yr.

4C.3.6.5 Plugging Leaky and Abandoned Oil Wells

Unplugged and leaking plugged wellbores pose a threat of pollution to the surface and subsurface waters by providing a pathway for the migration of fluids (in particular oil and saltwater) from hydrocarbon bearing zones into formations containing usable quality water and into surface waters. As long as a well remains unplugged, the potential threat remains until it is eliminated by properly plugging the wellbore.

The State of Texas has maintained a well plugging fund since 1965 to plug abandoned wells that pose a pollution hazard when: the responsible owner/operator cannot be located; is insolvent; or the responsible owner/operator is unwilling to plug the well. Wells are considered in the Nueces River and Lake Corpus Christi for plugging when they become non-compliant or inactive for at least 12 months and have not received an approved permit extension. A priority system is used to rate the need for plugging non-compliant wells based upon 20 human health, safety, environmental, and wildlife factors. Leaking wells receive the highest priority (Level 1) and all other wells receive a priority between 2 and 4 depending on the level of threat to the environment. Wells with a priority of 1, 2, or 3 are recommended for plugging with Oil Field Cleanup Funds. The Texas Railroad Commission has utilized the Oil Field Cleanup (OFCU) Fund to plug more that 15,000 wells within the state of Texas. Of those, 139 wells have been in San Patricio County and 96 were in Nueces County. However, thousands of additional abandoned wells remain in Texas. There are currently 193 and 184 non-compliant wells in San Patricio and Nueces Counties, respectively. Of these non-compliant wells, only 31 have a Level 4 priority. It is unknown how many improperly plugged wells are leaking and are in need of repair. Within San Patricio and Nueces Counties, there were 16 total wells scheduled to be plugged in 2000 at an average estimated cost of $21,000 per well. Additional study is needed to determine the impact of the leaking wells on the lower Nueces River.

[11] CRR/LCC updates, 2005.

4C.3.6.6 Potential Interconnections to the Mary Rhodes Pipeline

For the 2011 Plan, a study was conducted to evaluate potential pipeline interconnections to the Mary Rhodes Pipeline to provide water supplies to two industries[12] that have intakes in the Calallen Pool.

4C.3.6.6.1 Water Quality Constituents of Interest

Discussions with industries that have intakes in the Calallen Pool area to provide Nueces River water and that do not currently have access to MRP supplies resulted in identification of the several specific water quality concerns. One primary concern is fluctuations in the total dissolved solids (TDS) of the Lower Nueces River water that causes treatment difficulties and additional costs for desalination when TDS concentrations are elevated. A related concern is the relatively high chlorides and other dissolved ions that increase corrosion potential. Other concerns included elevated hardness which increases the scaling potential and requires additional softening for removal. Additional softening treatment to remove hardness increases treatment costs and increases the quantity of treatment sludge requiring disposal. Based on these water quality concerns, the primary water quality constituents of interest for blended water qualities and treatment requirements at the industrial facilities are shown in Table 4C.3-5.

Table 4C.3-5.
Water Quality Constituents
and General Impacts on Water Treatment

Water Quality Constituent	*General Impact on Treatment*
Turbidity	Sludge production
Total Hardness	Required lime dose and sludge production, corrosion chemistry
Total Dissolved Solids (TDS)	Desalination and softening requirements, corrosion chemistry
Chloride	Desalination and softening requirements, corrosion chemistry

4C.3.6.6.2 Blending Scenarios

The composition of raw water supplies treated at these industrial facilities has historically been 100% Nueces River water. Water diverted directly from MRP currently consists of 100% Lake Texana water. The City has a contract with the Lavaca-Navidad River Authority to divert 41,840 acft/yr on a firm basis and up to 12,000 acft/yr on an interruptible basis from Lake

[12] Flint Hills Resources also receives treated water supplies from the City of Corpus Christi.

Texana (up to 53,840 acft/yr). Based on the raw water source data provided by the City, interruptible supplies have varied from 0 to 2,300 acft/yr over the past few years based on need and water availability. For the blending scenarios, the current supply of Lake Texana water was assumed to continue while additional supplies are added. Three blending scenarios were evaluated to simulate the integration of different combinations of potential future supplies to be delivered through the MRP (utilizing from 61% to 95% of the pipeline capacity[13]). The blending scenarios are:

(1) Addition of Gulf Coast Aquifer groundwater supplies from Bee County.
(2) Addition of Garwood Project supplies from the Colorado River – delivered via pipeline around Lake Texana that connects directly into the MRP.
(3) Addition of both the Gulf Coast Aquifer groundwater and Garwood Project supplies from the Colorado River (piped from the Colorado river directly into the MRP).

Table 4C.3-6 shows the blending ratios evaluated and quantity of each water source in the blended water supply. The blended water scenario with all three water supply sources (Scenario # 3) is based on the contract maximums delivered through MRP for an estimated total supply up to 106,840 acft/yr, or 95% of the pipeline capacity. The other blending scenarios were based on the firm Lake Texana supply and do not include interruptible Lake Texana supplies

Table 4C.3-6.
Blended Water Percentages and Quantities

Label	*Existing 100% Nueces*	*100% Texana*	*Texana with 30% Groundwater*	*Texana with 45% Colorado*	*Blend All Three Based on Existing Operations and Contract Maximums*
Nueces River	100.0%	0.0%	0.0%	0.0%	0.0%
Lake Texana	0.0%	100.0%	70.0%	55.0%	50.0%
Colorado River	0.0%	0.0%	0.0%	45.0%	33.0%
Groundwater	0.0%	0.0%	30.0%	0.0%	17.0%
Water Quantity (acft/yr)					
Lake Texana		41,840	41,840	41,840	53,840
Colorado River				35,000	35,000
Groundwater			18,000		18,000
Total Quantity		**41,840**	**59,840**	**76,840**	**106,840**

[13] Although the MRP is sized to deliver 112,000 acft/yr, the current MRP *pumping* capacity is 77,000 acft. A fourth pump would need to be installed in each of the three pump stations to deliver the full Garwood Project of 35,000 acft/yr in addition to the permitted Lake Texana Supplies.

4C.3.6.6.3 Water Quality for Blending Scenarios

The median raw water quality for the blends considered is shown in Table 4C.3-7. The water quality variability of each constituent for each of the four water sources is summarized in Figures 4C.3-39 through 4C.3-42. These figures show the low concentration (only 35% of samples lower than this value), median concentration (50% of samples lower than this value), and high concentration (65% of samples lower than this value).

Table 4C.3-7.
Median Raw Water Quality of Blends

Label	Existing 100% Nueces	100% Texana	Texana with 30% Groundwater	Texana with 45% Colorado	Blend All Three Based on Existing Operations and Contract Maximums
Nueces River	100.0%	0.0%	0.0%	0.0%	0.0%
Lake Texana	0.0%	100.0%	70.0%	55.0%	50.0%
Colorado River	0.0%	0.0%	0.0%	45.0%	33.0%
Groundwater	0.0%	0.0%	30.0%	0.0%	17.0%
Water Quality					
Turbidity, NTU	23	57	40	54	38
Total Dissolved Solids, mg/L	620	121	368	258	358
Chloride, mg/L	210	14	107	34	81
Total Hardness, mg/L as CaCO3	279	77	133	132	149

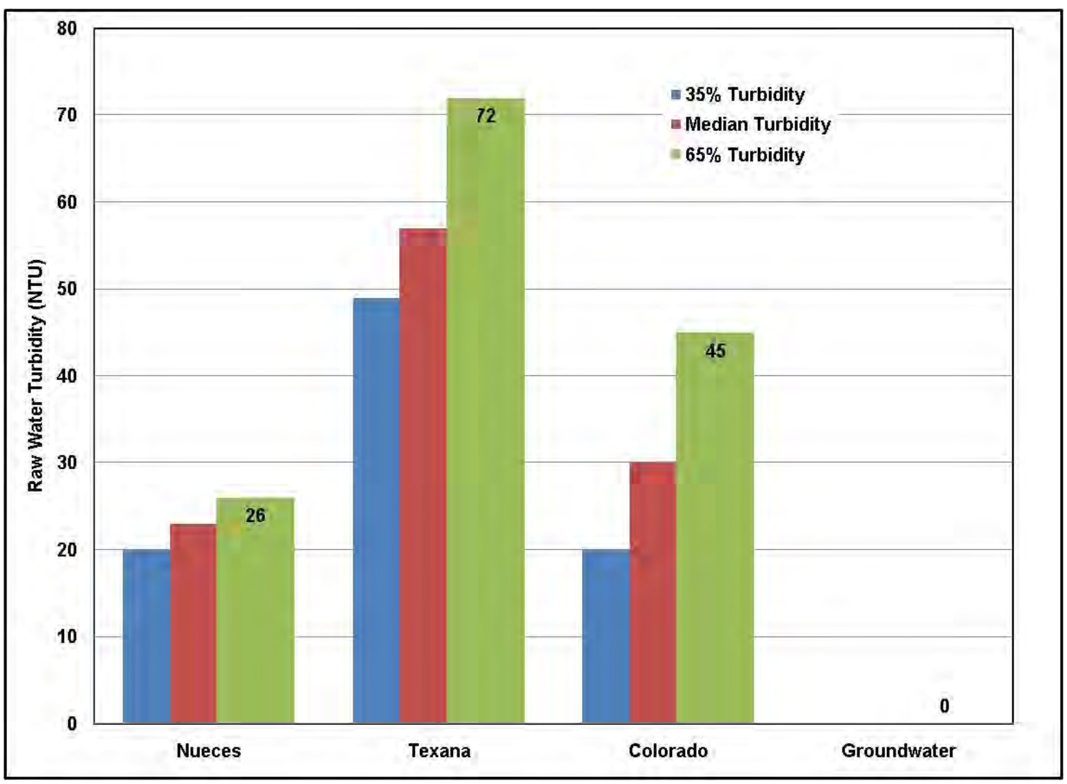


Figure 4C.3-39. Raw Water Turbidity for Each Water Source

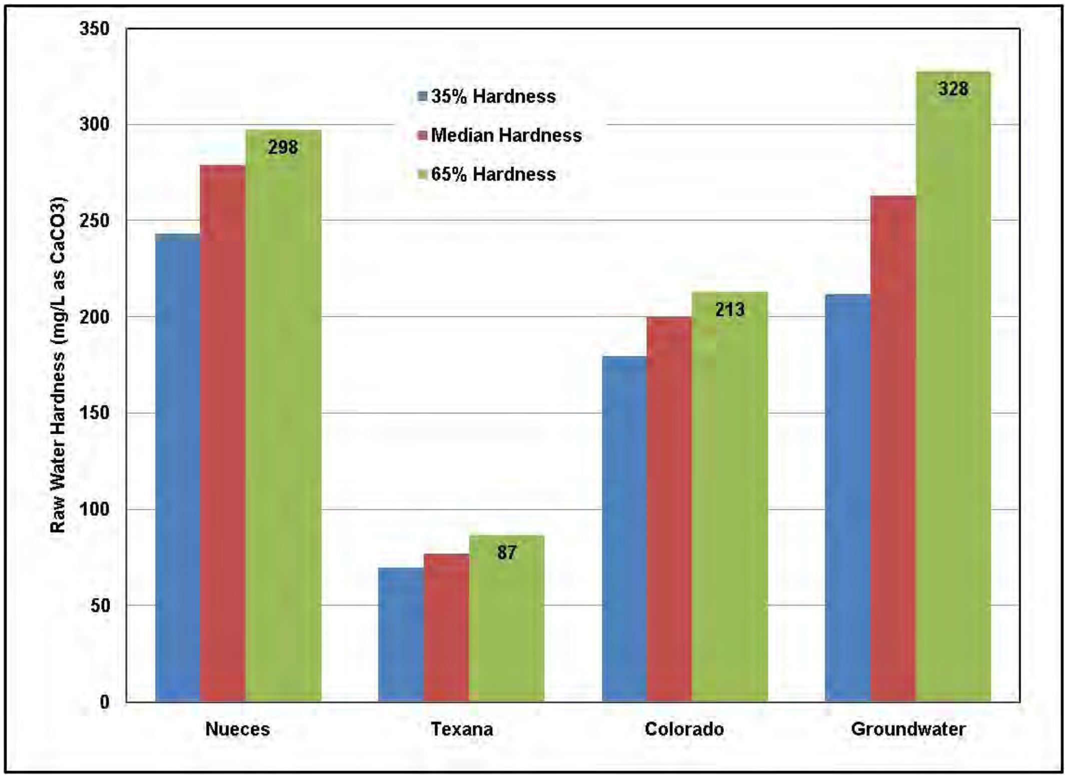


Figure 4C.3-40. Raw Water Hardness for Each Water Source

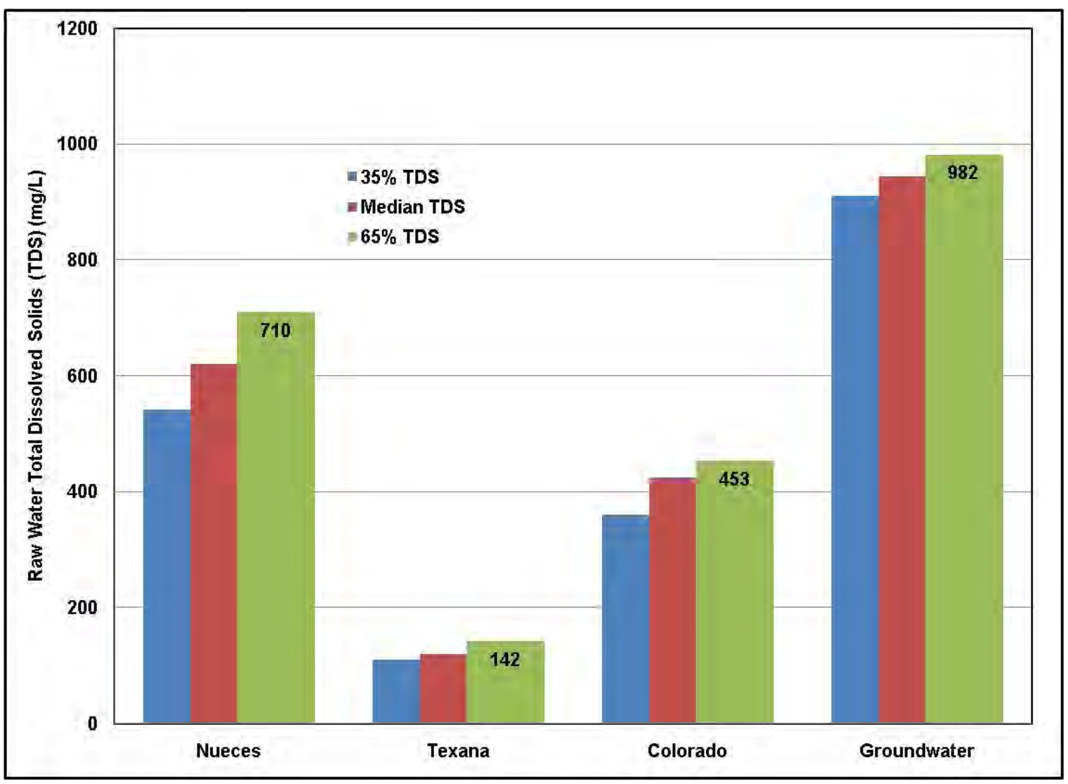


Figure 4C.3-41. Raw Water TDS for Each Water Source

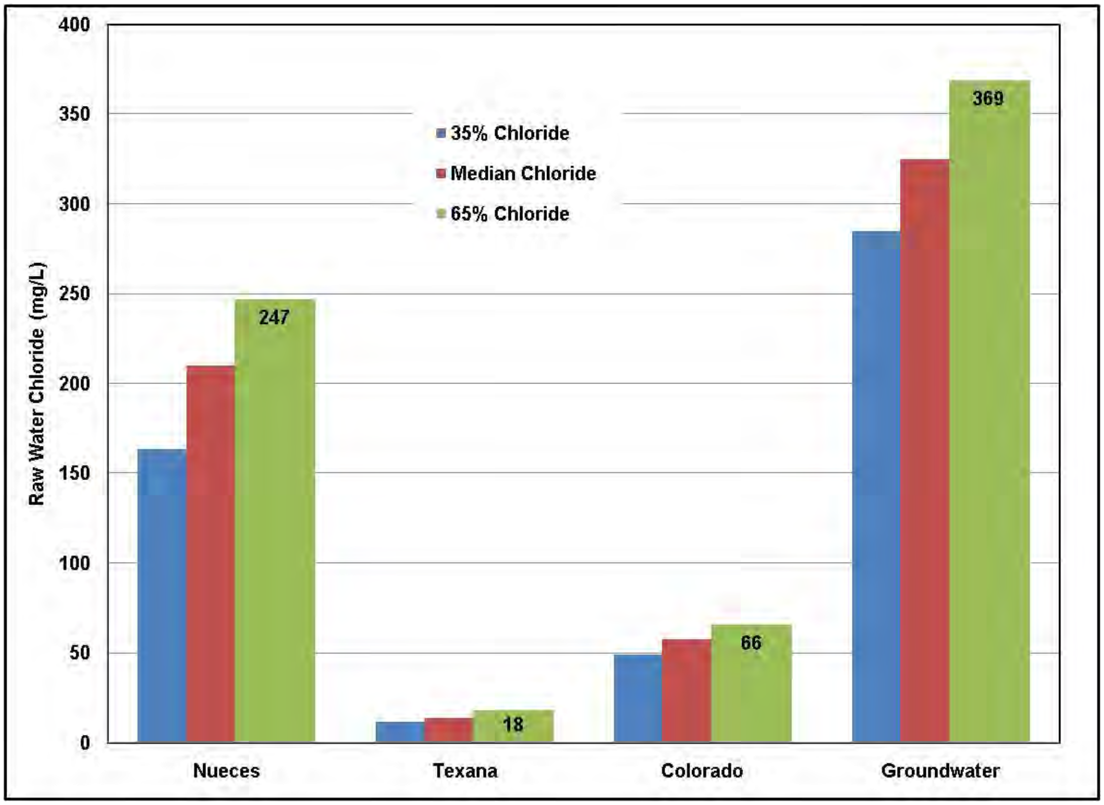


Figure 4C.3-42. Raw Water Chloride for Each Water Source

4C.3.6.6.4 *Summary of Water Quality and Blending Analysis*

The blending analysis and resulting water treatment estimates are based on the median water quality for each water supply. The quantity of sludge produced, level of desalination required, and quantity of water required to meet industrial needs will vary if water quality of any of the raw water sources changes considerably throughout the year or from year to year. However, based on the range of historical water quality for each water source, the water quality of all the evaluated water sources vary within ranges that can successfully be treated by industrial users with existing treatment methods.

The analysis is based on a total average water use for industrial users supplied directly from MRP of 5 MGD (5,600 acft/yr). The treatment impacts assume that there is not an off-channel reservoir prior to the industrial treatment systems, and therefore, the quantity of sludge produced by lime treatment is impacted by the turbidity of the raw water. Higher turbidity is removed in treatment producing more sludge that must be disposed. Table 4C.3-8 shows the assumed quantity of 100% Nueces water that is currently being used in cooling towers and boiler feed and the associated treatment required for each use.

Table 4C.3-8.
Quantity of Water for Each Industrial Use

Water Use (Treatment Required)	***%***	***Quantity (MGD)***
Cooling Tower (Lime Softening)	85.0%	4.25
Boiler (Lime Softening + Desalination)	15.0%	0.75

All the water currently supplied to industrial users is treated by lime softening to remove suspended solids, reduce hardness, and remove other impurities. A simplified estimate of lime softening treatment cost differences for different blended water qualities was developed based on an estimate of the quantity of sludge produced. The quantity of sludge produced from lime softening is primarily dependent on the hardness and alkalinity of the raw water. During lime softening treatment, lime (calcium hydroxide) is added to the raw water to raise the pH and therefore precipitate hardness and other impurities that are more soluble at lower pH's. The higher the hardness concentration in the raw water, the larger the quantity of hardness that will be removed by lime softening treatment creating more sludge for disposal. Similarly, higher concentrations of alkalinity buffer the water requiring higher doses of lime to raise pH. The higher dose of lime adds more calcium hardness that is subsequently precipitated at the higher pH resulting in higher quantities of treatment sludge. To develop the relative cost differences for lime treatment, a unit cost for sludge disposal of 0.10 $/pound was assumed. There are other treatment processes such as filtration and disinfection utilized for the water supplied to the cooling towers. However, for this cost analysis those treatment processes are not considered because the potential changes in treatment costs for those processes are relatively insignificant when compared to potential cost differences in the lime softening process due to water quality changes.

In addition to lime softening treatment, the portion of water used for boiler feed at industrial facilities is treated with reverse osmosis for desalination and ion exchange softening to reduce the level of hardness and impurities to low levels. This ultrapure water can more efficiently be used in boilers for steam generation. The lime softening treatment step does not remove all total dissolved solids and removes very little or none of some constituents such as single-valent ions like chloride. Therefore, water with higher concentrations of total dissolved solids and especially higher concentrations of chlorides will require more extensive desalination prior to being utilized for boiler feed. For this simplified estimate of desalination treatment costs the relative concentration of dissolved solids was utilized to estimate the relative desalination costs for the different blended water qualities. The cost to treat 0.75 MGD of boiler feed water with desalination treatment steps for the existing supply of 100% Nueces water was assumed to be $300,000 per year. Water supplied from MRP with lower dissolved solids will have lower desalination treatment costs due to better desalination treatment performance including lower pressure required and better recovery rates for reverse osmosis systems. A summary of estimated differences in treatment costs for each blended water scenario is shown in Table 4C.3-9.

Improved water quality can result in decreased total water supply required to meet industrial demands. There will be a decrease in water demand if cooling tower cycles are increased. When water can be concentrated more by recycling through the cooling tower more times then less water is lost as blowdown. Scaling due to elevated concentrations of constituents such as hardness will limit the number of cooling tower cycles. Similarly, corrosion due to elevated concentrations of constituents such as chloride will also limit the number of cooling tower cycles. Industrial users indicated that with the existing raw water supply of 100% Nueces it was generally possible to utilize 5 cooling tower cycles. For this analysis, the number of cooling tower cycles that may be utilized for each of the blended water scenarios was estimated based on the relative concentration of hardness and chloride in the raw water with higher concentrations of hardness and chloride resulting in a lower number of cooling tower cycles.

A decrease in total dissolved solids concentration in the industrial water supply can also result in decreased water demand due to less water requiring desalination and improvement in the recovery rate from reverse osmosis treatment. For this estimate, the quantity of water lost as concentrate during desalination treatment was assumed to be 10% for the current supply of 100% Nueces water. Water lost from desalination for the blend scenarios was estimated to be proportional to the total dissolved solids concentration with lower concentrations resulting in less desalination water lost. Table 4C.3-10 shows the estimated differences in the quantity of raw water necessary to meet industrial demands for each of the blend scenarios.

A potential pipe route to connect the MRP to the existing industrial raw water intake pump stations that are currently drawing water from the Nueces River is shown in Figure 4C.3-43. Costs are presented in Section 4C.3.8.6.

Table 4C.3-9.
Industrial Water Treatment Cost Differences for Blends

		Existing 100% Nueces	*100% Texana*	*Texana with 30% Groundwater*	*Texana with 45% Colorado*	*Blend All Three Based on Existing Operations and Contract Maximums*
Lime Sludge Produced and Cost of Disposal (Cooling Tower and Boiler Water Treated = 100% of Total = 5.0 MGD)						
Quantity of Lime Sludge	PPD	14,600	5,300	9,200	9,600	10,500
Cost of Lime Sludge Disposal	$/Year	$533,000	$193,000	$336,000	$350,000	$383,000
Suspended Solids Sludge Produced and Cost of Disposal (All Water Treated Total = 5.0 MGD)						
Turbidity	mg/L	23	57	40	45	38
Sludge from Suspended Solids	PPD	1,000	2,400	1,700	1,900	1,600
Cost of Solids Sludge Disposal	$/Year	$37,000	$88,000	$62,000	$69,000	$58,000
Desalination Costs (Boiler Water Treated = 15% of Total = 0.75 MGD)						
Desalination Costs	$/Year	$300,000	$59,000	$178,000	$122,000	$173,000
Total Sludge and Desalination Costs						
Total Sludge and Desalination Cost	$/Year	$870,000	$340,000	$576,000	$541,000	$614,000
% Decrease from 100% Nueces	%	0.0%	60.9%	33.8%	37.8%	29.4%
Note: PPD = Pounds per Day						

Table 4C.3-10.
Industrial Water Quantity Use Differences for Blends

		Existing 100% Nueces	*100% Texana*	*Texana with 30% Groundwater*	*Texana with 45% Colorado*	*Blend All Three Based on Existing Operations and Contract Maximums*
Cooling Tower Water Blowdown Quantity of Water						
Cooling Tower Cycles		5	10	7	8	7
Cooling Tower Blowdown Quantity	MGD	0.85	0.38	0.57	0.49	0.57
Evaporative Loss	MGD	3.40	3.40	3.40	3.40	3.40
Total Cooling Tower Water	MGD	4.25	3.78	3.97	3.89	3.97
Desalination Quantity of Water Due to Recovery Rate and Quantity of Water Desalinated						
Desalination % of Water Lost	% of Total	10.0	2.0	5.9	4.1	5.8
Quantity of Desalinated Product Water	MGD	0.68	0.68	0.68	0.68	0.68
Desalination Water Lost	MGD	0.07	0.01	0.04	0.03	0.04
Total Desalination Water	MGD	0.75	0.69	0.72	0.71	0.72
Total Water Use Change						
Total Water Use	MGD	5.00	4.47	4.69	4.60	4.69
Quantity Decrease from 100% Nueces	MGD	0.00	0.53	0.31	0.40	0.31
Quantity Decrease from 100% Nueces	acre-ft/yr	0	591	346	452	347
% Decrease from 100% Nueces	%	0.0%	10.6%	6.2%	8.1%	6.2%

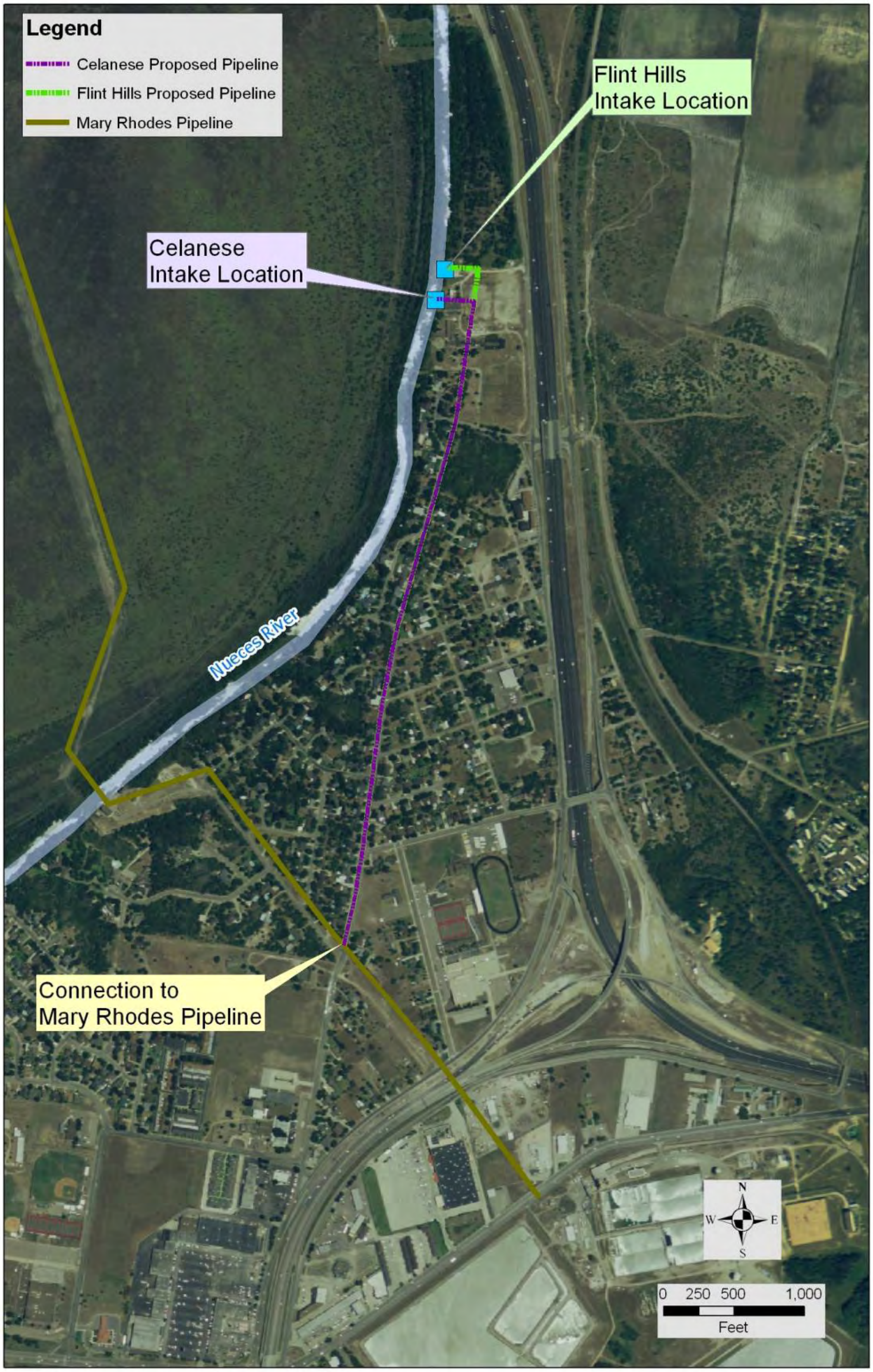


Figure 4C.3-43. MRP Interconnect Pipeline Route

4C.3.7 Environmental Issues

Any major construction undertaken within the Nueces River channel or along the riparian corridor such as intake modifications, building a siphon system to remove high TDS or a pipeline, will have some, though minor, environmental impacts.

Construction of the siphon system will include up to eight intake structures placed in the Nueces River. As the water volumes to be moved by this system will be relatively small (6 MGD, an intake stream of about 1.2 cfs at each of the eight intakes), the intake structures will be small. Disturbance of riparian and riverine habitats due to construction of eight intake structures is expected to total substantially less than one acre. Construction of the approximately 1.7 mile long pipeline to the upper end of Segment 2101 (Nueces River Tidal) will disturb about 6.7 acres of ground cover within a 30 foot wide construction easement. Impacts to riparian areas can be minimized by locating the pipeline outside of the very narrow wooded corridor that lines the left bank of the Nueces River in this reach.

Operation of the siphon system will result in changes in the ambient Nueces River TDS concentrations that are within the tolerance limits of the freshwater fish and invertebrate species of the lower Nueces River. Likewise, the relatively small discharge of Nueces River bottom water into the tidal segment will still be well within the generally accepted freshwater range (i.e., <2,500 mg/L), and will mix with brackish bay waters through tidal action, as is the case with existing Nueces River flows over Calallen Dam.

The operation of the siphon is expected to have a negligible effect on the estuary, as water quality of the releases will be fresh relative to the estuary salinity.

Additional studies should be conducted prior to implementing a siphon system at Calallen Pool to evaluate water quality constituents (other than salinity and TDS) and impacts associated with leaky and abandoned oil wells.

The proposed Lake Corpus Christi to Calallen pipeline corridor would be within Jim Wells and San Patricio Counties. The pipeline is intended to transfer water without using the bed and banks of the Nueces River. The construction of a 21- mile pipeline from LCC to the Calallen Dam would result in soil and vegetation disturbance within the approximately 245 acre pipeline construction corridor. Longer-term terrestrial impacts would be confined to the 105-acre maintained right-of-way. Prior to implementation of this strategy, further studies to evaluate environmental impacts of the project will be required. The major environmental issues related to pumping water via a pipeline from Lake Corpus Christi to Calallen include the effects of changes in Nueces River flows. The remaining flows in the river would include pass throughs to the estuary from Lake Corpus Christi and natural inflows. Further studies would be needed to assess the required flows within the channel to maintain stream habitat and the project's impact on these flows.

All of the options result in conservation of manufacturing water use by improving water quality and thereby increasing the amount of water available for other users. Also, reducing the dissolved solids content of the water entering the manufacturing industries' cooling systems reduces the mineral loading content of the final plant effluent. Plugging leaky and abandoned oil wells reduces hydrocarbon pollution and contamination by saline water to surface and subsurface water.

4C.3.8 Engineering and Costing

4C.3.8.1 Blending Lake Texana Water with Nueces River Water

The blend ratio considered for this option includes 75 percent Nueces River water and 25 percent Texana water, since Lake Texana supplies constitute approximately 25 percent of the safe yield supply of 205,000 acft in 2010.

4C.3.8.2 Outlet Works to Remove High TDS from Calallen Pool

The cost estimate for the pipe system facilities to remove water with high TDS from the bottom of the Calallen Pool is shown in Table 4C.3-11. The total capital cost is estimated at $2,067,000. The project cost is $2,904,000. The total annual cost is estimated to be $273,000. Assuming that the outlet works are implemented in conjunction with blending Texana and Nueces River water for the industries, the additional system yield savings of 150 to 730 acft/yr results in a unit cost ranging from $374 to $1,820 per acft/yr.

4C.3.8.3 Intake Modifications

The benefit of intake modifications is considered in conjunction with the outlet works and siphon pipeline. The approximate capital cost of each intake modification is estimated to range from $260,000 to $1,300,000 per intake. Considering there are four intake structures that would benefit from modification, the capital cost is estimated to be about $3,413,000. The four intakes include one operated by the Celanese Bishop Plant Facility, two by the City of Corpus

Christi and one operated by Nueces County WCID #3. Intake modification with the outlet works is estimated to save an additional 150 to 300 acft/yr for 2010 and 2060. The cost estimate for this control strategy is shown in Table 4C.3-12. The total capital cost is estimated at $5,480,000. The project cost is $7,694,000. The total annual cost is estimated to be $777,000. Therefore the unit cost of water saved is estimated to be about $2,590 to $5,180 per acft per year.

Table 4C.3-11.
Cost Estimate Summary for Outlet Works and Siphon to Remove High TDS from Calallen Pool (September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Siphons , Control Valves and Vaults (8 siphons)	$226,000
Intake at Dam, Valves and Vaults at Intake	946,000
Gravity Pipeline (12”, 14”, 18” and 24” telescopic line)	895,000
Total Capital Cost	**$2,067,000**
Engineering, Contingencies and Legal Costs	$621,000
Environmental & Archaeology Studies and Mitigation	43,000
Pipeline Land Acquisition and Surveying (6.2 acres)	64,000
Interest During Construction (1 year)	108,000
Total Project Cost	**$2,904,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$253,000
Operation and Maintenance	20,000
Total Annual Cost	**$273,000**
Available Project Yield (acft/yr)	**150 to 730**
Total Annual Cost of Water ($ per acft)	**$374 to $1,820**
Annual Cost of Water ($ per 1,000 gallons)	**$1.15 to $5.59**

Table 4C.3-12.
Cost Estimate Summary for Intake Modifications and Outlet Works to Remove High TDS from Calallen Pool (September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Intake Modifications	$3,413,000
Siphons (8), Control Valves and Vaults	226,000
Intake (250 cfs) and Outlet Structure at Dam, Valves and Flow Meters	946,000
Gravity Pipeline (12-, 14-, 18- and 24-inch telescopic line)	895,000
Total Capital Cost	**$5,480,000**
Engineering, Contingencies and Legal Costs	$1,816,000
Environmental & Archaeology Studies, Mitigation, and Permitting	43,000
Pipeline Land Acquisition and Surveying (107 acres)	59,000
Interest During Construction (1 year)	296,000
Total Project Cost	**$7,694,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$671,000
Operation and Maintenance	106,000
Total Annual Cost	**$777,000**
Available Project Yield (acft/yr)	**150 to 300**
Total Annual Cost of Water ($ per acft)	**$2,590 to $5,180**
Annual Cost of Water ($ per 1,000 gallons)	**$7.95 to $15.90**

4C.3.8.4 Pipeline from Lake Corpus Christi to O.N. Stevens Water Treatment Plant

The major facilities needed to deliver 150,000 acft/yr of raw water from Lake Corpus Christi to the Calallen Dam include an intake pump station and 21-mile transmission pipeline. The pipeline capacity was calculated based upon a peak day to average day ratio of 1.75 and is capable of transferring up to 234 MGD. The cost for the facilities is shown in Table 4C.3-13. The total capital cost is estimated at $112,002,000. The total project cost is $159,655,000. The total annual cost is estimated to be $17,184,000. Increases in yield include reduced channel losses (16,500 acft/yr) and increased manufacturing water conservation (3,100 to 6,600 acft/yr), resulting in total savings of between 19,600 and 23,100 acft/yr and a unit cost of $744 to $877 per acft/yr.

4C.3.8.5 Plugging Leaky and Abandoned Oil Wells

Within San Patricio and Nueces Counties, there were 16 wells scheduled to be plugged by the Texas Railroad Commission in 2000 at an average estimated cost of $21,000 per well. It is unknown how many old plugged wells continue to leak and are in need of repair. Additional study is needed to determine the impact of the leaking wells on the lower Nueces River.

Table 4C.3-13.
Cost Estimate Summary for
Pipeline from Lake Corpus Christi to Calallen Dam
(September 2008 Prices)

Item	Estimated Costs
Capital Costs	
Intake and Pump Station (234 MGD)	$13,944,000
Transmission Pipeline (114-inch dia., 21 miles)	98,058,000
Total Capital Cost	**$112,002,000**
Engineering, Contingencies and Legal Costs	$34,298,000
Environmental & Archaeology Studies, Mitigation, and Permitting	536,000
Pipeline Land Acquisition and Surveying (105 acres)	992,000
Interest During Construction (2 years)	11,827,000
Total Project Cost	**$159,655,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$13,919,000
O&M: Intake, Pipeline, Pump Station	1,329,000
Pumping Energy Costs (21,513,004 kWh @ $0.09 per kWh)	1,936,000
Total Annual Cost	**$17,184,000**
Available Project Yield (acft/yr)	**19,600 to 23,100**
Total Annual Cost of Water ($ per acft)	**$744 to $877**
Annual Cost of Water ($ per 1,000 gallons)	**$2.28 to $2.69**

4C.3.8.6 Potential Interconnections to the Mary Rhodes Pipeline

4C.3.8.6.1 Pipeline Cost Estimate

The cost estimate shown in Table 4C.3-14 assumes there is adequate residual pressure in the MRP at the point of connection to transfer 5 MGD of water from MRP to a new ground storage tank located adjacent to the existing Celanese and Flint Hills pump stations. These existing raw water pump stations will be used to draw MRP water from the new ground storage tank and pump to Celanese and Flint Hills through existing pipelines that are currently transmitting raw Nueces water to the respective industrial facilities. The estimate includes a new 1 mile long, 16 inch pipeline to connect MRP to a new ground storage tank that is sized at 5% of total flow (250,000 gallons).

4C.3.8.6.2 Summary Cost Differences for Implementation of MRP Interconnect

Table 4C.3-15 contains a summary of the overall cost differences estimated between the current water supply consisting of 100% Nueces water versus the construction costs of a new interconnect to MRP and the associated potential water treatment cost savings for the blended water supplies from MRP. The "Net Cost Savings at Same Quantity" is determined by subtracting the new costs associated with constructing the MRP interconnect pipeline and tank shown in Table 4C.3-15 ($132,000/yr) from the cost savings associated with improvements in water quality for each blend scenario that will lower treatment costs. The unit cost savings per acft assuming the full 5 MGD (5,600 acft/yr) of water continues to be used by industries after changing the water supply to a blend delivered directly from MRP is calculated by dividing the annual cost savings by 5,600 acft/yr to determine the cost savings per acft. To capture some of the additional cost savings associated with a lower quantity of water necessary when utilizing blend water from MRP, a current water supply cost of 400 $/acft was assumed for the water supply currently consisting of 100% Nueces water. This current assumed Nueces water supply cost includes the treatment and delivery costs. A revised unit water cost with MRP blends is calculated by subtracting the "Net Cost Savings per acft" associated with lowered treatment costs for the MRP blends. The "Total Cost Savings with MRP" in $/year is the difference between the current water costs with 100% Nueces minus the estimated water costs determined from the lowered treatment costs and lowered quantity of water required.

Table 4C.3-14.
MRP Interconnect Pipeline and Tank Cost Estimate - 5 MGD Supply
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pipeline (16 in dia., 1 miles)	$709,000
Storage Tank (0.25 MG)	$255,000
Total Capital Cost	**$964,000**
Engineering, Legal Costs and Contingencies	$302,000
Environmental & Archaeology Studies and Mitigation	$34,000
Land Acquisition and Surveying (6 acres)	$46,000
Interest During Construction (1 years)	$54,000
Total Project Cost	**$1,400,000**
Annual Costs	
Debt Service (6 percent, 20 years)	$122,000
Operation and Maintenance	
Pipeline, Tank	$10,000
Total Annual Cost	**$132,000**
Available Project Yield (acft/yr)	5,000 to 5,250
Annual Cost of Water ($ per acft)	$26
Annual Cost of Water ($ per 1,000 gallons)	$0.08

Table 4C.3-15.
Summary Cost Differences for Implementation of MRP Interconnect

		Existing 100% Nueces	100% Texana	Texana with 30% Groundwater	Texana with 45% Colorado	Blend All Three Based on Existing Operations and Contract Maximums
Total Sludge and Desalination Cost Savings (Addition)						
Total Sludge and Desalination Cost	$/yr	$870,000	$340,000	$576,000	$541,000	$614,000
Cost Difference from 100% Nueces	$/yr	$0	$530,000	$294,000	$329,000	$256,000
Pipeline and Tank Capital Debt Service and O&M Total Annual Cost (Subtraction)						
Total Annual Cost	$/yr	$0	$132,000	$132,000	$132,000	$132,000
Net Cost Savings at Same Quantity = Total Sludge and Desalination Cost Savings - Pipe and Tank Cost						
Net Cost Savings	$/yr	$0	$398,000	$162,000	$197,000	$124,000
Current Water Use	acft/yr	5,600	5,600	5,600	5,600	5,600
Cost Savings per acft	$ / acft	$0	$71	$29	$35	$22
Total Cost Savings Including Water Use Quantity Change						
Current Assumed Unit Water Cost	$/acft	$400	$400	$400	$400	$400
Current Water Use	acft/yr	5,600	5,600	5,600	5,600	5,600
Total Current Water Cost	$/yr	$2,240,000	$2,240,000	$2,240,000	$2,240,000	$2,240,000
Quantity Decrease from 100% Nueces	acft/yr	0	591	346	452	347
Revised Water Use with MRP Blend	acft/yr	5,600	5,009	5,254	5,148	5,253
Revised Unit Water Cost with MRP	$/acft	$400	$329	$371	$365	$378
Revised Total Water Cost with MRP	$/yr	$2,240,000	$1,650,000	$1,950,000	$1,880,000	$1,980,000
Total Cost Savings with MRP Blend	$/yr	$0	$590,000	$290,000	$360,000	$260,000

The total yearly estimated cost savings for industrial users currently treating 100% Nueces changing to a water supply from MRP was highest at $590,000/year if the water delivered from MRP is 100% Texana water as is currently delivered in MRP. The estimated cost savings decrease if water supplies from Gulf Coast groundwater and/or Colorado River water are blended in the future. The cost savings decrease as the proportion of Texana water decreases because the other water sources have relatively high concentrations of hardness, TDS, and chloride relative to Texana. The lowest estimated cost savings is for the blending scenario with all three water sources at $260,000/year because this scenario has the lowest proportion of Texana water delivered in MRP. The project costs to implement future water supply projects for delivery through the MRP such as Garwood (Colorado River water) and Gulf Coast groundwater projects was not included in the cost estimate. It is assumed that such projects would be funded by wholesale water providers and included in customer water rates.

4C.3.9 Implementation Issues

4C.3.9.1 Blending of Texana Water

With current contracts, the water supply from Lake Texana is approximately 25% of the safe yield supply. Blending of Lake Texana water with Nueces River water is already occurring and local industries that currently do not benefit from these water quality improvements should consider water pumping facilities to allow for blending.

4C.3.9.2 Outlet Works to Remove High TDS from Calallen Pool

Releases of water from the Calallen Pool through the siphon line should contribute towards Lake Corpus Christi's Bay and Estuary release credits. Permits and potential mitigation requirements would be needed for construction of the pipeline and Calallen Dam bypass. The construction of the outlet works may require an USCOE Section 404 Permit and would require cultural resource studies along the pipeline route.

4C.3.9.3 Intake Modifications

Intake modifications within the Nueces River channel may require an USACE Section 404 permit. Also, major modifications may require the intake pump station to be out of service for a portion of the construction period. However, it is possible to complete the construction in phases in order to minimize or eliminate down time.

4C.3.9.4 Pipeline from Lake Corpus Christi to the O.N. Stevens Water Treatment Plant

The primary implementation issue that would need to be addressed would be the impact of the reduced flows in the Nueces River downstream of Lake Corpus Christi. An evaluation of the impacts of reduced flows on the river and riparian water rights would have to 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. Also, before a significant expenditure of funds would be considered for this alternative, a detailed long-term investigation of channel losses should be undertaken to fully understand the seasonality and variability of channel losses that occur within the river reach. Additional implementation issues for the development of a water supply from Lake Corpus Christi to Calallen include:

- USCOE Sections 10 and 404 dredge and fill permits for the pipelines.
- GLO Sand and Gravel Removal permit for pipeline stream crossings.
- GLO Easement for use of State-owned land (if any).
- TPWD Sand, Gravel, and Marl permit.
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.
- Cultural resource studies would need to be performed along the pipeline route.

4C.3.9.5 Plugging Leaky and Abandoned Oil Wells

Although the Texas Railroad Commission conducts an active well plugging program, the extent of contamination from these wells to surface waters prior to plugging is unknown. Also, it is possible that there are many undetected leaking wells that were plugged decades ago, but have since degraded. It is an important issue to investigate this possible contamination source.

4C.3.9.6 Potential Interconnections to the Mary Rhodes Pipeline

Although this strategy would reduce water quality fluctuations that industries with intakes in the Calallen Pool have been experiencing, implementation of this strategy would reduce the amount of Mary Rhodes Pipeline supplies currently delivered to the City of Corpus Christi O.N. Stevens Water Treatment Plant and could impact water quality for wholesale water providers and their customers.

4C.3.10 Evaluation Summary

Evaluation summaries of this regional water management strategy are provided in Tables 4C.3-16 and 4C.3-17.

Table 4C.3-16.
Evaluation Summary of Manufacturing Water Conservation Strategies

Impact Category	***Comment(s)***
a. Water Supply	
1. Quantity	1. Estimated savings are shown in Table 4C.3-17.
2. Reliability	2. Unknown – additional studies needed.
3. Cost of Treated Water	3. Unit costs are shown in Table 4C.3-17.
b. Environmental factors	
1. Instream flows	1. Some impact since pipeline to Lake Corpus Christi would reduce flows in Lower Nueces River.
2. Bay and Estuary Inflows	2. Return flows of about 10,000 to 12,000 acft/yr would increase flows to the Nueces Estuary.
3. Wildlife Habitat	3. Possible minor impacts to wildlife habitat from construction of facilities.
4. Wetlands	4. Possible benefit to wetlands due to enhanced water quality.
5. Threatened and Endangered Species	5. Pipeline to Lake Corpus Christi would require detailed studies of Lower Nueces River to determine impacts to threatened and endangered species.
6. Cultural Resources	6. Cultural resource investigations should be conducted along pipeline route to evaluate impacts. Cultural resources will need to be avoided when facilities are constructed.
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. During drought conditions sampling indicates worsening of water quality. Water quality improvements benefit manufacturing and municipal entities, and Nueces Bay and Estuary. The CBRWPG identified six water quality concerns associated with manufacturing water conservation strategy, as described below. a. Water quality improvement projects will reduce total dissolved solids. b. None or low impact. c. None or low impact. d. Water quality improvement projects will reduce chloride levels in Lower Nueces River.

Table 4C.3-16 (Concluded)

Impact Category	***Comment(s)***
7. Water Quality (continued)	e. Water quality improvement projects will reduce bromide levels in Lower Nueces River. f. Further studies should be conducted to determine impacts of water quality improvement projects on sulfate levels in Lower Nueces River. g. None or low impact. h. None or low impact. i. CBRWPG also identified dissolved oxygen and hardness as water quality concerns related to this water management strategy. Dissolved oxygen decreases with depth within the channel. The Nueces River Dissolved Minerals Study addresses this concern. Hardness can be reduced by implementation of water quality improvement projects.
c. Impacts to State water resources	• No significant impacts.
d. Threats to agriculture and natural resources in region	• None
e. Recreational impacts	• None, except pipeline to Lake Corpus Christi would reduce flows in Lower Nueces River.
f. Equitable Comparison of Strategies	• Water quality improvements benefit both manufacturing and municipal entities.
g. Interbasin transfers	• None.
h. Third party social and economic impacts from voluntary redistribution of water	• None.
i. Efficient use of existing water supplies and regional opportunities	• Increases existing system efficiency.
j. Effect on navigation	• None

Table 4C.3-17.
Summary of Water Quality Control Strategies

Water Options	***Amount of Water Conserved (acft/yr)***	***Total Annual Cost of Water ($ per acft)***
1. Blending of Lake Texana Water with Nueces River Water	940 to 2,050	None*
2. Outlet Works to Remove High TDS from the Calallen Pool	150 to 730	$374 to $1,820
3. Modification to Existing Intakes	150 to 300	$2,590 to $5,180
4. Pipeline from Lake Corpus Christi to Calallen	19,600 to 23,100	$744 to $877
5. Potential Interconnections to MRP	346 to 591	$26
* No additional costs to be incurred unless additional water is purchased from LNRA from Lake Texana.		

4C.4 Mining Water Conservation (N-4)

4C.4.1 Description of Strategy

Water for mining uses is primarily associated with oil and gas extraction, coal mining, metal mining, and nonmetallic mineral operations. Gross state domestic product data released from the U.S. Department of Commerce showed mining economic outputs of $114.1 billion for 2007 and $138.4 billion for 2008.[1] Individual county data is not readily available. The TWDB water demand projections for mining users is generally based on projected economic output, assuming that past and current water use trends remain constant over time.

For this round of regional water planning, the TWDB did not provide updates to water demand projections for mining industries. The mining water demand projections used in this plan for the Coastal Bend Region are the same as those used in the 2006 Regional Water Plan.

In the Coastal Bend Region, the trends for mining water demands are projected to increase each decade with a maximum demand of 19,114 acft by 2060, as shown in Figure 4C.4-1. The increase in water demand is due to anticipated economic growth in mining activities in the Coastal Bend Region. Duval, Live Oak, and Kleberg Counties have the largest projected mining water demands, constituting 85 percent of the regional mining water demand (Figure 4C.4-2).

In the Coastal Bend Region, 10 of the 11 counties (except Nueces County) receive their full mining water supply from groundwater sources. Nueces County mining users receive groundwater and surface water supplies from the City of Corpus Christi.

In the Coastal Bend Region, three counties (Duval, Live Oak, and Nueces) are projected to have mining needs (shortages) during the 2000 to 2060 planning period, as shown in Table 4C.4-1. Groundwater supply for Duval County-Mining is limited by Coastal Bend Region drawdown criteria, described in Section 3.4. Duval County-Mining can receive 51 percent of their projected water demand in 2060 and still meet drawdown criteria, resulting in a shortage of 4,205 acft in 2060. Similarly, Live Oak County-Mining has a shortage of groundwater supplies limited by Coastal Bend Region drawdown criteria. Live Oak-Mining can receive 67 percent of their projected groundwater use in 2060 and still meet drawdown criteria, resulting in a shortage of 1,755 acft in 2060. Nueces County-Mining has a shortage of surface water supplies limited by treatment capacity of the City of Corpus Christi's O.N. Stevens WTP.

[1] Bureau of Economic Analysis, U.S. Department of Commerce.

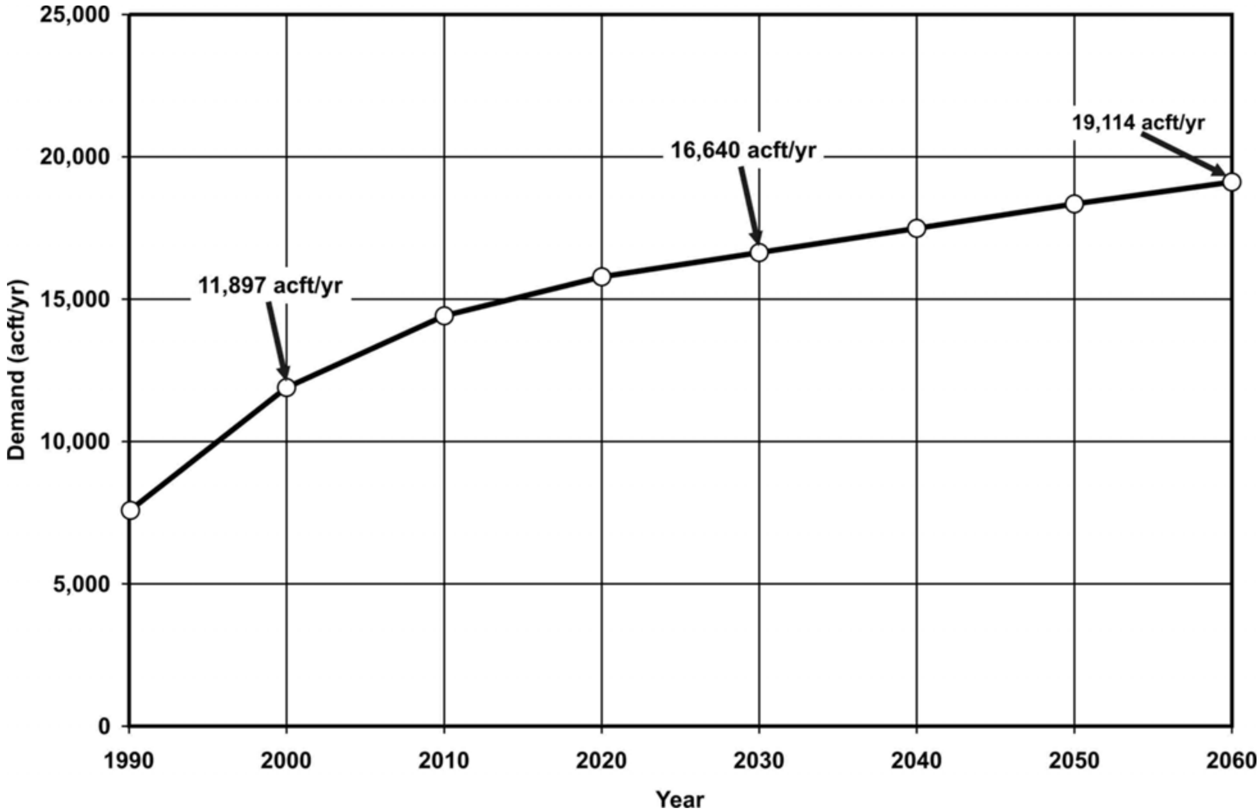


Figure 4C.4-1 Coastal Bend Region Mining Water Demand Projections

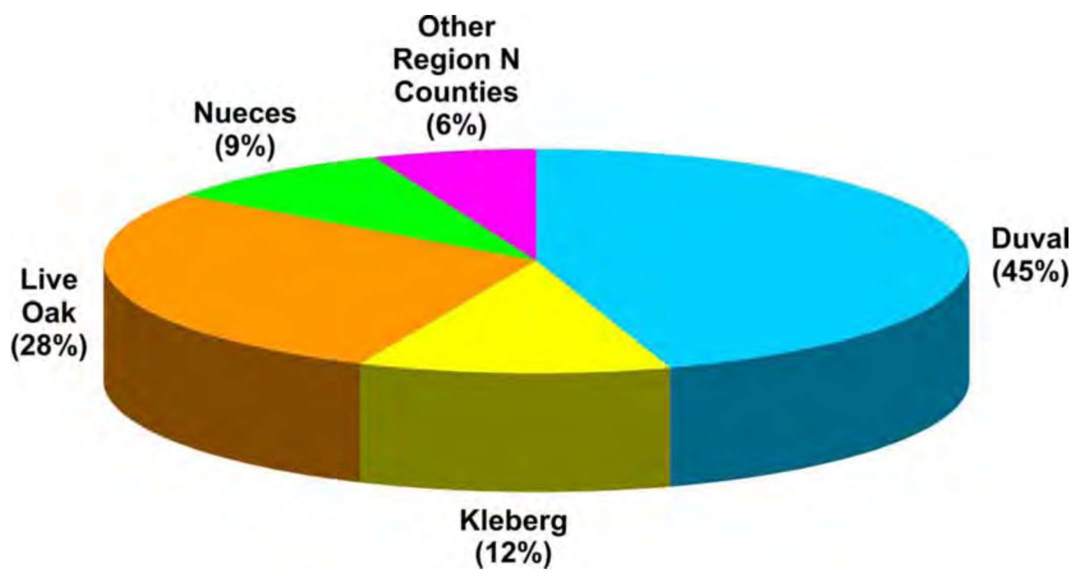


Figure 4C.4-2. 2060 Percentages of Mining Water Demand by County Total Demand for Coastal Bend Region—19,114 acft

Table 4C.4-1.
Projected Water Demands, Supplies, and Water Needs (Shortages) for Mining Users Duval, Live Oak, and Nueces Counties

	Water Projections						
	2000 (acft)	***2010 (acft)***	***2020 (acft)***	***2030 (acft)***	***2040 (acft)***	***2050 (acft)***	***2060 (acft)***
Duval							
Mining Demand	4,544	5,860	6,630	7,119	7,610	8,108	8,553
Mining Existing Supply							
Groundwater	4,544	4,122	4,112	4,146	4,224	4,299	4,348
Surface water	—	—	—	—	—	—	—
Total Mining Supply	4,544	4,122	4,112	4,146	4,224	4,299	4,348
Mining Balance	—	(1,738)	(2,518)	(2,973)	(3,386)	(3,809)	(4,205)
Live Oak							
Mining Demand	3,105	3,894	4,319	4,583	4,845	5,108	5,341
Mining Existing Supply							
Groundwater	3,105	3,830	3,841	3,655	3,611	3,604	3,586
Surface water	—	—	—	—	—	—	—
Total Mining Supply	3,105	3,830	3,841	3,655	3,611	3,604	3,586
Mining Balance	—	(64)	(478)	(928)	(1,234)	(1,504)	(1,755)
Nueces							
Mining Demand	1,275	1,472	1,555	1,599	1,641	1,682	1,724
Mining Existing Supply							
Groundwater	74	85	90	93	95	98	100
Surface water	1,201	1,387	1,465	936	—	—	—
Total Mining Supply	1,275	1,472	1,555	1,029	95	98	100
Mining Balance	—	—	—	(570)	(1,546)	(1,584)	(1,624)

TWDB Rules for regional water planning require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). In addition, the Rules direct water conservation BMPs, as identified by the Water Conservation Implementation Task Force (Task Force), be considered in the development of the water conservation water management strategy.

4C.4.2 Available Yield

As part of the 2006 regional water planning process, the CBRWPG recommended that counties with projected mining needs (shortages) reduce their mining water demands by 15 percent by 2060 using BMPs identified by the Task Force. A 15 percent reduction in mining water demand by 2060, results in a maximum savings of 2,343 acft, as shown in Table 4C.4-2.

Table 4C.4-2.
Projected Water Demands and Needs (Shortages) for
Mining Users Considering a 15 Percent Demand Reduction by 2060
Duval, Live Oak, and Nueces Counties

	Water Projections					
	2010 (acft)	*2020 (acft)*	*2030 (acft)*	*2040 (acft)*	*2050 (acft)*	*2060 (acft)*
Duval						
New Demand	5,714	6,299	6,585	6,849	7,095	7,270
Expected Savings	147	332	534	761	1,014	1,283
New Shortage	(1,592)	(2,187)	(2,439)	(2,625)	(2,796)	(2,922)
Shortage Reduction	8%	13%	18%	22%	27%	31%
Live Oak						
New Demand	3,797	4,103	4,239	4,361	4,470	4,540
Expected Savings	97	216	344	485	639	801
New Shortage	—	(262)	(584)	(750)	(866)	(954)
Shortage Reduction	100%	45%	37%	39%	42%	46%
Nueces						
New Demand	1,435	1,477	1,479	1,477	1,472	1,465
Expected Savings	37	78	120	164	210	259
New Shortage	—	—	(450)	(1,382)	(1,374)	(1,365)
Shortage Reduction	—	—	21%	11%	13%	16%
Total Mining Savings (Region)	**244**	**547**	**938**	**1,369**	**1,841**	**2,343**

The Task Force report lists the following industrial BMPs that may be used to achieve the recommended water savings:[2]

1. Industrial Water Audit
2. Industrial Water Waste Reduction
3. Industrial Submetering
4. Cooling Towers
5. Cooling Systems (other than Cooling Towers)
6. Industrial Alternative Sources and Reuse and Recirculation of Process Water
7. Rinsing/Cleaning
8. Water Treatment
9. Boiler and Steam Systems
10. Refrigeration (including Chilled Water)
11. Once-Through Cooling
12. Management and Employee Programs
13. Industrial Landscape
14. Industrial Site Specific Conservation

The Task Force report describes the above BMP methods and how they reduce water use, however information regarding specific water savings and costs to implement conservation programs is generally unavailable. Conservation savings and costs are by nature facility specific. Since mining entities are presented on a county basis and are not individually identified, identification of specific water management strategies are not a reasonable expectation.

4C.4.3 Environmental Issues

The Task Force BMPs have been developed and tested through public and private sector research, and have been applied within the region. Such programs have been installed, and are in operation today, and are not expected to have significant environmental issues associated with implementation. For example, most BMPs improve water use efficiency without making changes to wildlife habitat. Thus, the proposed conservation practices do not have anticipated potential adverse effects, and in fact have potentially beneficial environmental effects.

[2] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board,

4C.4.4 Engineering and Costing

Consistent with the approach used in the 2006 Plan, the CBRWPG recommends implementing water conservation for mining users with shortages to reduce their water demand by 15 percent by 2060. The three counties with projected shortages (Duval, Live Oak, and Nueces) can save up to 2,343 acft in 2060. Costs to implement BMPs vary from site to site and the Coastal Bend Region recognizes that mining industries will pursue conservation strategies that are economically feasible with water savings benefits. For this reason, it is impractical to evaluate the costs of implementing mining water conservation strategies.

4C.4.5 Implementation Issues

Demand reduction through water conservation is being implemented throughout the Coastal Bend Region. The rate of adoption of efficient water-using practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing.

There is public support for mining water conservation and it is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach greater potentials. The TWDB has industrial water conservation programs including presentations and workshops for utilities who wish to train staff to develop local programs including water use site surveys, publications on industrial water reuse potential, and information on tax incentives for industries that conserve or reuse water. Future planning efforts should consider the use of detailed studies to fully determine the maximum potential benefits of mining conservation.

4C.4.6 Evaluation Summary

An evaluation summary of this water management option is provided in Table 4C.4-3.

Table 4C.4-3.
Evaluation Summary of Mining Water Conservation

Impact Category	*Comment(s)*
a. Water Supply 1 Quantity 2. Reliability	 1. Firm Yield: 2,343 acft/yr 2. Cost: Highly variable based on BMP selected and facility specifics.
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. None or low impact. 2. None or low impact. 3. None or low impact. 4. None or low impact. 5. None. 6. No cultural resources affected. 7. None or low impact.
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	• None
h. Third party social and economic impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions by reducing the rate of decline of local groundwater levels.
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

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4C.5 Reclaimed Wastewater Supplies (N-5)

4C.5.1 Description of Strategy

A part of the quantity of water that is used for municipal and industrial purposes is consumed and a part is used for sanitary waste removal from homes, and for sanitary and process-related water use in commercial and industrial establishments. In the Coastal Bend Area, wastewater is collected, treated to acceptable standards as specified by regulatory agencies—Texas Commission on Environmental Quality (TCEQ) and U.S. Environmental Protection Agency (EPA)—and is either reused for non-potable purposes such as industrial uses or golf course irrigation or discharged to some receiving water. In the Corpus Christi area, significant treated effluent quantities are discharged into streams that flow into the bays and meet a part of the freshwater needs of the Nueces Estuary. The purpose of this section is to describe reclaimed wastewater reuse options and present estimates of the quantities of water supply that may be made available through: (1) wastewater reuse for municipal and industrial non-potable purposes; (2) wastewater diversions to the Nueces Delta to enhance biological productivity of estuarine marshes (in comparison to the present practice of direct discharge of wastewater into the bays and into streams that flow into the bays); and (3) discussions of wastewater reuse and water conservation effects upon estuarine inflows.

Both reuse and diversion to the Nueces Delta present opportunities to increase the Corpus Christi area water supply. In the Interim Order[1] of March 9, 1992, the TCEQ established temporary operational procedures for the City's reservoirs that included a monthly schedule of minimum desired inflows to Nueces Bay. The 1992 Interim Order directed studies of the effects of freshwater releases upon the estuary and the feasibility of relocating wastewater discharges to the upper estuary locations where increased biological productivity could justify an inflow credit computed by multiplying the amount of discharge by a number greater than one. These studies included the Allison Wastewater Treatment Plant (WWTP) Demonstration Project.

[1] Interim Order Establishing Operational Procedures Pertaining to Special Condition 5.B, Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, Nueces River Authority, and the City of Three Rivers, Texas Water Commission (now TCEQ), Austin, Texas, March 9, 1992.

On April 28, 1995, the TCEQ replaced the 1992 Interim Order with an Agreed Order[2] (1995 Agreed Order) amending the Choke Canyon Reservoir/Lake Corpus Christi (CCR/LCC) System operational procedures. The 1995 Agreed Order directed the Nueces Estuary Advisory Council (NEAC) to continue studying the development of a methodology using a multiplier system for granting credits for specific return flows that increase biological productivity.

On April 17, 2001, the TCEQ issued an amendment to the 1995 Agreed Order to revise operational procedures in accordance with revisions requested by the City of Corpus Christi. Changes included: (1) passage of inflows to Nueces Bay and Estuary at 40 percent and 30 percent reservoir system capacity upon institution of mandatory outdoor watering restrictions; (2) calculating reservoir system storage capacity based on most recently completed bathymetric surveys; and (3) provisions for operating Rincon Bayou diversions and conveyance facility from Calallen Pool to enhance the amount of freshwater to the Nueces Delta. Nueces Delta projects, such as Rincon Bayou and Allison WWTP Demonstration Projects, include the following potential benefits: increased water supply, increase positive flow events for Nueces Delta, and increased sources of nitrogen and lower salinity levels for the upper delta. A study completed in 2006[3] outlined the positive benefits of the Allison WWTP Demonstration Project. This report concluded that there was an increase in vegetation and creation of additional areas of salt marsh which was accompanied by more shorebirds being attracted to the area. The report also noted that with the additional water diverted to the marsh area, there was an approximately 50 percent removal of wastewater discharge into the Nueces River, reducing the potential for nutrient driven algal blooms. To evaluate the potential benefits, the 2001 Agreed Order included implementation of an ongoing monitoring program to facilitate an adaptive management program for freshwater inflows to the Nueces Estuary. NEAC prepared a recommended monitoring plan in July 2002, which was initiated in 2003.[4]

The Rincon Bayou Diversion Pipeline and Pump Station (Rincon pipeline) was constructed by the City of Corpus Christi pursuant to the 2001 Agreed Order and became operational in November 2007. Although not required by the Agreed Order, the City is in the

[2] Agreed Order Establishing Operational Procedures Pertaining to Special Condition 5.B., Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, Nueces River Authority, and the City of Three Rivers, Texas Natural Resource Conservation Commission, Austin, Texas, April 26, 1995.
[3] Concluding Report: Allison Wastewater Treatment Plant Effluent Diversion Demonstration Project, Volume I: Executive Summary. The University of Austin, Marine Science Institute, Port Aransas, Texas and Texas A&M University-Corpus Christi, Center for Coastal Studies, Corpus Christi, Texas, 2006.
[4] City of Corpus Christi, Final Integrated Monitoring Plan Fiscal Year 2005, January 2005.

process of developing an operations plan for the Rincon pipeline to provide inflow to the Upper Rincon Bayou. Salinity monitors have been positioned throughout the estuary to tract flow rate and retention time of water diverted through the Rincon Pipeline. A discussion of additional monitoring studies of the Nueces Delta is included in Section 4C.5.7.3.

A literature review of recent Nueces Bay and Estuary studies is included in Appendix J. The City continues to provide on-going funding for biological studies of the Nueces Bay and Estuary.[5]

These agreements and their history are very important and must be considered in water supply planning, water reuse options, and water management programs for the Corpus Christi area. In the following subsections of this report, estimates of the quantities of municipal and industrial wastewater currently discharged are presented, and wastewater reuse practices and plans by cities and industries, and potential wastewater diversion to the Nueces Delta are described.

4C.5.2 Inventory and Location of Existing Wastewater Sources

There are about 62 active, permitted domestic and industrial WWTP discharges that discharge to the Nueces Estuary System in the 11-county Coastal Bend Region. These domestic and industrial discharges total about 252,650 acft/yr, based on annual discharges summarized in the TCEQ and Nueces River Authority's 2008 Effluent Monitoring Report (Table 4C.5-1). Figure 4C.5-1 shows the location of the City of Corpus Christi WWTPs, which are the major municipal discharges into the system. Of the 252,650 acft, major municipal/domestic discharges generate about 43,179 acft/yr and are italicized in Table 4C.5-1 (17 percent), while industrial discharges generate about 209,471 acft/yr (83 percent).

4C.5.3 Local Wastewater Treatment Plant Considerations

Since the 1995 Trans-Texas Water Program Study, the City of Corpus Christi has initiated some programs related to their wastewater facilities plan that may impact analyses of alternatives for diversions of effluent to the Nueces Delta. The changes include potentially closing the Broadway WWTP and pump all flows to the Greenwood WWTP, the construction and operation of the Allison WWTP Nueces Delta Demonstration Project, and assessing the diversion of Greenwood WWTP effluent to the Nueces Delta.

[5] The City's 2009 – 2010 budget includes $250,000 for on-going studies of the Nueces Bay, Estuary, or Delta areas.

Table 4C.5-1.
Summary of Annual Permitted Wastewater Discharges for 2008 into the Corpus Christi Bay and Nueces Bay System[1,2]

Facility	Acre-Feet Discharged
City of Woodsboro	*128.17*
City of Odem	*127.47*
City of Sinton	*385.40*
City of Corpus Christi – Allison Plant (Nueces River Tidal)	*1,050.17*
Texas Department of Transportation	0.21
St. Paul WSC	*49.89*
San Patricio Co. Municipal Utility District #1	*12.95*
City of Orange Grove	*140.19*
Bishop Consolidated Independent School District	*2.43*
City of Agua Dulce	*33.13*
City of Driscoll	*46.48*
Nueces Co. Water Conservation & Improvement District #5	*80.65*
Teen Challenge of South Texas	*5.80*
City of Rockport	*982.09*
Town of Bayside	*7.87*
City of Taft	*417.07*
Nueces Co. Water Conservation & Improvement District #4	*1,066.65*
U.S. Dept of Navy	572.95
City of Gregory	*161.67*
City of Ingleside	*805.02*
E.I. Dupont de Nemours & Co.	2,417.21
Occidental Chemical Corp.	1,353.47
City of Portland	*1,600.92*
Sublight Enterprises	1.34
Aker Gulf Marine Fabricators	9.73
City of Aransas Pass	*425.69*
Citgo Refining & Chemicals	29,448.30
Citgo Refining & Chemicals	2,714.68
Citgo Refining & Chemicals,	6,563.21
City of Corpus Christi – Broadway	*5,437.15*
Coastal Refining & Marketing	2,285.88
Holiday Beach WSC	*24.60*
Reynolds Metals Company	0.00
City of Corpus Christi- Allison Plant (Nueces Bay)	*1,915.60*

Table 4C.5-1 (Concluded)

Facility	***Acre-Feet Discharged***
Martin Operating	1.76
American Chrome	5,427.94
Trigeant Ltd.	10.26
Valero Logistics Operations	0.00
San Diego MUD #1	*316.61*
Javelina Company	0.00
Flint Hills Resources, LP	2,542.49
Equistar Chemicals, L.P.	943.99
Valero Refining Company, Texas LP	2,109.93
City of C.C. Peoples Baptist Church	*11.06*
City of Corpus Christi – Oso Plant	*12,506.94*
City of Corpus Christi – Greenwood	*6,913.28*
City of Corpus Christi – Laguna Madre	*1,993.55*
City of Robstown	*1,178.76*
Duval County CRD	*3.85*
Tennessee Pipeline Co.	2.37
Texas A & M University System Shrimp Mariculture Research	*12.53*
City of Corpus Christi – White Cap	*892.16*
City of Alice	*1,691.88*
City of Alice	*615.25*
City of Kingsville	*1,421.88*
Kleberg County	*5.09*
Kleberg County	*19.99*
Rivera Water Conservation & Improvement District	*36.73*
U.S. Dept. of Navy	132.82
Ticona Polymers, Inc	152,932.57
City of Bishop	*252.31*
City of Kingsville	*399.75*
Total Discharges	252,649.78

[1] These wastewater dischargers are recognized by the Nueces River Authority and the TCEQ as contributors to freshwater inflows to the Nueces Estuary System.

[2] Annual wastewater discharged, in acft, for 2008. Total Municipal/Domestic discharges – 43,178.89 acft. Total Industrial Discharges – 209,470.89 acft. *Italicized facilities were included in total municipal/domestic discharge calculation.*

Source: TCEQ and Nueces River Authority's 2008 Effluent Monitoring Report.

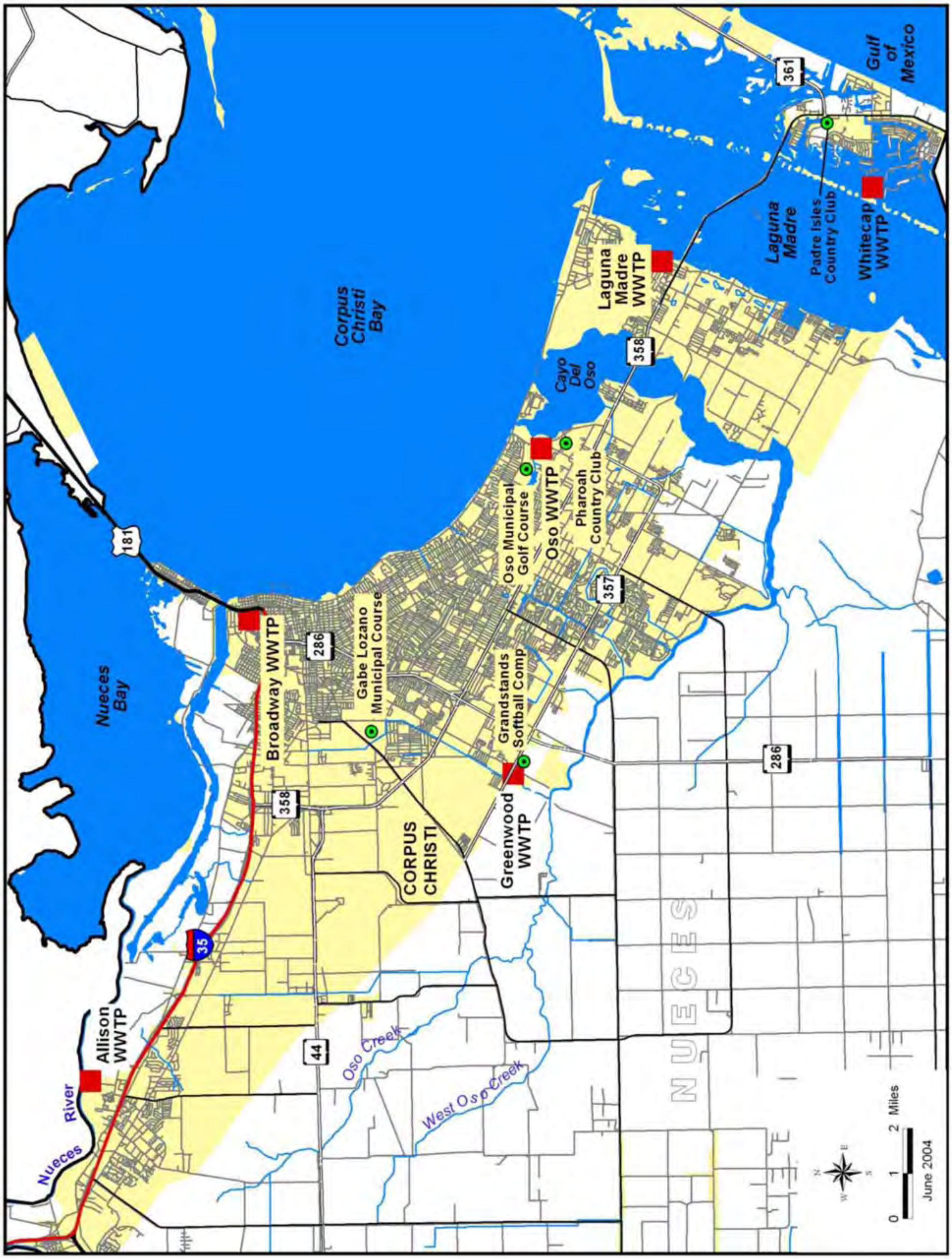


Figure 4C.5-1. City of Corpus Christi Wastewater Treatment Plants

In mid-1997, the City began preparing a plan to work with State and Federal agencies involved with the Agreed Order that would provide the freshwater flow needs of the Nueces Bay System during drought conditions through diversions of treated wastewater effluent, rather than the passage of CCR/LCC System inflows. The strategy involved constructing and operating facilities to divert both industrial and municipal wastewater effluents to locations in the Nueces Delta based on the productivity benefits determined by the preliminary findings from the Allison WWTP Project.

In 1997 to 1998, the City constructed a pipeline from the Allison WWTP to the Nueces Delta as part of a demonstration project to assess the impact of the WWTP effluent on the estuary. The Allison WWTP Demonstration Project was completed and in October 1998, the City began diverting approximately 2 million gallons per day (or 2,240 acft/yr) of effluent from Allison WWTP to the Nueces Delta. Intensive data collection programs were conducted for 5 years (from 1999 to 2003) and the final summary report was issued in 2006 summarizing study results.[6]

The 2001 Agreed Order allows the City relief from inflow requirements when the reservoir system is below 30 percent and Drought Condition III has been implemented, however return flows directed at the Nueces Bay and/or Nueces Delta shall continue. The changes in the operating plan increase the freshwater availability for Nueces Bay through return flows during drought conditions and increase the amount of dependable water supply available from the CCR/LCC System for municipal and industrial use.

An important issue associated with any diversion of domestic wastewater to the Nueces Delta is the level of wastewater treatment necessary for the wastewater diverted. Studies to date have shown that the enhancement of productivity in the Delta is dependent upon the volume of freshwater flow and concentration of nutrients in the wastewater; therefore, effluent treated to a higher quality may prove to be less effective for primary production in the Delta. Thus, the cost savings in wastewater treatment to remove more nutrients would lower the overall costs of implementing projects to divert wastewater to the Nueces Delta and thereby further reduce the costs of yield recovered from the CCR/LCC System.

[6] City of Corpus Christi, "Concluding Report: Allison Wastewater Treatment Plant Effluent Diversion Demonstration Project, Volume I: Executive Summary and Volume II: Monitoring Results 1997-2003," October 2006.

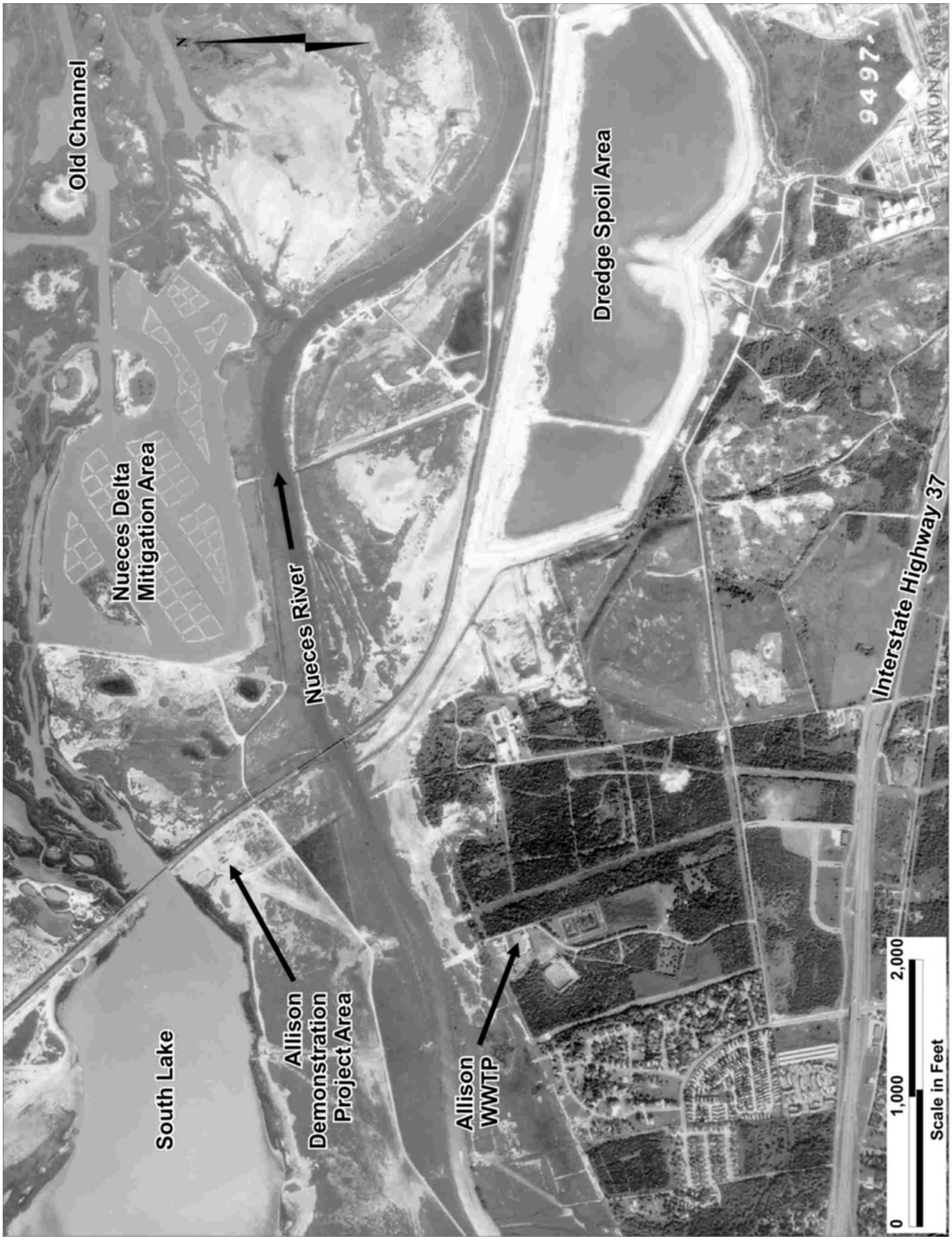
In January 2004, a study[7] was conducted to evaluate groundwater discharge to the Nueces Bay and quantify the potential nutrient flow to the Bay from groundwater. Nitrate concentrations were used to measure nutrients. The results indicated between 15,000 to 40,000 kg of nitrate are released to the Nueces Bay through groundwater discharge. This estimate is only exceeded as a source of nitrogen by treated wastewater return flows.

4C.5.4 Choke Canyon/Lake Corpus Christi Yield Recovery through Diversion of the City of Corpus Christi Wastewater Treatment Plant Effluent and/or Freshwater River Diversions through the Rincon Pipeline to the Nueces Delta

4C.5.4.1 Description of Project

The 1992 Interim Order established operational procedures and included a monthly schedule of desired inflows to Nueces Bay to be comprised of releases, spills, and return flows from the CCR/LCC System. The 1992 Interim Order directed studies of several topics including effects of releases upon the reservoir system and the feasibility of relocating wastewater discharges to locations where increased biological productivity could justify an inflow credit computed by multiplying the amount of discharge by a number greater than one.[8] Studies have been conducted to evaluate increased productivity from diverting a combination of Nueces River water and wastewater through the Nueces Delta to Nueces Bay instead of releasing river and wastewater flows directly into the Nueces River. Prior to reopening the Rincon Bayou Demonstration Project in 2001, the Nueces River bypassed the Nueces Delta and flowed directly into Nueces Bay except during periods of high flow (Figure 4C.5-2). Previous studies have shown that diversions of both river water and treated wastewater to the Nueces Delta can be expected to increase primary production by factors of about three to five, respectively, when compared to allowing these waters to enter Nueces Bay via the Nueces River.[9]

[7] Breier, Edmonds, and Villareal, "Submarine Groundwater Discharge and Associated Nutrient Fluxes to the Corpus Christi Bay System," January 2004.
[8] Interim Order Establishing operational Procedures Pertaining to Special Condition 5.b., Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, Nueces River Authority, and the City of Three Rivers, Texas Water Commission, Austin, Texas March 9, 1992.
[9] HDR Engineering, Inc. (HDR), et al., "Regional Wastewater Planning Study – Phase II, Nueces Estuary," prepared for the City of Corpus Christi, et al., Austin, Texas, June 1993.



Source: Naismith Engineering, Inc.

Figure 4C.5-2. Diversion of Corpus Christi WWTP Effluent to the Nueces Delta

In a study[10] performed in 1993, estimates were made of the increase in yield of the CCR/LCC System for alternative river and wastewater diversions under the 1992 Interim Order, considering a productivity increase factor of three for freshwater river diversions and five for wastewater effluent diversions to the Nueces Delta. The 1993 study showed that of diversion alternatives evaluated, the highest yield recovery and lowest cost per acre-foot of yield recovered for treated wastewater alternatives was the alternative which uses 8.8 MGD (or 820 acft/mo) of wastewater from the Allison and Broadway WWTPs. This alternative was reevaluated under the 1995 Agreed Order with and without biological productivity factors for wastewater diversions to the delta.[11] As shown previously in the 2006 Plan, the average annual yield recovered for 8.8 MGD treated wastewater from the Allison and Broadway WWTPs is 1,100 acft/yr without biological productivity multipliers.

The 2001 Agreed Order maintains the same monthly inflow requirements based on CCR/LCC storage capacities as the 1995 Agreed Order, with an added requirement to operate a conveyance facility to deliver up to 3,000 acft/mo from Calallen Pool to Upper Rincon Bayou. The conveyance facility has been constructed and is being operated by the City of Corpus Christi since the development of the 2006 plan.

A literature review was conducted of recent, major efforts in ecological studies supporting benefits of freshwater diversions to the Nueces Delta (Appendix J).

4C.5.4.2 Available Yield

This strategy is updated for the Coastal Bend 2011 Regional Water Plan and assumes that 2 MGD of wastewater from Allison WWTP and up to 32 MGD (or up to 3,000 acft/mo) of river water from Calallen Pool through the Rincon Pipeline could be discharged into the Nueces Estuary with minimal or no infrastructure improvements. Based on the yield recovery discussed above for a 8.8 MGD treated wastewater project, 2 MGD of wastewater from the Allison WWTP would be expected to yield 250 acft/yr without biological productivity multipliers. A series of model runs were performed using the updated Corpus Christi Water Supply Model (formerly known as the Lower Nueces Basin and Estuary Model (NUBAY) in the previous Coastal Bend Regional Water Plans) to evaluate these scenarios for increased system yield. A series of runs

[10] Ibid.

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

were performed to determine and quantify water supply benefits associated with different quantities of water being delivered to the Nueces Estuary for a range of biological multipliers.

Two different diversion rates of 11 and 32 MGD (1,000 and 3,000 acft/mo, respectively) were evaluated for the Rincon Pipeline using multipliers of 2 – 5. Recent discharges into the Nueces Bay were summarized using the latest information available from the EPA website and confirmed that about 5.35 MGD of treated effluent is currently being discharged into the Nueces Bay area. However, of this 5.35 MGD only 2 MGD of effluent, proposed from the Allison WWTP owned by the City of Corpus Christi, was evaluated with the 2-5 multipliers for this water management strategy. This is the only readily accessible supply that has been and could easily be discharged directly into the Nueces Estuary. Another set of scenarios were developed that combined a 2 MGD treated wastewater diversion with that of the 11 MGD (or 1,000 acft/mo) river water diverted through the Rincon Pipeline.

Table 4C.5-2 summarizes the model simulation results. The yield increase ranges from just under 1,000 acft for diverting 2 MGD of treated wastewater to the Nueces Estuary with a multiplier of 2 to over 17,000 acft with a river diversion of 32 MGD and a multiplier of 5. A 2 MGD treated effluent diversion project with a multiplier of 5 is roughly equivalent in terms of increased yield to a combination project of 13 MGD diverted to the Nueces Estuary (11 MGD of river water and 2 MGD of treated effluent) with a multiplier of 2. The 32 MGD scenarios produce the highest yield increases compared to the other scenarios. By changing a biological multiplier of 2 to 5, at least for the volumes evaluated herein, an increase of about 2.4 to 2.5 times in firm yield would be expected.

4C.5.4.3 Engineering and Costs

Much of the infrastructure is already in place for this water management strategy. The Rincon Pipeline was built by the City of Corpus Christi and became operational in November 2007. The City has used the facility to deliver some of the fresh water inflow targets from the Calallen pool over to the Rincon Bayou area of the Nueces Estuary. The Allison WWTP owned and operated by the City of Corpus Christi also has some infrastructure still in place from the Allison demonstration project. These facilities can deliver about 2 MGD from the plant.

Table 4C.5-2.
Summary of Average Annual Yield Recovered for Various Wastewater Transfer and River Diversion Alternatives

Diversion or Transfer Capability		*Biological Productivity Factors*		*Average Annual Yield Recovered (acft)*
River Diversion (MGD)	*Allison WWTP (MGD)*	*River Water*	*Wastewater*	
11 MGD (1,000 acft/mo) River Water Diversion from Rincon Pipeline				
11	0	2	—	4,254
11	0	3	—	7,062
11	0	4	—	8,843
11	0	5	—	10,298
2 MGD (186 acft/mo) Effluent Discharge from Allison WWTP				
0	2	—	2	935
0	2	—	3	1,972
0	2	—	4	2,964
0	2	—	5	4,894
11 MGD River Water Diversion + 2 MGD Effluent Discharge (1,186 acft/mo)				
11	2	2	2	4,713
11	2	3	3	8,119
11	2	4	4	10,254
11	2	5	5	11,961
32 MGD (3,000 acft/mo) River Water Diversion from Rincon Pipeline				
32	0	2	—	7,019
32	0	3	—	10,365
32	0	4	—	12,936
32	0	5	—	17,060[1]

1 This value was estimated using the ratio of the increased yield associated with the 4 to 5 multiplier for the 11 MGD runs and the combined 11 MGD plus 2 MGD runs.

The estimated operating costs to deliver 2 MGD from the Allison WWTP are approximately $84,000 per year. This annual costs produces a unit cost ranging from $90.23 per acft for a multiplier of 2 down to $17.25 per acft for a multiplier of 5.

The estimated annual operating costs for the Rincon Pipeline are $464,000 for delivering 11 MGD, which results in unit costs ranging from $109.07 per acft for a multiplier of 2 down to $45.08 per acft for a multiplier of 5.

If the options were combined with both the 11 MGD of river water and 2 MGD of effluent the annual operating costs are estimated to be $548,000. This annual costs produces a unit cost ranging from $116.35 per acft for a multiplier of 2 down to $45.85 per acft for a multiplier of 5.

4C.5.5 Environmental

A key concern regarding use of biological multipliers applied to water that goes to meet the Agreed Order freshwater inflow targets for the Bay and Estuary is that it reduces the volume of that target for a specifically placed lesser quantity of freshwater-quality water. For example, if the B&E target were 2,000 acft for a month, and 1,000 acft were being diverted from the Calallen pool and being discharged into the estuary at a 2 multiplier, the target would be satisfied, and the environment in the estuary would likely benefit at least twice as much from the discharge, but only 1,000 acft of water was physically passed into the bay and estuary. So while there is certainly some benefit, there are also impacts that would need to be considered prior to implementation of biological productivity multipliers. The analysis performed for this strategy showed a range of median estuary inflow reduction of a minimum of 200 acft/yr to a maximum of 2,900 acft/yr depending on size of project and multiplier.

The City of Corpus Christi is evaluating benefits that may be achieved by aggregating freshwater inflow targets for multiple months. The analyses include consideration of holding target inflows for months that have smaller targets and combining with larger target months to provide larger pass-through during critical months for biological productivity.

Additional environmental aspects of treated wastewater reuse and discharge into the Nueces Delta is discussed in Section 4C.5.7.2.

4C.5.6 Wastewater Reuse for Municipal and Industrial Purposes

4C.5.6.1 Texas Administrative Code, Chapter 210 – Use of Reclaimed Water

There are two general qualities of treated wastewater allowed for reclaimed water use under TCEQ rules, Chapter 210. These are grouped and defined as Type I and Type II uses.

Broadly defined, Type I reclaimed water quality is required where contact between humans and the reclaimed water is likely. The types of water uses for which Type I reclaimed water could be generally used are:

- Residential irrigation;
- Urban irrigation for public parks, golf courses with unrestricted public access, school yards or athletic fields;
- Fire protection;
- Irrigation of food crops where the reclaimed water may have direct contact with the edible part of the crop;
- Irrigation of pastures for milking animals;
- Maintenance of water bodies where recreation may occur;
- Toilet or urinal flushing; and
- Other similar activities where unintentional human exposure may occur.

Type I water can also be used for all Type II uses listed below.

Type II water quality is where such human contact is unlikely. The types of water uses that would generally be considered as eligible for Type II reclaimed water are:

- Irrigation of sod farms, silviculture, limited access highway rights-of-way, and other areas where human access is restricted (restricted access can include remote sites, fenced or walled borders with controlled access, or the site not being used by the public when normal irrigation operations are in process);
- Irrigation of food crops where the reclaimed water is not likely to have direct contact with the edible part of the crop;
- Irrigation of animal feed crops, other than pasture for milking animals;
- Maintenance of water bodies where direct human contact is unlikely;
- Certain soil compaction or dust control uses;
- Cooling tower makeup water;
- Irrigation or other non-potable uses of reclaimed water at a wastewater treatment facility; and
- Any eligible Type I water uses.

At a minimum, the TCEQ requires that the reclaimed water will be of the quality specified in the rules (Table 4C.5-3).

A summary of the existing municipal wastewater reuse projects currently in operation in the Coastal Bend Region is presented in Table 4C.5-4. Many of these projects are discussed in more detail in the subsequent sections.

Table 4C.5-3.
Quality Standards for Using Reclaimed Water (30-day Average)

Type I	
BOD_5 or $CBOD_5$	5 mg/L
Turbidity	3 NTU
Fecal Coliform	20 CFU/100 ml (geometric mean)
Fecal Coliform (not to exceed)	75 CFU/100 ml (single grab sample)
Type II Other than Pond Systems	
BOD_5	20 mg/L
Or $CBOD_5$	15 mg/L
Fecal Coliform	200 CFU/100 ml (geometric mean)
Fecal Coliform (not to exceed)	800 CFU/100 ml (single grab sample)
Type II Pond Systems	
BOD_5	30 mg/L
Fecal Coliform	200 CFU/100 ml (geometric mean)
Fecal Coliform (not to exceed)	800 CFU/100 ml (single grab sample)

mg/L = milligrams per liter
BOD_5 = Biochemical Oxygen Demand (5-day)
C/BOD_5 = Carbonaceous Biochemical Oxygen Demand (5-day)
CFU/100 ml = Colony Forming Units per 100 milliliter
Source: TNRCC, 1997

Table 4C.5-4.
Existing Municipal Wastewater Reuse Projects in Coastal Bend Region

County	Entity	Use	Flow (MGD)
Aransas	City of Rockport	Golf course irrigation	0.6065[1]
Bee	City of Beeville	WWTP, irrigation, construction	0.6907[2]
Jim Wells	City of Alice	Golf course irrigation, Coastal Bermuda turf irrigation	0.1906[1]
Live Oak	City of George West	Local landowner irrigation	0.0056[2]
Nueces	City of Corpus Christi	Pharoah Valley Golf Course irrigation	0.107[3]
		Oso Golf Course irrigation	0.143[3]
		Gabe Lozano Golf Course irrigation	0.249[3]
		Baseball field irrigation	0.006[3]
		Padre Isles Golf Course irrigation	0.574[3]
San Patricio	City of Mathis	Local Landowner irrigation	0.0446[1]
	City of Aransas Pass	Wetlands enhancement (proposed)	0.0936[4]
		Irrigation of industrial land (proposed)	0.8424[4]

Sources:
1 Historical self-reporting reuse data compiled by TWDB (2001 data).
2 Historical self-reporting reuse data compiled by TWDB (2000 data).
3 Wastewater Reuse Study prepared for City of Corpus Christi by HDR Engineering, Inc. and correspondence with Carl Crull, February 2002.
4 Confirmed by Don Roach, San Patricio Municipal Water District, July 2004. Engineering Feasibility Report for Northshore Resource Conservation Project prepared for San Patricio Municipal Water District by Naismith Engineering, Inc., October 1999.

4C.5.6.2 City of Corpus Christi Wastewater Reuse

The City of Corpus Christi's present water conservation and reuse plans emphasize education and changes to the water rate structure to promote conservation and reuse. Water customers have been requested to reduce water usage wherever possible through the installation of more efficient plumbing fixtures and through landscape watering schedules. The City adopted plans to reduce water use by diverting a portion of its WWTP effluent to some public facilities for irrigation purpose (i.e., for golf course and park irrigation). Currently, the City has reuse facilities at three of their WWTP, which serve four golf courses and one sports complex.[12] The City is considering Oso Plant Effluent Reuse Improvements to include two new golf courses and one sports complex that currently irrigate with potable (municipal) water supplies. The following improvements are being considered by the City: (1) Oso WWTP Effluent Diversion Pump Station, (2) 18,276 LF of 16" Effluent Distribution Main, (3) 9,905 LF of 16" Effluent Force Main for King's Crossing Lateral, (4) 3,000 LF of 16" Effluent Force Main for Bill Witt Park Lateral, and (5) Bill Witt Park Lagoon and Re-Pumping Facilities.

Although an Agreed Order with the TCEQ is in place that requires the City to release a portion of their WWTP effluent into local bay systems as freshwater inflows, it is estimated that from the Oso WWTP alone, there is still an available supply of approximately 7.0 MGD (7,848 ac-ft/yr) that could be used for irrigation while still meeting the pass-through requirements of the TCEQ Agreed Order. Of that amount, less than 10% of the available effluent supply from Oso WWTP would be captured by the City's proposed project. Based on records of potable water use for irrigation by the King's Crossing Country Club and the Corpus Christi Country Club from the year 2000, the new supply yield (reduced demand on treated supplies) would be approximately 615 ac-ft/yr. It is possible that the infrastructure that will be put in place by this strategy would yield more supply, however, additional customers beyond these two golf courses and the Bill Witt Park sports complex have not been identified or quantified at this time.

In the year 2000, the City provided a total of 1,471 ac-ft of effluent to four golf courses and one sports complex. This practice has some limitations, as the need for wastewater for irrigation is not continuous and is often highly variable. Thus, the wastewater is not reused in the same amount every month. For example, it is not used after heavy rains and it is not used during winter months when the grass is not growing and will not consume the wastewater. For example,

[12] Information regarding the Oso Plant Effluent Reuse was provided by the City of Corpus Christi, August 2009.

in 2001, wastewater reuse from the City's WWTPs for golf course and baseball park irrigation was about 394 million gallons (or 1,210 acft/yr). In 2002, the wastewater reuse was reduced to 333 million gallons (or 1,020 acft).

Water conservation can impact the quantity of wastewater generated, and thus available for reuse and/or for credit to meet freshwater needs of the Nueces Estuary. Figure 4C.5-3 shows that while the general population of the City of Corpus Christi is growing, the total quantity of wastewater treated and discharged has remained relatively constant.

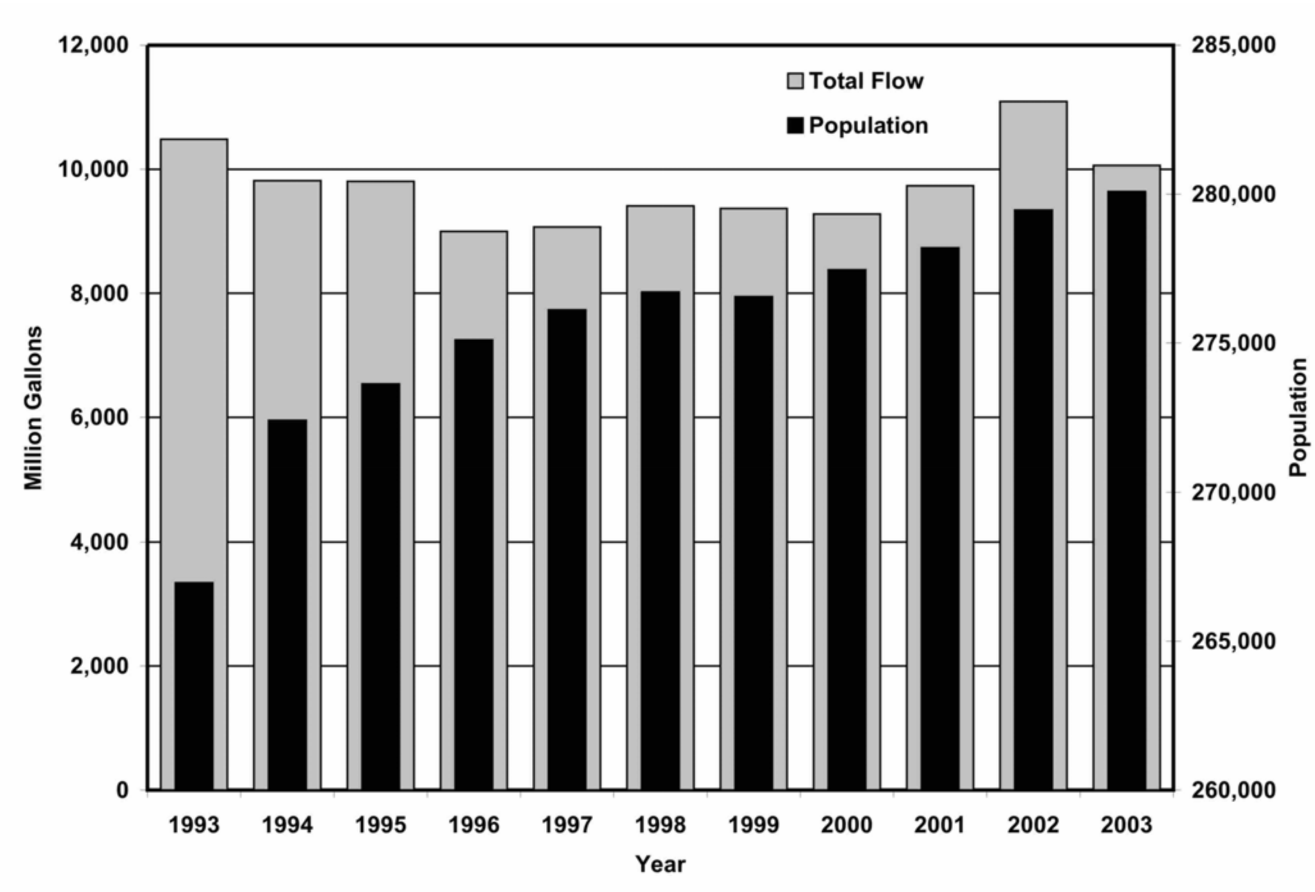


Figure 4C.5-3. City of Corpus Christi Wastewater Flows versus Population

During the 1984 drought, treated wastewater was made available to the public for use in irrigating lawns; this plan remains in effect within the City's operational framework and can be fully implemented in the event it is necessary. During the drought of 1984, the City considered diverting treated wastewater to local industrial facilities for cooling tower make-up water in an attempt to reduce the quantity of CCR/LCC System water needed for these purposes. However, this plan was severely limited as the WWTPs are not conveniently located and the discharge is not readily available to industrial plants, requiring the construction of extensive forcemains to deliver the wastewater to these facilities. In addition, high chloride concentrations existed in the wastewater effluent, particularly from the Broadway WWTP, making this source unattractive since high chloride concentrations require costly treatment before industries can use the water.[13]

Since the industrial facilities are large consumers of both raw and treated water from the CCR/LCC System, and since it was not possible to economically substitute significant quantities of wastewater for industrial uses during the drought, as noted above, the City asked industries to minimize water usage without seriously jeopardizing production. The industrial facilities in the area responded by carefully studying ways to more efficiently use and re-use the water they receive and by considering alternative sources of water. Many of the options studied by industry for reuse of their own wastewater have been implemented.

4C.5.6.3 Industrial Wastewater Reuse

4C.5.6.3.1 Process Descriptions and Water Use

In general, primary industrial customers utilize similar facility processes that are mainly responsible for water consumption, such as cooling towers and boilers. In addition, industry also uses freshwater for drinking water, sanitary use, and equipment washdown and fire protection. The primary differences in water usage, however, are product related. Process requirements influence the size and type of cooling systems and boilers needed for steam production. Process and product differences affect water quantity and quality needs. Depending on the industrial facility's plant size, age, and market conditions, different plants in the same industry category can have different water needs and water use efficiencies.

The petroleum refinery and petrochemical industries produce numerous products such as fuel oil, gasoline, petrochemicals and kerosene. The diverse chemical manufacturing industry served by the City of Corpus Christi water system produces various products such as high quality plastics, weather resistant paints, alumina, chromium compounds, Freon, adhesives, formaldehyde, synthetic resins, and pharmaceuticals. In general, the chemical manufacturing industry requires more water per unit production due to the nature of the chemical manufacturing process and the water content of certain produced chemicals.

[13] During the 1984 drought, one refinery used some wastewater from the City's Broadway Wastewater Treatment Plant. The treated wastewater was mixed with the treated water and the refinery's industrial wastewater but required 8 hours of chlorination to control viruses and lime softening to control hardness.

In most area industries, heat dissipation is the single largest demand for water within a plant. Typically, water is used to remove heat from process streams. The heated water is cooled by a cooling water system. Cooling water systems in the study area are either recirculating freshwater cooling systems, which use cooling towers, or are once-through cooling systems. Once-through cooling systems in the study area are primarily steam-electric power plants that use very large volumes of seawater to cool the steam (for reuse) required to turn turbines for electric power generation. In order to prevent unacceptable build-up of minerals and salts, a portion of the cooling water from the cooling tower is discharged or blown down. Thus a continuous supply of new water (make-up) is required to supplement the freshwater lost due to evaporation and blow down.

Boiler-feed water is the second largest use of freshwater. This involves heating water to produce steam for process use. Steam is used to add heat to process streams and to power turbines for generating electricity. Steam is also used to drive pumps, compressors and fans, as well as in the process to facilitate fractionation in petroleum refineries and chemical plants. This steam is condensed and returned to the boiler feed water system to be reused.

The third largest industrial use of City water is in the process stream, where water is used as a feedstock, for example, in the reforming process to produce hydrogen in refineries and to scrub air contaminants (cleaning a contaminated airstream with a liquid), in digesters, or for chemical and product separation. The remaining use of freshwater within industry is primarily for drinking water, sanitary use, equipment washdown, and fire protection.

For most chemical and refining plants, cooling accounts for 60 to 75 percent of the water use, boiler water use accounts for 20 to 30 percent, process water accounts for 5 to 9 percent, and potable or sanitary use accounts for 1 percent. Chemical plants typically utilize more water in their process streams and in their products, while refineries, which produce steam for electrical generation, utilize more water for boiler use.

The following factors influence and control current water use, the potential for industrial water conservation, and the potential for area industries to use alternative sources of water, including treated municipal wastewater, brackish groundwater, and seawater. The list of important factors includes:

- The location of each water-using industrial plant in relation to a source or sources of water;

- The location of each water-using industrial plant in relation to streams or other features into which wastewater can be discharged;
- The type of industry, which determines the type of water use (i.e., refineries which use varying and/or different grades of crude petroleum, refineries which are producing reformulated gas, chemical plants which produce a range of chemicals and pharmaceuticals, and plants which extract compounds from ores to produce metals and other products); and
- The metallurgy of equipment in the cooling system that would come in contact with the cooling water.

4C.5.6.3.2 Industry Water Conservation and Water Quality Needs

During the 1984 drought, the City requested that its industrial water customers minimize water use from the CCR/LCC System without seriously jeopardizing production. Industry representatives responded by carefully studying ways to reduce water demands through increased efficiency in the use of existing supplies, reuse of available supplies, and development and use of alternative water supplies. In response to water shortages during the drought of 1984, concerns about rising costs of water, increased regulation and rising costs of wastewater treatment and disposal, and public interest in water conservation, Corpus Christi area industries implemented water conservation and water reuse measures that have significantly reduced quantities of water needed per unit of production. For example, Corpus Christi area petroleum refineries use between 35 and 46 gallons of water per barrel of crude oil refined, while refineries in Houston use 91 gallons, and refineries in Beaumont use 96 gallons.

As a result of these events, the major Corpus Christi area industrial customers have implemented various water conservation measures since the 1984 drought period and especially in the last 3 to 5 years, particularly during periods of plant expansion. Since 1984 there has been increasing quantities of water conserved by local industry. Provided in Table 4C.5-5 is a list of water conservation measures, which have been implemented by industry as well as future water conservation strategies, including wastewater reuse. In comparison to other Texas industry, the industries in Corpus Christi have one of the best records of water use efficiency based on results of the TWDB's "Pequod Survey."[14]

[14] Texas Industrial Water Usage Survey, Pequod Associates, Inc. and TWDB, Austin, Texas, August 1993.

Table 4C.5-5.
Water Conservation Measures
Corpus Christi Area Industry

Current Measures

- Recycling Cooling Tower and Boiler Blowdown
- Improved Control Systems
- Dry Cooling, Air Cooled Heat Exchangers
- More Efficient Drift Eliminators
- Changed Washdown Procedures
- Automatic Cooling Tower Blowdown
- Leak Detection/Repair
- Steam Condensate Recovery
- Reuse Wastewater Treatment Effluent for Firewater, Cooling Tower Make-up
- Cycling-Up Cooling Towers
- Stormwater Reuse
- Salt Water for Area Washdown
- Salt Water Lubrication of Circulating Water Feed Pumps
- Reverse Osmosis with Demineralization
- Voluntary Water Conservation Planning
- Regulatory Requirement to Consider Reuse
- Saltwater for Cooling

Future Measures

- Uniform blending of Lake Texana/Nueces River waters to provide consistently better water quality with less variation in dissolved minerals.
- Increased Evaluation of Alternative Water Sources to Replace Treated City Water
- Additional Application of Reverse Osmosis Treatment
- Increased Wastewater Treatment Plant Effluent Reuse
- Possible Side-Stream Softening
- New Process Changes
- Additional Steam Leak Repair
- New Chemical Treatment Technology
- Increased Water Audit by Industry
- Possible Water Conservation Incentives
- Possible Regulatory or Local Government Water Conservation Planning Goals
- Increasing Water Conservation Research and Education
- Additional Industry Pursuing Water Conservation Measures

The water quality requirements of industry in the area are determined by the water quality constraints for cooling tower make-up, boiler make-up, process water, and potable water. Since water used for cooling tower make-up and boiler make-up are the predominant industrial uses of water, the opportunities to substitute alternative water sources for cooling towers, and boiler make-up present the greatest potential opportunities to conserve existing freshwater supplies. Because cooling tower make-up can utilize water of poorer quality as compared to the high quality water required in a boiler, the reuse of wastewater effluent in cooling towers provides the best opportunity for this alternative water supply.

The quality of water used by an industry can have numerous impacts on their facilities. Industrial process equipment can degrade, cooling efficiency can be reduced, health and safety problems can develop, and permitted wastewater discharge limits can be exceeded if the water has undesirable qualities. The most frequent water quality problems within industrial water systems are scaling, corrosion, biological growth, fouling, and foaming. In addition, permitted wastewater discharge parameters, as well as cooling tower solid waste characteristics, are influenced by cooling tower water quality. Solid wastes generated from water treatment and control facilities such as cooling tower basin sludge, have characteristics that affect the costs of handling and disposal, triggering new regulatory requirements, and may affect waste minimization programs.

The high degree of purity required for boiler water is critical because it is used to make steam. If water quality is not properly controlled, contamination from minerals such as calcium and magnesium will be deposited on boilers, restricting the transfer of heat to the boiler water. In addition, boiler metal will corrode and deposits in the steam system will adversely affect the other equipment. Water sources, which have higher concentrations of minerals, create a greater potential for requiring costly pretreatment.

4C.5.6.4 Potential Industrial Reuse of Broadway Municipal Effluent Feasibility Study

The potential for industrial reuse of the City of Corpus Christi Broadway WWTP effluent was considered in a 1996 study[15] that evaluated the feasibility for major industries along the Corpus Christi Ship Channel to reuse the Broadway WWTP effluent. Since the Broadway WWTP is located in close proximity to a number of major industries, it was considered by the

[15] Feasibility Study of Industry Reuse of Broadway Municipal Wastewater Treatment Plant Effluent, prepared for the City of Corpus Christi and the Port of Corpus Christi, Board of Trade, July 1996.

City as the source of effluent to be evaluated for reuse. Since each industry has their own unique set of water quality needs and constraints that affect their ability to reuse municipal WWTP effluent, the type of industry and their needs influenced the feasibility of wastewater reuse.

The study identified conditions necessary to convey effluent from the Broadway WWTP to the major industries in the area. In addition, this study identified issues associated with industrial reuse in general.

The preliminary feasibility study determined that the Broadway WWTP effluent is a renewable alternative water supply which can be used by industry in their water supply mix. Particularly when drought conditions limit water supplies, the Broadway effluent can be a cost effective water supply option. Depending on the cost of Broadway WWTP effluent water, including pumping and piping delivery costs, operation and maintenance costs, and potential wastewater treatment equipment and chemical costs, reuse of the Broadway WWTP effluent might be an attractive water supply alternative. However, water quality would need to be considered as previous studies have indicated that elevated chloride levels may reduce reuse opportunities. Coordination with each industry on a case-by-case basis would be necessary to determine the most cost-effective plan for industry reuse of the Broadway effluent. The study recommended that a plan for providing Broadway effluent to industries be evaluated along with future plans for long-term operation of the Broadway WWTP. Since the Broadway WWTP is scheduled to close, Greenwood WWTP may be considered a more reliable effluent source for reuse projects.

4C.5.6.5 City of Corpus Christi Broadway Wastewater Treatment Plant Diversion Project

In 1997, an additional study[16] was undertaken regarding the City of Corpus Christi Broadway WWTP. This plant is the City's oldest WWTP. The plant service area has experienced an approximate 39 percent reduction in population due to an out-migration starting in 1960. The City's latest plan considers phased elimination of the Broadway WWTP, diverting flows to the Greenwood (Westside) WWTP, which is currently being expanded to treat additional wastewater flow. A feasibility study of Broadway to Greenwood implementation alternatives was completed in late 1999. The wastewater discharges from Greenwood WWTP have increased from 3,939 acft/yr in 1998 to 13,486 acft/yr in 2002.

[16] "City of Corpus Christi Wastewater Facilities Implementation Plan, Oso & Greenwood Service Areas and Broadway Plant Diversion," City of Corpus Christi, February 1997.

With the potential diversion of wastewater flow from the Broadway WWTP to the Greenwood WWTP, the direct use of effluent from the Broadway WWTP site is not an economical option. Diversion of effluent from the Greenwood WWTP to the upper Nueces Delta is an alternative under consideration by the City of Corpus Christi. If the City proceeds with the facilities implementation plan recommendation, approximately 15 MGD of Greenwood WWTP effluent could be diverted to the Nueces Delta by the year 2025.[17] The City is actively considering Oso WWTP reuse projects, rather than reuse from Greenwood WWTP since the Oso WWTP effluent water quality is better than Greenwood WWTP. Total dissolved solids in effluent from Greenwood WWTP would need to be considered when determining the feasibility of implementing reuse programs.

Previous 2001 and 2006 Coastal Bend Regional Water Plans included an analysis of potential effluent diversion projects for treated wastewater from Allison WWTP, Broadway, and Greenwood WWTP. The study also evaluated potential impacts on reservoir operations and increases in system yield. For the 2011 Plan, the costs of proposed projects were updated to reflect September 2008 Prices. The results of the analysis are included in Section 4C.9.

4C.5.6.6 Oxy Petrochemicals Municipal Wastewater Reuse Feasibility Study

In 1996, Oxy Petrochemicals, Corpus Christi, Texas (now known as Equistar Chemicals, L.P.), conducted a feasibility study[18] to assess the reuse of the City of Robstown WWTP effluent to supplement their industrial water supply.

Equistar Chemicals, L.P. receives all of its water supply from the City of Corpus Christi. The City water is used for drinking, domestic use, fire suppression, cooling tower make-up, equipment washdown, and other small uses. The City of Robstown WWTP effluent would have been reused as cooling tower make-up water, thus reducing the use of water purchased from the City of Corpus Christi.

According to TWDB records, Equistar Chemicals, L.P. used 305 acft reclaimed wastewater supplies in 1998; 283 acft in 1999; 258 acft in 2000; and 234 acft in 2001.

[17] Ibid.

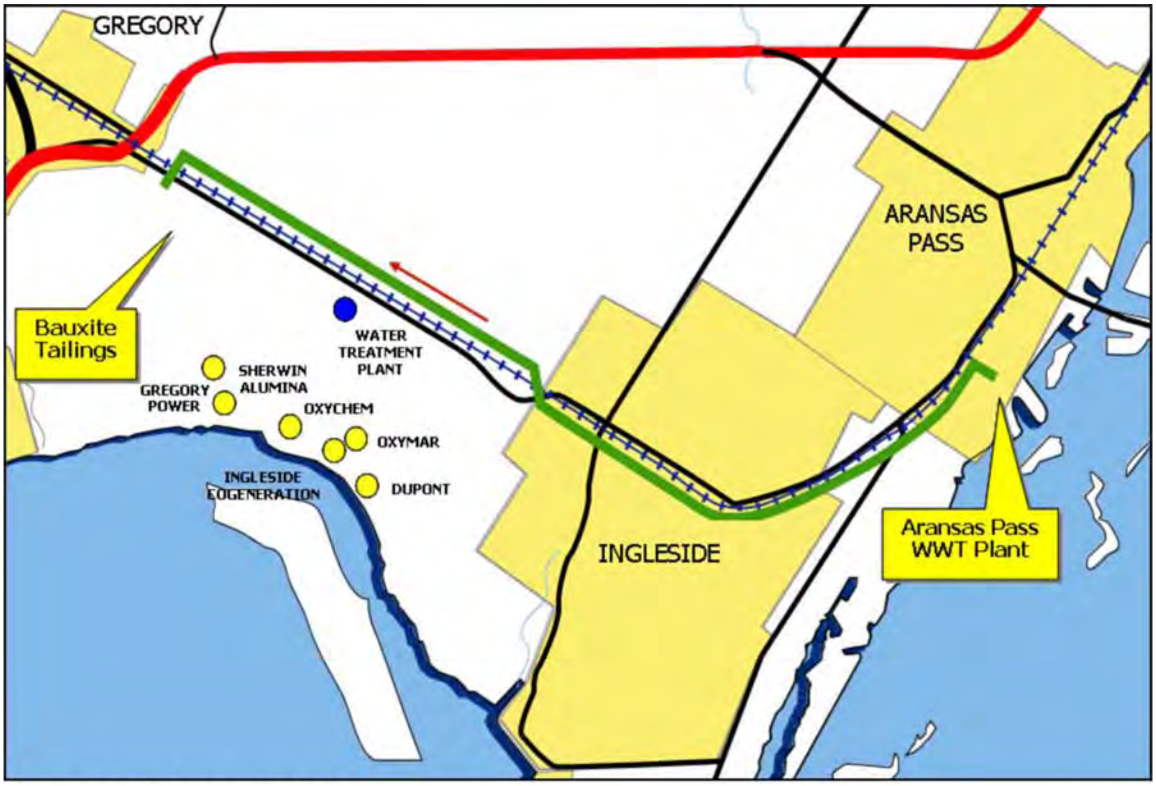
[18] "Municipal Wastewater Reuse Feasibility Study, Oxy Petrochemicals, Corpus Christi, Texas," Oxy Petrochemicals, August 1996.

4C.5.6.7 Water Supply Effect of Northshore Regional Wastewater Reuse Project of San Patricio County

The Northshore area of San Patricio County includes the Cities of Portland, Gregory, Ingleside, Ingleside-on-the-Bay, and Aransas Pass. The Northshore Regional Wastewater Reuse, Water Supply, and Flood Control Planning Study indicated that municipal wastewater reuse was a cost effective water supply alternative. As a result, the Northshore Resource Conservation Project - Phase I[19] was implemented. This wastewater reuse project includes implementation of the reuse of treated effluent and sewage sludge from the City of Aransas Pass. This reuse project will reduce demands on existing freshwater supplies and help meet water conservation plan requirements for area industries. The City of Aransas Pass WWTP currently discharges to Redfish Bay and the effluent and sludge to Sherwin Alumina Company reuse project.

The Northshore Resource Conservation Project has been developed to implement two conservation measures: (1) beneficial reuse of municipal sewage sludge from the City of Aransas Pass; and (2) replacing some of the freshwater Sherwin Alumina Company uses with reclaimed municipal wastewater. A pipeline was constructed from the City of Aransas Pass WWTP to the Sherwin Alumina Company tailing beds. Figure 4C.5-4 shows the pipeline route and the North Shore area in the vicinity of this project. The pipeline is designed to deliver either wet sludge or a slurry of sludge and reclaimed water and replaces the current use of tanker trucks to transport the sludge, used as a soil amendment for the tailings. The reclaimed water has been used to establish vegetation on barren areas and irrigate areas where vegetation has previously been established.

[19] "Engineering Feasibility Report and Environmental Assessment for the Northshore Resource Conservation Project – Phase I," San Patricio Municipal Water District, June 1997 (Updated October 1999).



Source: San Patricio Municipal Water District

Figure 4C.5-4. Pipeline Route and the North Shore Area

Sherwin Alumina Company (formerly Reynolds Metals Company), a major area industry located between the Cities of Portland and Ingleside, has been using municipal wastewater from the City of Aransas Pass for non-potable purposes since 1998 and has reduced water use from the CCR/LCC System. The SPMWD, who obtains both treated water and raw water from the CCR/LCC System, supplies municipal and industrial water to the area. In both 2001 and 2002, Sherwin Alumina Company reused 2,688 acft/yr. However, delivery of treated wastewater in 2003 was only 382 acft from the City of Aransas Pass due to wet weather.[20]

In addition, a small portion of the Aransas Pass WWTP effluent has been utilized at the Aransas Pass Nature Area for wetlands enhancement. This project is funded by a Coastal Management Program grant and is not a part of the Northshore Resource Conservation Project. Approximately ten percent (10 percent) of the current average daily flow of 0.8 MGD (or 80,000 gpd) has been made available for diversion. Additional funding for the Nature Area is

[20] Correspondence with Jim Naismith, SPMWD, June 2004.

being requested from the Texas Parks and Wildlife Department, Coastal Management Program, and the Coastal Bend Bays and Estuaries Program.

Recently, SPMWD estimated that they could reduce future water demands by 4 MGD (4,480 acft/yr) by implementing wastewater reuse programs with the City of Portland, Gregory, City of Ingleside, and Oxychem, in addition to continuing reuse projects with Sherwin Alumina Company.[21] In 2001, these entities discharged wastewater effluent totaling 3,500 acft to Nueces Bay, which was credited toward freshwater inflow requirements for Nueces Bay (specified in both the 1995 Agreed Order and 2001 Agreed Order). Since Sherwin Alumina Company is a no discharge facility, there are no return flows from its water use. Additional studies are necessary to evaluate the effects on yields from CCR/LCC System when eliminating 3,500 acft of wastewater flows to Nueces Bay. The 2001 Agreed Order gives credit of 54,000 acft of return flows from WWTPs. SPMWD and other regional entities should coordinate wastewater reuse projects to minimize impacts to CCR/LCC yield and reduce additional CCR/LCC releases to Nueces Bay to offset the loss of the wastewater effluent. The regional wastewater collection and treatment system described above may be implemented as a future project.

The SPMWD had previously requested assistance for two other reclaimed water reuse projects. A related project, reuse of reclaimed water from the City of Portland's WWTP, is on hold because of a potential conflict with the operational plan for the CCR/LCC System. Another possible project involves reclaimed water reuse from the City of Ingleside WWTP. High chloride levels in the wastewater from Ingleside are currently preventing its reuse.

4C.5.7 Wastewater Reuse for Landscape and Agricultural Use

In 2002, the City of Corpus Christi studied the feasibility of irrigating City-owned landscape with reclaimed wastewater.[22] The following observations were made regarding specific uses of reclaimed water:

1. Golf course irrigation with reclaimed water was successful;
2. The capital and operating costs, both for treatment and delivery, of irrigating public areas with reclaimed water is, in general, higher than the cost of potable water. The cost of park maintenance will increase with the use of reclaimed water.
3. Agricultural use appears to be economical from a pure cost of water standpoint for supplies up to 7 MGD at a cost of approximately $83/acft (or $0.26 per 1,000 dollars). However, depending on the crop and rainfall amount, frequency and timing,

[21] Conversation with Jim Naismith and Don Roach, SPMWD, February 2, 2005.
[22] HDR, Effluent Reuse Study, February 2002.

demand may be sporadic. The cost of the water may not be offset by increased crop yields.

Within the City, various categories of public facilities and recreation areas/undeveloped areas have been identified where landscape irrigation could be applied (Table 4C.5-6).

In the assessing the feasibility of landscape irrigation, various factors must be considered. These factors affect the capital costs and annual maintenance costs. Such factors include:

- The additional wastewater treatment necessary to meet Texas Administrative Code, Chapter 210, Use of Reclaimed Water standards (Section 4C.5.4.1);
- Infrastructure (pumps, piping, distribution system) necessary to deliver the reclaimed wastewater to the site;
- Additional maintenance of irrigated areas (increased frequency of mowing); and
- Long-term potential for chloride build-up in clay soils and the addition of soil amendments.

The quantity of wastewater reused for golf course and/or public park irrigation in the Coastal Bend Region is estimated to be a small percentage (less than 4 to 5 percent) of the total municipal wastewater flow. In 2001, the City of Corpus Christi diverted approximately 1,210 acft to area golf courses and a baseball park. This represents approximately 3 percent of

Table 4C.5-6.
City of Corpus Christi Public Facilities and Recreation/Undeveloped Areas with Landscape Irrigation Needs

Category	*Number*	*Acres*
Beach Parks	4	72
Baseball/Softball Fields	8	383
Golf Courses	2	370
Libraries	5	4.5
Street Medians	34	141
Parks	168	913
Pools	10	9
Road Right-of-Ways	57	51
Recreation Centers	7	2.5
Special Areas (T-Head, L-Head, wildlife area, City Hall, cemeteries, nursery, Botanical Gardens, bayfront areas, Oso Creek areas, etc.)	40	1,098
Senior Citizen Centers	11	19
Total Acres		**3,063**
Source: City of Corpus Christi from 2001 Plan.		

the City's wastewater discharge from its six WWTPs. As discussed previously, the City is considering Oso Plant Effluent Reuse Improvements to include two new golf courses and one sports complex that currently irrigate with potable (municipal) water supplies. The City of Corpus Christi is considering providing reclaimed wastewater supplies to two golf courses, Corpus Christi County Club and King's Crossing County Club, and Bill Witt Park with estimated water savings of 615 acft/yr.[23]

A possibility for municipal WWTP effluent reuse that would replace an existing potable water use and thus increase the available CCR/LCC water supply is nursery reuse. Nurseries in the City are wastewater reuse candidates but the capital costs associated with pump stations, piping, and distribution systems would necessitate a feasibility study of such a reuse system. In Corpus Christi, most nurseries are retail sellers, meaning they purchase their stock from wholesale growers. Based on a conversation with a retail nursery owner, the potential for reuse of municipal WWTP effluent for nursery irrigation would be limited. The retail nurseries use City water and typically only have containerized plants, purchased from wholesale sellers. With retail nurseries spread out across the City and the small demand, supplying effluent for reuse would very likely not be cost-effective.

Wholesale nurseries would have the best potential for cost effective reuse of municipal WWTP effluent as they would use more water for irrigating acres of plants, sod, etc. for supplying retail nurseries. There is only one wholesale grower in Corpus Christi. The larger wholesale growers in this region are located in San Antonio, Houston, and the Rio Grande Valley. Logistically, this wholesale grower is approximately 5.5 miles from the nearest city WWTP (Laguna Madre WWTP). In a conversation with the wholesale grower, he indicated that he uses approximately 30,000 gpd of water during peak use. The water quality of the WWTP effluent would be a major concern. The growers' current water source is a mix of potable water (City of Corpus Christi) and untreated groundwater. The predominant use is groundwater. With the water quality issues, pump station and forcemain costs, and seasonal demand for the water minimizes the cost-effective use of the wastewater.

The groundwater is used to offset the expense of purchasing potable water and to dilute the salinity, total dissolved solids, and alkalinity concentrations of the potable water. The tropical plants grown at the wholesale nursery have specific water quality tolerances related to those

[23] Based on records of potable water use for irrigation by the King's Crossing Country Club and the Corpus Christi Country Club from the year 2000 as provided by the City of Corpus Christi.

parameters. The nursery owner expressed concern regarding the water quality of the WWTP effluent and the cost effectiveness of treatment or dilution to achieve an acceptable water quality.

4C.5.8 Analyses and Discussion of Consumptive Wastewater Reuse and Advanced Conservation as Related to Estuaries Inflow Requirements

4C.5.8.1 Introduction

Under the 2001 Agreed Order, effluent credits for discharges to Nueces Bay are applied on a one-to-one basis and effluent credits for the Nueces Estuary, excluding Nueces Bay, are set at 54,000 acft/yr until such time as it is shown that actual wastewater flows exceed this amount. If the discharge of treated effluent increases and/or multipliers are applied to compute credits for effluent discharge in the Nueces Delta, releases from the CCR/LCC System to meet monthly desired Nueces Bay inflows can be reduced with a consequent increase in system firm yield. Without implementation of water conservation measures, which restrict water use, wastewater flows are projected to increase at a rate of about 900 acft per year. If selected accelerated conservation measures are implemented, then wastewater flows could be expected to be reduced, depending on the type of conservation measures. For example, if conservation measures that accelerate the retrofit of existing plumbing fixtures to low-flow fixtures are implemented, then wastewater flows would be reduced to the degree the program is effective. However, if conservation measures were selected to limit or reduce summer season irrigation of lawn and landscaped areas, wastewater flows would be unaffected. Simply stated, the benefit of increased water supply associated with advanced conservation must be carefully weighed against the resultant reductions in the steady discharge of treated effluent containing nutrients to primary productivity in the Nueces Estuary.

4C.5.8.2 Environmental Aspect

It has been estimated that between 47 percent and 52 percent of the water diverted and used by the City is returned to various points in the estuary as treated wastewater.[24,25] Presently, the largest portion of these discharges flow into the Nueces River, the Corpus Christi Inner Harbor, Oso Creek, Corpus Christi Bay, and Oso Bay. This alternative involves reusing this treated wastewater 1) for the irrigation of municipal and residential properties (e.g., golf courses and lawns) and for meeting industrial needs (e.g., cooling water makeup), and 2) moving treated

[24] HDR, et al., Op. Cit., September 1995.
[25] 2003 survey results, as reported in Table 4C.5-1.

wastewater discharges from their present discharge points to the Nueces Delta (e.g., Rincon Bayou and associated shallow ponds). Since the needs for irrigating lawns and golf courses are sporadic and somewhat unpredictable, and because of the logistical problems inherent in redistributing treated wastewater for municipal and industrial needs as described earlier, it appears unlikely that large volumes of treated wastewater can efficiently be used for these purposes. Thus, the environmental effects of wastewater reuse for municipal irrigation and for meeting certain industrial water needs also would be relatively small. The discharge of treated wastewater to the Nueces Delta offers greater potential for benefits in terms of increasing freshwater availability to meet municipal and industrial requirements in Corpus Christi, while at the same time potentially enhancing the productivity of Nueces Delta. The Coastal Bend Region provides habitat for several endangered species and the resources critical to their continued existence, migratory bird use areas, wetlands, and marine fish and invertebrate nursery areas. Because phytoplankton and emergent plants provide food and habitat for animals, especially during early developmental stages, and these in turn provide food for larger animals, changes in primary productivity and plant diversity can be expected to influence the assemblage of animals resident in the estuary. Previous studies indicate that the Nueces Delta and Nueces Bay are critically important as the site of much of the planktonic primary production that drives biological processes throughout the Nueces Estuary. These studies indicate that treated wastewater could have as much as a five-fold stimulatory effect on primary productivity if discharged into the Nueces Delta rather than being discharged into the Nueces River.[26,27] Therefore, it has been recommended that wastewater be diverted and discharged into the Nueces Delta to help meet the freshwater inflow requirement, as specified in the 2001 Agreed Order, under which the CCR/LCC System now operates. This proposed wastewater discharge to the Nueces Delta would increase water availability from the CCR/LCC System if credits at a greater than 1:1 ratio can be obtained, thereby reducing freshwater releases designed to meet Nueces Bay inflow requirements.

[26] HDR et al., "Regional Wastewater Planning Study, Nueces Estuary, Phase I," City of Corpus Christi, et al., November 1991.

[27] HDR et al., "Regional Wastewater Planning Study, Nueces Estuary, Phase II," City of Corpus Christi, et al., March 1993.

4C.5.8.3 Impact Assessment

The 2005 Integrated Monitoring Plan[28] presents a consolidated description of monitoring programs associated with Nueces Delta projects (i.e., Rincon Bayou and Allison Demonstration Projects). The Nueces Delta Mitigation Project, conducted by the United States Army Corps of Engineers (USCOE) and Corpus Christi Port Authority until August 1997, studied wetland losses due to dredging in the Corpus Christi Ship Channel. Studies designed to assess the effects of diverting wastewater to the Nueces Delta have been conducted by researchers from the University of Texas Marine Science Institute.[29,30] These studies involved determinations of monthly salinity, temperature, dissolved oxygen, dissolved inorganic nitrogen (that is available to support plant growth), phosphate, silicate, and water transparency at 25 sampling stations. Additionally, primary production was measured at five sites. Primary production and phytoplankton pigment biomass, and the biomass, species diversity and species abundance of emergent vegetation was measured at four sites in each of 1991 and 1992. These studies indicate that primary productivity is positively correlated with the concentration of nutrients in the water. Increased flow and nutrient concentrations appeared to increase the relative abundance and species diversity of emergent vegetation.[31] The effects of wastewater on relative abundance and species diversity varied among study sites indicating that other factors, in addition to freshwater flows and nutrient concentrations (e.g., initial species composition and abundance, duration of flooding, and frequency of flooding), may affect the relative abundance and diversity of species. An intensive, 5-year study was conducted for the Allison WWTP Demonstration Project (1999 to 2003) to assess the potential effects of wastewater on the relative abundance and diversity of species in the Nueces Estuary. The concluding report was completed in 2006.[32]

The Rincon overflow channel was restored by the 2001 Agreed Order. Salinity monitors have been positioned throughout the estuary to tract flow rate and retention time of water diverted through the Rincon Pipeline.

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[28] City of Corpus Christi, Integrated Monitoring Plan Fiscal Year 2005, January 2005.
[29] Whitledge, T.E. and D.A. Stockwell, "The Effects of Mandated Freshwater Releases on the Nutrient and Pigment Environment in Nueces Bay and Rincon Delta: 1990 – 1994," Water for Texas, Research Leads the Way (Jensen, Red.), Proceedings of the 24th Water for Texas Conference, 1995.
[30] Dunton, K.H., B. Hardegree, and T.E. Whitledge, "Annual Variations in Biomass and Distribution of Emergent Marsh Vegetation on the Nueces River Delta," In: Water for Texas, Research Leads the Way (Jensen, Red.), Proceedings of the 24th Water for Texas Conference, 1995.
[31] Ibid.
[32] Concluding Report: Allison Wastewater Treatment Plant Effluent Diversion Demonstration Project, Volume I: Executive Summary. The University of Austin, Marine Science Institute, Port Aransas, Texas and Texas A&M University-Corpus Christi, Center for Coastal Studies, Corpus Christi, Texas, 2006.

Also, a TMDL study is underway by TCEQ and Texas A&M University Corpus Christi to determine the distribution of zinc in water and sediment in Nueces Bay. The TCEQ has included the Nueces Bay on the 303(d) list of impaired waters of the State due to contamination of oysters with elevated levels of zinc.

A more recent study[33] was conducted using hydrological data measured by multiple continuous monitors over a 14-year period (1994 to 2008) to determine objective and consistent separation of wet and dry periods. The second part combined wet and dry period information with water quality, benthic macrofauna, and marsh vegetation for comparison of biological responses to inflow events. Benthic macrofauna, vegetation, and water quality samples were collected by three research groups from 10 sites divided into three zones: upper Rincon Bayou, lower Rincon Bayou, and Nueces Bay. Statistical approaches were used to investigate the relationships between each of the biotic communities (macrofauna and vegetation) with water quality variables. The overall results suggest that the effects of freshwater inflow are restricted even during periods of extended flooding.

4C.5.8.4 Implementation Issues

Major implementation issues include wastewater treatment levels required by regulatory agencies (TCEQ), wastewater discharge permit modifications to allow discharge in the Nueces Delta, and the impacts to the Nueces Delta from the diversion of wastewater. In addition, implementation of these strategies will require NPDES Stormwater Pollution Prevention Plan permits. Cultural resources will also need to be investigated along the pipeline routes and avoided where possible. Implementation of this alternative should be considered in conjunction with the City's wastewater master plan as well as the results of studies from the U.S. Bureau of Reclamation's Rincon Bayou Demonstration Project.

4C.5.9 Evaluation Summary

An evaluation summary of this regional water management option is provided in Table 4C.5-7.

[33] Response of the Nueces Estuarine Marsh System to Freshwater Inflow: An Integrative Data Synthesis of Baseline Conditions for Faunal Communities, Publication 62, 2009.

Table 4C.5-7.
Evaluation Summary of the Reclaimed Wastewater Supplies

Impact Category	Comment(s)
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Firm yield: Highly variable 2. Reliability: Poor to Good 3. Cost: Highly variable
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. Potential for environmental impacts to streams currently receiving wastewater effluent 2. Environmental impact to estuary in potential reduction of freshwater inflows 3. None or low impact. 4. None or low impact. 5. None or low impact. 6. Cultural resource investigations will be required for all pipeline routes 7. The City's Integrated Plan provides on-going studies of water quality issues of the Nueces Delta. 7a. Dissolved solids are a concern to be addressed with further studies. 7b. Salinity is a concern to be addressed with further studies. 7c. Bacteria is a concern to be addressed with further studies. 7d. Chlorides are a concern to be addressed. 7e-h. None or low impact. 7i. Alkalinity is a concern and will need to be addressed. Zinc in wastewater discharges into Nueces Bay is a concern to be addressed with further studies.
c. 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	• None
f. Comparison and consistency equities	• Standard analyses and methods used for portions
g. Interbasin transfers	• Authorization has been obtained for the Rincon Diversion Project
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 reuse opportunities of water supplies
j. Effect on navigation	• None.

4C.6 Carrizo-Wilcox Aquifer Supplies (N-6)

4C.6.1 Description of Strategy

The City of Corpus Christi (City) owns a standby groundwater supply system of four wells located near the City of Campbellton in Atascosa County (Figure 4C.6-1). This groundwater system is part of the Corpus Christi Drought Contingency Plan and is used to supplement the Choke Canyon Reservoir and Lake Corpus Christi (CCR/LCC) System during times of critical drought. The Campbellton well field taps the Carrizo-Wilcox Aquifer and lies within the Evergreen UWCD, a special legislative district that has jurisdiction in Atascosa, Wilson, Frio, and Karnes Counties to regulate new wells, well spacing, and export of groundwater out of the district.

The wells were installed in 1951, and are not currently in use. During the 1950s, drought water was pumped from these wells into the Atascosa River for delivery to LCC. Although no data are available to document the amount of water that actually reached the reservoir, local officials report that as much as 90 percent of the water pumped into the channel was lost to bank storage and evaporation. The 63-mile reach of the Frio and Nueces Rivers downstream of CCR to LCC, including seepage losses within LCC, can be as high as 37.8 percent.[1] For this reason, as well as the environmental issues involved with pumping relatively hot water into an active stream channel, this method of conveyance was not evaluated. Given the proximity of the Campbellton wells to CCR, the option being considered in this section involves pumping water from the Campbellton well field and conveying it via pipeline to CCR, approximately 20 miles to the south. In order to bring the wells online, they will need to be inspected and redeveloped to maximize productivity. Well pumps will need to be purchased and installed, and a well field

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[1] 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. A field channel loss study from CCR to LCC was conducted on behalf of the CBRWPG from March 3-28,2009 as part of Phase I of the 2011 Plan. The results showed an overall loss estimated to be between 2 and 3 percent for the 17.4 mile stretch from CCR to the Nueces River near Sulphur Creek. The remaining 45.6 river mile segment downstream of the Nueces River near Sulphur Creek to Wesley Seale Dam at LCC (to total 63-river miles) was not characterized due to the influence of water stored in LCC. LCC was full or nearly full from June 2007 through March 2008. When LCC is at or near storage capacity, the alluvium system influenced by LCC stores water and would be expected to result in less channel losses from the Nueces River near Three Rivers to LCC. A more detailed discussion is included in the CBRWPG Phase I 2011 Regional Water Plan-Study 3 Report (April 2009).

collection system of pipelines must be constructed to deliver the water to a terminal storage tank. From this storage tank, the water will be pumped via pipeline across the Atascosa River and over the Lipan Hills to CCR.

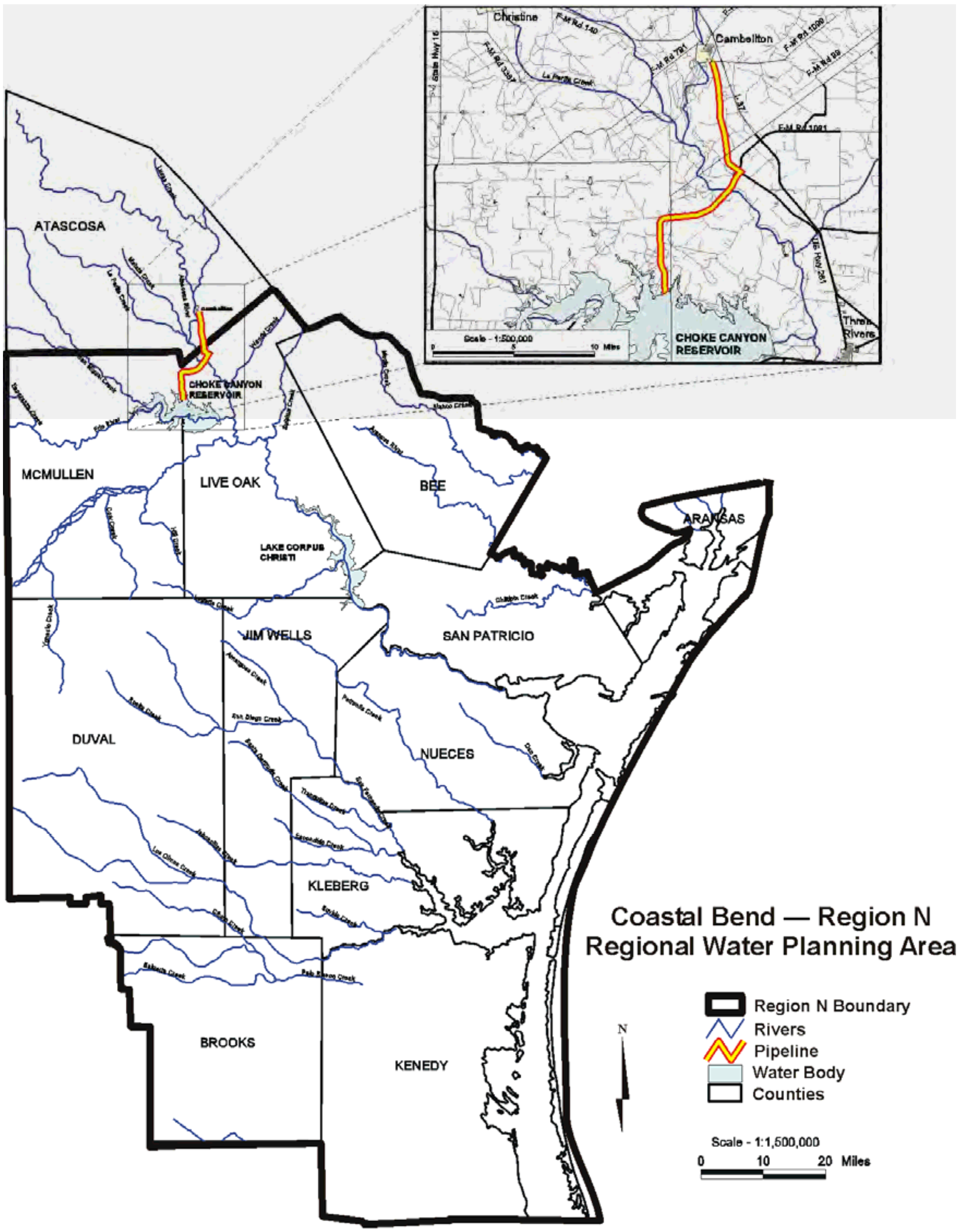

Figure 4C.6-1. Carrizo-Wilcox Supply Option

A pipeline route in this vicinity was previously considered for the Trans-Texas study to convey San Antonio River water in addition to Campbellton well water. This pipeline route was evaluated and altered to reflect the differences in project scope. The route selected was changed to reflect different delivery rates, and to minimize the number of road and stream crossings. From the terminal storage tank south of the City of Campbellton, the pipeline will parallel the route of U.S. Route 281 south until the Town of Whitsett, where it will turn west and parallel Route 99 until it empties into CCR.

CCR delivers water through the Nueces River to LCC for the City and other water users. Another possibility is the sale or transfer of water to the South Central Texas Region (Region L RWPG) in exchange for other water. It is possible that water from the Campbellton well field could be included in potential options for water transfers across basin boundaries with Region L in exchange for an equivalent replacement volume or outright purchase.

In June 2001, a study was conducted to evaluate the Campbellton wells as a standby groundwater supply for the City to utilize during emergency conditions to supplement their water supply. The study[2] concluded that although the Campbellton wells may no longer be needed by the City, they may have a value for local water use (i.e., City of Campbellton) and recommended that the City sell or transfer ownership of the Campbellton wells and associated properties. According to TCEQ, the water quality of the wells does not meet standards. Water quality issues would need to be addressed in the future prior to implementing as a recommended water management strategy.

4C.6.2 Available Yield

The Campbellton wells (TWDB Well Numbers AL-78-22-201, AL-78-22-202, AL-78-14-801, and AL-78-14-802) are screened in the Carrizo-Wilcox Aquifer, which underlies a wide portion of south central Texas. The aquifer consists of hydrologically connected sands of the Wilcox Group and the Carrizo Formation. The aquifer yields fresh to slightly saline water. Water quality analyses performed at the time of well construction indicate that the water has slightly elevated sodium levels, but is acceptable for most uses. The wells range in total depth from 3,663 to 4,132 feet. Due to the thermal gradient associated with these depths, groundwater from these wells is relatively hot, with temperatures up to 140 degrees Fahrenheit.

[2] HDR Engineering, Inc., “City of Corpus Christi Standby Groundwater Supply Evaluation,” June 2001.

In 1993, during investigations concerning the Trans-Texas pipeline project, LBG-Guyton & Associates (LBG) was retained to conduct a preliminary investigation and computer analysis of the aquifer properties around Campbellton to determine if pumpage of the Campbellton wells would result in unreasonable lowering of aquifer water levels. The results of LBG's preliminary analysis indicate that a maximum pumpage of 6 MGD (6,720 acft/yr) can likely be achieved from the Campbellton wells without unreasonably lowering water levels in the aquifer. The artesian head of the Campbellton wells is approximately 65 feet above ground surface. Water levels in the wells after one year of pumping are estimated to be more than 150 feet below ground surface and approximately 200 to 300 feet below ground surface after 50 years. These projections were based on specific yield values obtained during pump tests at the time of well installation, and assume a lowering of groundwater levels by 2 feet per year due to regional pumping from the Carrizo Aquifer. The computer simulation also indicated that water levels north of Campbellton near Jourdanton/Pleasanton and Poteet would be lowered by 8 to 15 feet during the next 50 years. Based on the results of their investigation, LBG estimated that pumping 6 MGD from the Campbellton wells would be a practical 50-year availability limit.

However, CCR is not the final distribution point for the water. As mentioned previously, water from the CCR is released downstream into the Nueces River to LCC, and ultimately to Calallen Diversion Dam. The yield for the CCR/LCC System as a whole was evaluated with the additional 6 MGD input into CCR using the system model NUBAY(an earlier version of the Corpus Christi Water Supply Model), which accounts for evaporative and channel losses during transmission. The increases in firm yield of the CCR/LCC System are estimated to be approximately 3,200 acft/yr for both 2010 and 2060 conditions. This represents approximately 48 percent of the 6,720 acft/yr of water pumped annually into CCR from the well field in Campbellton.

4C.6.3 Environmental Issues

Environmental issues related to transferring groundwater from the Campbellton wells to CCR are:

- Effects related to pipeline construction and maintenance
- Effects related to increased flows to CCR
- Effects related to water quality in CCR due to the mixing of groundwater with surface water supplies

The Campbellton wells in Atascosa County would be connected by pipeline to CCR through Live Oak and McMullen Counties. The estimated 17-mile pipeline would, to the extent possible, follow existing right-of-way along Highway 281 Alternate and State Route 99 to CCR. Acreage impacted during construction and for maintenance following completion of the pipeline would be approximately 255 acres and 73 acres, respectively.

Increased flows to CCR would raise the average operational level of the lake only slightly, about three-tenths of a foot. Downstream effects would probably be undetectable. Blending Carrizo Aquifer water with water from CCR and LCC will mitigate the slightly elevated sodium levels characteristic of the aquifer. Water quality changes in the reservoirs would be slight to undetectable and are not expected to affect aquatic life.

The predominant habitat type of concern along the proposed route of this option is mesquite-invaded pasture. The pipeline route traverses upland mesquite-blackbrush west of the Atascosa River until it terminates at CCR.[3] Pipeline construction would affect an estimated 217 acres of brushland and 38 acres of cropland and grasslands if it is constructed entirely outside of the existing rights-of-way. The pipeline would cross the Atascosa River near the SH 99 Bridge. The river is approximately 50 feet wide bank to bank and well channelized, which would minimize the acreage of wetland and bottomland hardwood impacted. Vegetation along the banks included cedar elm, hackberry, pecan, green briar and black willow. The pipeline crossing at the Atascosa River would be constructed using directional drilling to minimize disturbance. The outflow structure construction at CCR would disturb approximately 2,500 square feet of littoral wetland. A pair of crested caracaras (*Polyborus plancus*), a rare to common resident of South and South-Central Texas, were observed perched in a tree during a spring reconnaissance survey. There are no recorded occurrences of protected species within the proposed pipeline corridor. Some dense brushland habitat suitable for the endangered ocelot (*Felis paradilis*) may be present in the vicinity of the pipeline corridor. State protected species that may be found in wetlands or temporarily wet areas are the Texas Garter Snake (*Thamnophis sirtalis annectens*), the Rio Grande lesser siren (*Siren intermedia texana*), and the sheep frog (*Hypopachus variolosus*). These may be found in the Atascosa River crossing corridor and the cove at CCR. The state protected Texas horned lizard (*Phrynosoma cornutum*) may be found in open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or

[3] McMahan, C.A., Frye, R.G., and Brown, K.L., "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Austin, Texas, 1984.

scrubby trees. The mesquite-blackbrush and mesquite granjeno parks in the vicinity of the pipeline corridor can provide good habitat for the Texas tortoise (*Gopherus berlandieri*), Indigo snake *(Drymarchon corais erebennus*), and the Reticulate Collared Lizard (*Crotaphytus reticulatis*).

The slight increase in inflows to the Nueces estuary from the return flows enhance by groundwater import would not be enough to result in perceptible salinity changes or impacts to estuarine communities.

Although no National Register of Historic Places are recorded in the pipeline corridor, a systematic pedestrian survey of the entire corridor will be required to search for surface indications of cultural deposits. Additional studies including aquifer impacts are recommended prior to considering this as a recommended strategy.

4C.6.4 Engineering and Costing

The costs for this strategy were based on the 2006 Plan, updated to September 2008 dollars based on Engineering News Record Construction Cost Indices. Infrastructure needs for this project system will include:

- Pumps for the wells,
- Well field collection pipelines from each well to a common terminal storage tank located at the pipeline pump station intake,
- Pump station and intake structure to pump water from the storage tank into the pipeline,
- Construction of a transmission pipeline to carry the water from Campbellton to CCR, and
- Outlet control in CCR.

The proposed project was sized to convey 6 MGD of groundwater from the Campbellton well field to CCR. This is equivalent to approximately 1,000 gallons per minute from each of the four wells on a continual basis. Separate hydraulic profiles were generated for the well field collection system and the transmission pipeline to CCR. A cost estimate for the combined system was generated using methodology appropriate to a studies level analysis, which is consistent with other projects evaluated under Senate Bill 1. In addition to capital costs detailed in the Table 4C.6-1, Evergreen UWCD collects export fees of $0.025 per 1,000 gallons exported. Since the 2006 Coastal Bend Regional Water Plan, Evergreen UWCD rules have been revised to limit production up to a maximum of 652,000 gallons (2 acre-ft) per acre for lands for which person can show possession of groundwater rights." Therefore, an entity can lease groundwater rights, which can be significantly less expensive than purchasing land within the district. The cost summary in Table 4C.6-1 includes leasing land and groundwater rights rather than land purchases.

Table 4C.6-1.
Cost Estimate Summary
Campbellton Well Water Supply Project Option
September 2008 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station (6 MGD)	$2,262,000
Transmission Pipeline and Storage Tank (20" and 16" diameter, 17 miles)	7,674,000
Well Fields	3,166,000
Water Cooling Facilities and Outfall Structure	506,000
Total Capital Cost	**$13,608,000**
Engineering, Legal Costs and Contingencies	$4,405,000
Environmental & Archaeology Studies and Mitigation	546,000
Land Acquisition (Right of Way) and Surveying	642,000
Interest During Construction (2 years)	1,581,000
Total Project Cost	**$20,782,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$1,811,000
Operation and Maintenance:	
Wells, Pipeline, Pump Station	165,000
Groundwater Leases (6,720 acft/yr)	527,000
Water Cooling Facilities	6,000
Pumping Energy Costs (10,634,667 kWh @ $.09 per kWh)	957,000
Water Export Fee (2,180,000 gallons at $0.025/ 1000 gallons)	55,000
Total Annual Cost	**$3,521,000**
Available Project Yield (acft/yr)	**3,200**
Annual Cost of Water ($ per acft)	**$1,100**

Results of the cost estimate indicate that total capital costs for infrastructure associated with the project would be approximately $13,608,000, as detailed in Table 4C.6-1. Annual costs would be on the order of $3,521,000. For the proposed project yield of 3,200 acft/yr, this is equivalent to a unit cost of water of $1,100 per acft.

4C.6.5 Implementation Issues

In order for this option to be implemented, the following issues will need to be addressed.

- Land Leasing/Groundwater Rights – Region N entities interested in pursuing Carrizo groundwater from Campbellton wells as a water supply option will need to negotiate groundwater leases subject to managed groundwater available and the desired future condition of the aquifer developed by the District and Groundwater Management Area 13. Evergreen UWCD assesses an export fee ($0.025 per 1,000 gallons) to use water outside the District. The Evergreen UWCD also requires flow monitoring devices which may incur additional costs not included in the cost summary.
- Installation of pumps into the dormant well field will require permitting from the Evergreen UWCD.
- Environmental/Water Quality Issues – TCEQ concerns regarding raw water quality (chemical and thermal) from the Carrizo Aquifer and the potential impact on CCR water quality will need to be addressed.
- Land easements along the proposed pipeline route will need to be purchased.
- Cultural resource surveys will be required when facilities need to be constructed.
- Water supply provisions for local water users (Campbellton area).

4C.6.6 Evaluation Summary

An evaluation summary of this water management option is provided in Table 4C.6-2.

Table 4C.6-2.
Evaluation Summary of
Campbellton Well Option to Enhance Water Supply Yield

Impact Category	***Comment(s)***
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Firm Yield: 3,200 acft/yr 2. Good, assuming ability to pump 6,720 acft/yr and recovery of 48 percent. 3. Cost: $1,100 per acft/yr.
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. Increase flows to CCR. 2. Slight increase in bay and estuary inflows. 3. Pipeline construction may temporarily disrupt local wildlife. 4. Minimal impact (pipeline crossing Atascosa River.) 5. Minimal impact along pipeline route. 6. Cultural resources will need to be avoided when facilities are constructed. 7. May have impacts to CCR due to mixing of groundwater with surface water supplies. b. Groundwater may be slightly saline. f. Groundwater may contain high sulfur content.
c. Impacts to State water resources	• Will result in lowering of groundwater levels in Campbellton area over time. No other apparent negative impacts on other water resources
d. Threats to agriculture and natural resources in region	• None
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Cost model for option is based on literature values
g. Interbasin transfers	• Potential for interbasin transfer or exchange for other water with Region L
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Slight improvement over current conditions
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• Potential impacts to wildlife habitat.

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4C.7 Gulf Coast Aquifer Supplies (N-7)

4C.7.1 Conjunctive Use of Groundwater Supplies from Refugio County

4C.7.1.1 Description of Strategy

The existing regional water system operated by the City of Corpus Christi (City) has two supplies of water—CCR/LCC System in the Nueces Basin and Lake Texana in the Lavaca River Basin. The City's O.N. Stevens Water Treatment Plant (Stevens WTP) at Calallen Dam receives the Nueces River water via the 'bed and banks' of the Nueces River and the Lake Texana water via pipeline. In addition to supplying its own needs, the City provides wholesale water to the South Texas Water Authority (STWA), to the San Patricio Municipal Water District (SPMWD), and numerous other municipal and industrial entities.

This option considers conjunctive use of groundwater with the existing surface water supplies and evaluates the feasibility of securing groundwater supplies from the Gulf Coast Aquifer in Refugio County. This analysis considers the operation of a new well field in western Refugio County (Figure 4C.7-1) to provide summer peaking supplies (June through September) and a much lower supply during the rest of the year. Other conjunctive use concepts could include the delivery of groundwater only when surface water supplies are low and as an emergency supply source.

This water management strategy was evaluated during the 2001 Plan, and study results have been carried over in the 2006 Plan and 2011 Plan with updates to costs. Prior to implementing this strategy, additional analyses are recommended to include (1) revising costs to install a fourth pump in the existing Mary Rhodes Pipeline pump stations to deliver groundwater supplies to the Stevens WTP which is necessary with contracted, interruptible supplies from Lake Texana, (2) consideration of updates to Refugio Groundwater Conservation District (GCD) rules or groundwater availability based on managed available groundwater supplies determined by the district, and (3) evaluation of well field using the TWDB Central Gulf Coast Groundwater Availability Model (CGCGAM) to update groundwater supply availability.

Corpus Christi currently has contracts from Lake Texana for 41,840 acft/yr on a firm basis and 12,000 acft/yr on an interruptible basis. As part of a plan for future supplies, the pipeline was upsized and is capable of delivering up to 112,000 acft/yr. Potential surface water supplies that could be transported via this pipeline include Colorado River, Guadalupe River, and

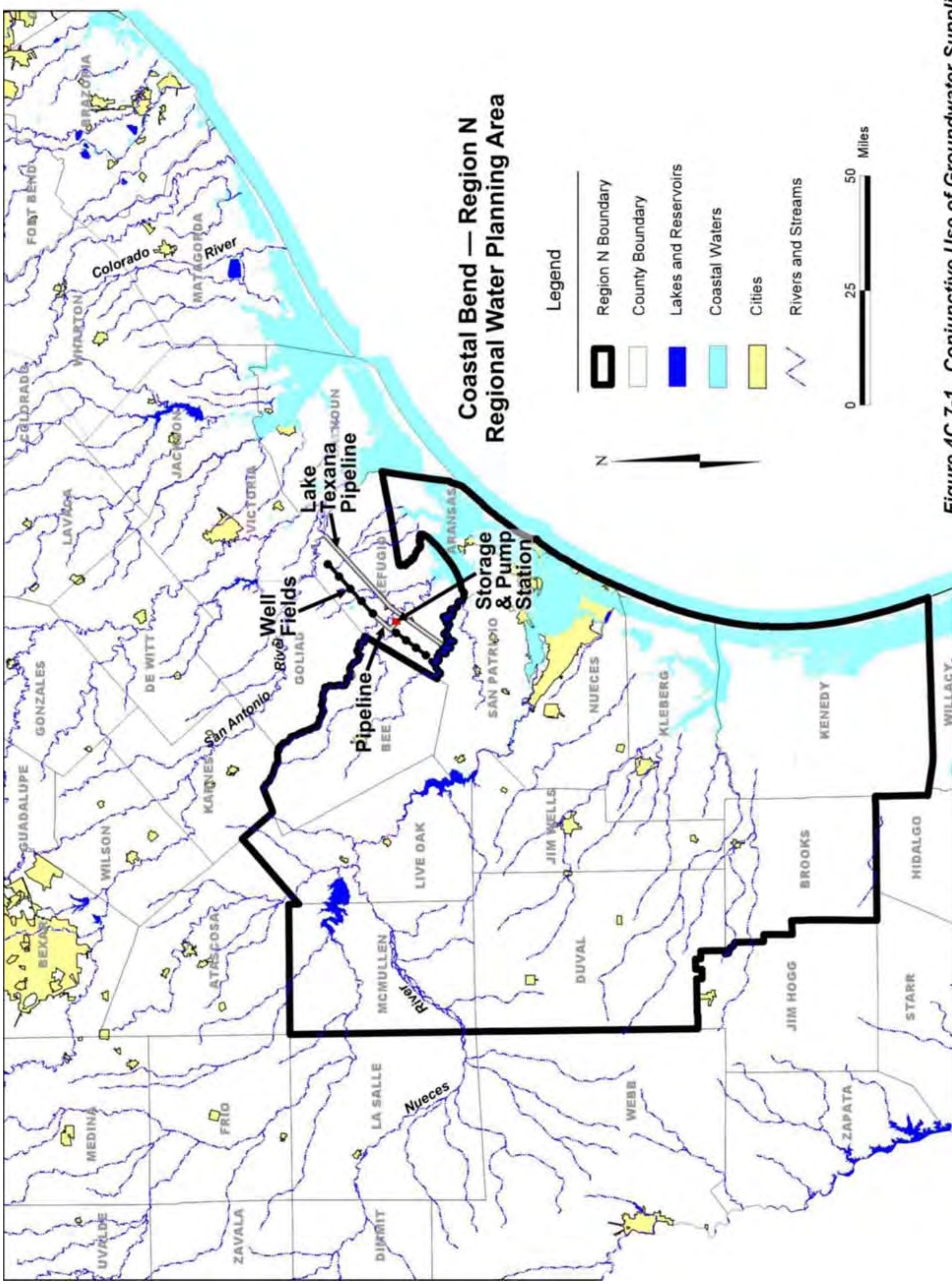

Figure 4C.7-1. Conjunctive Use of Groundwater Supplies from Refugio County additional Lake Texana water as well as potential groundwater supplies from the Gulf Coast Aquifer. Along the pipeline, the greatest amount of undeveloped groundwater is in Refugio County.[1]

The Refugio GCD was created in the 76th Texas Legislature and adopted Management Rules in July 2004, which were amended in August 2005. The rules[2] specify annual maximum groundwater production of ½ acft per contiguous surface acre up to 500 acres (or 250 acft/yr) with production limits on property greater than 500 contiguous acres subject to Refugio GCD board determination. Groundwater transported outside the Refugio GCD boundaries requires a Transport Permit issued by the Refugio GCD's Board. According to spacing requirements, new wells must be spaced at least 2 feet for every gallon per minute of the permitted flow from nearest existing or authorized well. The spacing requirements were met for this water management strategy.

4C.7.1.2 Available Yield and Water Quality

The principal freshwater-bearing formations in Refugio County include the Goliad Sands, the Lissie Formation, and the Beaumont Clay. The Goliad Sands, called the Evangeline Aquifer, underlies the Lissie and Beaumont Clay, which are called the Chicot Aquifer. The sediments are non-marine in origin and consist chiefly of sand, clay, and gravel. The Goliad Sand can provide, by far, the greatest supply of water to wells. Its outcrop is located in Bee and Goliad Counties in a northeast-trending belt of 15 to 20 miles wide, dips to the southeast toward the coast at about 10 to 40 feet per mile, and ranges from 300 to 600 feet thick in the confined section.

The first major study of groundwater supplies in Refugio County estimated about 42,000 acft/yr of water containing less than 300 milligrams per liter (mg/L) of chloride could be pumped indefinitely from the Goliad Sand and Lissie Formation.[3] These computations were based on the ability of the aquifer to transmit water to the areas favorable for development without considering drawdown from pumping wells. The areas identified for either favorable for moderate or large-scale development are generally west of US Hwy 77 and 2 to 8 miles north of

[1] Dodson, Karen K., "Identifying Underutilized Groundwater Resources in the Coastal Bend Region of Texas," Master's Thesis in Environmental Science at Texas A&M University-Corpus Christi, 1997.
[2] Rules of Refugio Groundwater Conservation District, August 29, 2005.
[3] Mason, Curtis C., "Ground-water Resources of Refugio County, Texas," Texas Water Commission Bulletin 6312, 48 pp., 1963.

the Aransas River. In these areas, the chloride concentration of groundwater in the Goliad Sand is generally less than 300 mg/L and the concentration of total dissolved solids is generally less than 1,000 mg/L. Comparisons of these water quality parameters with both the Nueces River water and the Lake Texana water indicate a significantly higher level of dissolved solids that may be problematic to local industries in the region. However, the blended water from the well field is expected to meet secondary drinking water standards.

A 1979 statewide study of the availability of groundwater by the Texas Department of Water Resources (currently the Texas Water Development Board) used a one-layer groundwater model with a grid of 10-mile by 10-mile cells for the analysis.[4] By assuming an allowable 100 feet drawdown at a line located midway between the centerline of the outcrop and the freshwater and saltwater interface, groundwater availability was estimated to be about 30,000 acft/yr in the area between the San Antonio River and Nueces River Basins.

A 1991 large-scale regional aquifer system analysis of the Texas Gulf Coast Aquifer System included the development of a groundwater model.[5] The Texas coastal lowlands part of the model includes five permeable zones and two confining units. Analysis of the findings and results of the model tests suggest the western half of Refugio County as having the capacity for additional groundwater development.

For the 2001 Plan, a comprehensive groundwater model was developed for the Coastal Bend Regional Water Planning Group (CBRWPG) to test the availability of groundwater in the Gulf Coast Aquifer System. Several tests of a range of drawdown criteria were made to provide information for a decision on an acceptable decline of water levels. These tests were made for each of the four water-bearing units of the Gulf Coast Aquifer System. Based on a region-wide pumping used in the tests and adopted criteria, which included limiting drawdowns to 100 feet, about 27,300 acft/yr of groundwater is estimated to be available from the Goliad Sand and about 2,000 acft/yr from all other water-bearing formations in Refugio County. Since the 2001 Plan, the TWDB has developed the CGCGAM to simulate steady-state, predevelopment and developed flow in the Gulf Coast Aquifer along the south Texas Gulf Coast and to assist in the determination of groundwater availability for the region. The model consists of four layers with

[4] Muller, D. A. and Robert D Price, "Ground-water Availability in Texas, Estimates and Projections through 2030," Texas Department of Water Resources Report 238, 77 pp., 1979.
[5] Ryder, Paul D. and Ann F. Ardis, "Hydrology of the Texas Gulf Coast Aquifer Systems," U.S. Geological Survey Open-file Report 91-64, 147p., 1991.

1-mile (5,280-foot) grid spacing and includes the Gulf Coast aquifer system in Refugio County (Figure 3-6).

The availability of groundwater for this option, after considering local demands, is estimated at 28,000 acft/yr and is based on the availability of groundwater estimated by the CBRWPG (about 29,300 acft/yr) less the amount of estimated groundwater demands in Refugio County in year 2060 (1,690 acft/yr[6]).

In the proposed well field, high-capacity wells drawing water from the Goliad Sand are about 1,000 feet in depth and commonly yield 1,000 to 1,500 gallons per minute (gpm). Limiting the total annual water production to 28,000 acft/yr, the withdrawals are set to a maximum production rate of 4,000 acft/month during the four summer months, and a base production rate of 1,500 acft/month during the other eight months of the year. Based on the summer demand, and with a contingency of 10 percent of the wells not in production, 28 wells would be required. The southwest well field would have about 12 wells and the northwest well field would have about 16 wells. The proposed wells, operating at a maximum production of 1,200 gpm, would be at a minimum 2,400 feet from existing wells to meet Refugio GCD spacing requirements.

4C.7.1.3 Environmental Issues

A previous study estimates up to 25% of recharge to the Gulf Coast Aquifer in nearby Wharton and Matagorda counties ends up as freshwater discharge to near-coast waters.[7]

The pumping of groundwater from the Gulf Coast Aquifer could have a very slight negative impact on baseflow in the downstream reaches of streams in these areas. However, many of the streams are dry most of the time; thus, no measurable impact on wildlife along the streams is expected.

The proposed well field in western Refugio County would be bounded by the Aransas River on the south and the San Antonio River on the north (Figure 4C.7-1). This area is rangeland characterized by varying degrees of brush. Plains Gumweed (*Grindelia oolepis*), which was considered for (but did not receive) federal protection, and Welder Machaeranthera (*Psilactis heterocapa*), which is a federal C2 candidate species, are reported to occur in the

[6] Local groundwater demand in Refugio County based on preliminary analyses conducted on behalf of Region L.

[7] Dutton, A.R., and Richter, B.C., 1990. "Regional geohydrology of the Gulf Coast Aquifer in Matagorda and Wharton Counties, Texas: Development of a numerical model to estimate the impact of water management strategies", The University of Texas at Austin and Bureau of Economic Geology.

project area. Both of these species are considered by TPWD to be very rare and vulnerable to extirpation.

In addition to 28 wells, construction impacts would include 37 miles of collection and transmission lines. This pipeline collection system is expected to affect 141 acres. The wells and collection system would be located in such a way as to avoid or minimize impacts to sensitive resources. The water would be delivered to the Lake Texana pipeline via the proposed water transmission line from the well field in western Refugio County.

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 could be impacted by infrastructure development (e.g., disturbance to endangered species habitat or cultural resource sites), changes in facility siting or pipeline alignment would generally be sufficient to avoid or minimize adverse effects.

Subsidence as a result of continuous groundwater withdrawal could potentially cause changes in land use, drainage patterns, wetlands and other habitats in the affected area. While the generally expected result, an increase in wetland habitat, may be viewed as beneficial, actual impacts will be critically dependent on the location in which subsidence takes place. Changes in drainage patterns, for example, could result in vegetated wetlands being converted into open water habitat less valuable to wildlife and waterfowl, or freshwater wetlands could be converted to a brackish condition. Where endangered species habitat is present in a proposed well field area, potential changes as a result of subsidence could be both substantial and difficult to avoid or mitigate. Of the areas mentioned in the preceding discussion, all have some potential to harbor endangered species whose habitat is both limited in distribution and would be sensitive to the changes that could result from subsidence.

4C.7.1.4 Engineering and Costing

For the conjunctive use of groundwater from the Gulf Coast Aquifer in Refugio County option, groundwater would be developed from two well fields along a southwest-northeast line about 3 miles west of the City of Refugio (Figure 4C.7-1). The line of wells has a blank section west of the City of Refugio to reduce the impact of water level declines in the City of Refugio's well field and to avoid an area where the groundwater salinity is slightly elevated.

Independent facilities would be constructed for each of the two well fields. These facilities include wells, collection and transmission pipelines, storage, and pump stations.

Based on the current Mary Rhodes Pipeline pumping capacity of 77,000 acft/yr, the addition of 28,000 acft/yr of groundwater supplies to permitted Lake Texana supplies requires installation of a fourth pump in each of the three Mary Rhodes Pipeline pump stations to deliver supplies to the Stevens WTP. The cost summary presented in Table 4C.7-1 does not explicitly include these costs.

Cost estimates were computed for capital costs, annual debt service, operation and maintenance, power, land, and environmental mitigation for uniform and peak day delivery. These costs are summarized in Table 4C.7-1. As shown, the annual costs, including debt service for a 20-year loan at 6 percent interest, operation and maintenance costs, including power and the purchase of groundwater, are estimated to be $12,996,000 for 28,000 acft of water. This option produces raw water delivered to the Stevens WTP at an estimated cost of $463 per acft (Table 4C.7-1). If treatment of water is necessary, the treated water cost is $789 per acft (assuming treatment costs of $326 per acft).

4C.7.1.5 Implementation Issues

The development of conjunctive water supplies from the Gulf Coast Aquifer (Goliad Sands) in Refugio County must address several issues. Major issues include:

- Impact on water levels in the aquifer, potential intrusion of saline groundwater into freshwater zones and land surface subsidence.
- Purchase of groundwater rights
- Competition for groundwater in the area
- Potential regulations and permitting by the Refugio GCD and/or Groundwater Management Area 15.
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the pipelines.
- GLO Sand and Gravel Removal permit for pipeline stream crossings.
- GLO Easement for use of State-owned land (if any).
- TPWD Sand, Gravel, and Marl permit.
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, avoidance of cultural resources, or additional land acquisition.

Table 4C.7-1.
Cost Estimate Summary
Conjunctive Use of Groundwater Supplies from Refugio County
(September 2008 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Field (28 wells; 1,200 gpm)	24,234,000
Well Field Collection Pipeline (12 to 36-inch dia.; 33 miles)	19,982,000
Transmission Pump Station	7,149,000
Transmission Pipeline (48-inch dia.; 3.5 miles)	3,561,000
Total Capital Cost	**$54,926,000**
Engineering, Legal Costs and Contingencies	$19,046,000
Environmental and Archaeology Studies and Mitigation	970,000
Land Acquisition and Surveying (153 acres)	1,328,000
Interest During Construction (2 years)	6,102,000
Total Project Cost	**$82,372,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$7,182,000
Operation and Maintenance:	
Pipeline, Pump Station, and Well Field	595,000
Pumping Energy Costs to Texana Pipeline (27,753,990 kWh @ $0.09 per kWh)	2,498,000
Purchase of Water (28,000 acft/yr @ $96.09 per acft)	2,691,000
Total Annual Cost	**$12,996,000**
Available Project Yield (acft/yr)	**28,000**
Annual Cost of Water ($ per acft)	**$463**
Annual Cost of Water ($ per 1000 gallons)	**$1.43**

4C.7.1.6 Evaluation Summary

An evaluation summary of this regional water management option is provided in Table 4C.7-2.

Table 4C.7-2.
Evaluation Summary of the Refugio County Groundwater

Impact Category	***Comment(s)***
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Firm Yield: 28,000 per acft/yr. 2. Water Quality: Fair. 3. Low cost: $463 per acft (raw), or $789 per acft (if treated).
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 decrease instream flow and discharge of freshwater into coastal estuaries due to local groundwater-surface water interaction. 2. May slightly decrease instream flow and discharge of freshwater into coastal estuaries due to local groundwater-surface water interaction. 3. Negligible impacts. 4. Negligible impacts. 5. Negligible impacts. 6. Cultural resources will have to be surveyed and avoided. 7. Low impacts. 7a. Total dissolved solids are generally high and may require blending with higher quality water. 7b. High salinity is a potential concern to address during the early phases of project development. 7c. Negligible impacts. 7d-e. Groundwater may contain high chloride and bromide levels and may require blending with higher quality water. 7f-i. Negligible impacts.
c. Impacts to State water resources	• No negative impacts on water resources other than the Gulf Coast Aquifer. • Potential benefit to Nueces Estuary from increased freshwater return flows.
d. Threats to agriculture and natural resources in region	• May slightly increase pumping costs for agricultural users in the area due to localized drawdowns.
e. Recreational impacts	• None.
f. Equitable Comparison of Strategies	• Standard analyses and methods used.
g. Interbasin transfers	• Not applicable to groundwater sources.
h. Third party social and economic impacts from voluntary redistribution of water	• May require the purchase of groundwater rights.
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities.
j. Effect on navigation	• None.

4C.7.2 Groundwater Alternative for Small Municipal and Rural Water Systems and Irrigation, Mining, and Manufacturing Water Users for the Coastal Bend Region

4C.7.2.1 Description of Strategy

The Gulf Coast Aquifer underlies all counties within the Coastal Bend Region and yields moderate to large amounts of fresh and slightly saline water. The Gulf Coast Aquifer, extending from Northern Mexico to Florida, is comprised of four water-bearing formations: Catahoula, Jasper, Evangeline, and Chicot. The Evangeline and Chicot Aquifers are the uppermost water-bearing formations, are the most productive and, consequently, are the formations utilized most commonly. The Evangeline Aquifer of the Gulf Coast Aquifer System features the highly transmissive Goliad Sands. The Chicot Aquifer is comprised of many different geologic formations; however, the Beaumont and Lissie Formations are predominant in the Coastal Bend area.

Municipal water systems and other water user groups in the Coastal Plains area of the Coastal Bend Water Planning Region commonly use the Gulf Coast Aquifer for their supply. These sources may be a strong preference because the water is usually readily available, inexpensive, and often suitable for public water supplies with minimal treatment, although elevated concentrations of TDS are present in some areas.

The purposes of this option are to:

- Evaluate aquifers and existing well field(s) of each WUG to meet projected water supply requirements through the year 2060, based on groundwater supply estimates derived from reported well capacity for other wells in the area.
- If additional supplies are needed, identify whether or not additional wells are the most likely water management strategy, or whether an alternative strategy, such as purchase from a wholesale water provider, is recommended.
- If the water needs to be treated, estimate when the expansion is needed and how much the facilities will cost.

The evaluation of individual WUG water systems is at a reconnaissance level and does not include:

- An engineering analysis of the water system as to the current condition or adequacy of the wells, transmission system, and storage facilities;
- A projection of maintenance costs or replacement costs of existing wells and facilities;
- The potential interference of new wells installed by others near the city's wells or at locations identified for new well fields;

- Impact of potential changes in groundwater use patterns in the vicinity of the city's well field and the county;
- Changes in rules and regulations that may be developed and implemented by a groundwater conservation district or the State; nor
- Consideration of additional wells or water treatment for local purposes such as reliability, water pressure, peaking capacity, and localized growth.

The evaluation of each municipal water system consisted of the following steps:

1. Compiled information prepared for the CBRWPG on current and projected population and water demand for each of the WUGs;
2. Estimated well depth and capacity for each WUG based on publicly available information for the water system from published groundwater reports and TCEQ and TWDB records;
4. If the estimated groundwater supply after adjustments was greater than the estimated groundwater demand in the year 2060, the evaluation concludes that the existing water supply is adequate;
5. If the estimated supply after adjustments was less than the estimated groundwater demand in the year 2060, the evaluation concluded that an additional water supply would be needed; and
6. If new wells are the most feasible water management strategy, estimated at what decade it is needed and the capital cost of adding the new wells to the water system.

The methodology presented in the following text deals specifically with those entities that show a projected unmet need that is likely to be met through development of local aquifer supplies; in other words, only those entities whose needs exceed the current estimation of local, currently accessible groundwater supply. These entities are shown in Figure 4C.7-2.

Because no specific project data regarding any of the local groundwater supply water management strategies is available, it is necessary to make a number of assumptions for costing and evaluation. For WUGs with needs to be met from local Gulf Coast Aquifers, characteristic well depth and well capacity (gpm) estimates were developed for costing purposes based on data from existing wells in the vicinity. For manufacturing and mining groundwater use, it was assumed that groundwater would be supplied at a constant annual rate, and that the water would be usable without treatment. For irrigation, it was assumed that all use would occur in 6 months of the year, so a peaking factor of two was used in estimating the number of wells necessary for cost estimation. In addition, it was assumed that irrigation water would be applied without treatment.

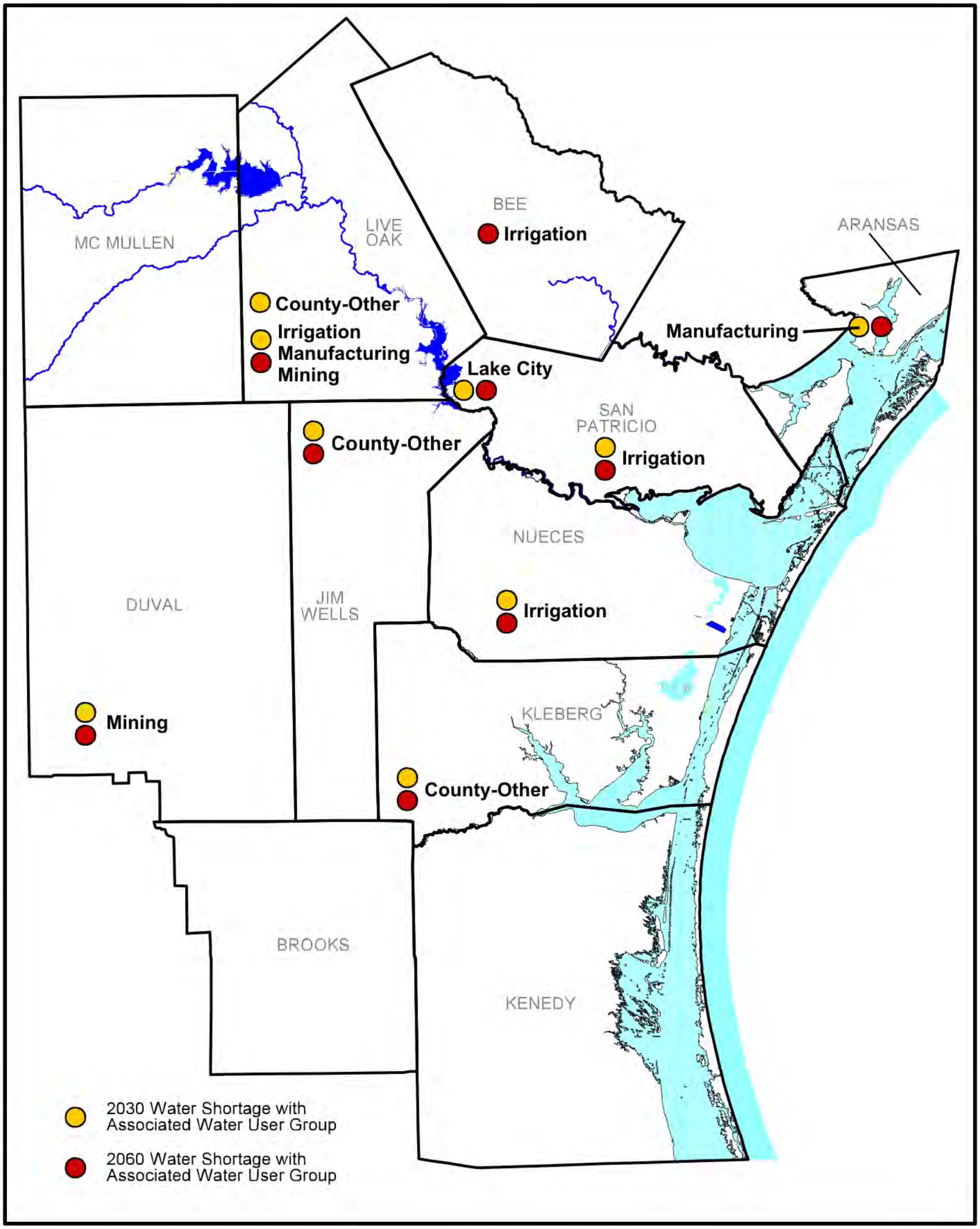

Figure 4C.7-2. Location and Type of Use for 2030 and 2060 Water Supply Shortages Relying on Groundwater Supplies

For county-other WUGs, which are understood to represent small rural water supply systems, it was assumed that the water suppliers would need to meet instantaneous peak demand rates of twice the annual average rate. Therefore, as in irrigation, twice the number of wells of a given capacity are required to meet the peak demand rate for costing purposes. No pipelines or pump stations were assigned for costing purposes. It was assumed that these proposed wells would connect directly to the demand center or local distribution system, and that the cost of any associated piping would be covered in the 35 percent project cost contingency factor. For the purposes of estimating well pumping power costs, a total dynamic head estimate of 300 feet was assumed—160 feet to bring water from pumping levels to the ground surface and 140 feet to pump into a pressurized distribution system maintained at 60 psi. This conservative estimate is intended to account for local drawdown and declining water levels with time. For municipal (and county-other) users it was also assumed, in the absence of any specific information to the contrary, that disinfection would be the only treatment needed to make the groundwater supply meet water quality standards, and that adequate treatment capacity would exist to meet peak demand rates.

All cost estimates were performed according to established HDR costing methodology. All costs were amortized over a 20-year loan period, with debt service and annualized O&M often being a significant proportion of costs. In addition, all wells are costed in present value, even if they are not scheduled to be needed until later decades. This is to maintain consistency in cost estimates with other projects. However, it should be noted that individual wells are not usually financed in this manner, and managers of affected WUGs may be more interested simply in the estimated capital cost for the wells. Also, cost estimates for new wells serving economic activities such as mining or irrigation are presented as a group with a single unit cost, although in reality these costs will be borne individually by multiple independent parties (farmers, mining operations, manufacturing plants, etc.) when and where the wells are needed and constructed.

4C.7.2.2 Water Availability Using the Central Gulf Coast Groundwater Availability Model

In order to define groundwater availability for planning purposes, the following drawdown and water quality constraints were adopted by the CBRWPG during the previous planning process:

1. In the unconfined aquifer:
   a. Water level declines were limited to no more than 125 feet below predevelopment levels; and
   b. A minimum saturated thickness of 150 feet.
2. In the confined aquifer:
   a. Water level declines were limited to no more than 250 feet below predevelopment levels; and
   b. Water level declines were not to exceed 62.5 percent of the elevation difference between predevelopment flow heads and the top of the aquifer.
3. Total dissolved solids concentrations less than 1,500 ppm.

The TWDB is currently working with the Groundwater Management Areas (GMAs) to determine desired future conditions for the aquifer. Once these have been determined, the approved Groundwater Availability Model's will be used to model those conditions to determine aquifer availability for future planning cycles. These values may be different than what has been previously adopted by the CBRWPG.

In order to determine if projected groundwater pumpage for local supply may exceed the criteria presented above, the local groundwater demands for each user group were simulated using the publicly-released version of the CGCGAM, sponsored and developed by the TWDB, which represents the partially-penetrating thickness of the Evangeline Aquifer. The CGCGAM extends from Wharton and Colorado counties in the northeast to Hidalgo and Starr County in the southwest (Figure 4C.7-3). It should be noted that groundwater modeling using the CGCGAM is not appropriate for modeling changes in TDS or other water quality criteria. It is only appropriate for evaluating changes in groundwater elevations.

Drawdown from 2000 to 2060 was calculated by the CGCGAM. After the groundwater demands for local supply were simulated, the resulting water levels were compared to water levels simulated in the steady-state version of the CGCGAM which are representative of pre-development conditions. If drawdown from pre-development conditions exceeded any of the criteria, these locations are noted. Drawdown for the Chicot, Evangeline, and Jasper Aquifers are presented in Figures 4C.7-4, 4C.7-5, and 4C.7-6, respectively. The Chicot Aquifer shows no significant drawdown during this simulation period.

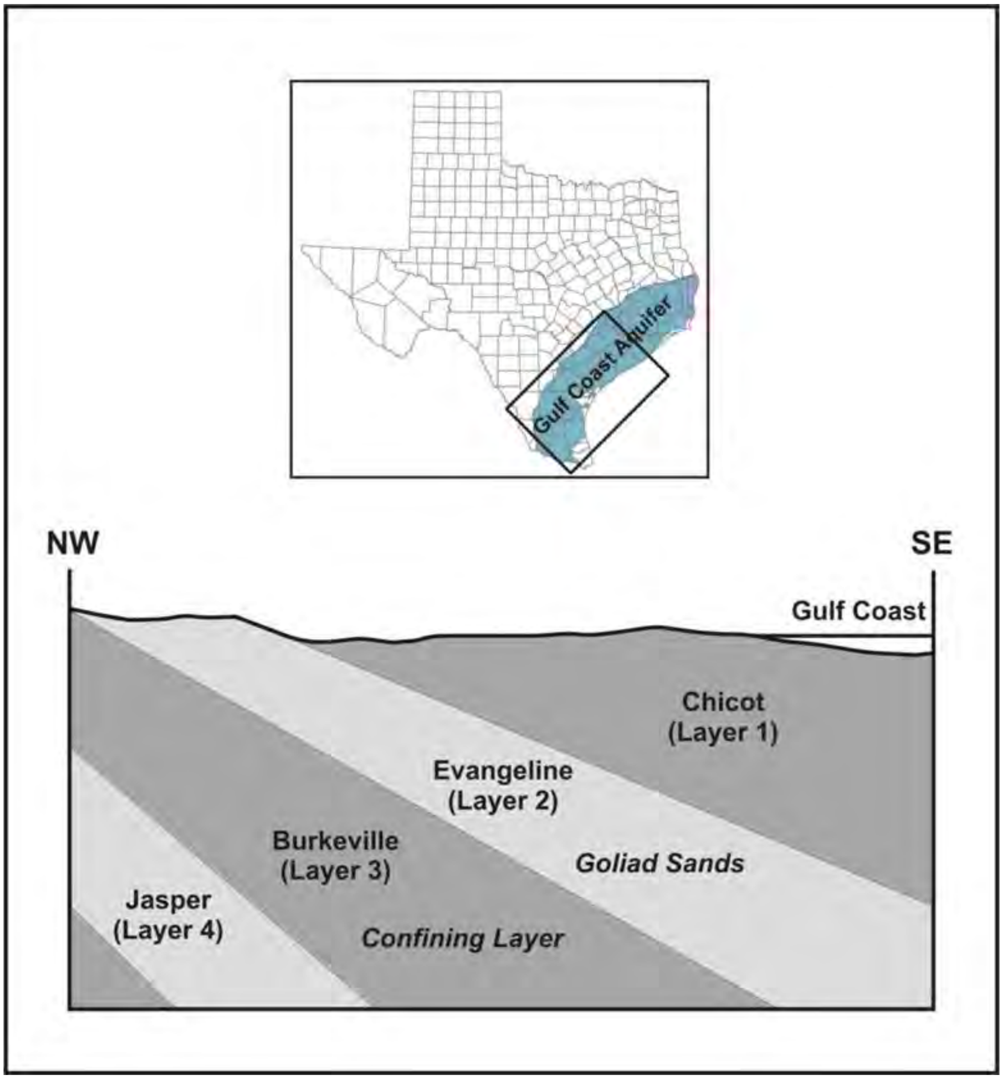

Figure 4C.7-3. Central Gulf Coast Groundwater Availability Model Boundaries and Layers

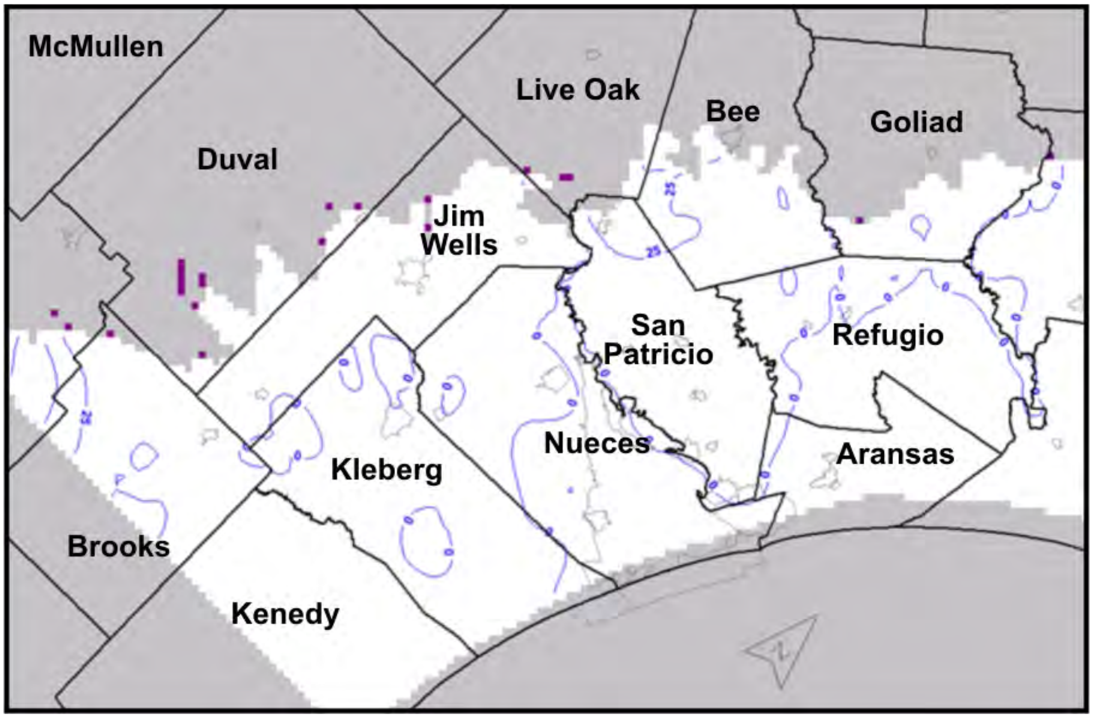

Figure 4C.7-4. 2000 to 2060 Chicot (Layer 1) Drawdown

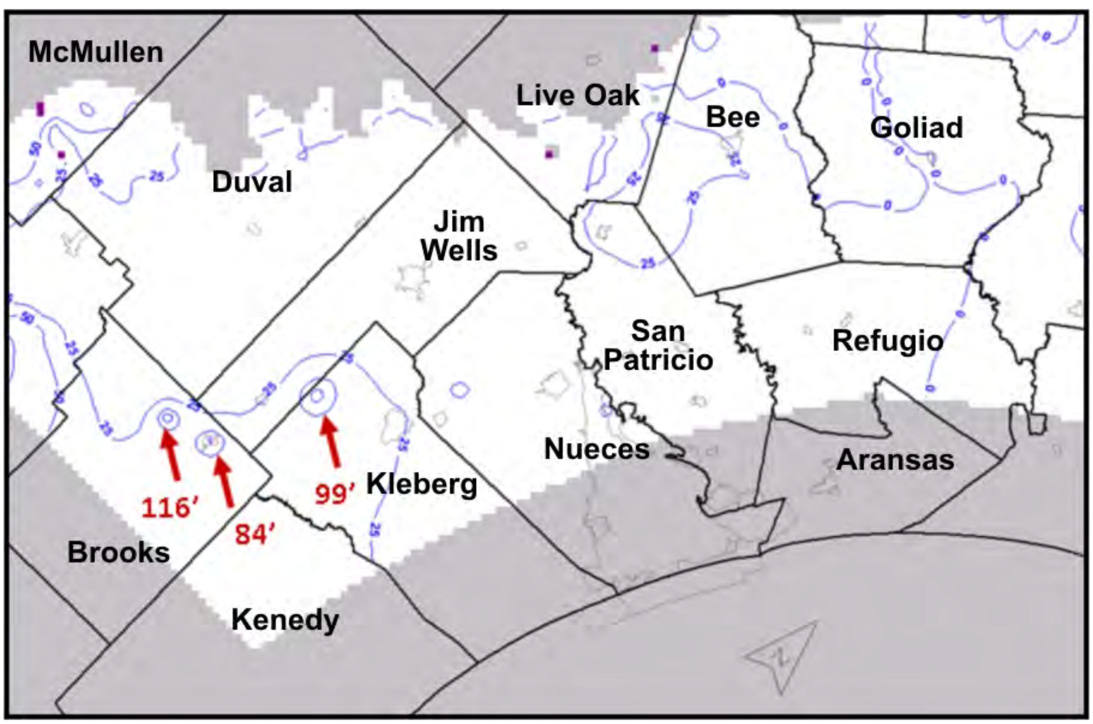

Figure 4C.7-5. 2000 to 2060 Evangeline (Layer 2) Drawdown

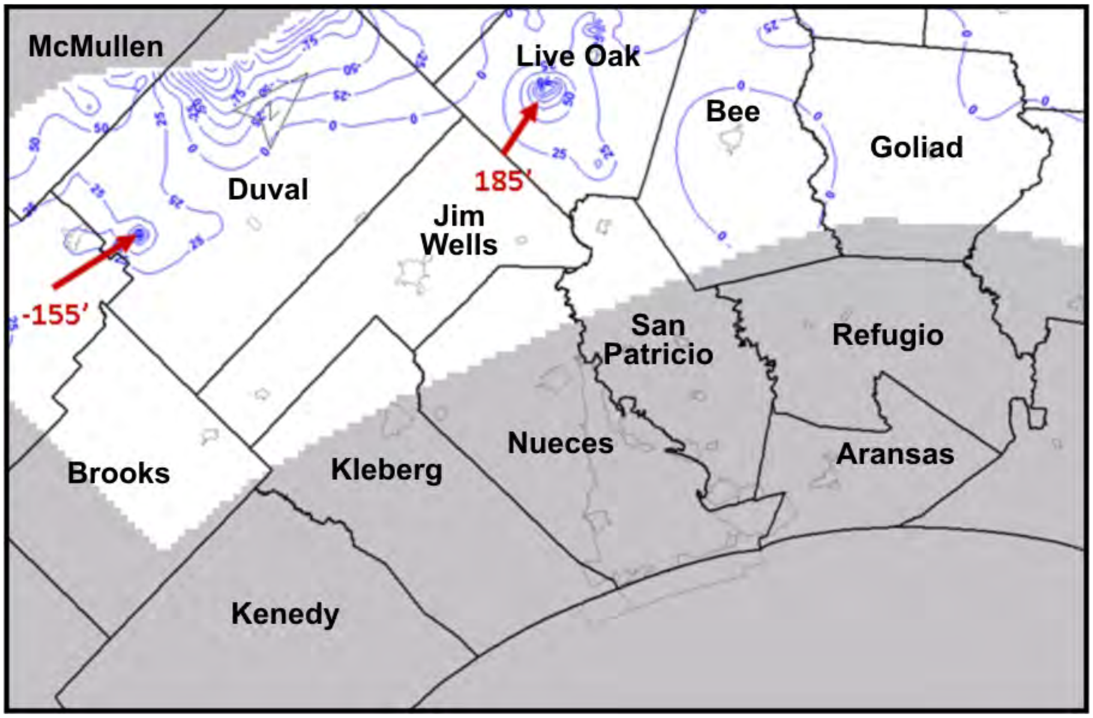

Figure 4C.7-6. 2000 to 2060 Jasper (Layer 4) Drawdown

The Evangeline Aquifer shows a large area of drawdown in Kleberg County of up to 99 feet, which is associated with mining activity and municipal pumping. There is also a large drawdown in Brooks County associated with the City of Falfurrias and local mining activities (although this mining pumpage is attributed to Duval County in TWDB records). The Jasper Aquifer shows a significant drawdown in Live Oak County, which is also attributed to mining and manufacturing[8]. In Duval County, the aquifer has rebounded due to reduced pumping from initial 1999 conditions.

Figure 4C.7-7 shows that the drawdown associated with Duval County-mining in the Evangeline Aquifer is the only area within Region N that exceeds the drawdown criteria. Figure 4C.7-8 displays model simulation results that indicate four areas in the Jasper Aquifer which exceed the drawdown criteria. These areas are all associated with mining or manufacturing enterprises in the Region, and are partially an artifact of the methodology that was used to determine spatial distribution of pumping within each county. It is probable that these entities could avoid excessive drawdowns by spreading out the area of their wells, instead of concentrating them all in a small area represented by a cluster of adjacent cells. However, the

[8] The drawdown indicated is after considering pumping cutbacks to meet CBRWPG drawdown criteria.

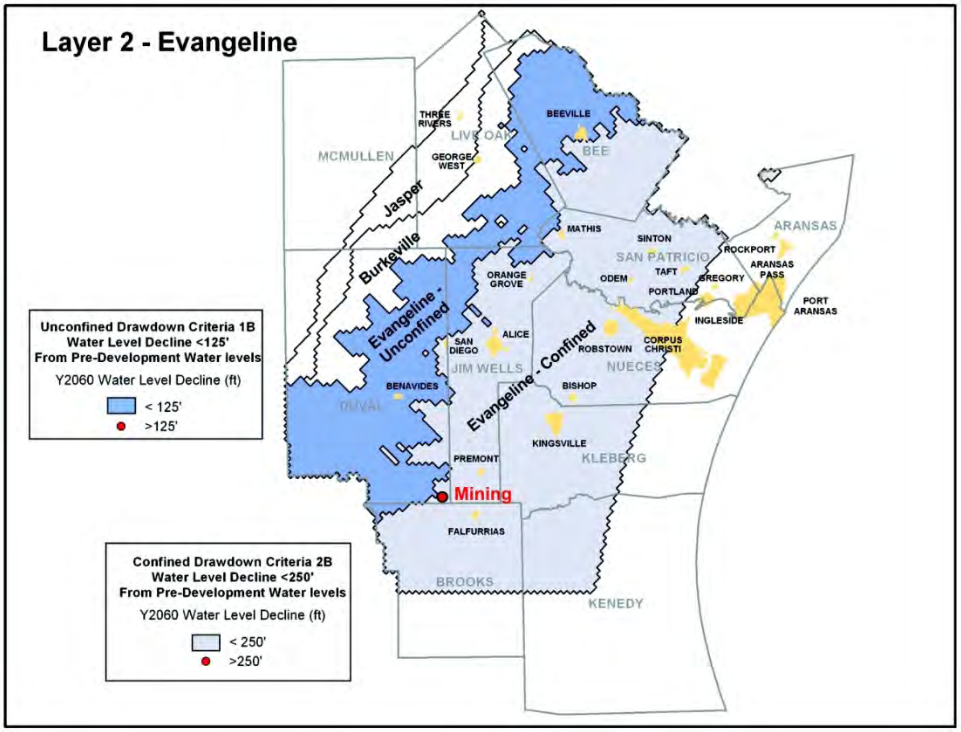

Figure 4C.7-7. Evangeline Aquifer Areas Exceeding Drawdown Criteria

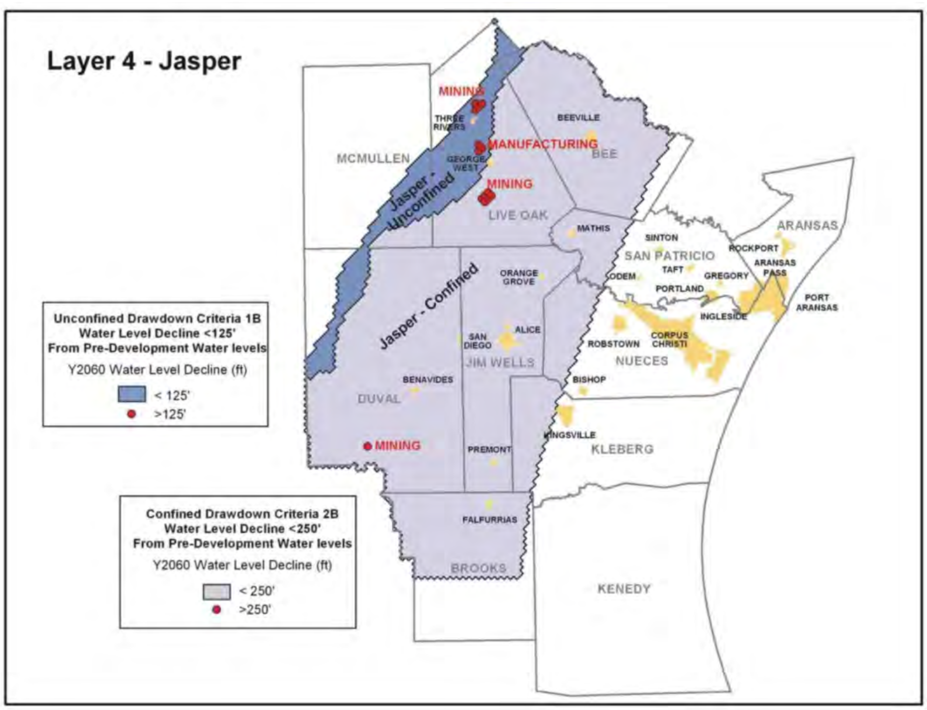

Figure 4C.7-8. Jasper Aquifer Areas Exceeding Drawdown Criteria local groundwater supply, associated with assigned individual pumping cells, cannot fully support the groundwater demand; therefore, the groundwater supply for Live Oak Mining and Manufacturing and Duval-Mining (shown in Section 4A) has been prorated back so that drawdown does not exceed the adopted criteria.

4C.7.2.3 Evaluation of Municipal Water Systems and Water Quality

The location of each municipal water system with a population in excess of about 500 that totally relies on local groundwater for a supply is presented in Figure 4C.7-9. The needs analysis indicate that none of the municipal systems identified had unmet needs within the planning period. However, there is some uncertainty as to the future water quality with prolonged pumping, since TDS exceeds drinking water standards throughout much of the planning region (Figure 4C.7-10). For drinking water supplies, the public drinking water standard for salinity is 1,000 mg/L of total dissolved solids.

If local utilities determine that a water treatment plant to desalinate the local brackish groundwater is needed, Table 4C.7-3 is provided to give an estimate of the capital cost for treating slightly saline water (up to 3,000 mg/L). This cost does not include connection to existing wells or the distribution system or the disposal of concentrate.

Freer is in an area of the Coastal Bend Water Planning Region and Duval County where the major water bearing zones of the Gulf Coast Aquifer are absent and where the Carrizo-Wilcox Aquifer is too deep, saline, and hot for a conventional public water supply. Locally, groundwater is produced for the city by the Freer Water Conservation and Improvement District from the Catahoula Tuff which is not classified as a major or minor aquifer by TWDB and is not included in the county’s groundwater availability estimates. In this area, the Catahoula Tuff supplies slightly saline water and yields 100 to 200 gpm to large wells. The groundwater from the Catahoula Formation routinely has TDS concentrations greater than 1,000 ppm. Although projections indicate that Freer’s current wells will produce adequate supply to meet their anticipated demand, there is local concern that the water quality of the water produced by the city’s wells will decline to the point that advanced treatment will be necessary to stay in compliance with regulatory water quality guidelines. The proposed treatment for groundwater

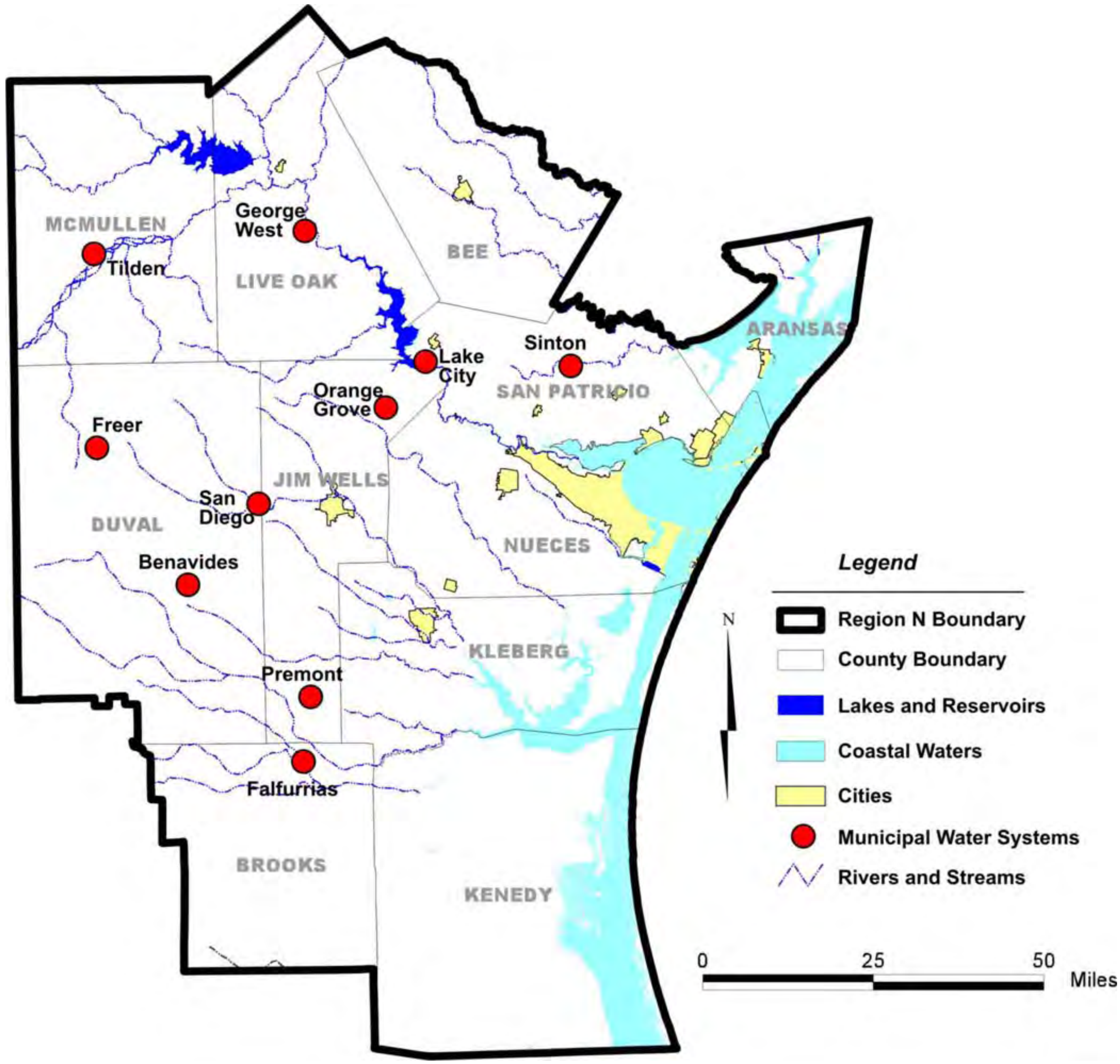

Figure 4C.7-9. Small Municipal Water Systems Relying Solely on Groundwater

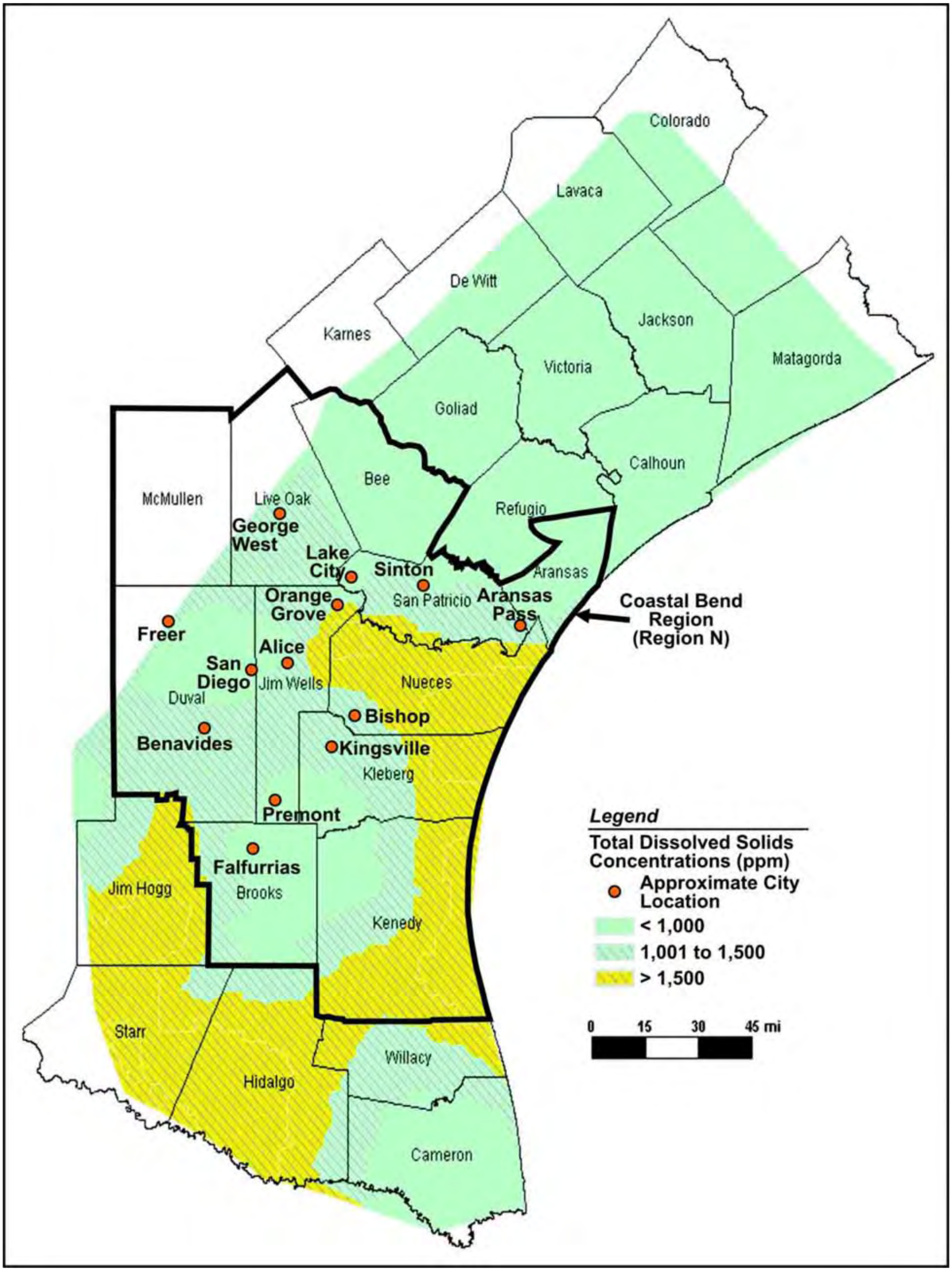

Figure 4C.7-10. TDS Concentrations in the Coastal Bend Region

salinity is through a reverse osmosis membrane system. Costs for this incorporating this treatment into the Freer water system were developed using the HDR costing methodology employed in all other project evaluations (i.e., 20-year debt service, 35 percent contingency factor, etc.). Freer's maximum projected groundwater use is 663 acft/yr in 2030. A peaking factor of two results in a maximum peak demand rate of 1.2 MGD. If no additional infrastructure is required, it is estimated that the total capital cost for a membrane WTP will be $4,733,000, and total project cost will be $6,899,000. Total annual cost will be $1,121,000, resulting in a unit cost of $834/acft, or $2.56/1,000 gallons, assuming full utilization of treatment plant.

Benavides in Duval County and San Diego located in both Duval and Jim Wells counties are areas of the Coastal Bend Water Planning Region supplied by Goliad Sands of the Gulf Coast Aquifer. Locally, groundwater is produced for the cities by Duval County Conservation and Reclamation District and San Diego Municipal Utility District. In these areas, the Goliad Sands supply slightly saline water with reported TDS concentrations ranging from 630- 1,280 ppm.[9] Although projections indicate that Benavides and San Diego's current wells will produce adequate supply to meet their anticipated demand, there is local concern that the water quality of the water produced by the city's wells will decline to the point that advanced treatment will be necessary to stay in compliance with regulatory water quality guidelines. The proposed treatment for groundwater salinity is through a reverse osmosis membrane system.

Costs for this incorporating this treatment into the Benavides and San Diego water systems were developed using the HDR costing methodology employed in all other project evaluations (i.e., 20-year debt service, 35 percent contingency factor, etc.). Benavides' maximum projected groundwater use is 334 acft/yr in 2030. A peaking factor of two results in a maximum peak demand rate of 0.6 MGD. If no additional infrastructure is required, it is estimated that the total capital cost for a membrane WTP will be $3,127,000, and total project cost will be $4,633,000. Total annual cost will be $688,000, resulting in a unit cost of $1,024/acft, or $3.14/1,000 gallons, assuming full utilization of the treatment plant. San Diego's maximum projected groundwater use for both Duval and Jim Wells counties combined is 587 acft/yr in 2020. A peaking factor of two results in a maximum peak demand rate of 1 MGD. If no additional infrastructure is required, it is estimated that the total capital cost for a membrane WTP will be $4,313,000, and total project cost will be $6,304,000. Total annual cost will be

[9] TWDB Groundwater Monitoring database, May 2005.

$1,000,000, resulting in a unit cost of $893/acft, or $2.74/1,000 gallons, assuming full utilization of treatment plant.

4C.7.2.4 Evaluation of Rural Municipal Water Systems and Water Supply Corporations and Water Quality

For purposes of this alternative, the relatively small public water systems within the county-other classification by the TWDB are reviewed in consideration of the overall groundwater availability and quality within a county. A summary of the review and analysis is given in the following sections. If a water treatment plant to desalinate the local brackish groundwater is needed, Table 4C.7-3 is provided to give an estimate of the capital cost for treating slightly saline water (up to 3,000 mg/L). This cost does not include connection to existing wells.

4C.7.2.4.1 Jim Wells, Kleberg, Live Oak, and San Patricio Counties

For Jim Wells, Kleberg, Live Oak, and San Patricio Counties the currently accessible groundwater availability is insufficient to meet the projected demands of rural water suppliers.[10] In addition, locally, the groundwater in these counties can vary from fresh (less than 1,000 mg/L) to slightly saline (up to 3,000 mg/L). To secure drinking water supplies that meet the salinity requirements, an alternative is desalination of local brackish groundwater. Entities can estimate the capital and operation and maintenance costs for a desalination water treatment plant from Table 4C.7-3.

Jim Wells County-Other has a small need in the county-other category that starts in 2010, peaks at 262 acft/yr in 2030, and declines after 2030. Two new wells are projected to meet needs.

Kleberg County-Other has a small need in the county-other user group beginning in 2020 and growing slightly and steadily through the planning period. This need can be met with a single well in 2020; no further wells are indicated after this time.

Live Oak County-Other has unmet needs likely to be supplied with local groundwater in the county-other category. Live Oak County also has a small need identified in the county-other category that appears in 2030, but declines and disappears by 2060.

Lake City in San Patricio County has a small need beginning in 2020 and increasing to 37 acft/yr in 2060. This need can be met with a single well in 2020.

[10] See methodology described in Section 4A.2.2 for estimating current groundwater supplies.

Table 4C.7-3.
Desalination of Brackish Groundwater (3,000 mg/L TDS)
Cost Estimate Summary

Item	Estimated Costs 0.1 MGD	Estimated Costs 0.5 MGD	Estimated Costs 1 MGD	Estimated Costs 3 MGD	Estimated Costs 5 MGD	Estimated Costs 10 MGD
Capital Costs						
Source Water Supply	$356,000	$657,000	$828,000	$2,012,000	$3,199,000	$6,860,000
Water Treatment Plant	$720,000	$1,721,000	$2,972,000	$5,803,000	$8,634,000	$15,712,000
Concentrate Disposal	$208,000	$278,000	$305,000	$417,000	$486,000	$528,000
Distribution	$104,000	$174,000	$208,000	$278,000	$312,000	$410,000
Total Capital Cost	**$1,388,000**	**$2,830,000**	**$4,313,000**	**$8,510,000**	**$12,631,000**	**$23,510,000**
Engineering, Legal Costs and Contingencies (35%)	$470,000	$968,000	$1,484,000	$2,943,000	$4,381,000	$8,182,000
Environmental & Archaeology Studies and Mitigation	$139,000	$144,000	$154,000	$209,000	$294,000	$385,000
Land Acquisition & Surveying	$110,000	$110,000	$110,000	$116,000	$122,000	$145,000
Interest During Construction (1 years)	$85,000	$163,000	$243,000	$472,000	$698,000	$1,289,000
Total Project Cost	**$2,192,000**	**$4,215,000**	**$6,304,000**	**$12,250,000**	**$18,126,000**	**$33,511,000**
Annual Costs						
Debt Service (6 percent, 20 years)	$191,000	$367,000	$550,000	$1,068,000	$1,580,000	$2,922,000
Operation and Maintenance						
Source Water Supply	$6,000	$18,000	$36,000	$105,000	$174,000	$351,000
Water Treatment Plant	$59,000	$181,000	$334,000	$835,000	$1,337,000	$2,590,000
Concentrate Disposal	$10,000	$14,000	$15,000	$21,000	$24,000	$26,000
Distribution	$5,000	$14,000	$24,000	$47,000	$72,000	$138,000
Pumping Energy Costs	$3,000	$16,000	$41,000	$131,000	$213,000	$422,000
Total						
Total Annual Cost	**$274,000**	**$610,000**	**$1,000,000**	**$2,207,000**	**$3,400,000**	**$6,449,000**
Available Project Yield (acft/yr)	**112**	**560**	**1,120**	**3,360**	**5,601**	**11,202**
Annual Cost of Water ($ per acft)	**$2,446**	**$1,089**	**$893**	**$657**	**$607**	**$576**
Annual Cost of Water ($ per 1,000 gallons)	**$7.51**	**$3.34**	**$2.74**	**$2.02**	**$1.86**	**$1.77**

[1]Costs for these items are site specific. Average costs used assume groundwater wells 1,000 ft deep, concentrate disposal to surface water, and distribution within 1 mile of treatment plant.

4C.7.2.5 Evaluation of Irrigation Water Users

Bee, Live Oak, and San Patricio Counties are all projected to have unmet needs for irrigation. Bee County has an irrigation shortage of 299 acft/yr in 2050, increasing to 890 acft/yr in 2060. Five new wells are projected to meet these needs considering peak demand rates.

Live Oak County has an irrigation shortage of 627 acft/yr in 2010. This need can be met with three new wells by 2010 considering peak demand rates. Since irrigation demands decline after this time, no additional wells are needed after 2010.

San Patricio County has an irrigation shortage of 750 acft/yr beginning in 2030 and increasing to 4,414 acft/yr by 2060. Twenty-three new wells are projected to meet these needs considering peak demand rates.

4C.7.2.6 Evaluation of Mining Water Users

There were two instances for mining users when the CBRWPG drawdown criteria were exceeded based on applying projected groundwater demands to individual model cells assigned with historical, manufacturing pumping. The groundwater supplies for Duval County Mining and Live Oak County Mining were prorated back so that drawdown does not exceed the adopted criteria, which resulted in a water supply shortage for both entities. Based on the response of pumping that is distributed uniformly across the county, Live Oak and Duval Counties can sustain this pumping on a county basis without exceeding the drawdown criteria and therefore groundwater supplies were considered for these two entities. The additional groundwater wells considered in this evaluation would need to be located sufficient distance from the mining demand centers that breached the drawdown constraints.

Duval County has significant needs in the mining sector that are likely to be met through development of local Gulf Coast Aquifer supplies. Mining needs grow from 1,738 acft/yr in 2010 to 4,205 acft/yr in 2060, and will need 11 new wells to meet this supply, according to the methodology employed. Live Oak County Mining needs are projected to grow steadily throughout the planning period to 1,755 acft/yr by 2060, with additional wells needed in most decades.

4C.7.2.7 Evaluation of Manufacturing Water Users

Aransas County has a small need in the manufacturing sector that begins in 2010 and grows steadily to 136 acft/yr by 2060. One new well is projected to meet this demand.

There was one instance for manufacturing users when the CBRWPG drawdown criteria was exceeded based on applying projected groundwater demands to individual model cells assigned with historical, manufacturing pumping. The groundwater supplies for Live Oak County Manufacturing were prorated back so that drawdown does not exceed the adopted criteria, which resulted in a water supply shortage. Based on the response of pumping that is distributed uniformly across the county, Live Oak County can sustain this pumping on a county basis without exceeding the drawdown criteria and therefore groundwater supplies were considered. The additional groundwater wells considered in this evaluation for Live Oak County Manufacturing would need to be located sufficient distance from the manufacturing demand centers that breached the drawdown constraints. Live Oak County manufacturing needs more than double throughout the planning period to 764 acft/yr in 2060; new wells are needed in 2010 and 2020.

4C.7.2.8 Environmental Issues

A previous study estimates up to 25% of recharge to the Gulf Coast Aquifer in nearby Wharton and Matagorda counties ends up as freshwater discharge to near-coast waters.[11]

The pumping of groundwater from the Gulf Coast Aquifer could have a very slight negative impact on baseflow in the downstream reaches of streams in these areas. However, many of the streams are dry most all the time; thus, no measurable impact on wildlife along the streams is expected.

The desalination of slightly saline groundwater produces a concentrate of salts in water that requires disposal. Depending upon location, environmental concerns can be addressed by discharging to saline aquifer by deep well injection, discharging to a salt-water body, or blending with wastewater.

Habitat studies and surveys for protected species may need to be conducted at the proposed well field sites and along any pipeline routes. 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,

[11] Dutton, A.R., and Richter, B.C., 1990. "Regional geohydrology of the Gulf Coast Aquifer in Matagorda and Wharton Counties, Texas: Development of a numerical model to estimate the impact of water management strategies", The University of Texas at Austin and Bureau of Economic Geology.

respectively. Wetland impacts, primary pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands may be required where impacts are unavoidable.

4C.7.2.9 Engineering and Costing

The entities that may need new local supply wells in the Gulf Coast Aquifer added to their system by the year 2060 are presented in Figure 4C.7-2 and summarized in Table 4C.7-4. Cost estimates for new wells were prepared according to the assumptions presented in the previous section. Table 4C.7-4 displays the projected unmet needs, by decade, for each of these entities, and the decades in which additional wells are estimated to be needed. The capital cost, project cost, annual cost, yield, and unit cost (in $/acft and $/1000 gallons) for water obtained under this strategy are presented in Table 4C.7-5 through 4C.7-15 for each entity county.

4C.7.2.10 Implementation Issues

The development of additional wells and the installation and operation of brackish water treatment plant, may have to address the following issues.

- Disposal of salt concentrate from water treatment plant;
- Impact on:
  - Endangered and other wildlife species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands;
- Capital and operation and maintenance costs;
- Skilled operators of desalination water treatment plants;
- Competition with others for groundwater in the area;
- Detailed feasibility evaluation including test drilling and aquifer water quality testing; and
- The potential for regulations by groundwater conservation districts in the future based on managed available groundwater identified by local districts or Groundwater Management Area, including the renewal of pumping permit at periodic intervals in counties where districts have been organized.

Table 4C.7-4.
Region N Local Gulf Coast Aquifer Supply Water Management Strategy Cost and Schedule Summary

County	User		Needs (acft/yr)[1] 2010	2020	2030	2040	2050	2060	Total Wells
Jim Wells	County-Other	Projected Needs	167	238	262	241	210	170	2
		New Wells	1	1	—	—	—	—	
Kleberg	County-Other	Projected Needs	0	31	81	108	153	155	1
		New Wells	—	1	—	—	—	—	
Live Oak	County-Other	Projected Needs	0	0	32	44	14	0	1
		New Wells	—	—	1	—	—	—	
San Patricio	Lake City	Projected Needs	0	1	11	19	28	37	1
		New Wells	—	1	—	—	—	—	
Bee	Irrigation	Projected Needs	0	0	0	0	299	890	5
		New Wells	—	—	—	—	2	3	
Live Oak	Irrigation	Projected Needs	627	569	514	464	416	373	3
		New Wells	3	—	—	—	—	—	
San Patricio	Irrigation	Projected Needs	0	0	750	1,852	3,069	4,414	23
		New Wells	—	—	4	6	6	7	
Duval	Mining	Projected Needs	1,738	2,518	2,973	3,386	3,809	4,205	11
		New Wells	5	2	1	1	1	1	
Live Oak	Mining	Projected Needs	64	478	928	1,234	1,504	1,755	5
		New Wells	1	1	1	1	—	1	
Aransas	Manufacturing	Projected Needs	72	86	97	107	116	136	1
		New Wells	1	—	—	—	—	—	
Live Oak	Manufacturing	Projected Needs	337	483	559	615	657	764	2
		New Wells	1	1	—	—	—	—	

[1]Indicates needs exceeding current estimate of local aquifer supply. See text for details.

Table 4C.7-5.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Jim Wells County-Other

Item	*Estimated Costs for Facilities*
Capital Costs	
Well Fields	$657,000
Water Treatment Plant (0.6 MGD)	41,000
Total Capital Cost	**$698,000**
Engineering, Legal Costs and Contingencies	$244,000
Interest During Construction (1 year)	38,000
Total Project Cost	**$980,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$85,000
Operation and Maintenance	
Pipeline	7,000
Water Treatment Plant	18,000
Pumping Energy Costs (108,407 kWh @ 0.09 $/kWh)	10,000
Total Annual Cost	**$120,000**
Available Project Yield (acft/yr)	**565**
Annual Cost of Water ($ per acft)	**$213**
Annual Cost of Water ($ per 1,000 gallons)	**$0.65**

Needs analysis indicates one well needed by 2010.
Cost estimate assumes County-Other delivery must meet seasonal peak rate of two times average annual rate.
Cost estimate assumes chlorine disinfection is the only treatment necessary for County-Other groundwater supply.

Table 4C.7-6.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Kleberg County-Other

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$387,000
Water Treatment Plant (0.4 MGD)	31,000
Total Capital Cost	**$418,000**
Engineering, Legal Costs and Contingencies	$146,000
Interest During Construction (1 year)	23,000
Total Project Cost	**$587,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$51,000
Operation and Maintenance	
Pipeline	4,000
Water Treatment Plant	12,000
Pumping Energy Costs (77,433 kWh @ 0.09 $/kWh)	7,000
Total Annual Cost	**$74,000**
Available Project Yield (acft/yr)	**400**
Annual Cost of Water ($ per acft)	**$185**
Annual Cost of Water ($ per 1,000 gallons)	**$0.57**

Needs analysis indicates one well needed by 2030.
Cost estimate assumes County-Other delivery must meet seasonal peak rate of two times average annual rate.
Cost estimate assumes chlorine disinfection is the only treatment necessary for County-Other groundwater supply.

Table 4C.7-7.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Live Oak County-Other

Item	Estimated Costs for Facilities
Capital Costs	
Well Fields	$208,000
Water Treatment Plant (0.1 MGD)	16,000
Total Capital Cost	**$224,000**
Engineering, Legal Costs and Contingencies	$78,000
Interest During Construction (1 year)	13,000
Total Project Cost	**$315,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$27,000
Operation and Maintenance	
Pipeline	2,000
Water Treatment Plant	5,000
Pumping Energy Costs (15,487 kWh @ 0.09 $/kWh)	1,000
Total Annual Cost	**$35,000**
Available Project Yield (acft/yr)	**80**
Annual Cost of Water ($ per acft)	**$438**
Annual Cost of Water ($ per 1,000 gallons)	**$1.34**

Needs analysis indicates one well needed by 2030.
Cost estimate assumes County-Other delivery must meet seasonal peak rate of two times average annual rate.
Cost estimate assumes chlorine disinfection is the only treatment necessary for County-Other groundwater supply.

Table 4C.7-8.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Lake City (in San Patricio County)

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$234,000
Water Treatment Plant (0.066 MGD)	10,000
Total Capital Cost	**$244,000**
Engineering, Legal Costs and Contingencies	$85,000
Interest During Construction (1 year)	14,000
Total Project Cost	**$343,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$30,000
Operation and Maintenance	
Pipeline	2,000
Water Treatment Plant	3,000
Pumping Energy Costs (15,487 kWh @ 0.09 $/kWh)	1,000
Total Annual Cost	**$36,000**
Available Project Yield (acft/yr)	**80**
Annual Cost of Water ($ per acft)	**$444**
Annual Cost of Water ($ per 1,000 gallons)	**$1.36**

Needs analysis indicates one well needed by 2020.
Cost estimate assumes County-Other delivery must meet seasonal peak rate of two times average annual rate.
Cost estimate assumes chlorine disinfection is the only treatment necessary for County-Other groundwater supply.

Table 4C.7-9.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Bee County Irrigation

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$927,000
Power Connection Costs	329,000
Total Capital Cost	**$1,256,000**
Engineering, Legal Costs and Contingencies	$439,000
Interest During Construction (1 year)	68,000
Total Project Cost	**$1,763,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$154,000
Operation and Maintenance	
Wells, Pipeline, Pumps	13,000
Pumping Energy Costs (232,300 kWh @ 0.09 $/kWh)	35,000
Total Annual Cost	**$202,000**
Available Project Yield (acft/yr)	**2,016**
Annual Cost of Water ($ per acft)	**$100**
Annual Cost of Water ($ per 1,000 gallons)	**$0.31**

Needs analysis indicates five additional wells are needed.
Cost estimate assumes irrigation groundwater supply delivered at seasonal peak rate of two times average rate.
Cost estimate assumes no water treatment is necessary for irrigation groundwater supply.

Table 4C.7-10.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Live Oak County Irrigation

Item	*Estimated Costs for Facilities*
Capital Costs	
Well Fields	$556,000
Power Connection Costs	197,000
Total Capital Cost	**$753,000**
Engineering, Legal Costs and Contingencies	$264,000
Interest During Construction (1 year)	41,000
Total Project Cost	**$1,058,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$92,000
Operation and Maintenance	
Wells, Pipeline, Pumps	8,000
Pumping Energy Costs (232,300 kWh @ 0.09 $/kWh)	21,000
Total Annual Cost	**$121,000**
Available Project Yield (acft/yr)	**1,210**
Annual Cost of Water ($ per acft)	**$100**
Annual Cost of Water ($ per 1,000 gallons)	**$0.31**

Needs analysis indicates three wells needed by 2010; demand declines after this.
Cost estimate assumes irrigation groundwater supply delivered at seasonal peak rate of two times average rate.
Cost estimate assumes no water treatment is necessary for irrigation groundwater supply.

Table 4C.7-11.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—San Patricio County Irrigation

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$4,264,000
Power Connection Costs	1,512,000
Total Capital Cost	**$5,776,000**
Engineering, Legal Costs and Contingencies	$2,022,000
Interest During Construction (1 year)	312,000
Total Project Cost	**$8,110,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$707,000
Operation and Maintenance	
Wells, Pipeline, Pumps	58,000
Pumping Energy Costs (232,300 kWh @ 0.09 $/kWh)	160,000
Total Annual Cost	**$925,000**
Available Project Yield (acft/yr)	**9,275**
Annual Cost of Water ($ per acft)	**$100**
Annual Cost of Water ($ per 1,000 gallons)	**$0.31**

Needs analysis indicates 23 additional wells are needed.
Cost estimate assumes irrigation groundwater supply delivered at seasonal peak rate of two times average rate.
Cost estimate assumes no water treatment is necessary for irrigation groundwater supply.

Table 4C.7-12.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Duval County Mining

Item	*Estimated Costs for Facilities*
Capital Costs	
Well Fields	$2,039,000
Power Connection Costs	723,000
Total Capital Cost	**$2,762,000**
Engineering, Legal Costs and Contingencies	$967,000
Interest During Construction (1 year)	150,000
Total Project Cost	**$3,879,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$338,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	28,000
Pumping Energy Costs (851,767 kWh @ 0.09 $/kWh)	77,000
Total Annual Cost	**$443,000**
Available Project Yield (acft/yr)	**4,400**
Annual Cost of Water ($ per acft)	**$101**
Annual Cost of Water ($ per 1,000 gallons)	**$0.31**

Needs analysis indicates 11 wells needed by 2060.
Cost estimate assumes mining groundwater supply delivered at uniform rate.
Cost estimate assumes no water treatment is necessary for mining groundwater supply.

Table 4C.7-13.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Live Oak County Mining

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$927,000
Power Connection Costs	329,000
Total Capital Cost	**$1,256,000**
Engineering, Legal Costs and Contingencies	$439,000
Interest During Construction (1 year)	68,000
Total Project Cost	**$1,763,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$154,000
Operation and Maintenance	
Wells, Pipeline, Pumps	13,000
Pumping Energy Costs (387,167 kWh @ 0.09 $/kWh)	35,000
Total Annual Cost	**$202,000**
Available Project Yield (acft/yr)	**2,000**
Annual Cost of Water ($ per acft)	**$100**
Annual Cost of Water ($ per 1,000 gallons)	**$0.31**

Needs analysis indicates five wells needed by 2060.
Cost estimate assumes mining groundwater supply delivered at uniform rate.
Cost estimate assumes no water treatment is necessary for mining groundwater supply.

Table 4C.7-14.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Aransas County Manufacturing

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$117,000
Power Connection Costs	66,000
Total Capital Cost	**$183,000**
Engineering, Legal Costs and Contingencies	$64,000
Interest During Construction (1 year)	10,000
Total Project Cost	**$257,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$22,000
Operation and Maintenance	
Wells, Pipeline, Pumps	2,000
Pumping Energy Costs (38,717 kWh @ 0.09 $/kWh)	3,000
Total Annual Cost	**$27,000**
Available Project Yield (acft/yr)	**200**
Annual Cost of Water ($ per acft)	**$135**
Annual Cost of Water ($ per 1,000 gallons)	**$0.41**

Needs analysis indicates one well needed by 2010.
Cost estimate assumes industrial groundwater supply delivered at uniform rate.
Cost estimate assumes no water treatment is necessary for industrial groundwater supply.

Table 4C.7-15.
Cost Estimate Summary
Water Supply Project Option
September 2008 Prices
Region N Local Gulf Coast Supplies—Live Oak County Manufacturing

Item	***Estimated Costs for Facilities***
Capital Costs	
Well Fields	$371,000
Power Connection Costs	131,000
Total Capital Cost	**$502,000**
Engineering, Legal Costs and Contingencies	$176,000
Interest During Construction (1 year)	28,000
Total Project Cost	**$706,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$62,000
Operation and Maintenance	
Wells, Pipeline, Pumps	5,000
Pumping Energy Costs (154,867 kWh @ 0.09 $/kWh)	14,000
Total Annual Cost	**$81,000**
Available Project Yield (acft/yr)	**800**
Annual Cost of Water ($ per acft)	**$101**
Annual Cost of Water ($ per 1,000 gallons)	**$0.31**

Needs analysis indicates two wells needed by 2020.
Cost estimate assumes manufacturing groundwater supply delivered at uniform rate.
Cost estimate assumes no water treatment is necessary for manufacturing groundwater supply.

4C.7.2.11 Evaluation Summary

An evaluation summary of this regional water management option is provided in Table 4C.7-16.

Table 4C.7-16. Evaluation Summary of the Alternative for Small Municipal and Rural Water Systems

Impact Category	*Comment(s)*
a. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Firm Yield: Varies from 80 to 9,275 acft. 2. Good reliability, if adequate water quality. 3. Cost: Varies from $100 to $438 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. May slightly decrease instream flow and discharge of freshwater into coastal estuaries due to local groundwater-surface water interaction. 2. May slightly decrease instream flow and discharge of freshwater into coastal estuaries due to local groundwater-surface water interaction. 3. Negligible impacts. 4. Negligible impacts 5. Negligible impacts. 6. Cultural resources will need to be surveyed and avoided. 7. Negligible impacts. a. Low to moderate impact. b. Low to moderate impact. c. No impact. d. Low to moderate impact. e. Low to moderate impact. f. Low to moderate impact. g-h. Low to moderate impact associated with mining. i. Boron may be a potential water quality concern.
c. Impacts to State water resources	• No negative impacts on water resources other than lowering Gulf Coast Aquifer levels
d. Threats to agriculture and natural resources in region	• May slightly increase pumping costs for agricultural users in the area due to localized drawdowns
e. Recreational impacts	• None
f. Equitable Comparison of Strategies	• Standard analyses and methods used
g. Interbasin transfers	• None
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 with local resources
j. Effect on navigation	• None
k. Consideration of water pipelines and other facilities used for water conveyance	• None

4C.7.3 Central Gulf Coast GAM Analyses for Future Water Supply Projects in Bee and San Patricio Counties

4C.7.3.1 Description of Strategy

In addition to baseline pumpage to meet local demand, several groundwater projects have been proposed for the Gulf Coast Aquifer in the Coastal Bend Water Planning Region (Region N). A brackish groundwater project in San Patricio and Bee Counties was evaluated to produce up to 24,000 acft/yr with results shown in Section 4C.20. A smaller project was proposed to utilize fresh water supplies as may be available in Bee and San Patricio Counties for SPMWD and the City. The neighboring South Central Texas Regional Water Planning Area (Region L) had previously considered a Lower Guadalupe Water Supply Project (LGWSP) to utilize groundwater supplies in Victoria, Refugio, and Goliad Counties. According to information provided by Region L, the groundwater supply component of the LGWSP is no longer being considered and is therefore not included in this description.

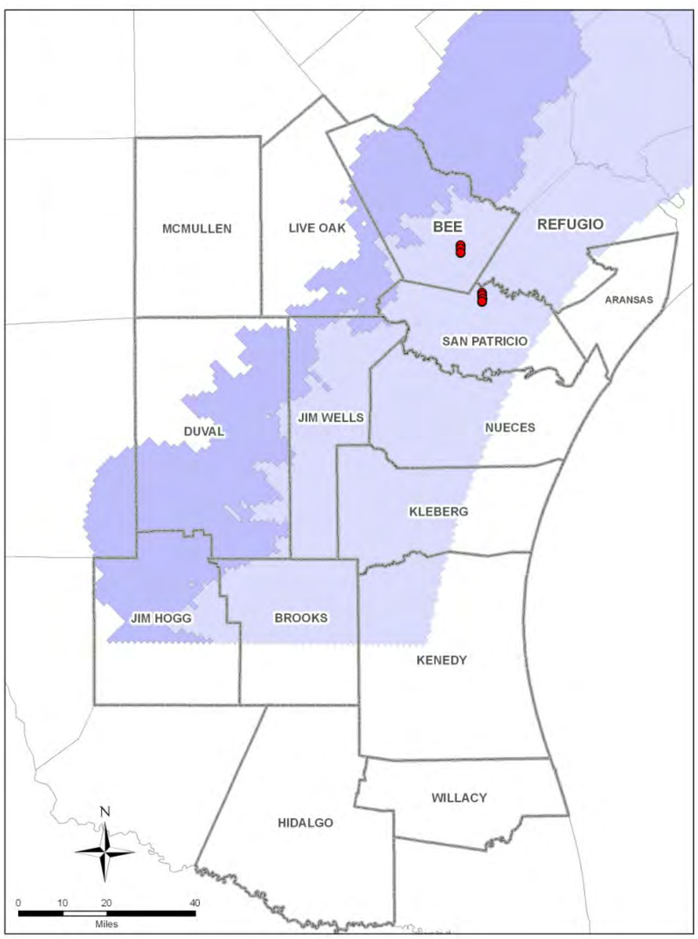

Figure 4C.7-11. Project Locations in the Evangeline Aquifer

SPMWD considered well fields in Bee and San Patricio Counties to produce up to 11,000 acft/yr at a constant annual rate starting in 2030. Starting in 2056, pumping ramps up by 7,000 acft/yr by 2060. The total pumping for both wellfields is 18,000 acft/yr in 2060. The project locations are shown in 4C.7-11.

According to recent study[12] by the CBRWPG, the addition of groundwater supplies from the Gulf Coast Aquifer blended with water supplies in the Mary Rhodes Pipeline increases median chloride levels. The study included a blending analysis of groundwater with supplies from Garwood and Lake Texana, and showed that there would not be any large treatment issues at the Stevens WTP with groundwater supplies limited to 20% of the total water supply. With 20% groundwater supplies, a blending water quality of 129 mg/L for chlorides is expected which is well below the Secondary Drinking Water Standards of 300 mg/L. With existing supplies, potential Garwood Project, and 20% groundwater supplies, a blending water quality of 124 mg/L for chlorides is expected.

4C.7.3.2 Available Yield and Drawdown

In order to evaluate the effect of these projects on water levels in the primary aquifers serving the region, these projects were simulated for the predictive period 2000 to 2060 using the version of the Central Gulf Coast Groundwater Availability Model (CGCGAM) sponsored and developed by the TWDB which represents the fully penetrating thickness of the Evangeline Aquifer. After the simulation was complete, the drawdown associated with the export projects was added to the drawdown associated with baseline pumpage for local supply, and the cumulative drawdown was compared against the criteria for groundwater availability as described in the previous section.

A graph displaying the simulated pumpage for each export project through the 60-year simulation period is presented in Figure 4C.7-12.

[12] 2011 Regional Water Plan, Study 1 – "Evaluation of Additional Potential Regional Water Supplies for Delivery through the Mary Rhodes Pipeline, Including Gulf Coast Groundwater and Garwood Project," April 2009.

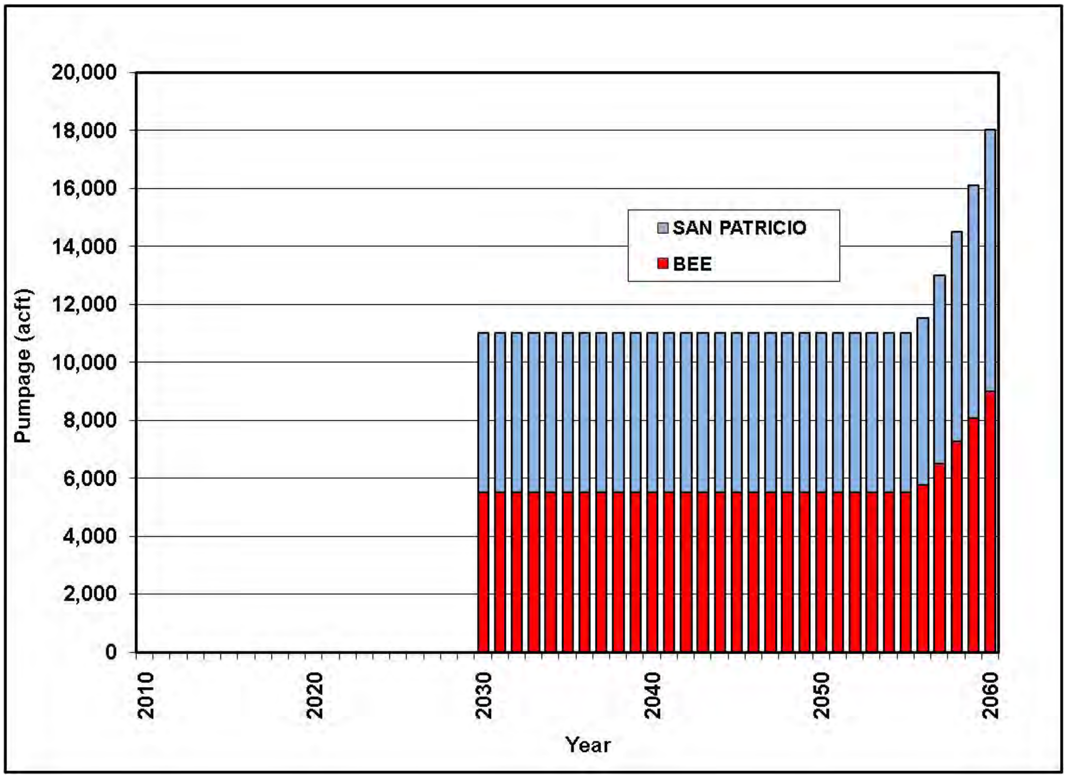

Figure 4C.7-12. Groundwater Export Projects Predictive Pumpage

The 2000 to 2060 cumulative drawdown for local pumpage and export projects is presented in Figure 4C.7-13 for the Chicot Aquifer and in Figure 4C.7-14 for the Evangeline Aquifer. The maximum drawdown in the Evangeline Aquifer near the SPMWD well fields is approximately 71-feet in Bee and 82-feet in San Patricio Counties, as shown in Figure 4C.7-14 and on the hydrographs in Figure 4C.7-15. The export projects do not exceed the drawdown criteria adopted by the CBRWPG.

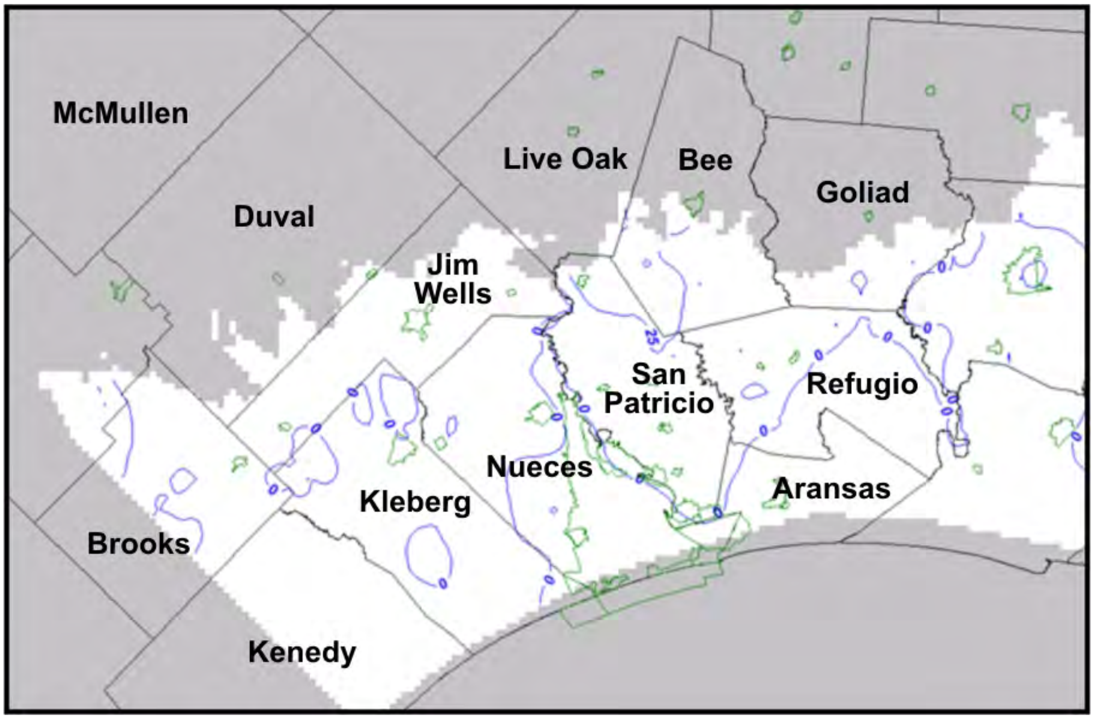

Figure 4C.7-13. 2000 to 2060 Drawdown for Local Pumpage and Export Projects in the Chicot Aquifer

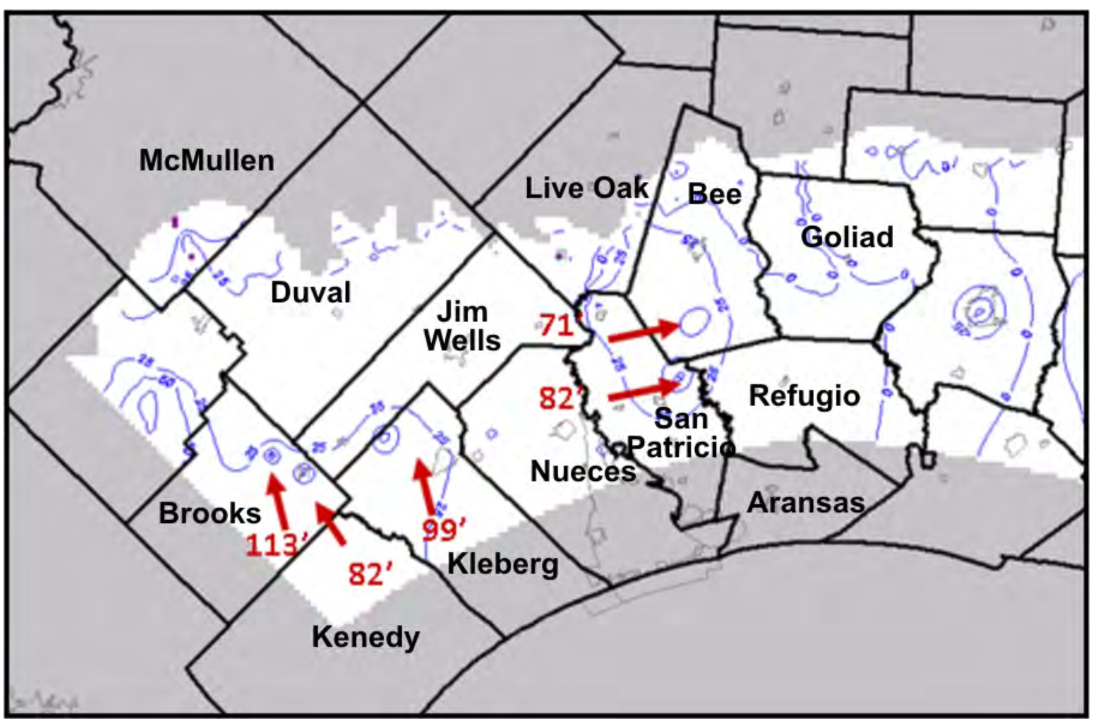

Figure 4C.7-14. 2000 to 2060 Drawdown for Local Pumpage and Export Projects in the Evangeline Aquifer

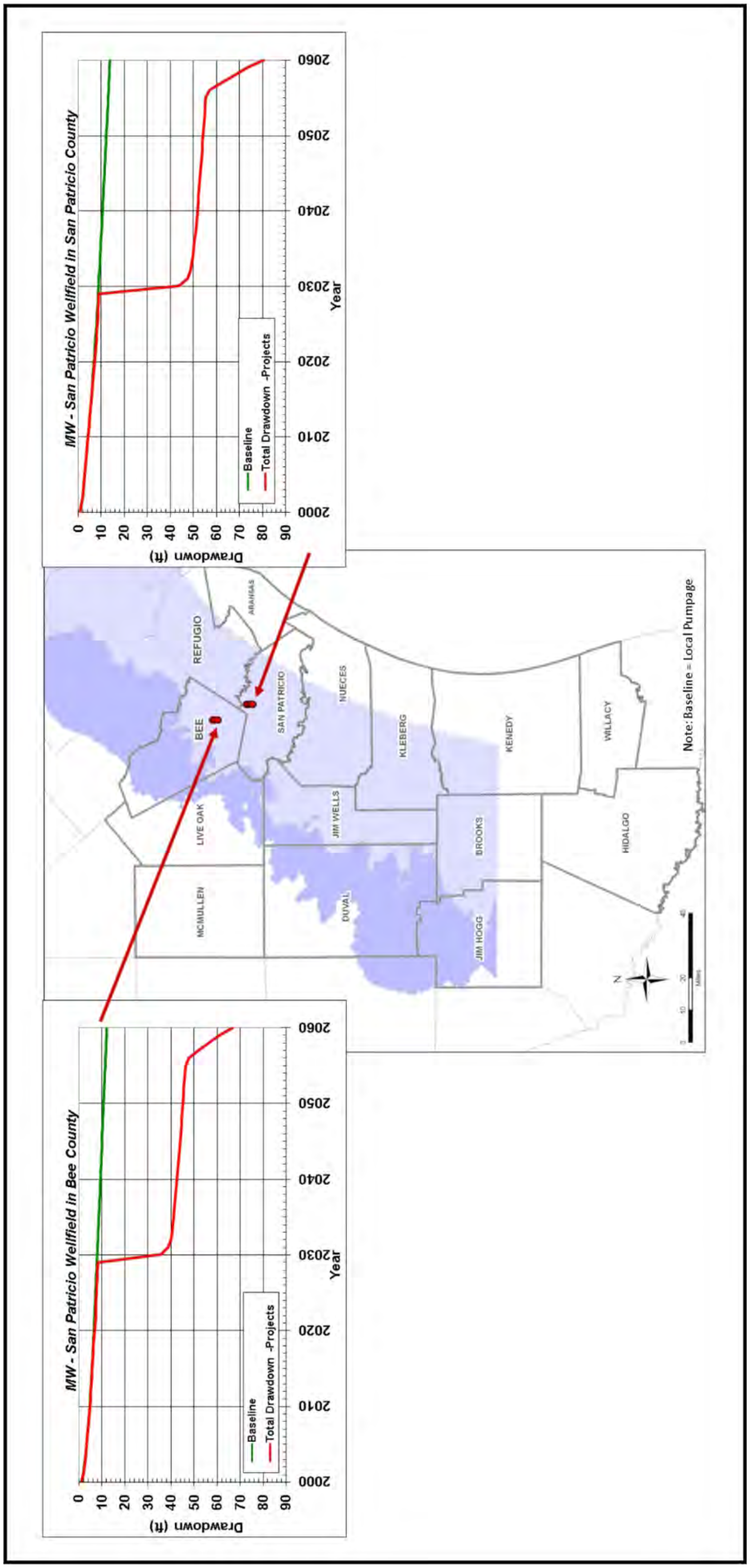

Figure 4C.7-15. Predictive Drawdown Hydrographs in the Evangeline Aquifer

4C.7.3.3 Environmental Issues

A previous study estimates up to 25% of recharge to the Gulf Coast Aquifer in nearby Wharton and Matagorda counties ends up as freshwater discharge to near-coast waters.[13]

The pumping of groundwater from the Gulf Coast Aquifer could have a very slight negative impact on baseflow in the downstream reaches of streams in these areas. However, many of the streams are dry most all the time; thus, no measurable impact on wildlife along the streams is expected.

The desalinization of slightly saline groundwater produces a concentrate of salts in water that requires disposal. Depending upon location, environmental concerns can be addressed by discharging to a saline aquifer by deep well injection, discharging to a salt-water body, or blending with wastewater.

Habitat studies and surveys for protected species may need to be conducted at the proposed well field sites and along any pipeline routes. 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, primary pipeline stream crossings, can be minimized by right-of-way selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands may be required where impacts are unavoidable.

4C.7.3.4 Evaluation Engineering and Costing

Cost estimates for development of both the SPMWD and the City of Corpus Christi well fields were estimated to be similar to the conjunctive use of groundwater from the Gulf Coast Aquifer in Refugio County option discussed in Section 4C.7.1. These well field costs were updated to reflect the development of 11 wells rather than 28 wells as in the conjunctive use option. The costs presented in Table 4C.7-17, include delivery of raw water to the Mary Rhodes Pipeline. Based on the current Mary Rhodes Pipeline pumping capacity of 77,000 acft/yr, the addition of 18,000 acft/yr of groundwater supplies to permitted Lake Texana supplies would not require installation of a fourth pump in each of the three Mary Rhodes Pipeline pump stations to deliver supplies to the Stevens WTP.

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[13] Dutton, A.R., and Richter, B.C., 1990. "Regional geohydrology of the Gulf Coast Aquifer in Matagorda and Wharton Counties, Texas: Development of a numerical model to estimate the impact of water management strategies", The University of Texas at Austin and Bureau of Economic Geology.

Table 4C.7-17.
Cost Estimate Summary
Groundwater Supplies from Bee and San Patricio Well Fields
September 2008 Prices

Item	Estimated Costs for Facilities
Capital Costs	
Well Fields (11 wells; 1,200 gpm)	$9,520,000
Well Field Collection Pipeline	18,865,000
Transmission Pipeline (48-inch dia., 3 miles)[1]	3,561,000
Transmission Pump Station(s) [1]	7,149,000
Total Capital Cost	**$39,095,000**
Engineering, Legal Costs and Contingencies	$13,505,000
Environmental and Archaeology Studies, Mitigation, GW District Application Fees	936,000
Land Acquisition and Surveying (145 acres)	1,320,000
Interest During Construction (2 years)	4,389,000
Total Project Cost	**$59,245,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$5,165,000
Operation and Maintenance	
Pipeline and Pump Station	437,000
Pumping Energy Costs (27,753,990 kWh @ 0.09 $/kWh)	2,498,000
GW District Fees, Purchase of Water (18,000 acft/yr @ 77.428 $/acft)	1,394,000
Total Annual Cost	**$9,494,000**
Available Project Yield (acft/yr)	**18,000**
Annual Cost of Water ($ per acft)	**$527**
Annual Cost of Water ($ per 1,000 gallons)	**$1.62**

[1] Transmission pipeline distances and pipeline size from Section 4C.7.1.

Cost estimates were computed for capital costs, annual debt service, operation and maintenance, power, land, and environmental mitigation for uniform and peak day delivery. The annual costs, including debt service for a 20-year loan at 6 percent interest, operation and maintenance costs, including power and the purchase of groundwater, are estimated to be $9,494,000 for 18,000 acft of water. This option produces raw water at an estimated cost of $527 per acft (Table 4C.7-17). Assuming treatment costs of $326 per acft, the treated water cost is $853 per acft.

4C.7.3.5 Implementation Issues

Implementation of the projects which are located in Region N are subject to the rules and management plans of local groundwater conservation districts. Bee County has a groundwater conservation district which limits production to 4 acft/acre of land. The San Patricio County Groundwater Conservation District was recently created and is in the process of developing a Groundwater Management Plan.

The development of additional wells and the installation and operation of brackish water treatment plant, may have to address the following issues.

- Disposal of salt concentrate from water treatment plant;
- Impact on:
  - Endangered and other wildlife species,
  - Water levels in the aquifer,
  - Baseflow in streams, and
  - Wetlands.
- Capital and operation and maintenance costs;
- Skilled operators of desalination water treatment plants;
- Competition with others for groundwater in the area;
- Detailed feasibility evaluation including test drilling and aquifer water quality testing; and
- The potential for regulations by groundwater conservation districts in the future, including the renewal of pumping permit at periodic intervals in counties where districts have been organized. In the future, regulations and permitting by local groundwater districts or Groundwater Management Area associated with managed available groundwater supplies will need to be considered prior to implementation.

4C.7.3.6 Evaluation Summary

An evaluation summary of this regional water management option is provided in Table 4C.7-18.

Table 4C.7-18.
Evaluation Summary of the Alternative for
Groundwater Export Projects for the Gulf Coast Aquifer

Impact Category	*Comment(s)*
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Firm yield: 18.000 acft/yr. 2. Water Quality: Fair. 3 Cost: $527 per acft (raw), or $853 per acft (treated)
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 decrease instream flow and discharge of freshwater into coastal estuaries due to local groundwater-surface water interaction. 2. May slightly decrease instream flow and discharge of freshwater into coastal estuaries due to local groundwater-surface water interaction. 3. Negligible impacts 4. Negligible impacts 5. Negligible impacts 6. Cultural resources will need to be surveyed and avoided 7. Negligible impacts. a. Low to moderate impact. b. Low to moderate impact. c. No impact. d. Low to moderate impact. e. Low to moderate impact. f. Low to moderate impact. g-h. Low to moderate impact associated with mining. i. Boron may be a potential water quality concern.
c. State water resources	• No negative impacts on water resources other than lowering Gulf Coast Aquifer. Potential benefit to Nueces Estuary from increased freshwater return flows.
d. Threats to agriculture and natural resources in region	• May slightly increase pumping costs for agricultural users in the area due to localized drawdowns
e. Recreational	• None
f. Equitable impacts comparison of strategies	• Standard analyses and methods used
g. Interbasin transfers	• Not applicable to groundwater sources.
h. Third party social and economic impacts from voluntary redistribution of water	• May require the purchase of groundwater rights.
i. Efficient use of existing water supplies and regional opportunities	• Provides regional opportunities with local resources
j. Effect on navigation	• None

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4C.8 Potential Aquifer Storage and Recovery (from the Gulf Coast Aquifer)(N-8)

4C.8.1 Description of Strategy

Aquifer Storage and Recovery (ASR) is useful to water utilities that have a surplus of water at times but do not have sufficient storage to save water for times of shortage. In other words, ASR is a way to store water in aquifers during times when water is available and recover the water when it is needed. ASR can be operated as a water management strategy on a seasonal or multi-year basis. If meeting high summer demands were the water supply issue, water would be injected into the aquifer during the fall, winter, and spring and pumped during the summer. Operating ASR on a seasonal basis strategy more fully utilizes the available capacities of the water treatment plant and, possibly, the availability of the supply to meet seasonal water demands. On the other hand, if ASR is operated on a multi-year basis for emergencies or drought, water would be stored in the aquifer for several years before it is recovered. ASR wells are designed to accommodate injection of treated water as well as recovery.

For purposes of this evaluation[1], ASR is operated on a multi-year basis and uses a dual-purpose well, or well field, to inject treated water into an aquifer for storage. The water is recovered at a later date and evaluated for increased yield to the CCR/LCC/Lake Texana System on a long-term basis.

The option evaluated here would function as a regional facility. It would be located in the Robstown-Driscoll area, and is evaluated on a long-term cycle. Under this option, water would be stored in the aquifer for up to several years before being recovered. During wet—or surplus—times, water would be injected into the aquifer for storage. The facility would be idle during neutral times, and then the water would be pumped back for distribution during the drought times. The locations of the ASR system considered here are shown in Figure 4C.8-1.[2]

4C.8.2 Robstown-Driscoll Regional Facility

A regional ASR system would serve the customers in the City of Corpus Christi area with a reserve of water for drought or emergencies. For this option, the ASR system would utilize the

[1] The ASR strategy described in this section was originally developed for the 2001 Regional Water Plan. There have been minimal updates for the 2006 and 2011 Regional Water Plans.
[2] The regional ASR facility presented in this evaluation is not located within the Corpus Christi Aquifer Storage and Recovery Groundwater Conservation District.

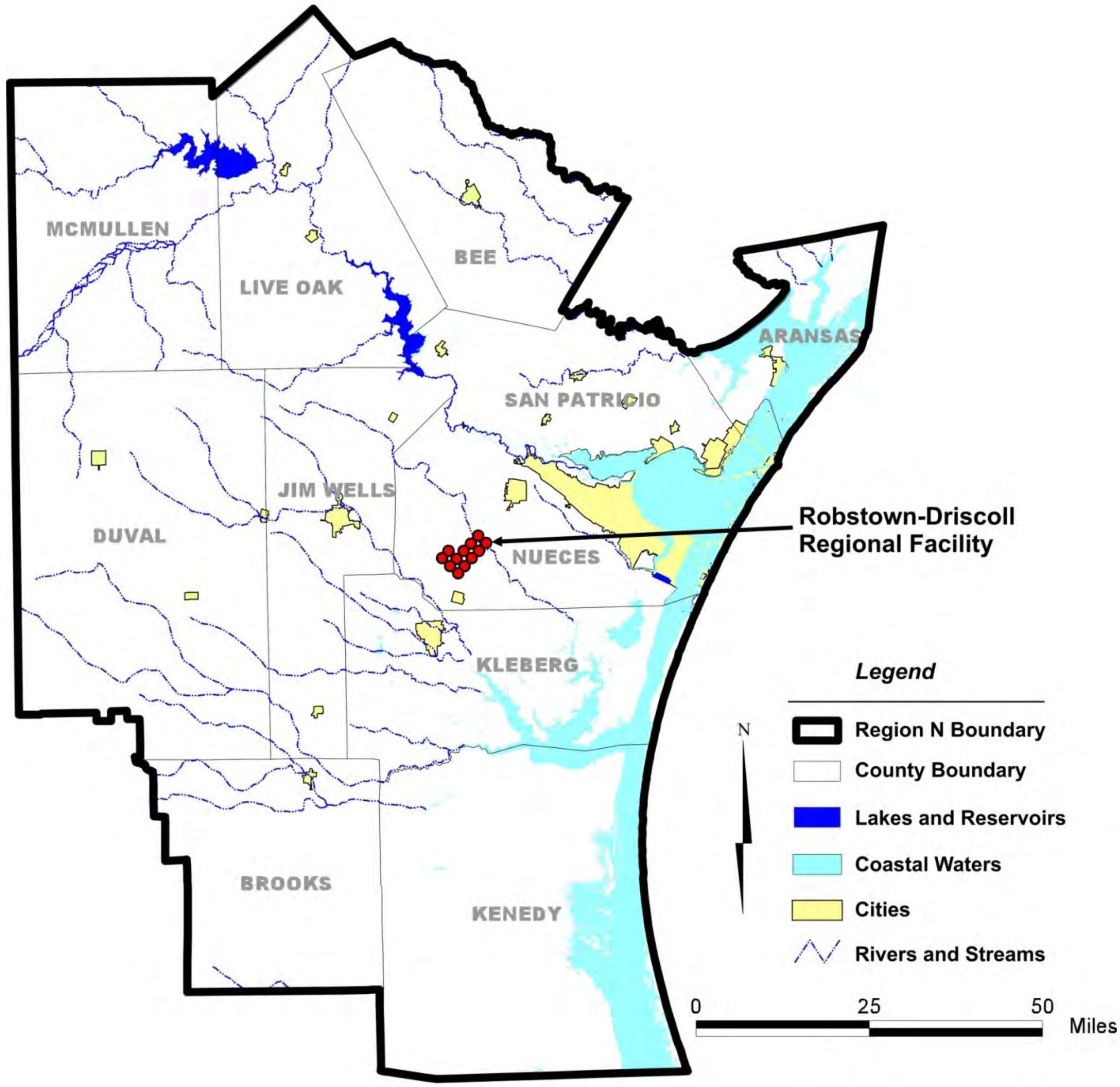


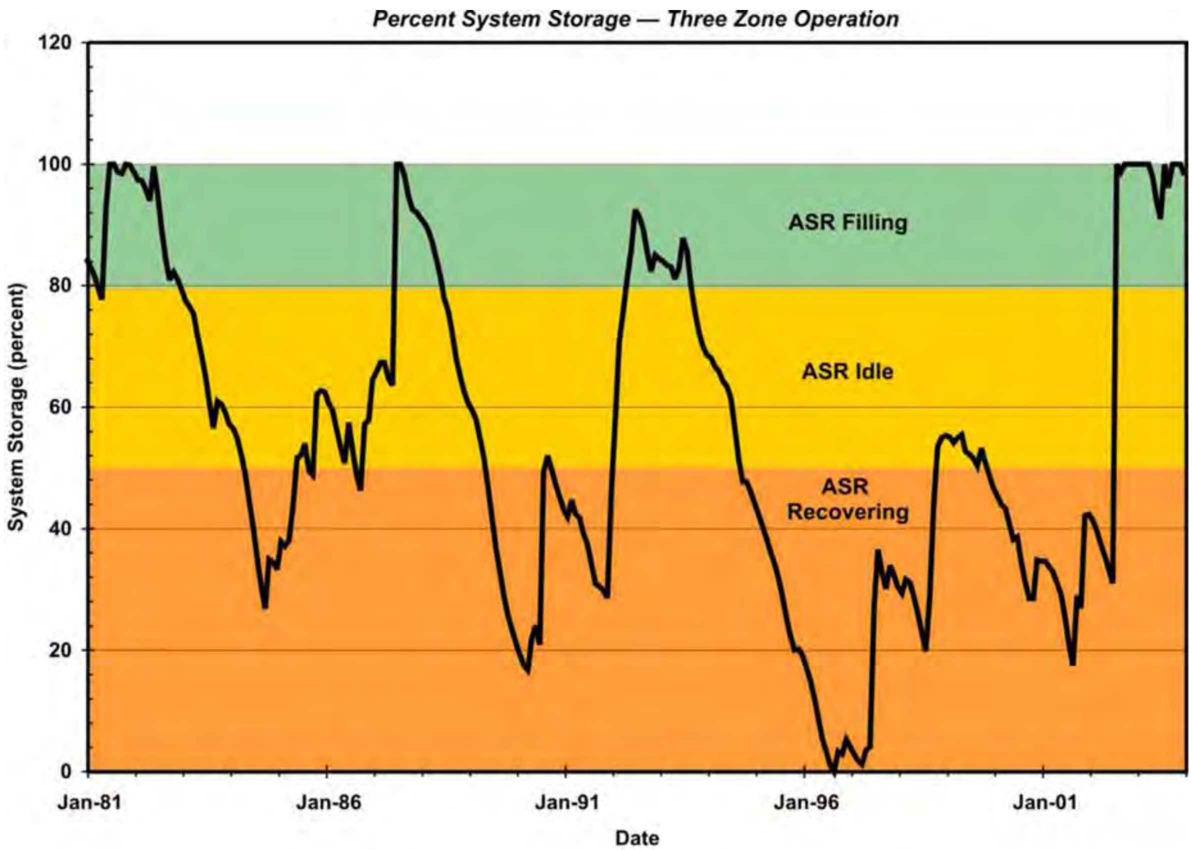
Figure 4C.8-1. Location of ASR Facility

supply, water treatment, and water distribution facilities of the City of Corpus Christi (City) and the regional water distribution system of the South Texas Water Authority (STWA). The water supply for the ASR facility during wet periods would come from surplus supply from the CCR/LCC/Texana System. This surplus supply would essentially result from over-drafting the reservoirs during wet times and recovering from ASR storage in the dry times. Water from the CCR/LCC/Lake Texana System would be treated by the City and then transported by the

STWA's pipeline to the ASR regional facility between Robstown and Driscoll. When needed, the stored water would be pumped by the ASR wells and discharged into the STWA's pipeline for distribution to regional customers or back to pumping facilities at the O.N. Stevens Water Treatment Plant to supplement the City's distribution system. The ASR system would need to be sized to be within the constraints of capacity of the Corpus Christi Water Treatment Plant, the STWA's pipeline, reasonable limits of an ASR well field, and the storage capacity of the Gulf Coast Aquifer. For purposes of this analysis, a capacity of 10 MGD was selected, which meets the constraints for analysis.

The potential benefit of incorporating a regional ASR project into the City's water supply system was analyzed using the Corpus Christi Water Supply Model (an updated modified version of the NUBAY Model). The modifications allowed the user to set at what levels water would be diverted into and out of the ASR system. The levels were tied to percent of system storage. For example, during the simulation ASR can be turned on when the combined system storage of CCR and LCC exceeds 80 percent. During these periods, ASR would attempt to take the full 10 MGD to inject to the ASR system for that month. The model was developed so that any number of user-defined zones could be analyzed.

Typically there were two different scenarios with which the ASR simulations were performed. One involved a three-zone setup with one zone for filling ASR, another zone for no activity, and the last zone for depleting ASR and supplying the system. The other series of runs involved staggering the filling and depleting with four zones, two for filling and two for depleting. When the system storage was in the top zone, the ASR would attempt to fill at full capacity. Then when the system storage passed to the next zone, it would only fill at partial capacity. Then, into the third and fourth zones, the same pump rates for recovery as used in injection phase were kept. The advantage of the four-zone system is it keeps the ASR system continually active. Figure 4C.8-2 represents these two ASR operating scenarios graphically. With either set of operating rules, the ASR option essentially attempted to overdraft the system during wet times, and then ASR would attempt to supplement supply during the dry times, with a typical fill pattern of several years, followed by a shorter period of supplementing supply.



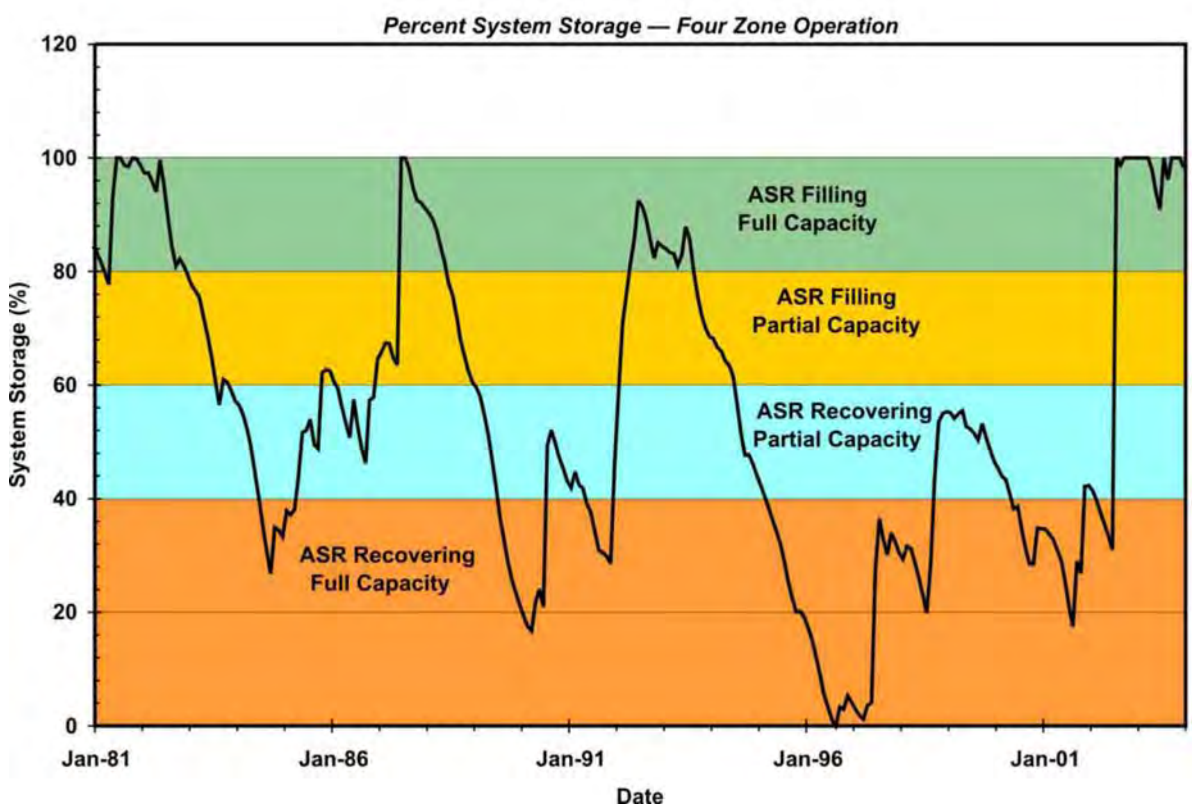


Figure 4C.8-2. ASR Operating Scenarios for Regional ASR Facility

4C.8.3 Guidelines for an ASR System and Comparison to Robstown-Driscoll Regional ASR

HDR Engineering, Inc (HDR) has developed the following set of guidelines for important elements involved in determining the feasibility of adding ASR wells to a water supply system. These guidelines are for screening purposes only and not criteria for suitability.

- Quality of Source Water to be Injected: When injecting water into an aquifer that is being used for drinking water supplies, TCEQ regulations require that the injected water be at least as good in quality as the water already in the aquifer (native water). This is generally interpreted to mean that the injected water has to be treated to Drinking Water Standards.
- Availability of Water: Water for recharge must be available in sufficient quantities, durations, and frequencies to balance the recharge and recovery cycles. In general, water for recharge needs to be available more than half of the time.
- Location of Facilities: ASR wells should be near the water treatment and distribution system in order to reduce the cost of constructing new pipelines and pumping the water to and from the ASR wells.
- Productivity of the Aquifer: The water yielding characteristics of an aquifer typically should allow the construction of wells producing 700 gallons per minute (gpm) (about 1 MGD) or more to improve the prospects of being able to make the project cost effective. The lowest yield of an ASR well that is documented in the literature is about 200 gpm.
- Aquifer Conditions: A confined water-bearing zone is preferable to a shallow water-table aquifer.
- Aquifer Thickness: The most suitable thickness of a target water-bearing zone is generally between 50 and 200 feet.
- Depth to Water-Bearing Zone: The most suitable depths are from 200 to 500 feet. However, depth to water-bearing zones up to 2,500 feet may prove to be cost-effective.
- Aquifer Material: A formation having a strong resistance to dissolution, such as sand, gravel, limestone, and sandstone is preferable. In any case, geochemical analyses are necessary to determine if any negative water quality issues are evident that could affect operation of an ASR facility, such as cation exchange or mineral precipitation, which would result from a reaction with clay in the aquifer.
- Water Quality: The most desirable aquifers have water quality that is at or near drinking water standards. However, successful ASR operations have been developed in aquifers with saline water in which the injection of freshwater would displace saline water and create a "freshwater bubble". In fact, aquifers with saline water may be preferable in some cases because of few or no other users of the aquifer, but the well design must consider the fact that freshwater is lighter than saline water and would tend to float to the top of water-bearing zones. Potential adverse geochemical processes such as precipitation, bacterial activity, ion exchange, and adsorption are possible and require a geochemical analysis to determine the expected reactions

between the native water and injected water. On the positive side, ASR may improve water quality through reductions in disinfection byproducts, iron and manganese, and hydrogen sulfides.

- Aquifer Water Levels and Wellhead Pressures: The desirable range in depth to water depends on the productivity of the aquifer. In aquifers with a high productivity, water levels can be near the land surface. For moderately transmissive water bearing zones, depth to water should be in the range of 100 to 300 feet below land surface. An existing cone of depression is desirable but not necessary. However, the formation of a water level mound that is above the land surface would increase springflows and cause uncapped wells to flow, which, in turn, would cause a waste of water and could damage existing property. In any event, well design and operational requirements must consider expected wellhead pressures of the project.
- Data Availability: Existing and reliable geophysical logs, geologic characteristics, water quality data, data on aquifer properties, hydrogeologic reports, and groundwater models are very helpful.
- Wells: Existing wells are often used, but many are unsuitable or would require modifications and more maintenance during operation. New wells, especially if constructed with PVC casing, are the most trouble free. Well screens should be stainless steel or PVC.
- Other Groundwater Users: Natural or regulatory restrictions are needed to prohibit unauthorized withdrawals of stored surface water.

A comparison of the Robstown-Driscoll Regional ASR option with the HDR guidelines is presented in Table 4C.8-1. The guidelines are exceeded only for the slightly saline water in the target storage zone and by some groundwater use in the area. Each of these exceedances is believed to be manageable.

4C.8.4 Results of Modeling Analysis for Long-Term Regional ASR System

The regional long-term ASR facilities were evaluated using the Corpus Christi Water Supply Model to determine their feasibility for becoming part of the City's water supply system. The assumption associated with the ASR facility is that when the system is operated in an over-draft mode during wet times to supply the ASR project that this water would be made available as additional supply to the system during drought times. It was initially believed that water savings would be achieved by reduced evaporation from the CCR/LCC Reservoirs and by recovery of water when the CCR/LCC System is spilling. However, after numerous model simulations, it was determined that this was not the case.

Table 4C.8-1.
Comparison of ASR Options with HDR's Guidelines for ASR Systems

Element	*Guideline*	*Robstown-Driscoll Regional Facility*
Quality of Source Water	Treated to Drinking Water Standards	Treated water from Corpus Christi Water Treatment Plant
Availability of Water	More than half the time	More than half the time
Location	Near water treatment and distribution facilities	Near distribution facilities
Productivity of Aquifer, as indicated by typical well capacities	700 gpm or more	About 750 gpm
Aquifer Conditions	Confined	Confined
Aquifer Thickness	50 to 200 feet	Two 100-foot zones
Depth to water-bearing zone	200 to 500 feet	About 500 feet
Aquifer Material	Resistance to dissolution	Mostly sand
Water Quality	At or near Drinking Water Standards, and Compatibility of injected water and aquifer materials	Slightly saline, and Appears to be compatible
Water Levels	100 to 300 feet below land surface	60 to 100 feet below land surface
Data Availability	Extensive reports and databases	Moderate detail in reports and databases
Wells	New	New
Other groundwater users	Limited	Few in potential well field, moderate number within 20 miles

The analysis indicated that the reason for this was twofold. The first observation indicated that the losses saved from lack of evaporation in the reservoir were not greater than the additional channel losses experienced when the over-drafted supply was released from LCC to be diverted at Calallen for delivery to the ASR system. In other words, the delivery of the additional water to ASR from LCC resulted in a larger amount having to be released from LCC to overcome the delivery losses down to Calallen. The second observation from the model analysis indicated that when the system was operated in over-draft mode for ASR, the system reservoirs entered the critical drawdown period sooner than in scenarios that did not include ASR operations. Therefore, even though there was additional supply available at the critical portion of the drought, the reservoirs entered the drought sooner, thereby reducing reservoir storage during the drought. Figure 4C.8-3 shows a section of the percent system storage trace through the recent drought of record both with and without project conditions. This figure illustrates how when ASR is turned on when the reservoir is full, ASR is filling, the overall system storage drops during the beginning of the drawdown. As the drawdown continues the two traces tend to parallel each other, and then towards the bottom of the drawdown the two lines come back together, with ASR providing supply. This shows that the best ASR can provide is a yield equal to the yield of the system without ASR. However, many of the simulations showed that with ASR turned on, that the overall system yield was actually slightly reduced.

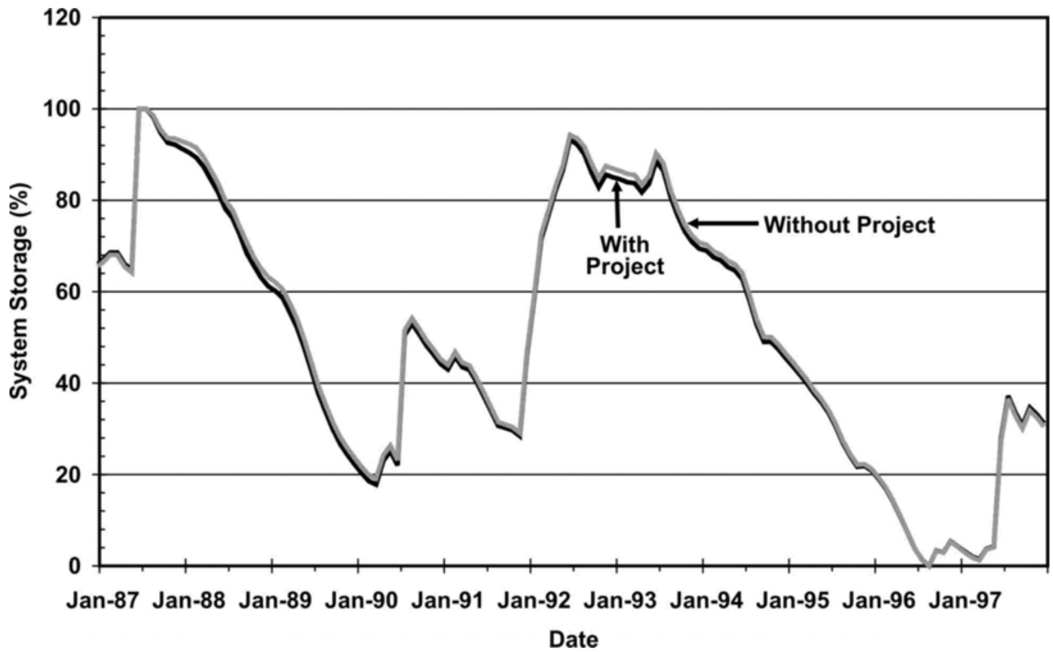


Figure 4C.8-3. CCR/LCC System Storage Traces With and Without ASR

The potential ASR project was also evaluated in conjunction with other proposed water management strategies, such as the CCR/LCC Pipeline, off-channel reservoir, and over drafting the system with interruptible water from Lake Texana. The results of the additional analysis were very similar to those developed when ASR was operated without any additional water management strategies. The same limitations were identified when operated conjunctively as those when it is operated independently. The ASR system as proposed in the analysis was unable to provide any meaningful water supply benefits whether operated in a stand-alone mode or conjunctively with other water management strategies. The additional yield in the conjunctive model runs was attributable to the other water management strategy not the ASR project.

Therefore, based on the results of the modeling analysis, ASR is not recommended as a viable management strategy to provide *additional* yield to the CCR/LCC/Texana water supply system. However, from an operational flexibility standpoint ASR could be utilized to store water during wet times that could be used during any catastrophic failure of the existing water supply system components. This would allow the city the ability to have a relatively "safe" water supply than can be relied upon during times of system failure. Also, seasonal ASR operations may prove to be beneficial to managing existing water supplies and providing additional water for peak demands.

4C.8.5 Additional Studies Currently Underway by the City of Corpus Christi

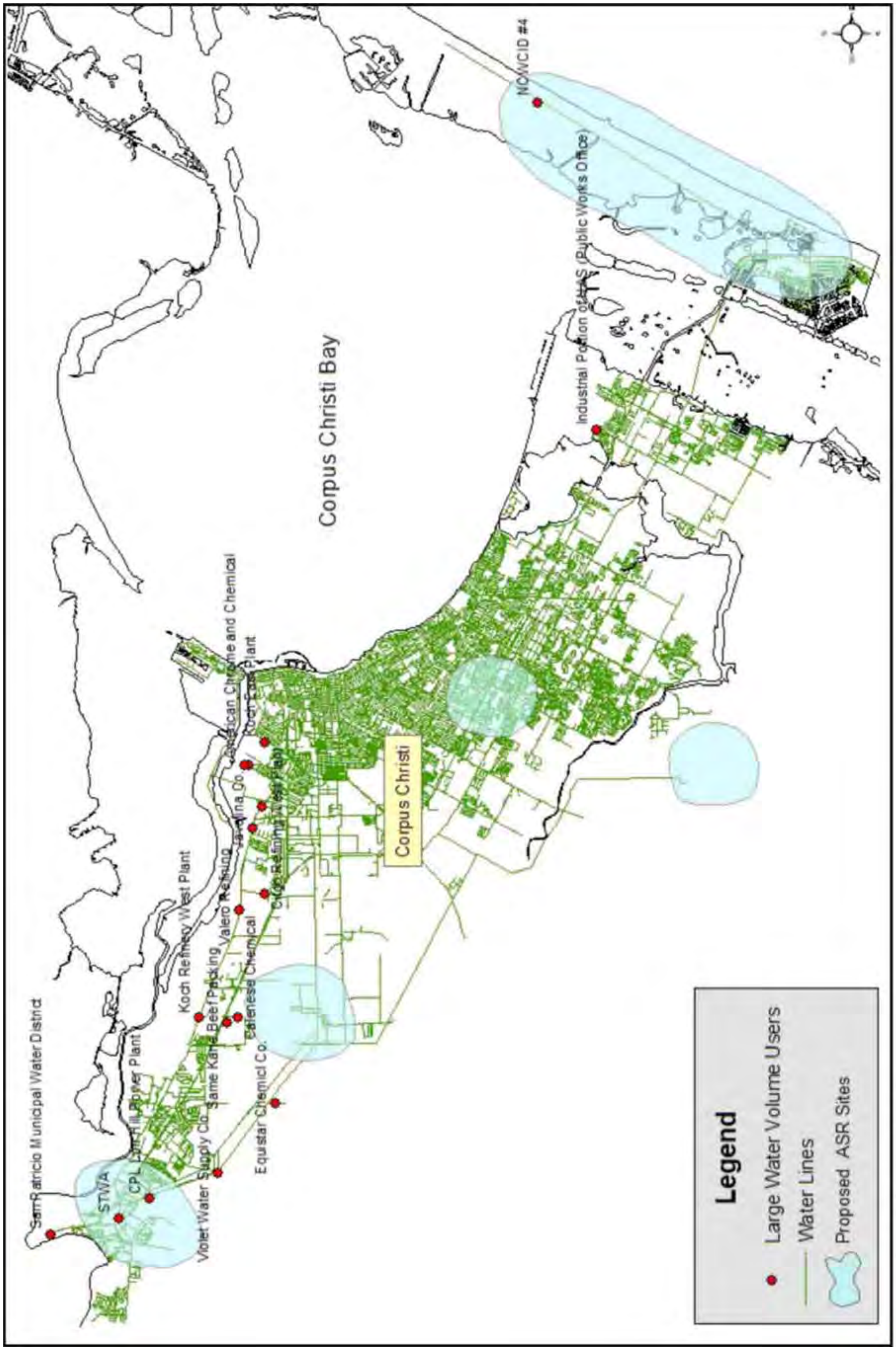
The Corpus Christi Aquifer Storage and Recovery Conservation District (District) was created in 2005 by the 79th Texas Legislature. The District is located in Aransas, Kleberg, Nueces, and San Patricio Counties. The primary purpose of the District is to facilitate the operation of aquifer storage and recovery operations by the City. The District adopted a Management Plan in June 2008. According to the Management Plan, the District's objectives include amongst others: (1) seasonal, long-term, and emergency strategic reserve storage, (2) augmentation of peak storage capacity, (3) improving system water quality by maintain minimum flows during seasons of low demands, and (4) helping to meet large retail customer needs. The District is in the process of developing an annual report and proposed 5-year plan.[3]

The City is evaluating seasonal ASR to manage their water supplies for seasonal, long-term, and possibly emergency water needs. The City is considering ASR projects at five different sites (Figure 4C.8-4). These studies are in the early phases of conceptual development and are located within the CCASR District area.

4C.8.6 Environmental Issues

The ASR option involves the construction of well fields in the Gulf Coast Aquifer System that would support a regional facility for the Corpus Christi area. The injection of water into aquifers and the pumping of groundwater from aquifers where ASR is practiced would be expected to contribute to variations in aquifer levels. However, the water level changes are not expected to change the gain or losses of streams in the area.

[3] The District's 5-year plan will provide guidance on: (1) the District's day-to-day operations, (2) studies that are needed to identify potential operational issues and develop a successful ASR program, and (3) compliance with Texas Commission on Environmental Quality regulations.



Source: City of Corpus Christi

Figure 4C.8-4. Locations of City of Corpus Christi ASR Studies

Habitat studies and surveys for protected species would need to be conducted at the proposed well field sites and along any pipeline routes. 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 revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

4C.8.7 Engineering and Costing

The multi-year ASR operation is not recommended as a viable management strategy to provide additional supply to the CCR/LCC/Texana water supply system. Costs are not included in this writing.

4C.8.8 Implementation Issues

Implementation of the ASR concepts includes the following issues:

- Suitable supplies of water for injection;
- Water treatment prior to injection;
- Uncertainty about the compatibility of the injected water with native groundwater and aquifer materials;
- Disposal of saline water during construction, development, and maintenance;
- Availability of access to local aquifers for an efficient application of ASR;
- Regulations by the TNRCC;
- Controlling the loss of injected water to neighboring groundwater users;
- Initial cost;
- Developing a management plan to efficiently use the ASR wells with balanced injection and recovery cycles, and/or
- Cultural resource surveys will need to be performed in order to avoid disturbance of any significant sites.

4C.8.9 Evaluation Summary

An evaluation summary of the Robstown-Driscoll Regional ASR Facility is provided in Table 4C.8-2.

Table 4C.8-2. Evaluation Summary of the Robstown-Driscoll Regional ASR Facility

Impact Category	*Comment(s)*
a. Water Supply 1. Quantity 2. Reliability 3. Cost of Treated Water	 1. Very limited firm yield 2. Not applicable 3 Unit cost would be high
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. Minor impacts during construction of wells and pipelines 2. None or low impact. 3. None or low impact. 4. None or low impact. 5. None or low impact. 6. Cultural resource survey will be needed to avoid impacts to any site 7. None or low impact. 7b. The proposed Robstown-Driscoll Regional Facility has slightly saline water. This is not expected to significantly affect recovery of water.
c. State water resources	• No negative impacts
d. Threats to agriculture and natural resources in region	• Negligible
e. Recreational	• None
f. Equitable impacts comparison of strategies	• Not applicable
g. Interbasin transfers	• None
h. Third party social and economic impacts from voluntary redistribution of water	• None
i. Efficient use of existing water supplies and regional opportunities	• Increases utilization of water treatment and transmission facilities
j. Effect on navigation	• None

4C.9 Modify Existing Reservoir Operating Policy and Safe Yield Analyses (N-9)

4C.9.1 Description of Strategy

In the late 1800s, the Corpus Christi Water Supply Company built a small dam near Calallen, Texas, to keep the saline waters of Nueces Bay from intruding into the fresh waters of the Nueces River and began to develop surface water supplies from the Nueces River. As the City grew and more and more water was needed, the dam at Calallen was raised several times and today the dam has a height of approximately 5.5 ft-msl and a capacity of about 1,175 acft. The City continued to expand and in 1934, La Fruta Dam was constructed on the Nueces River about 35 miles upstream of the Calallen Dam and initially it impounded approximately 60,000 acft of water. In 1958, Wesley Seale Dam was completed just downstream of the old La Fruta Dam, and the new Lake Corpus Christi was formed, which engulfed the old dam and reservoir and expanded storage to about 302,000 acft.

In the late 1960s, following an extreme drought that occurred from 1961 to 1963, planning began for an additional water supply for the City and its growing number of water customers. For more than a decade, studies were performed to evaluate alternative water supply options. Following considerable debate, Choke Canyon Reservoir, located on the Frio River 63.3 river miles upstream of Lake Corpus Christi, was constructed. Choke Canyon Dam was constructed by the United States Bureau of Reclamation (USBR). The dam was completed in 1982 and the reservoir first filled to capacity in 1987. Choke Canyon Reservoir has approximately 690,000 acft of conservation storage capacity, based on original USBR estimates. The TWDB has conducted volumetric surveys for Lake Corpus Christi and Choke Canyon Reservoir. In 2002, an updated volumetric survey of Lake Corpus Christi was completed by the TWDB and reported the capacity at 256,961 acft. The volumetric survey performed by the TWDB in 1993 reported the capacity of Choke Canyon Reservoir to be 695,271 acft. Today, the City operates these three reservoirs (Calallen, Lake Corpus Christi, and Choke Canyon Reservoir) and Lake Texana as a system to supply water for municipal and industrial users of the Coastal Bend Region.

The physical and hydrologic data for the three reservoirs in the Nueces Basin and two river reaches affecting the delivery of raw water from the Nueces River Basin to the City and its customers is summarized in Table 4C.9-1. As indicated in this table, approximately 94 percent of the demand occurs at the Calallen Reservoir pool, while about 73 percent of stored water is located 98 miles upstream at Choke Canyon Reservoir, with the remaining 27 percent of the stored water being located 35 miles upstream in Lake Corpus Christi. Water stored in Choke Canyon Reservoir is released into the river channel and delivered to Lake Corpus Christi. Water is then released from Lake Corpus Christi into the Nueces River channel, by which it flows to the Calallen pool. At the Calallen pool, the City and some of its customers divert raw water to their respective treatment plants, from which it is then distributed for use. Studies[1,2,3,4,5] performed throughout the years have indicted that a significant portion of the water that is released from Choke Canyon Reservoir and Lake Corpus Christi is lost to evaporation, evapotranspiration, and seepage along the river channels as it travels from one reservoir to the next.

Table 4C.9-1
Summary of Physical and Hydrologic Data
for Three Reservoirs and Two River Reaches

Reservoir or River Reach	*Capacity (acft)*	*Percent of Total System Storage*	*Average Annual Reservoir Evaporation (feet)*	*River Reach Distance (miles)*	*Estimated Delivery Losses (percent)*	*Percent of System Demand in Area of Reservoir*
Choke Canyon Reservoir	695,271[1]	72.9%	3.26	—	—	1%
River Reach between Choke Canyon Reservoir and Lake Corpus Christi	—	—	—	63.3	37.8[2]	—
Lake Corpus Christi	257,260[1]	27%	2.85	—	—	4%
River Reach between Lake Corpus Christi and Calallen	—	—	—	35	11[3]	
Calallen Reservoir	1,175[4]	0.1%	2.85	—	—	94%
Total	953,706	100%	—	98.3	—	100%

[1] Updated based on TWDB volumetric survey results of Lake Corpus Christi (2002) and Choke Canyon Reservoir (2003).
[2] Includes losses from Lake Corpus Christi to local aquifer, and represents average percentage lost, updated in 2005. As discussed in Section 4C.10, the delivery losses do not reflect channel loss results from Phase I analysis.
[3] Represents average percentage lost. River reach between Lake Corpus Christi and Calallen was updated to reflect new channel loss information, 2005.
[4] Based on previous 1990 analyses as included in the 2001 and 2006 Regional Water Plans.

[1] U.S. Bureau of Reclamation (USBR), "Nueces River Basin: A Special Report for the Texas Basins Project," U.S. Dept. of the Interior, December 1983.
[2] USBR, "Nueces River Project, Texas: Feasibility Report," U.S. Dept. of the Interior, July 1971.
[3] HDR Engineering, Inc. (HDR), et al., "Nueces River Basin Regional Water Supply Planning Study – Phase I," Vols. 1, 2, and 3, Nueces River Authority, et al., May 1991.
[4] Rauschuber and Associates, Inc., "Potential for Development of Additional Water Supply from the Nueces River Between Simmons and Calallen Diversion Dam," Subcommittee on Additional Water Supply from the Nueces River Watershed, December 1985.
[5] United States Geological Survey (USGS), "Water Delivery Study, Lower Nueces River Valley, Texas, TWDB Report 75," in cooperation with the Lower Nueces River Water Supply District, May 1968.

As shown in Table 4C.9-1, losses from Choke Canyon Reservoir downstream to, and including losses from, Lake Corpus Christi average 37.8 percent, while losses downstream of Lake Corpus Christi to the Calallen pool average about 11 percent. As discussed in Section 4C.10, the delivery losses were not updated during this planning effort. In addition, under a 2001 Agreed Order from the TCEQ,[6] the City is required to pass specified volumes of inflows to the reservoirs in accordance with a monthly schedule to mitigate the impacts of Choke Canyon Reservoir and maintain the health of the Nueces Estuary. In the 2001 Agreed Order, the City is not required to release when combined reservoir storage is less than 30 percent. All of the above items are significant factors that must be taken into account in the operation of the reservoir system.

The City of Corpus Christi initially had a four-phased operation plan for the CCR/LCC System. The objective of each phase was to provide the people of the Coastal Bend area with a dependable water supply as their needs grow, while at the same time, attempt to meet the need for consistent quality raw water by proper management of the two reservoirs. Additionally, recreational uses of the reservoirs as related to water surface elevations are a concern, as well as adherence to the TCEQ Order that specifies target inflows to the downstream bays and estuaries from wastewater return flows and spills, or releases of inflows from the reservoirs.

The initial operation plan consisted of four phases, with the first phase (Phase I) having been applicable prior to the initial filling of Choke Canyon Reservoir. Under each of the City's operation plan phases, a minimum of 2,000 acft/month is to be released from Choke Canyon Reservoir to meet the instream flow requirements within the water rights permit for Choke Canyon Reservoir.[7] In 1987, Choke Canyon Reservoir officially filled and the operating policy shifted to Phase II. The Phase II policy was intended to apply to the CCR/LCC System until water user demand is more than 150,000 acft/yr. The operational guidelines under this policy are as follows:

1. When conditions are such that the water surface elevation in Lake Corpus Christi is at or below 88 ft-msl and the water surface elevation in Choke Canyon Reservoir is above 204 ft-msl, releases will be made from Choke Canyon Reservoir to maintain the water surface elevation at Lake Corpus Christi at 88 ft-msl; and

[6] Texas Commission on Environmental Quality (TCEQ), Agreed Order Establishing Operational Procedures Pertaining to Special Condition B, Certificate of Adjudication No. 21-3214, Held by City of Corpus Christ, et al., April 28, 1995.
[7] TCEQ, Certificate of Adjudication No. 21-3214, Held by the City of Corpus Christi, et al.

2. When Lake Corpus Christi's water surface elevation is at or below 88 ft-msl and Choke Canyon Reservoir's water surface elevation is below 204 ft-msl, the Choke Canyon Reservoir release made for the current month will be equal to the release made at Lake Corpus Christi in the previous month.

The Phase II release rules were devised in an effort to minimize the drawdown of Lake Corpus Christi, primarily to ensure a consistent quality of water by mixing the Choke Canyon Reservoir releases with the stored water in Lake Corpus Christi, but also for recreation considerations.

The third operational policy (Phase III) was initially intended to apply to the system when water use is between 150,000 and 200,000 acft annually. This operational policy was promulgated by the USBR and is very similar to the Phase II policy. Under Phase III, when the water surface elevation at Lake Corpus Christi is at or below 88 ft-msl, steps are taken to draw the two reservoirs down together.

The fourth operation policy (Phase IV) is the maximum yield policy and was initially intended to apply to the system when water user demand exceeds 200,000 acft annually. Under this policy, the system is operated as follows:

1. When Lake Corpus Christi's water surface elevation is at or below 76 ft-msl and the water surface elevation in Choke Canyon Reservoir is above 155 ft-msl, releases are made from Choke Canyon Reservoir to maintain Lake Corpus Christi at 76 ft-msl; and
2. When Lake Corpus Christi's water surface elevation is at or below 76 ft-msl and Choke Canyon Reservoir's water surface elevation is below 155 ft-msl, Lake Corpus Christi is allowed to draw down to its minimum elevation and Choke Canyon Reservoir releases are made only to meet water supply shortages.

In April 1995, in response to requirements in the water rights permit for Choke Canyon Reservoir,[8] a bay and estuary release order (1995 Agreed Order) was adopted governing freshwater pass-through requirements to the Nueces Estuary. The major provisions of the 1995 Agreed Order are as follows:

1. The water passed through from the CCR/LCC System to satisfy the TCEQ bay and estuary release requirement in a given month is limited to no more than the inflow to Lake Corpus Christi as if Choke Canyon Reservoir did not exist; and
2. When the System storage is above 70 percent, the monthly bay and estuary release schedule provides for a target of 138,000 acft/yr of water to Nueces Bay and/or the Nueces Delta by a combination of return flows, reservoir releases and spills, and measured runoff downstream of Lake Corpus Christi. When the system storage is less

[8] Ibid.

than 70 percent but more than 40 percent, the target schedule is reduced so as to provide 97,000 acft/yr to Nueces Bay and/or the Nueces Delta. In any month when the System storage is less than 40 percent but great than 30 percent, the target Nueces Bay inflow requirement may be reduced to 1,200 acft/month when the City and its customers implement Condition II of the City's Water Conservation and Drought Contingency Plan (Plan). If System storage drops below 30 percent, bay and estuary releases may be suspended when the City and its customers implement Condition III of the Plan.

3. In April 1995, in response to requirements in the water rights permit for Choke Canyon Reservoir,[9] a bay and estuary release order (1995 Agreed Order) was adopted governing freshwater pass-through requirements to the Nueces Estuary.

On April 17, 2001, the TCEQ issued an amendment to the 1995 Agreed Order to revise operational procedures in accordance with revisions requested by the City of Corpus Christi. The major provisions of the new 2001 Agreed Order are as follows:

1. Revisions to passage of inflows to Nueces Bay and Estuary at 40 percent and 30 percent reservoir system capacity upon institution of mandatory outdoor watering restrictions. In any month when the System storage is less than 40 percent but greater than 30 percent, the target Nueces Bay inflow requirement may be reduced to 1,200 acft/month when the City and its customers implement Condition II of the City's Water Conservation and Drought Contingency Plan (Plan). If System storage drops below 30 percent, bay and estuary releases (except for return flows) may be suspended when the City and its customers implement Condition III of the Plan.
2. Supported calculating reservoir system storage capacity based on most recently completed bathymetric surveys; and
3. Included provisions for operating Rincon Bayou diversions and conveyance facility from Calallen Pool to enhance the amount of freshwater to the Nueces Bay and Delta.

4C.9.2 Available Yield

During the mid-1990s, in response to drought conditions, the City of Corpus Christi changed the Reservoir Operating Plan to Phase IV (i.e., Maximum Yield Policy) in order to maximize the yield of the CCR/LCC System. In addition, the City modified the Phase IV Policy making elevation 74 ft-msl Lake Corpus Christi's target elevation and brought in Lake Texana water supplies in late-1990s. A summary of the firm yield of the system in 2010 and 2060, assuming Phase IV operations, including water supplies from Lake Texana, and the 2001 Agreed

[9] Ibid.

Order, and computed by the Corpus Christi Water Supply Model (formerly known as the Lower Nueces River Basin and Estuary (NUBAY) Model[10]) is provided in Table 4C.9-2.

Table 4C.9-2. CCR/LCC/Lake Texana System Firm Yields (Phase IV Policy)

Reservoir Sedimentation Year	***CCR/LCC/Lake Texana System Firm Yield (acft/yr)***
2010	227,000
2060	219,000

The reservoir system yields tabulated in Table 4C.9-2 are essentially the maximum yields available under the City's current reservoir operating policies and existing schedule governing freshwater pass-throughs to the bay and estuary.

For the 2006 Plan, the CBRWPG adopted the use of safe yield analyses for the CCR/LCC/Lake Texana System. Safe yield supply represents a more conservative approach to determining minimum annual availability in areas where the severity of droughts is uncertain. In March 2009, the CBRWPG requested use of safe yield supplies for development of the 2011 Plan. On April 30, 2009, the TWDB approved continued use of safe yield for development of the 2011 Plan. Safe yield supply is the amount of water that can be withdrawn from a reservoir such that a given volume remains in reservoir storage during the critical month of the drought of record. The surface water availabilities for the largest water rights in the Nueces Basin (i.e., City of Corpus Christi and their customers) are based on safe yield analyses and assume a reserve of 75,000 acft (i.e., 7 percent LCC/CCR System storage) for future drought conditions.

[10] In 1990, the need for a tool that could be used to evaluate the effects of water supply options in the region, as well as the need to evaluate various reservoir operation policies, led to the development of the Lower Nueces River Basin and Estuary Model – NUBAY (HDR, et al., "Nueces River Basin Regional Water Supply Planning Study – Phase I," Vols. 1, 2, and 3, Nueces River Authority, et al., May 1991). This model originally operated on a monthly timestep over the 1934 to 1989 period of record, which includes significant droughts in the 1950s, 1960s, and 1980s. Computations in the model simulate evaporation losses in the reservoirs, as well as channel losses in the rivers associated with water delivery from Choke Canyon Reservoir to Lake Corpus Christi, and from Lake Corpus Christi to the City's water supply intake at the Calallen diversion dam. In addition, due to sediment deposition in Choke Canyon Reservoir and Lake Corpus Christi, the model allows for a variety of sediment conditions ranging from the 1990 storage volumes in the lakes to the projected 2060 system storage capacities. The model has been developed and updated through a series of projects since 1991. During this planning cycle, the model was updated to include the new drought of record and currently operates on a 1934 to 2003 period of record (HDR, et al., "Nueces Estuary Regional Wastewater Planning Study, Phase 1," City of Corpus Christi, et al., November 1991; HDR, et al., "Nueces Estuary Regional Wastewater Planning Study, Phase 2," City of Corpus Christi, et al., March 1993; HDR, "Water Supply Update for City of Corpus Christi Service Area," City of Corpus Christi, January 1999; HDR, Supplemental Funding Work Item for 2006 Coastal Bend Regional Water Plan, 2005).

Figure 4C.9-1 shows how 3-year average annual inflows for the major reservoir system have been reduced for each of the past four significant droughts.

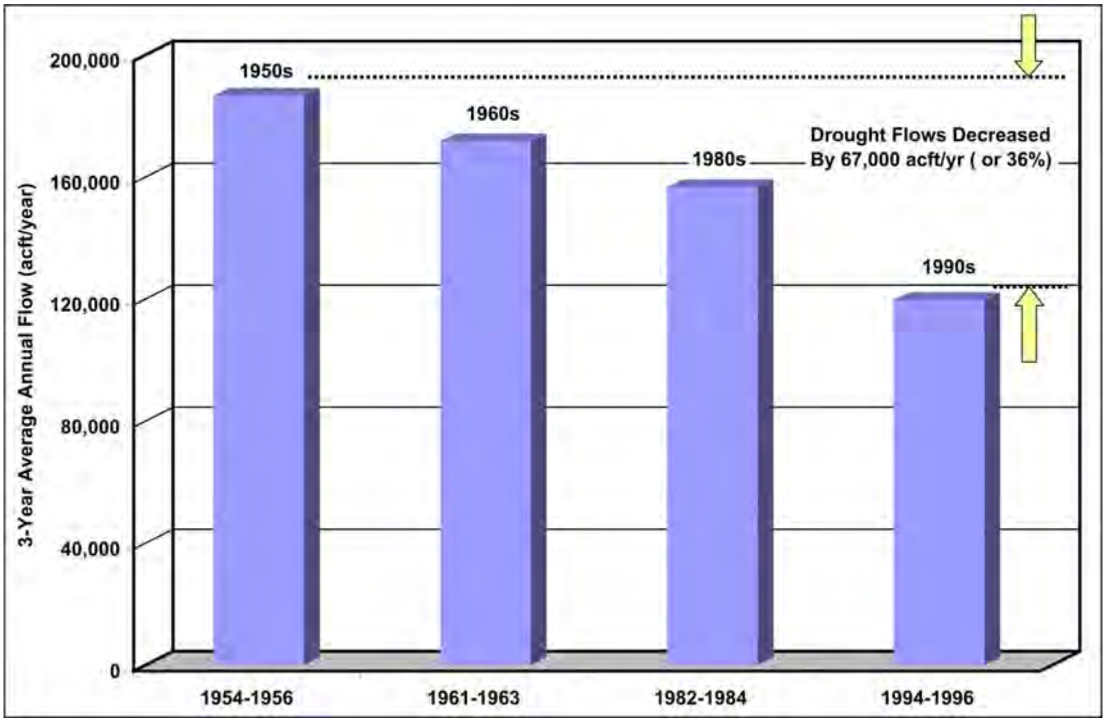


Figure 4C.9-1. 3-Year Reservoir Inflows

A summary of the safe yield of the system in 2010 and 2060, assuming Phase IV operations, including water supplies from Lake Texana, and the 2001 Agreed Order, and computed by the Corpus Christi Water Supply Model[11] is provided in Table 4C.9-3.

[11] In 1990, the need for a tool that could be used to evaluate the effects of water supply options in the region, as well as the need to evaluate various reservoir operation policies, led to the development of the Lower Nueces River Basin and Estuary Model – NUBAY (HDR, et al., "Nueces River Basin Regional Water Supply Planning Study – Phase I," Vols. 1, 2, and 3, Nueces River Authority, et al., May 1991). This model originally operated on a monthly timestep over the 1934 to 1989 period of record, which includes significant droughts in the 1950s, 1960s, and 1980s. Computations in the model simulate evaporation losses in the reservoirs, as well as channel losses in the rivers associated with water delivery from Choke Canyon Reservoir to Lake Corpus Christi, and from Lake Corpus Christi to the City's water supply intake at the Calallen diversion dam. In addition, due to sediment deposition in Choke Canyon Reservoir and Lake Corpus Christi, the model allows for a variety of sediment conditions ranging from the 1990 storage volumes in the lakes to the projected 2060 system storage capacities. The model has been developed and updated through a series of projects since 1991. During this planning cycle, the model was updated to include the new drought of record and currently operates on a 1934 to 2003 period of record (HDR, et al., "Nueces Estuary Regional Wastewater Planning Study, Phase 1," City of Corpus Christi, et al., November 1991; HDR, et al., "Nueces Estuary Regional Wastewater Planning Study, Phase 2," City of Corpus Christi, et al., March 1993; HDR, "Water Supply Update for City of Corpus Christi Service Area," City of Corpus Christi, January 1999; HDR, Supplemental Funding Work Item for 2006 Coastal Bend Regional Water Plan, 2005).

Table 4C.9-3.
CCR/LCC/Lake Texana System Safe Yields
(Phase IV Policy)

Reservoir Sedimentation Year	*CCR/LCC/Lake Texana System Safe Yield (acft/yr)*
2010	205,000
2060	200,000

With safe yield supplies, the yield of the system is reduced by 22,000 acft/yr in 2010 and 19,000 acft/yr in 2060, based on sedimentation conditions. Safe yield supplies were considered for the City of Corpus Christi and their customers (including Wholesale Water Providers).

Since the decision was made in the 1970s to pursue a second reservoir in the Nueces River Basin to enhance the yield of Lake Corpus Christi reservoir, a considerable amount of attention has been given to the potential effects of reduced freshwater inflow to the upper Nueces Bay and Nueces Delta. The following sections provide a brief history of ecological studies in the Nueces Estuary and a management strategy for maximizing the productivity of the Nueces Delta ecosystem while increasing the firm yield of the CCR/LCC System.

Appendix J includes a summary of ecological studies supporting the benefits of freshwater diversions to the Nueces Delta.

4C.9.3 CCR/LCC System Yield Recovery

4C.9.3.1 Summary of Ecological Studies of the Nueces Estuary

Beginning with the USBR's Environmental Impact Statement (EIS) for the Choke Canyon project,[12] the impact of an additional reservoir in the Lower Nueces River Basin on freshwater inflows to the Nueces Estuary has been discussed, studied, and debated. In the late 1970's and 1980's, a series of studies and reports were published regarding the freshwater needs of the Nueces Estuary. Studies by the United States Fish and Wildlife Service (USFWS),[13,14] the Texas Department of Water Resources (predecessor agency to the Texas Water Development

[12] USBR, "Environmental Impact Statement for Choke Canyon Reservoir," December 1975.
[13] United States Fish and Wildlife Service (USFWS), "Supplemental Fish and Wildlife Coordination Act Report, Choke Canyon Dam and Reservoir, Nueces River Project, Texas," 1984.
[14] USFWS, "Phase 4 Report – Studies of Freshwater Needs of Fish and Wildlife Resources in Nueces-Corpus Christi Bay Area, Texas," August 1980.

Board),[15] Espey, Huston and Associates,[16] and unpublished research by scientists at the University of Texas Marine Science Institute (UTMSI) regarding effects of freshwater inflows to the Nueces Delta were conducted with a variety of differing goals and objectives. However, each study arrived at a similar set of conclusions: (1) the construction and operation of Choke Canyon Reservoir would reduce the volume of freshwater inflows to the Nueces Estuary; and (2) direct diversions of river flows and/or wastewater effluent return flows to the upper Nueces Delta could provide considerable mitigation for the reduction in freshwater inflows to the Nueces Estuary due to the CCR/LCC System.

In 1990, after the completion of Choke Canyon Reservoir, a Technical Advisory Committee (TAC) was formed by the Texas Water Commission (predecessor to the TCEQ) to assist the Commission in formulating a permanent freshwater inflow operating procedure for the Choke Canyon/Lake Corpus Christi reservoir system in accordance with Special Provision 5.B in the water rights permit for Choke Canyon Reservoir.[17] As the TAC process called attention to the need to formulate a long-term operating plan for freshwater inflows to the Nueces Estuary, it also created new interest in using diversions of both freshwater inflows and wastewater return flows as mechanisms to make optimal use of these limited resources.

In 1991, the City of Corpus Christi and several other local sponsors initiated what became a two-phased study[18,19] of the potential to divert freshwater into the Nueces Delta with the objective of reducing requirements to "release" water from the reservoir system. Findings of these reports included recommendations for one or two demonstration projects to be developed to evaluate the feasibility of both river diversions and wastewater effluent diversions into the Nueces Delta, and additional scientific monitoring to routinely collect pertinent data to improve the scientific understanding of the Nueces Delta and Bay ecosystems. Additionally, detailed results of studies of primary productivity in the Nueces Delta/Bay system reported in the Phase II

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[15] Texas Department of Water Resources, "Nueces and Mission-Aransas Estuaries: A Study of the Influence of Freshwater Inflows," January 1981.

[16] Espey, Huston and Associates, "Enhancement Potential Determination for the Nueces River/Deltaic Marsh System Study," 1981.

[17] TCEQ, Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, et al.

[18] HDR, et al., "Nueces Estuary Regional Wastewater Planning Study, Phase 1," City of Corpus Christi, et al., November 1991.

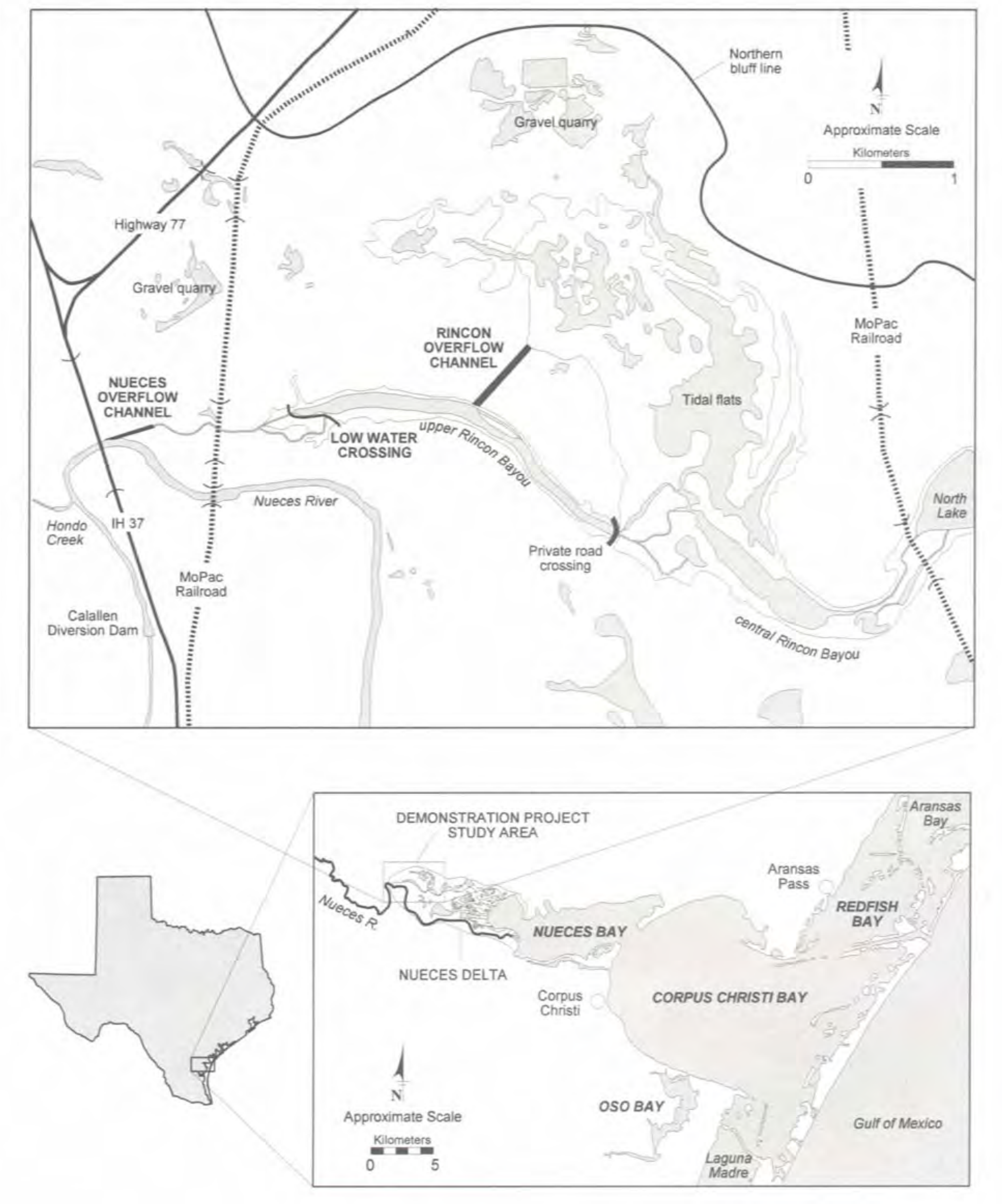
[19] HDR, et al., "Nueces Estuary Regional Wastewater Planning Study, Phase 2," City of Corpus Christi, et al., March 1993.

Study[20] supported the concept that placing freshwater into marsh systems in the delta could provide three to five times the levels of primary productivity that the same amount of freshwater would produce when discharged into the water column of Nueces Bay via the Nueces River tidal segment. A recent study to evaluate biological productivity multipliers and impacts on system yield was conducted for the 2011 Plan and is summarized in Section 4C.5. The Phase II Study conducted in 1993 provided the impetus for the eventual development of the two freshwater diversion demonstration projects that have been implemented to date: the USBR's Rincon Bayou Demonstration Project and the Allison Wastewater Treatment Plant Effluent Diversion Demonstration Project, sponsored by the City of Corpus Christi.

The Rincon Bayou Demonstration Project involved the excavation the Nueces Overflow Channel and the Rincon Overflow Channel in 1995, and subsequent monitoring activities through December 1999 (Figure 4C.9-2). The Bureau conducted water quality and biological studies of the Nueces Delta and Estuary from October 1994 to December 1999. While the demonstration project term expired in September 2000, and the Nueces Overflow Channel was subsequently filled in, the project's Concluding Report[21] describes the successes achieved during this relatively short period of time in restoring much of the ecological function of the Rincon Bayou portion of the Nueces Delta. A summary of the results of this demonstration project are highlighted below. Excerpts from the plan's Abstract and Executive Summary[22] are included below and the main features of the Demonstration Project are shown in Figure 4C.9-2.

> *Composing a complex array of channels, pools, marshes, and tidal flats, the Nueces Delta is one of the most extensive marsh ecosystems on the Texas Gulf Coast and an integral component of the Nueces Estuary. As part of the link between the riverine habitats of the Nueces River and the marine habitats of the Gulf of Mexico, the delta provides a critical transitional environment utilized by both estuarine and marine plants and animals. Functioning normally, the delta is inundated regularly by salt water from the bay via tides and wind, and occasionally by fresh water when the Nueces River spills over its banks. The periodic freshwater inundations by the river, which typically occur during the spring and fall, are essential in maintaining the ecological function of the delta. However, as regional municipal and industrial water demands from the Nueces River have increased, freshwater inflow to the delta has been greatly reduced.*

[20] Ibid.
[21] USBR, "Rincon Bayou Demonstration Project, Concluding Report," Volumes I and II, U.S. Dept. of the Interior, et al., September 2000.
[22] U.S. Bureau of Reclamation, "Rincon Bayou Demonstration Project, Concluding Report," Volume 1, U.S. Dept. of the Interior, et al., September 2000.



Source: Rincon Bayou Demonstration Project, Concluding Report, Volume I, Executive Summary, USBR, September 2000.

Figure 4C.9-2. Location of the Nueces Delta (below) and of the Rincon Bayou Demonstration Project Features (above)

As regular exchange with the Nueces River has diminished, the Nueces Delta has ceased to function as a viable component of the estuarine ecosystem. The freshwater inflow events that do occur are too small and too infrequent to offset the natural importation of salt into the delta by tide, which is then concentrated by evaporation. Consequently, extensive areas of hypersaline water and soils have developed in the delta, resulting in a "reverse estuary" condition, where salinity values are lowest in Nueces Bay and increase with distance into Rincon Bayou. While many estuarine species can tolerate this harsher environment for short periods, prolonged conditions of salinity-caused stress have stunted active growth and reproduction, leading to lower biological productivity and less species diversity.

In 1993, the U.S. Bureau of Reclamation (Reclamation) initiated a demonstration project with the following objectives:

1) *To increase the opportunity for freshwater flow events into the upper Nueces Delta, and*

2) *To monitor subsequent changes in delta productivity.*

The primary features of the Rincon Bayou Demonstration Project were two excavated channels (the Nueces Overflow Channel and the Rincon Overflow Channel, which were completed in October 1995. Monitoring activities were conducted from October 1994 through December 1999, and were focused on the response of organisms in the water column, sediments and tidal flats of the delta.

The Rincon Bayou Demonstration Project significantly lowered the minimum flooding threshold of the upper Nueces Delta, thereby increasing the opportunity for larger, more frequent diversions of fresh water from the Nueces River. During the 50-month demonstration period, the amount of fresh water diverted into the upper Nueces Delta was increased by about 732%. Five freshwater inflow events were sufficient to activate the project's Rincon Overflow Channel and inundate, to varying degrees, the tidal flats of the upper delta. These tidal flats would not have otherwise been directly freshened. As a result, in a relatively short period of time (only 4.2 years after the opening of the project's Nueces Overflow Channel), the average salinity gradient in the upper delta reverted to a more natural form, with average salinity concentrations in upper Rincon Bayou becoming the lowest in Nueces Delta.

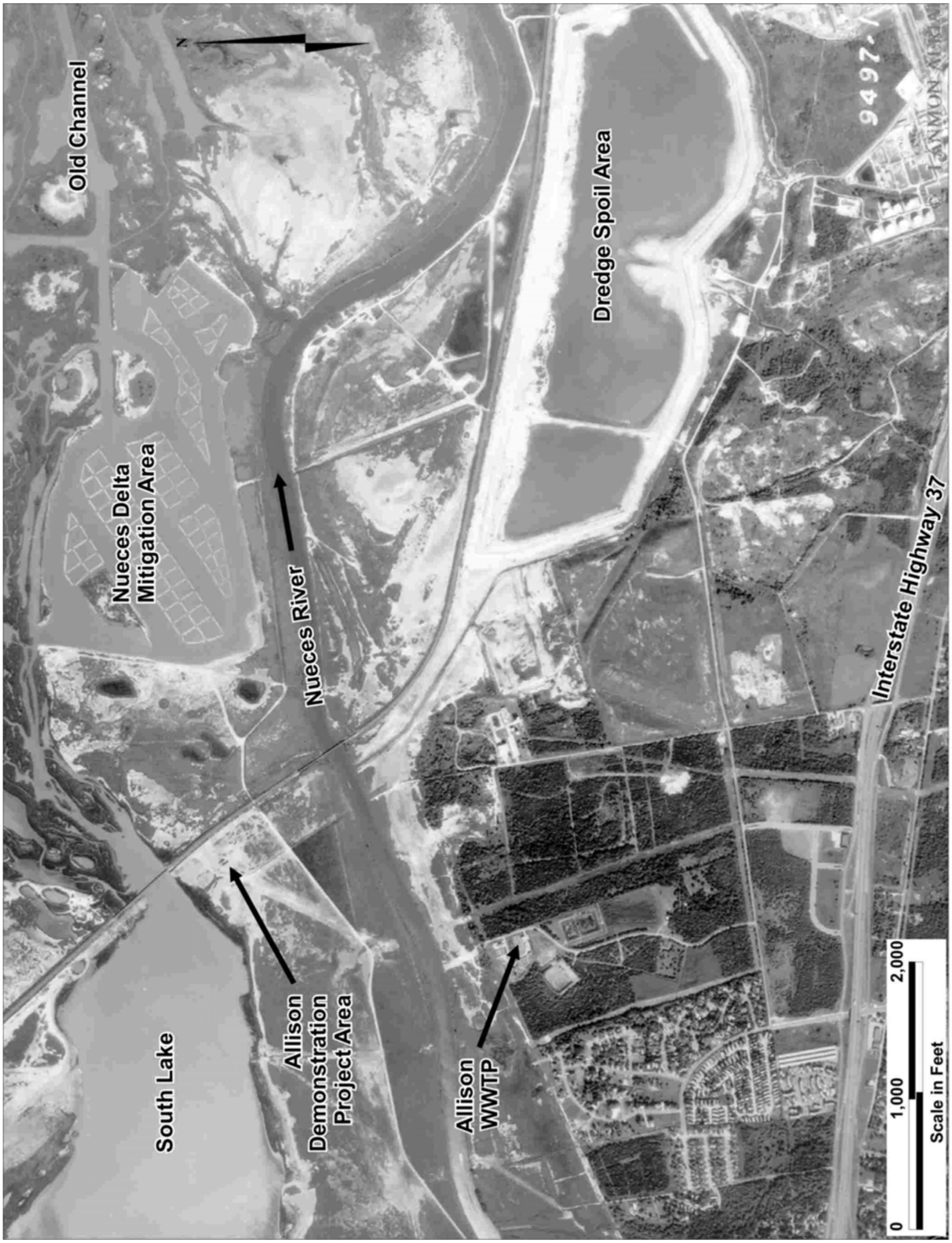
The effects of the demonstration project on the ecology of Rincon Bayou and the upper Nueces Delta were positive to the environment. Single-celled plant communities in the water column (phytoplankton) and on the surface of the sediments (microphytobenthos) evidenced increases in primary productivity with the reduction of salinity concentrations. Benthic communities (composed of bottom-dwelling organisms) evidenced increase in abundance, biomass and diversity. And, vegetation communities evidenced increases in plant cover and decreases in bare area. In summary, it was observed that freshwater inflow

> *controlled, to a great extent, the ecological function of the upper delta ecosystem by regulating critical biological mechanisms.*
>
> *A significant degree of ecological function was returned to the Nueces Delta and Nueces Estuary ecosystems by the demonstration project. Prior to the project, persistently high salinity concentrations severely inhibited the function of the Nueces Delta, and the delta's natural contribution to the greater estuary ecosystem was limited to infrequent periods when natural flow events occurred. With the restored regular interaction between the Nueces River and Rincon Bayou, fresh water and nutrients were more consistently introduced into the upper delta. As a result, estuarine habitat in the delta component of the Nueces Estuary improved in both quality and quantity, and foraging opportunities for many estuarine species were increased.*

Based on the benefits demonstrated by the Rincon Bayou Demonstration Project and the 2001 Agreed Order, the City reopened the channels and conducts an on-going monitoring program to facilitate an adaptive management program for freshwater inflows to the Nueces Estuary.[23] The Rincon Bayou Diversion Pipeline and Pump Station (Rincon pipeline) was constructed by the City of Corpus Christi pursuant to the 2001 Agreed Order and became operational in November 2007. Although not required by the Agreed Order, the City is in the process of developing an operations plan for the Rincon pipeline to provide inflow to the Upper Rincon Bayou. Salinity monitors have been positioned throughout the estuary to tract flow rate and retention time of water diverted through the Rincon Pipeline.

The Allison Wastewater Diversion Project completed a 5-year data collection program in September 2003 (see Figure 4C.9-3). The data collection program (1999 to 2003) was conducted by Texas A&M University at Corpus Christi and University of Texas Marine Science Institute. A study completed in 2006[24] outlined the positive benefits of the Allison WWTP Demonstration Project. This report concluded that there was an increase in vegetation and creation of additional areas of salt marsh which was accompanied by more shorebirds being attracted to the area. The report also noted that with the additional water diverted to the marsh area, there was an approximately 50 percent removal of wastewater discharge into the Nueces River, reducing the potential for nutrient driven algal blooms. The City of Corpus Christi maintains an extensive

[23] City of Corpus Christi, Integrated Monitoring Plan Fiscal Year 2005, January 2005.
[24] Concluding Report: Allison Wastewater Treatment Plant Effluent Diversion Demonstration Project, Volume I: Executive Summary. The University of Austin, Marine Science Institute, Port Aransas, Texas and Texas A&M University-Corpus Christi, Center for Coastal Studies, Corpus Christi, Texas, 2006.



Source: Naismith Engineering, Inc.

Figure 4C.9-3. Diversion of Corpus Christi WWTP Effluent to the Nueces Delta

monitoring program designed to assess the benefits of the 2 MGD of effluent being discharged into the wetlands of the South Lake area of the Nueces Delta and/or Rincon pipeline freshwater diversions. The location of treated effluent discharges is important to consider when evaluating the benefits to the Nueces Delta and Estuary. Effluent discharges returned to the upper portions of the Nueces Bay and Estuary will have greater potential benefits. These results should be evaluated in conjunction with the results of Rincon pipeline diversions in order to determine a long-term plan for diversion of river water and wastewaters to the Nueces Delta.

4C.9.3.2 Potential Effluent Diversion Projects and Associated Firm Yield Impacts

As shown in the previous studies detailed above, the location of freshwater inflows to the Nueces Estuary can be as important as the volume of flow. In this water management strategy evaluated during previous planning efforts, the NUBAY Model was used to evaluate the increase in CCR/LCC System firm yield due to alternative reservoir operating policies regarding freshwater inflows to upper Nueces Bay and Estuary. For the 2011 Plan, the costs have been updated to September 2008 prices. In the analysis, it was assumed that effluent from the City of Corpus Christi's wastewater treatment plants (WWTP) would be diverted to the Rincon Delta in exchange for freshwater pass-throughs from the CCR/LCC System. The three scenarios for the additional effluent diversions analyzed are summarized in Table 4C.9-4.

Table 4C.9-4.
Summary of Effluent Diversion Volumes and Sources

Scenario Number	Additional Diversion Volume	Effluent Source(s)
1	4 MGD	Allison WWTP
2	9 MGD	Allison and Broadway WWTPs
3	20 MGD	Allison, Broadway, and Greenwood WWTPs
Note: Diversion volumes include future expected wastewater effluent volumes and do not include existing 3 MGD at Allison that is currently discharged to Nueces Bay and the Allison Effluent Diversion Demonstration Project or 4 MGD of existing discharge to the Greenwood WWTP receiving stream.		

Under Scenario 1, future effluent discharges from the City of Corpus Christi's Allison WWTP (up to 4 MGD by 2020) would be discharged into the Nueces Delta. Similarly, under Scenario 2, the City's existing Broadway WWTP would be retired and up to 5 MGD of wastewater would be sent to the Allison WWTP. Under this scenario, the Allison WWTP would be expanded to treat the additional effluent from Broadway and the total additional effluent available for diversion to the bay or delta would be 9 MGD. In the last scenario, the Broadway WWTP would be retired and up to 5 MGD of wastewater sent to the City's Greenwood WWTP. Expansions at Greenwood would provide for an additional combined 16 MGD of effluent under future conditions for diversion to Nueces Bay or Delta. This effluent would be piped to the Allison WWTP and combined with the additional effluent from Allison (4 MGD) and discharged into the bay or delta. Figures 4C.9-4 and 4C.9-5 show the location of the WWTPs and the proposed pipelines to divert water to the bay or delta for Scenarios 2 and 3. No additional transmission facilities would be necessary for implementation of Scenario 1.

Under this water management strategy, in return for the additional effluent diversions to the Nueces Bay or Delta the CCR/LCC System would be allowed to suspend freshwater pass-throughs to Nueces Bay when CCR/LCC System storage drops below the selected threshold. While the reservoirs are operating above these system storage threshold triggers, the additional effluent diverted to the delta could satisfy a significant part of the Agreed Order pass-through requirements leaving additional freshwater in storage and thereby enhancing the CCR/LCC System firm yield. For purposes of these analyses, the following thresholds were used: 60, 50 and 40 percent of system storage. A series of model runs were performed for the above combinations. The incremental increases in CCR/LCC System firm yield range from a low of 7,100 acft/yr (Scenario 1 with a 40 percent system storage trigger) to a high of 13,100 acft/yr (Scenario 3 with a 60 percent system storage trigger). As shown in Table 4C.9-5 and Figure 4C.9-6, in general, as one increases the volume of effluent to the delta and/or increases the percent of system storage at which pass-throughs are suspended, the firm yield of the CCR/LCC System increases.

4C.9.4 Environmental Issues

Fifty-two percent of the water diverted and used by the City is returned to various points in the estuary as treated wastewater. Presently, the largest portion of these discharges is made into the Nueces River, the Ship Channel, Oso Creek, and Oso Bay. This alternative involves reusing a portion of this treated wastewater by moving treated wastewater discharges from their present discharge points to the Nueces Delta (e.g., Rincon Bayou and Upper Nueces Delta.) The discharge of treated wastewater to the Nueces Delta offers potential for benefits in terms of

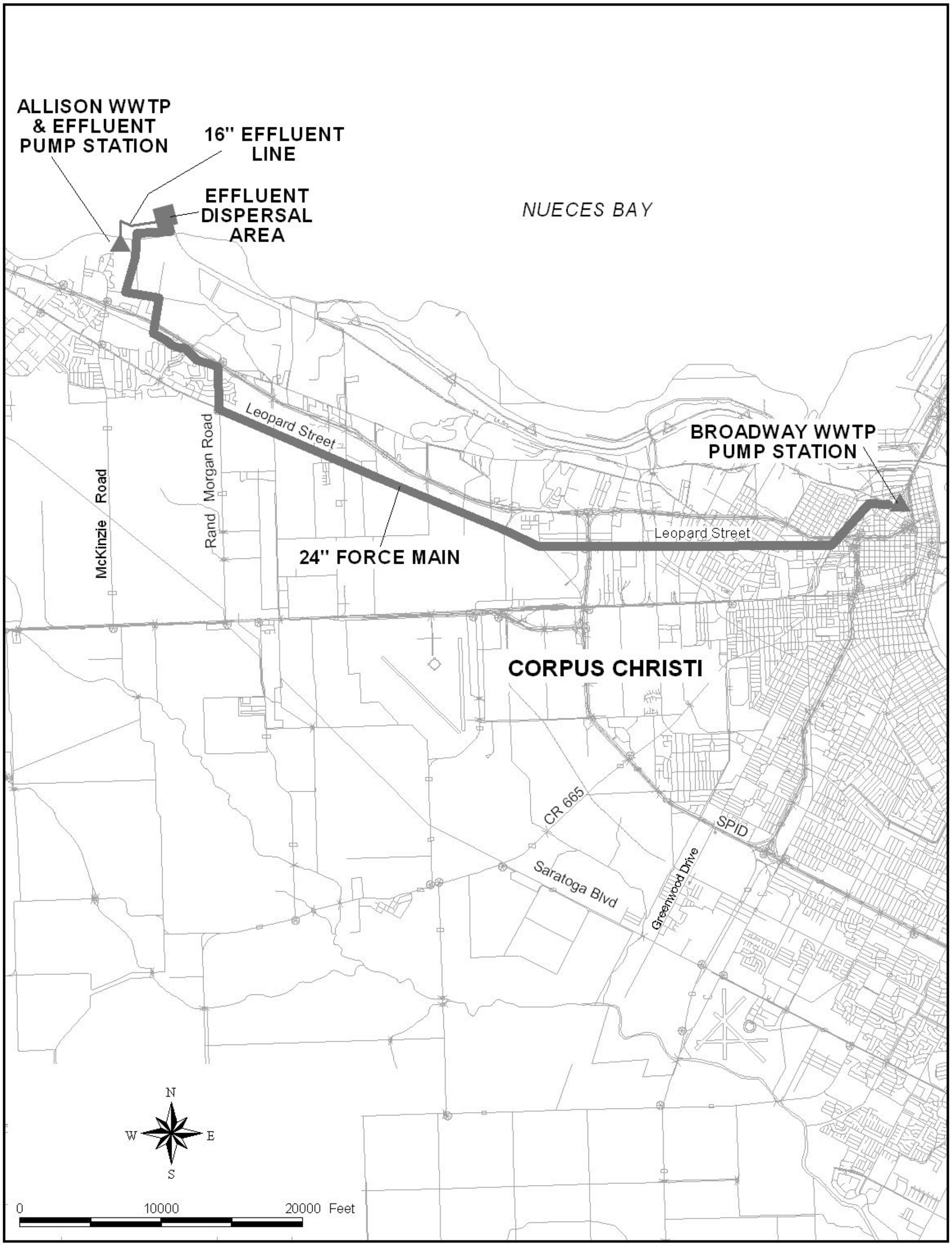


Figure 4C.9-4. Effluent Diversion Scenario 2

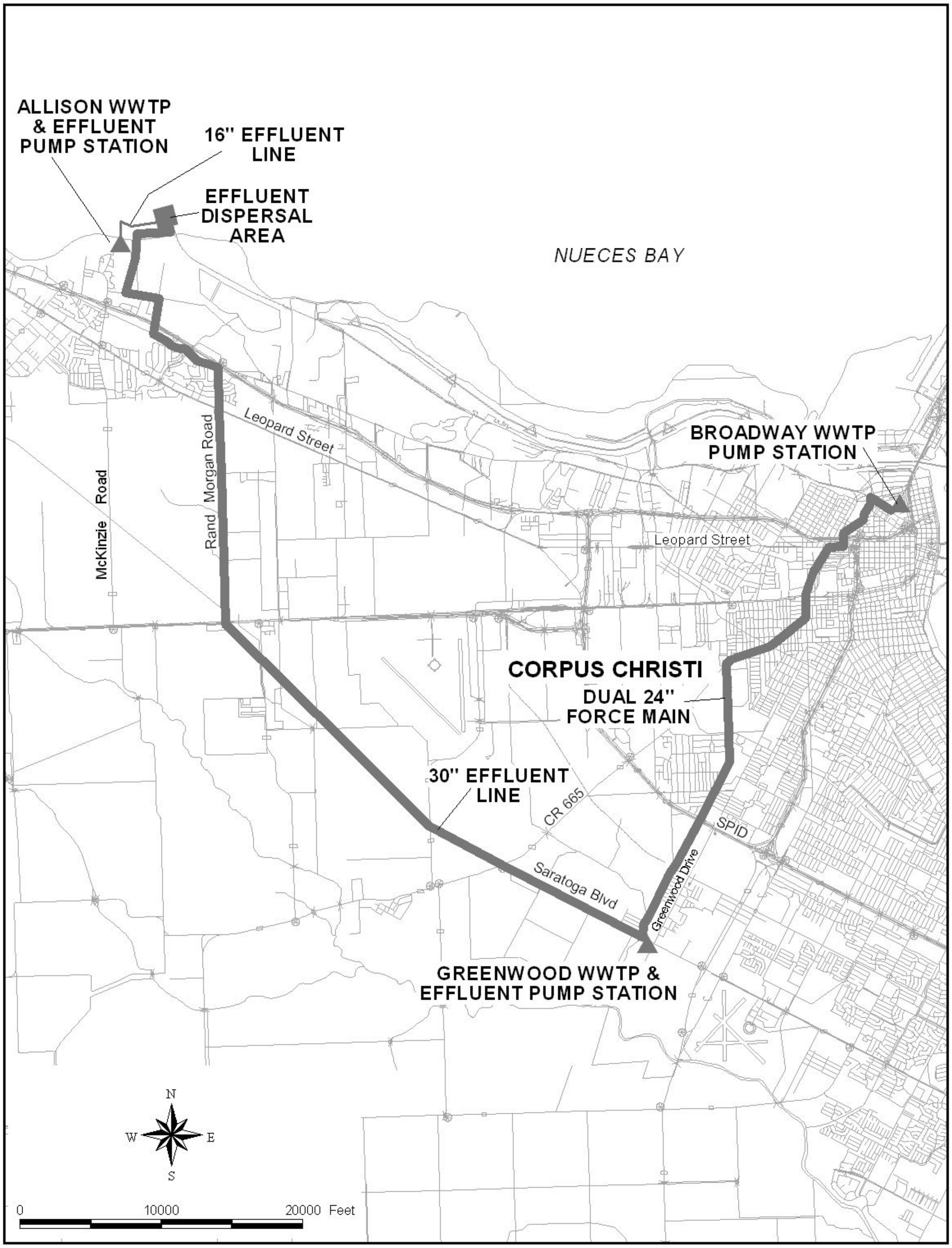


Figure 4C.9-5. Effluent Diversion Scenario 3

Table 4C.9-5.
Incremental Firm Yield Increases for
Alternative CCR/LCC Operating Scenarios (acft/yr)

	System Storage Trigger below which Freshwater Pass-Throughs are Suspended		
Scenario	***40%***	***50%***	***60%***
1	7,100	9,100	10,700
2	7,100	10,200	11,400
3	9,100	12,100	13,100

1. 2010 Reservoir Sediment Conditions.
2. Phase IV Reservoir Operating Policy
3. Baseline CCR/LCC System Demand = 180,000 acft/yr

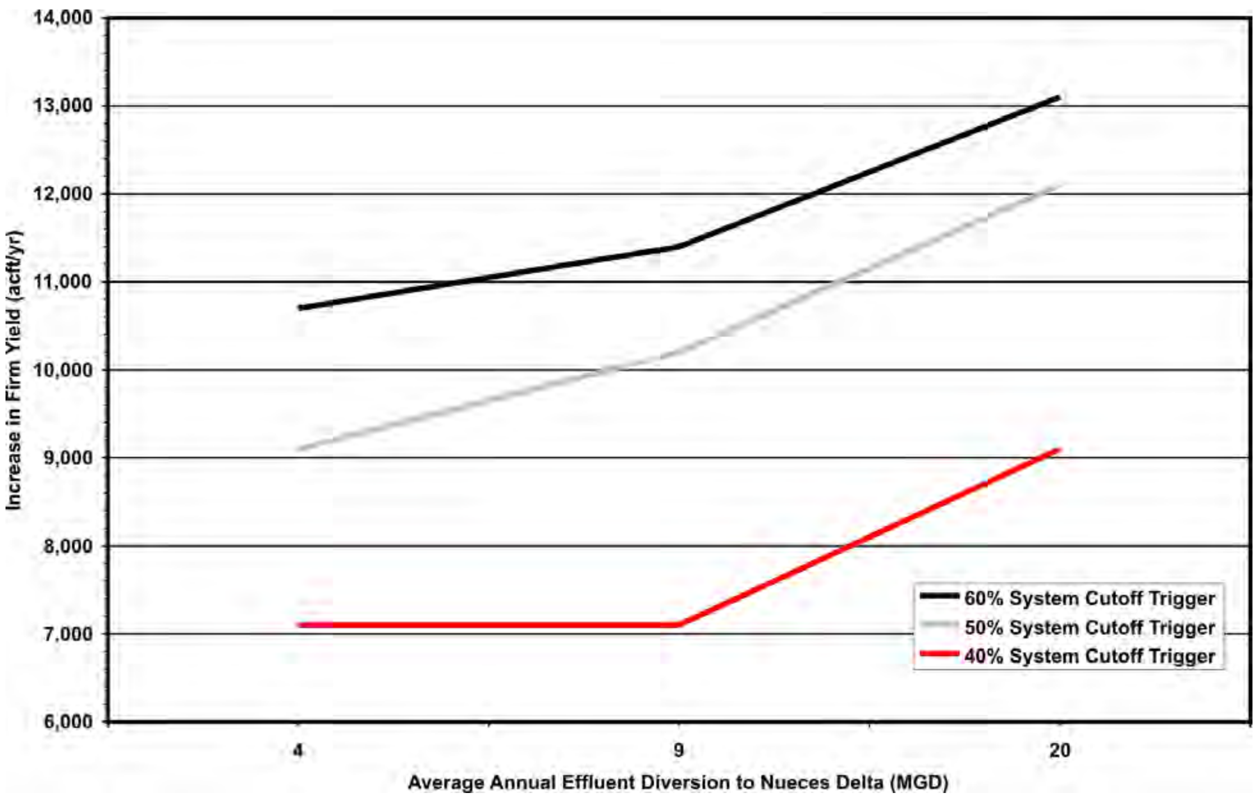


Figure 4C.9-6. Increase in Firm Yield versus Effluent Diversion to Nueces Delta

increasing freshwater availability to meet municipal and industrial requirements in Corpus Christi, while at the same time potentially enhancing the productivity of Nueces Delta.

The Nueces-Corpus Christi Bay system supports several endangered species and the resources critical to their continued existence, migratory bird use areas, wetlands, and marine fish and invertebrate nursery areas. Because phytoplankton and emergent plants provide food and habitat for animals, especially during early developmental stages, and these in turn provide food for larger animals, changes in primary productivity and plant diversity can be expected to influence the assemblage of animals resident in the estuary. Previous studies indicate that the Nueces Delta and Nueces Bay are critically important as the site of much of the planktonic primary production that drives biological processes throughout the Nueces Estuary, and that nutrients are utilized relatively inefficiently by primary producers in Corpus Christi Bay because of its turbidity and depth. These studies indicate that treated wastewater could have as much as a fivefold stimulatory effect on primary productivity if discharged into the Nueces Delta rather than being discharged into the Nueces River.[25,26] Therefore, it has been suggested that wastewater be diverted and discharged into the delta to help meet the freshwater inflow requirement, as specified in the 2001 Agreed Order, under which the CCR/LCC System now operates. This proposed wastewater discharge to the Nueces Delta would increase water availability from the CCR/LCC System by obtaining potential relief from freshwater pass-throughs designed to meet Nueces Bay inflow requirements.

Studies designed to assess the effects of diverting wastewater to the Nueces Delta have been conducted by researchers from the UTMSI.[27,28] These studies involved determinations of monthly salinity, temperature, dissolved oxygen, dissolved inorganic nitrogen (that is available to support plant growth), phosphate, silicate, and water transparency at 25 sampling stations. Additionally, primary production was measured at five sites. Primary production and phytoplankton pigment biomass, and the biomass, species diversity and species abundance of emergent vegetation were measured at four sites in each of 1991 and 1992. Additionally, the

[25] HDR et al., Op. Cit., November 1991.
[26] HDR et al., Op. Cit., March 1993.
[27] Whitledge, T.E. and D.A. Stockwell, "The Effects of Mandated Freshwater Releases on the Nutrient and Pigment Environment in Nueces Bay and Rincon Delta: 1990-1994." In: Water for Texas, Research Leads the Way (Jensen, R. ed.). Proceedings of the 24th Water for Texas Conference, 1995.
[28] Dunton, K.H., B. Hardegree, and T.E. Whitledge, "Annual Variations in Biomass and Distribution of Emergent Marsh Vegetation in the Nueces River Delta." In: Water for Texas, Research Leads the Way (Jensen, R. ed). Proceedings of the 24th Water for Texas Conference, 1995.

City's ongoing studies of the Nueces Delta monitor water quality parameters as part of the 2001 Agreed Order.

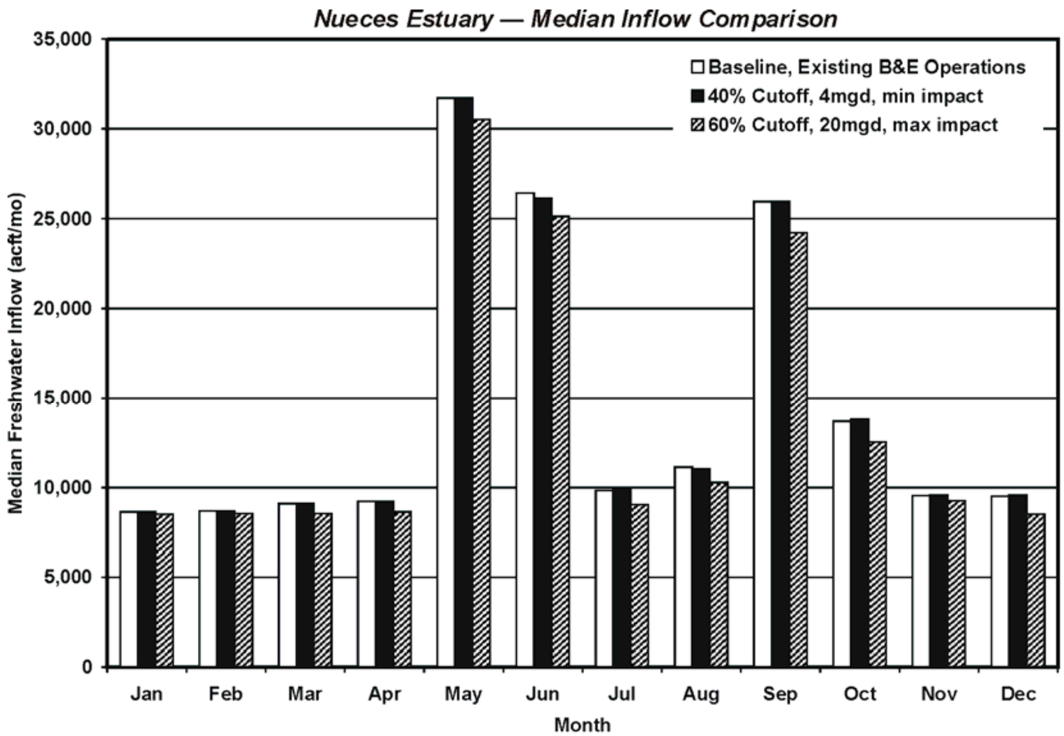
These studies indicate that primary productivity is positively correlated with the concentration of nutrients in the water. Increased flow and nutrient concentrations appeared to increase the relative abundance and species diversity of emergent vegetation.[29] The effects of wastewater on relative abundance and species diversity varied among study sites indicating that other factors, in addition to freshwater flows and nutrient concentrations (e.g. initial species composition and abundance, duration of flooding, and frequency of flooding), may affect the relative abundance and diversity of species. More comprehensive, long-term studies would be needed to assess the potential effects of wastewater on the relative abundance and diversity of species in the Nueces Estuary.

Pipelines necessary to route discharges to the Nueces Delta would be constructed primarily in existing right-of-ways which are located in urban areas. Less than 30 acres of delta wetlands and brushy uplands would be affected.

Use of these pipelines to transport effluent from Broadway and Greenwood WWTPs will reduce discharges at each of the facilities. Current plans by the City of Corpus Christi are to retire the Broadway WWTP and expand either Greenwood or Allison WWTP to handle the wastewater currently being treated at Broadway. Therefore, this management strategy will not additionally impact effluent discharges at Broadway as they are planned to be discontinued whether this project is implemented or not. In addition, scenarios presented herein assume that a minimum effluent discharge of 4 MGD will be maintained at the Greenwood WWTP in order to maintain the ecology of the receiving stream downstream of the WWTP outfall. Lastly, the additional flows at Allison WWTP that are proposed to be diverted to the Nueces Delta are future return flows above and beyond existing discharges.

Figure 4C.9-7 shows the potential changes in flow to the entire Nueces Estuary (including Nueces Delta, Nueces Bay, Corpus Christi Bay, Oso Bay and other adjacent receiving estuaries) based on 2001 Plan. Figure 4C.9-8 shows the potential changes in flow to the Upper Nueces Delta and Bay in particular. Although not evaluated separately during the 2006 planning process, since the reservoir systems are operating with safe yield supply, these inflows may be greater than presented since the reservoir system would be operating with safe storage. The

[29] Ibid.



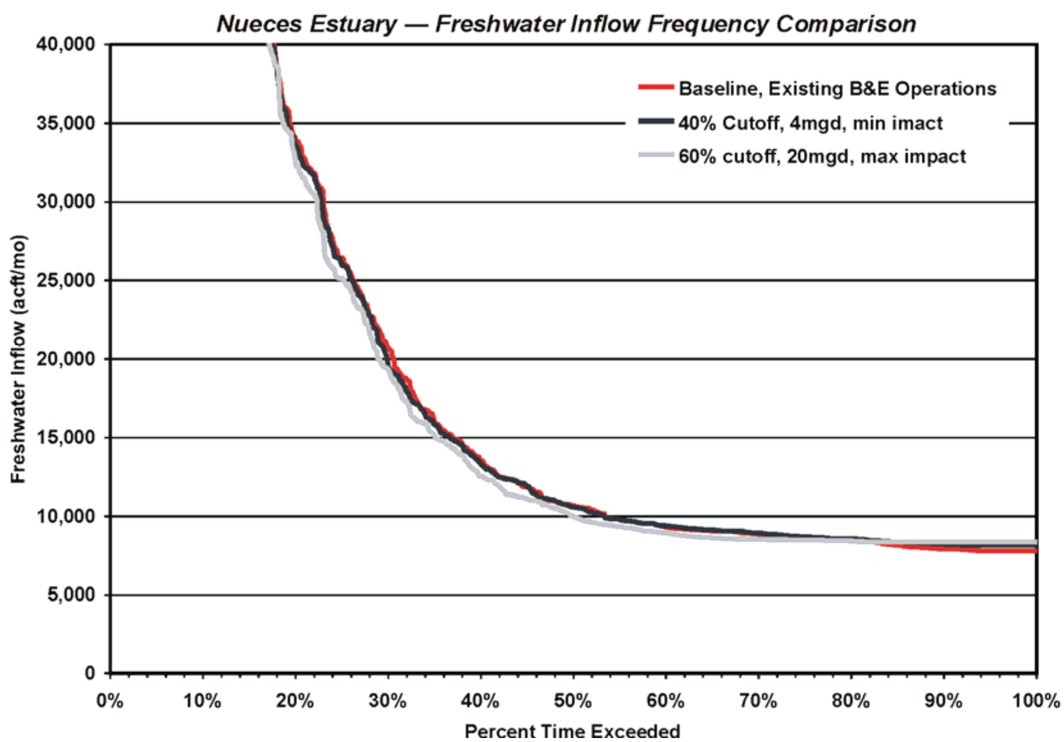
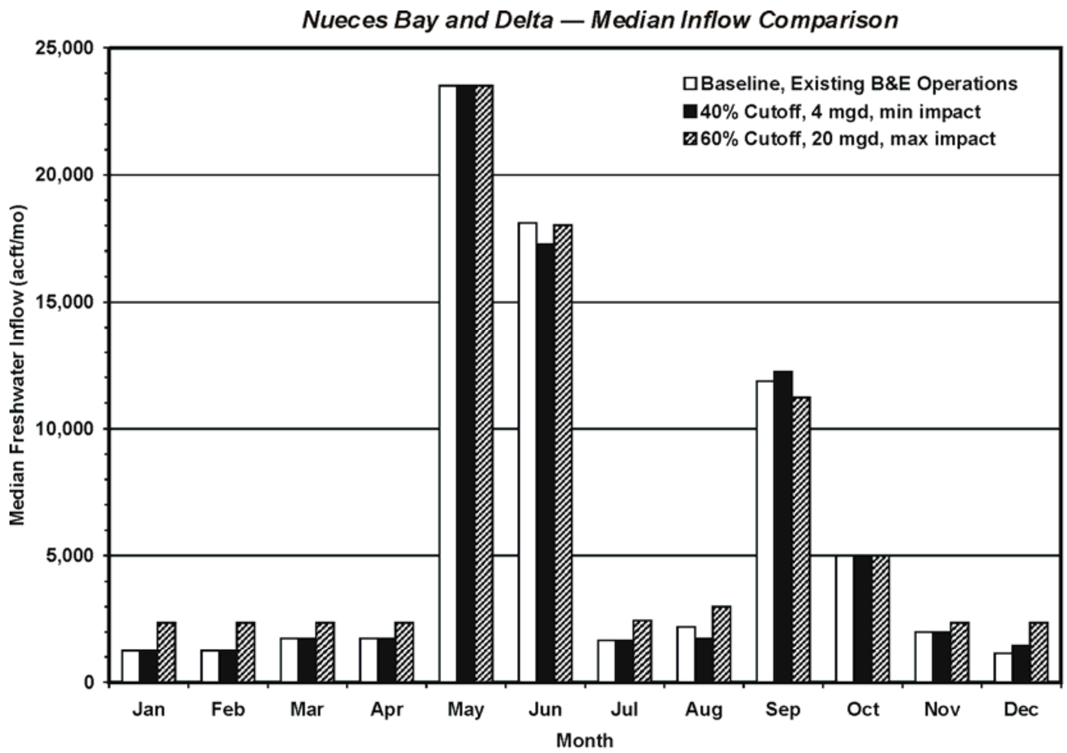


Figure 4C.9-7. Impacts to Freshwater Inflows to Nueces Estuary



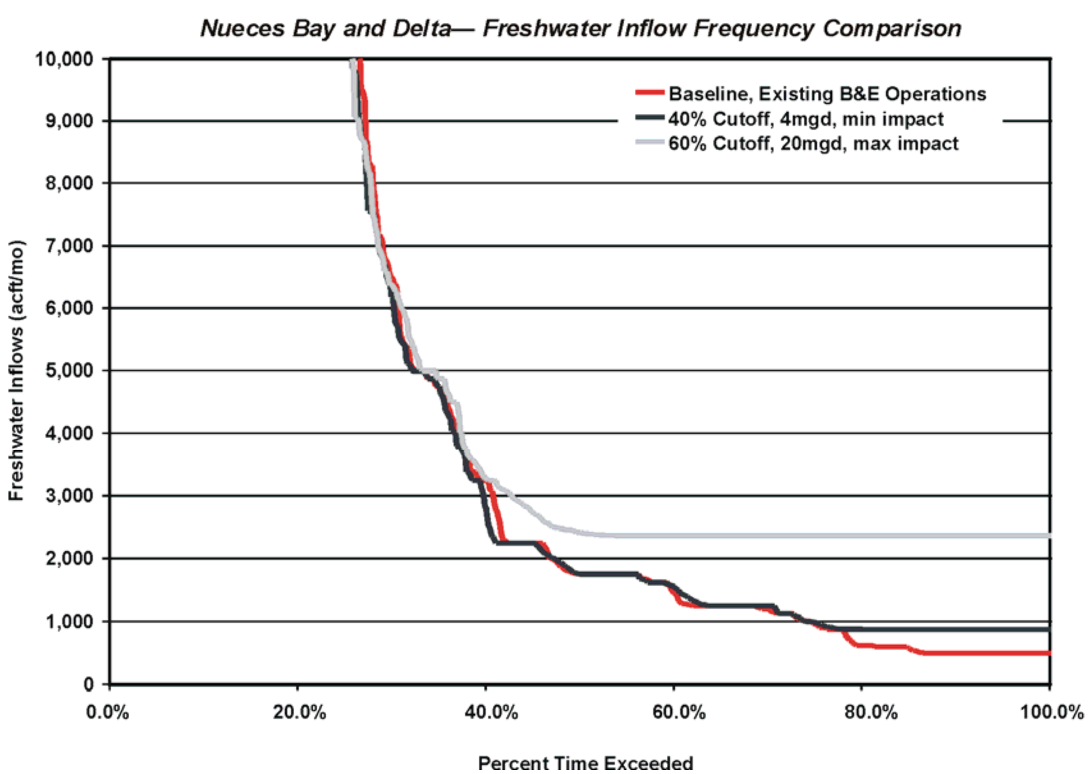


Figure 4C.9-8. Impacts to Freshwater Inflows to Nueces Bay and Delta

evaluations were made using 1995 Agreed Order freshwater inflows targets, which are essentially the same for the 2001 Agreed Order. Each of the graphs in these two figures shows three scenarios: the baseline (existing 2001 Agreed Order), a minimum impact scenario (Scenario 1 with a system storage pass-through suspension target of 40 percent) and a maximum impact scenario (Scenario 3 with a system storage pass-through suspension target of 60 percent). Maximum and minimum impact was determined for this analysis as the maximum and minimum decrease in average annual estuarine inflow compared to the baseline condition.

As shown in these two sets of figures, the trade-off in freshwater inflows are an increase in freshwater inflow to the Upper Nueces bay and delta in exchange for an overall decrease in freshwater inflows to the estuary. As shown in each of the plots, the difference in monthly median freshwater inflows to the estuary and/or bay are relatively unaffected by the operations under the minimum impact scenario. In addition, as shown in the frequency curve on Figure 4C.9-8, for the lowest 20 percent of freshwater inflows to Nueces Bay and Delta (i.e., 80- to 100-percent exceeded on the bottom plot), flows are almost doubled under the minimum impact scenario as compared to existing operations. A review of the maximum impact scenario as compared to the baseline condition reveals that the in the summer (June through August) and winter and spring (November through April) median monthly streamflows to the estuary are slightly decreased while inflows to the upper delta and bay are significantly increased. In addition, in the lower 60 percent of the flows to the upper delta and bay (i.e., 40- to 100-percent exceeded on the bottom plot of Figure 4C.9-8), more water is delivered to the bay and delta under the maximum impact scenario (over four times as much in the lowest 20 percent of the flows). However, a review of the frequency plot for flows to the estuary (Figure 4C.9-7) reveals that changes to total flow to the estuary during low flow conditions are minor.

Some caution is warranted when analyzing the median monthly flow plots for Nueces Bay. The changes in flow in this plot should be compared to the existing 2001 Agreed Order flows (shown in the white bars). It is notable that these medians may or may not meet the monthly inflow targets established in the 2001 Agreed Order (for freshwater inflows to Nueces Bay), but reflect simulated, reservoir inflow-limited, freshwater pass-throughs which are dominated in the low flow months by wastewater return flows. As a result, during these low flow months, freshwater inflow to Nueces Bay and Delta is enhanced by effluent diversions to the upper Nueces Bay and Delta.

In addition to effluent diversions to the Rincon Delta, the USBR Rincon Bayou Demonstration Project[30] (see Section 4C.9.3.1) showed favorable enhancements to the ecology of the delta through cutting a diversion notch in the bank of the Nueces River and allowing freshwater pass-throughs from Lake Corpus Christi, as well as tidal fluctuations in the river, to frequently wet the bayou. The City of Corpus Christi has re-opened the Nueces and Rincon overflow channels as a part of the overall plan to enhance the Nueces Estuary ecosystem.

The Rincon Bayou Rincon Bayou Diversion Pipeline and Pump Station (Rincon pipeline) was constructed by the City of Corpus Christi pursuant to the 2001 Agreed Order and became operational in November 2007. A recent study to evaluate biological productivity multipliers and impacts on system yield was conducted for the 2011 Plan and is summarized in Section 4C.5.

4C.9.5 Engineering and Costing

Three scenarios were costed for delivery of additional wastewater effluent from the City's WWTPs to the Rincon Delta. Scenario 1 (4 MGD of additional effluent to delta) requires no construction of new facilities, only increased pumping and O&M costs for the increased diversion. These costs were updated to reflect September 2008 Prices. Table 4C.9-6 provides a cost breakdown for Scenario 1.

Scenario 2 (9 MGD of additional wastewater to the delta) requires the following facilities and improvements:

- Wastewater pump station at the Broadway WWTP;
- Transmission pipeline and intermediate pump station from Broadway WWTP to Allison WWTP; and
- Upgraded effluent pump station, pipeline, and dispersion capacity at Allison WWTP.

Table 4C.9-7 summarizes the costs for Scenario 2.

The total capital cost for building the transmission facilities for Scenario 2 is $23,424,000. After land acquisition costs and cost for engineering, legal, environmental mitigation, and interest during construction, the total project cost comes to $35,287,000. The debt service at 6 percent over 20 years and the annual operations and maintenance costs including energy results in a total annual cost of $3,547,000.

[30] USBR, Op.Cit., September 2000.

Table 4C.9-6.
Cost Estimate Summary for
Effluent Diversion Scenario 1[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Effluent Force Main	$0
Effluent Pump Station	0
Total Capital Costs	**$0**
Engineering, Legal Costs and Contingencies	0
Environmental & Archaeology Studies and Mitigation	0
Land Acquisition and Surveying	0
Interest During Construction (1 year)	0
Total Project Cost	**$ (See Note 2)**
Annual Costs	
Debt Service (6 percent for 20 years)	$ (See Note 2)
Operation and Maintenance:	
Effluent Force Main and Pump Station	18,490
Pumping Energy Costs	21,090
Total Annual Cost	**$39,580**
Available Project Yield (acft/yr)	7,100 to 10,700[3]
Annual Cost of Water ($ per acft)	$5.57 to $3.70[3]
Annual Cost of Water ($ per 1,000 gallons)	$0.02 to $0.01[3]

1 Diversion of 4 MGD effluent from Allison WWTP to Nueces Delta.
2 No new facilities are required for this scenario. Existing effluent facilities constructed for demonstration project will handle this diversion.
3 Range in yield due to varying system storage cutoff trigger from 40 to 60 percent

Table 4C.9-7.
Cost Estimate Summary for
Effluent Diversion Scenario 2[1]
(September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Pipelines (20" diameter; 14.4 miles)	$19,770,000
Pump Stations	3,654,000
Total Capital Costs	**$23,424,000**
Engineering, Legal Costs and Contingencies	7,210,000
Environmental & Archaeology Studies and Mitigation	365,000
Land Acquisition and Surveying	507,000
Interest During Construction (3 years)	3,781,000
Total Project Cost	**$35,287,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$3,076,000
Operation and Maintenance:	
Pipelines and Pump Stations	289,000
Pumping Energy Costs	182,000
Total Annual Cost	**$3,547,000**
Available Project Yield (acft/yr)	**7,100 to 11,400**
Annual Cost of Water ($ per acft)	**$500 to $311**[3]
Annual Cost of Water ($ per 1,000 gallons)	**$1.53 to $0.95**[3]

[1] Diversion of all raw wastewater from Broadway WWTP to Allison WWTP, then diversion of 9 MGD effluent from Allison WWTP to Nueces Delta.

[2] New facilities required for this scenario include: (1) new pump station at Broadway WWTP, (2) 20" force main to diversion pump station near I-37 and Crosstown Expressway, (3) new diversion pump station, (4) dual 24" force main from diversion pump station to Allison WWTP, (5) parallel 16" effluent force main from Allison WWTP to Nueces Delta, and (6) additional pumping capacity at existing demonstration project pump station.

[3] Range in yield due to varying system storage cutoff trigger from 40% to 60%.

Scenario 3 (20 MGD of additional wastewater to the delta) requires these additional facilities:

- Wastewater pump station at Broadway WWTP;
- Dual transmission pipelines and intermediate pump station from Broadway WWTP to Greenwood WWTP;
- Effluent pump station at Greenwood WWTP;
- Transmission pipeline from Greenwood WWTP to Allison WWTP; and
- Upgraded effluent pump station, pipeline and dispersion capacity at Allison WWTP.

Table 4C.9-8 provides a cost breakdown for Scenario 3.

The estimated capital cost associated with Scenario 3 is $29,966,000. The additional costs associated with land acquisition, engineering, legal, environmental mitigation, and interest during construction bring the total project cost to $47,107,000. The annual debt service, operations and maintenance, and energy costs result in an annual cost of $5,120,000.

4C.9.6 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 City of Corpus Christi at the Allison Wastewater Treatment Plant.

Since the TCEQ 1995 Agreed Order regarding freshwater pass-throughs, as currently written, does not allow operations like those presented herein, the potential amendment of the TCEQ permit would have to be considered before implementing such a project.

In addition to providing a cost effective water supply source to the City, additional benefits of such a project could be reduced WWTP upgrade costs. The cost of upgrading facilities to higher levels of effluent treatment could be saved since the higher treated water would not be as effective in promoting biological activity in the delta. Therefore, increased effluent treatment at the WWTPs could be counter-productive when the water is diverted to the delta.

Table 4C.9-8. Cost Estimate Summary for Effluent Diversion Scenario 3[1] (September 2008 Prices)

Item	*Estimated Costs*
Capital Costs	
Pipelines (20.6 miles)	$21,761,000
Pump Stations	8,205,000
Total Capital Costs	**$29,966,000**
Engineering, Legal Costs and Contingencies	9,400,000
Environmental & Archaeology Studies and Mitigation	520,000
Land Acquisition and Surveying	723,000
Interest During Construction (4 years)	6,498,000
Total Project Cost	**$47,107,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$4,107,000
Operation and Maintenance**:**	
Pipelines and Pump Stations	423,000
Pumping Energy Costs	590,000
Total Annual Cost	**$5,120,000**
Available Project Yield (acft/yr)	9,100 to 13,100
Annual Cost of Water ($ per acft)	$563 to $391[3]
Annual Cost of Water ($ per 1,000 gallons)	$1.73 to $1.20[3]

[1] Diversion of all raw wastewater from Broadway WWTP to Greenwood WWTP, then diversion of 16 MGD effluent from Greenwood WWTP to Nueces Delta and 4 MGD effluent from Allison WWTP to Nueces Delta.
[2] No new facilities are required at Allison WWTP. Existing effluent facilities constructed for demonstration project will handle this diversion. New facilities required for this scenario include: (1) new pump station at Broadway WWTP, (2) 20" force main to diversion pump station near I37 and Crosstown Expressway, (3) new diversion pump station, (4) dual 24" force main from diversion pump station to Greenwood WWTP, (5) 30" effluent force main from Greenwood WWTP to Nueces Delta, and (6) effluent pump station at Greenwood WWTP.
[3] Range in yield due to varying system storage cutoff trigger from 40 to 60 percent.

4C.9.6.1 Requirements Specific to Transfer of Water

1. It will be necessary to obtain these permits:
   a. Permit amendment from TCEQ to existing 1995 Agreed Order;
   b. Nueces Estuary Advisory Committee review;
   c. TPWD Sand, Gravel, and Marl permit;
   d. GLO Sand and Gravel Removal permits; and
   e. Wastewater permit amendments from TCEQ.
2. Permitting, at a minimum, will require these studies:
   a. Evaluation of biological impacts in the Nueces Delta;
   b. Habitat mitigation plan;
   c. Environmental studies; and
   d. Cultural resource studies.
3. Land and easements will need to be acquired by negotiations or condemnation.

4C.9.6.2 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. GLO Sand and Gravel Removal permits;
   c. Coastal Coordinating Council review; and
   d. TPWD Sand, Gravel, and Marl permit for river crossings.
2. Approval from various agencies for these crossings:
   a. Highways and railroads;
   b. Creeks and rivers;
   c. Other utilities.

4C.9.7 Evaluation Summary

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

Table 4C.9-9.
Evaluation Summary of Modifications to Existing Reservoir Operating Policy

Impact Category	***Comment(s)***
a. Water supply: 1. Quantity 2. Reliability 3. Cost of treated water	 1. Firm yield: 7,100 to 13,100 acft/yr (in 2010) 2. Good reliability. 3. Generally low cost; between $4 to $563 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. Increases in freshwater inflow to Upper Nueces Bay. Potential environmental impact due to reduced freshwater inflow to Estuary. 2. Positive impacts to biological activity in the Nueces Estuary & Upper Nueces Delta by increasing returned flows. Potential environmental impact due to reduced freshwater inflow to Estuary. 3. None or low impact. 4. None or low impact. 5. Positive impacts to biological activity in the Nueces Estuary & Upper Nueces Delta by increasing returned flows. Potential environmental impact due to reduced freshwater inflow to Estuary. 6. Cultural Resource Survey will be needed to avoid any significant sites 7. The City's Integrated Plan provides on-going studies of water quality issues of the Nueces Delta. 7a. Dissolved solids are a concern to be addressed with further studies. 7b. Salinity is a concern to be addressed with further studies. 7c. Bacteria is a concern to be addressed with further studies. 7d. Chlorides are a concern to be addressed. 7e-h. None or low impact. 7i. Alkalinity a concern and will need to be addressed.
c. State water resources	• No negative impacts on other water resources • Potential benefit to Nueces Estuary from increase freshwater return flows
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	• Potentially could require the transfer of water from the Nueces River Basin to the San Antonio-Nueces Coastal 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 enhanced recreational opportunities (birding in Upper Nueces Delta)
j. Effect on navigation	• None

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