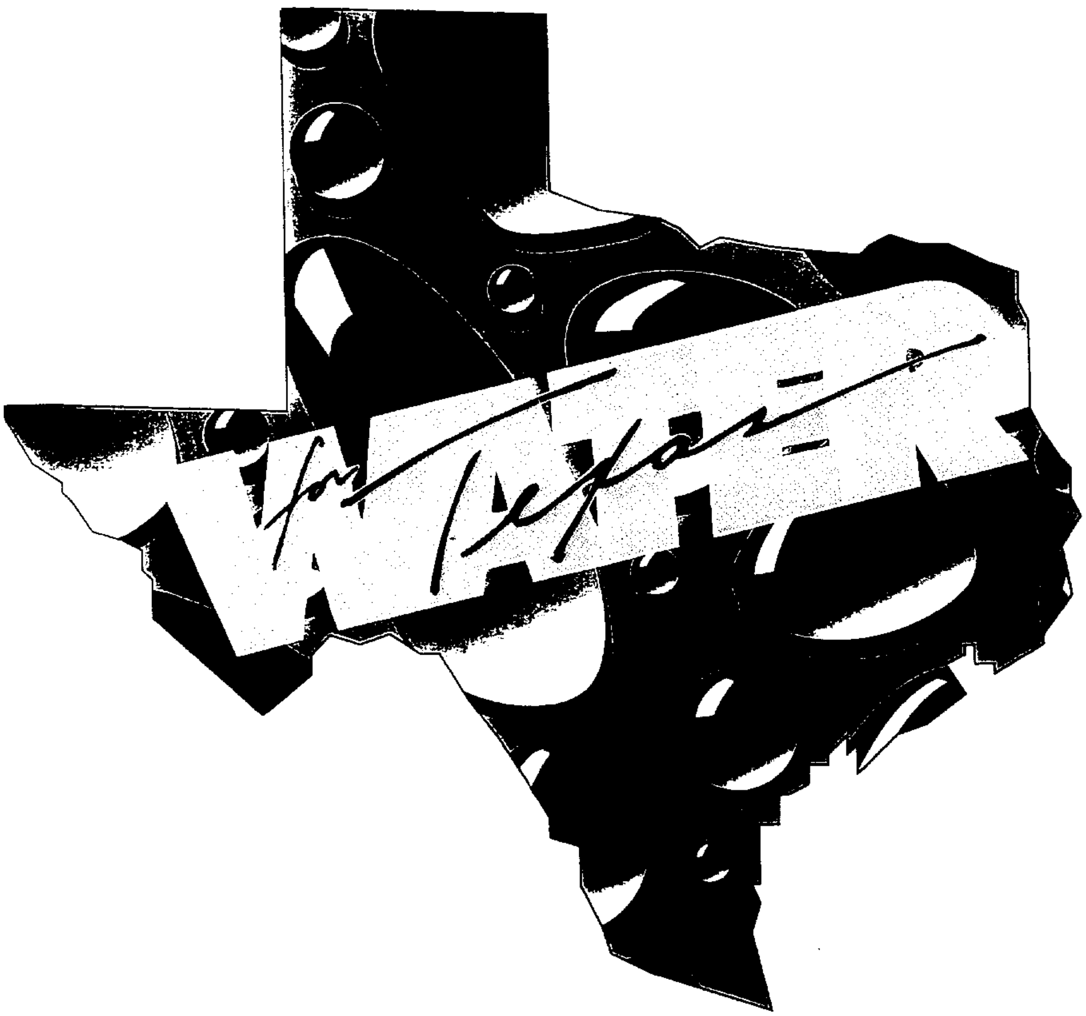
TRANS-TEXAS WATER PROGRAM



Corpus Christi Study Area

Phase II Report

Volume 2- Technical Report

City of Corpus Christi

Port of Corpus Christi Authority

Corpus Christi Board of Trade

Texas Water Development Board

Lavaca-Navidad River Authority

September, 1995

HDR

HDR Engineering, Inc.
in association with
Naismith Engineering, Inc.
Paul Price Associates, Inc.

TRANS-TEXAS WATER PROGRAM
CORPUS CHRISTI SERVICE AREA

PHASE II REPORT

VOLUME 2

TECHNICAL REPORT

Prepared For
City of Corpus Christi
Port of Corpus Christi Authority
Corpus Christi Board of Trade
Texas Water Development Board
Lavaca-Navidad River Authority

by
HDR Engineering, Inc.
in association with
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TRANS-TEXAS WATER PROGRAM
Corpus Christi Service Area
Phase II Report

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TRANS-TEXAS WATER PROGRAM

South Central Trans-Texas Region

1.0 INTRODUCTION

The Texas Water Development Board (TWDB) is the state agency responsible for the preparation and maintenance of a comprehensive state water plan to be used as a flexible guide for the orderly development and management of the state's water resources in order that sufficient water will be available at a reasonable cost to further the economic development of the entire state (Texas Water Code; Sections 16.051 and 16.055). In its 1990 Texas Water Plan, the TWDB 50-year projections of population and water demand identified immediate water supply needs in the metropolitan areas of southeast and south central Texas (Houston, Corpus Christi, and San Antonio).[1] The 1990 Water Plan also identified significant quantities of water supply in existing reservoirs of eastern Texas that are surplus to the projected demands of the basins in which the reservoirs are located.

On May 7, 1992, the TWDB, city leaders of Houston, Corpus Christi, and San Antonio, leaders of water supply organizations of the area, and other state officials met and initiated the Trans-Texas Water Program in an effort to address the water supply needs of these areas in coordinated, logical, and environmentally responsible manner. In later months, Austin and neighboring Williamson County areas joined the Trans-Texas Program. The Trans-Texas Water Program is anticipated to become and integral part of the State Water Plan.

The Trans-Texas Water Program planning studies and implementation actions are being conducted in multiple phases. In Phase I, water demands were identified for the ensuing 50-year period, and available options to meet projected demands were identified and assessed in terms of costs and environmental advantages and disadvantages. From the results of the Phase I studies, options were selected for more detailed evaluations in Phase II. Upon completion of the Phase II studies, a recommended plan of action to meet the demands of each respective area will be developed for implementation by the local entities, as appropriate. Following Phase II

---

[1] "Water for Texas--Trans-Texas Water Program; Overall Program Description," Texas Water Development Board, Austin, Texas, June 1992. In its 1995 Consensus Water Planning projections, the TWDB reconfirmed the needs for additional water supplies in these and in other metropolitan areas of the state.

studies will be the implementation phases which include phases which include:

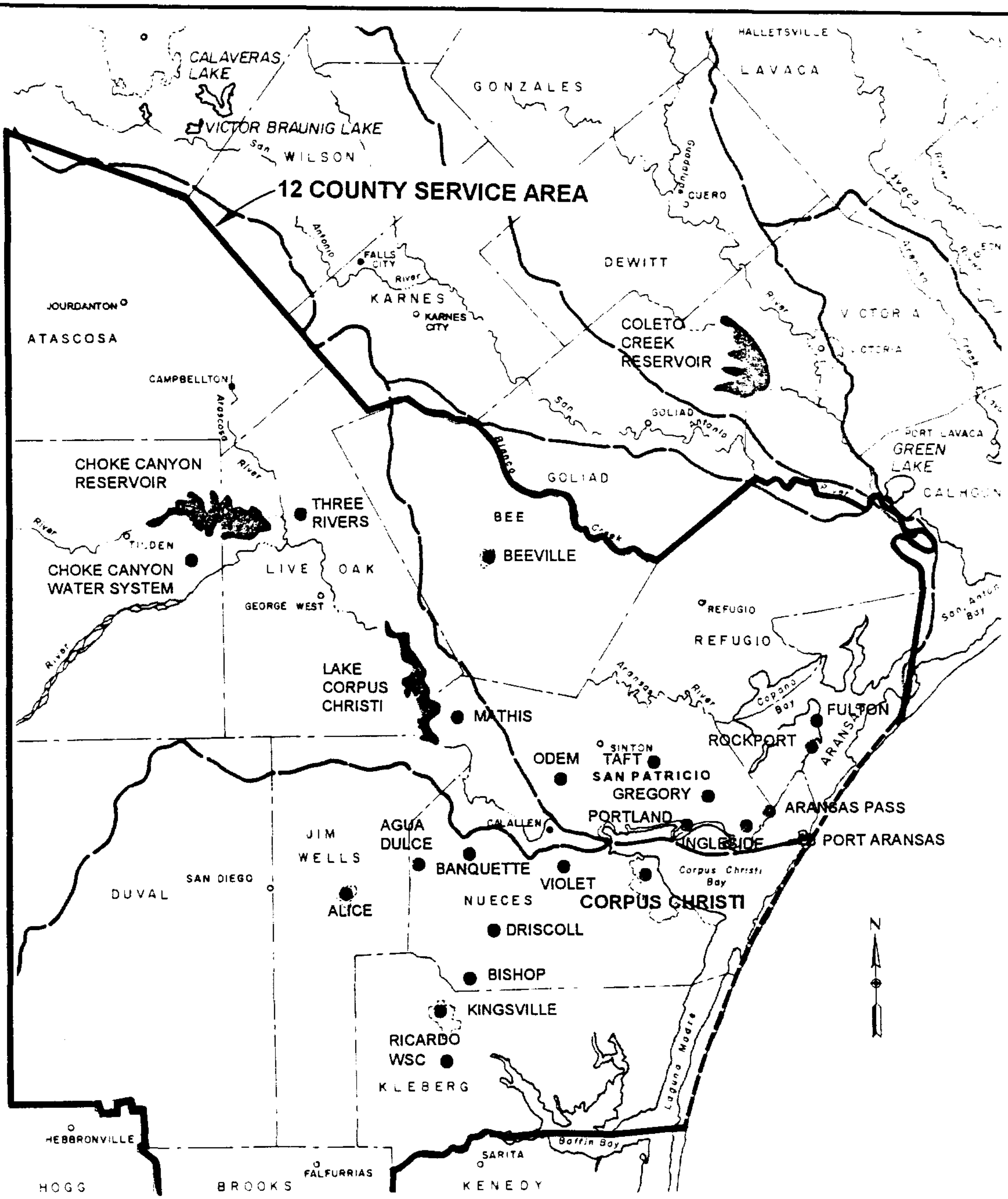
Phase III	- Preliminary Design/State and Federal Permitting
Phase IV	- Property Acquisition/Final Design
Phase V	- Projection Construction Design

This document is the Phase II Study Report for the South Central study area of the Trans-Texas Water Program which was begun in 1992. The South Central Trans-Texas study area includes the area served by the Choke Canyon/Lake Corpus Christi Reservoir System operated by the City of Corpus Christi.

1.1 The Study Area

The South Central Trans-Texas Water Program study area includes the following 12 counties: Aransas, Atascosa, Bee, Brooks, Duval, Jim Wells, Kleberg, Live Oak, McMullen, Nueces, Refugio, and San Patricio (Figure 1.1-1). Population of the area was 530,878 in 1990, and is projected to grow at an average annual rate of 1.02 percent to the year 2050, at which time the population of the area would be 975,874. The economy of the area is diverse, with urban centers of industry, business, and tourism, and rural enterprises of irrigated and dryland crop production and ranching. The climate of the area is semiarid with average annual precipitation of 32 inches in the east and 24 inches in the west. Water supplies for the rural parts of the study are obtained from Carrizo and Gulf Coast aquifers and are limited in relation to present and future needs. In the coastal counties (Nueces and San Patricio) municipal and industrial water users led by the City of Corpus Christi were forced to develop surface water supplies of the Nueces River Basin beginning in the early 1900's (certified filings for appropriations of water in the Nueces River Basin, City of Corpus Christi, Texas, December 13, 1913).[2] the present surface water system is composed of Lake Corpus Christi which was completed in 1958 (replaced original Mathis dam completed in 1934), Choke Canyon Reservoir, whose dam was completed in 1978 and dedicated on October 13, 1978, Calallen Diversion Dam, and water treatment plants at Calallen near the mouth of the Nueces River. In the 1980's, cities of other coastal counties and some neighboring inland counties whose wells had declined in both quantity and quality installed pipelines to the Corpus Christi surface water system in order to

[2] Records of Certified Filings, Texas Water Commission, Austin, Texas, Book 1, pp.227-245.



Legend

● Entities Supplied from Lake Corpus Christi/ Choke Canyon Reservoir System

▬ ▬ River Basin Divide

Scale

0 10 20 Miles

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

12 - COUNTY SERVICE AREA FOR LAKE CORPUS CHRISTI/ CHOKE CANYON RESERVOIR SYSTEM

FIGURE 1.1-1

meet their needs. At the present time, Choke Canyon/Lake Corpus Christi Reservoir System (CC/LCC) supplies water for municipal and industrial purposes to cities, industries, and water supply authorities and corporations in seven of the 12 study area counties (Aransas, Bee, Jim Wells, Kleberg, Live Oak, Nueces, and San Patricio), and the permits authorize water use from these projects in three additional counties (Atascosa, Duval, and McMullen). Groundwater is used to some extent in each of the 12 study area counties and at present time is the sole source of supply in five of the study area counties (Atascosa, Brooks, Duval, McMullen, and Refugio). Although groundwater supplied 15 percent of municipal and industrial needs in 1990, supplies are limited and quality is marginal to poor, with high concentrations of chlorides, sulfates, and total dissolved solids.

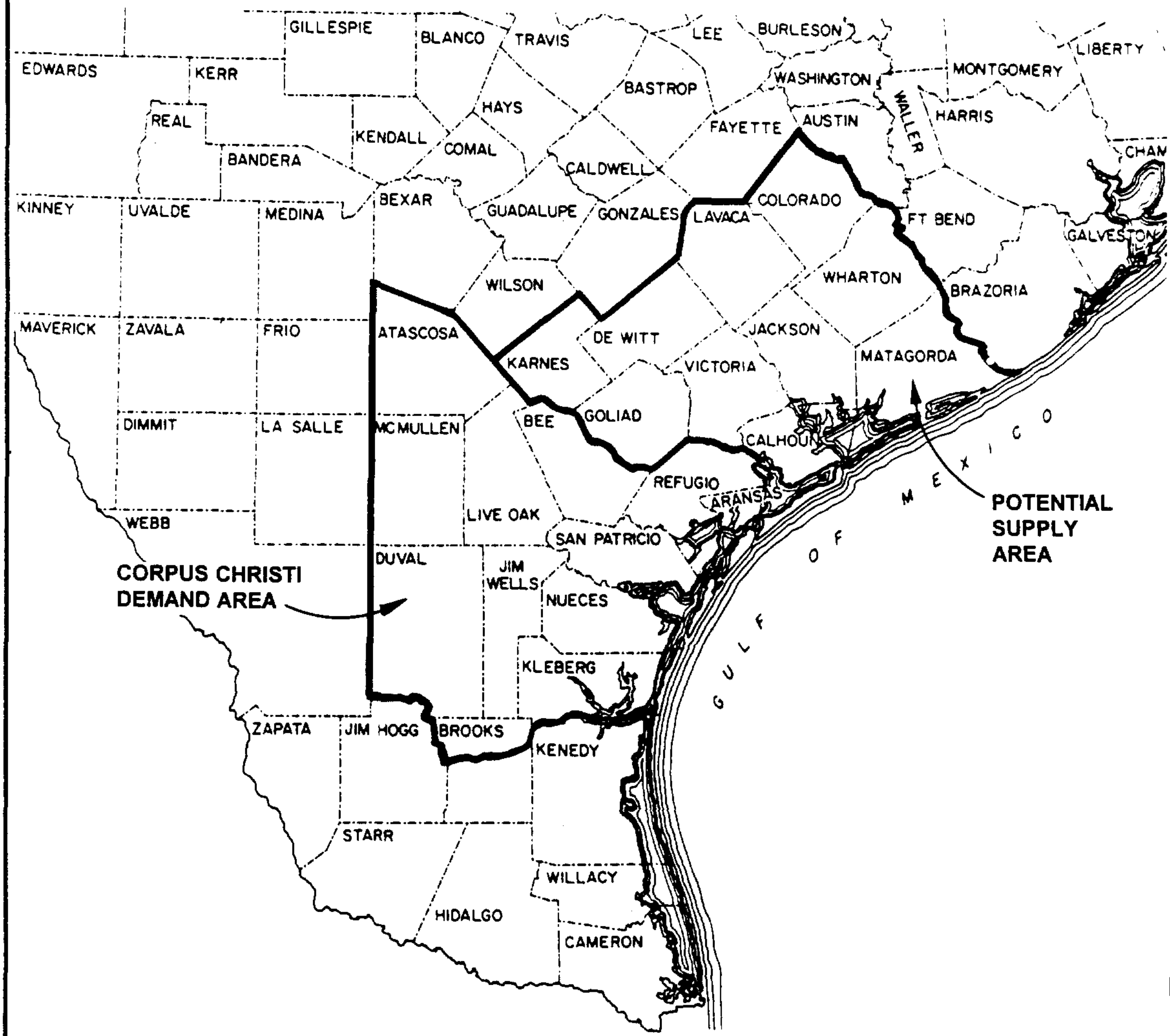
The South Central Trans-Texas study area suffers from droughts and is experiencing population and economic growth. Projections show that additional supplies will be needed shortly after the year 2000. In light of the fact that both ground and surface water resources are limited, water planning and management are essential.

1.2 Objectives

The objectives of the Phase II South Central Trans-Texas Water Program study are to:

1. Present projections of water demands of the 12-county study area for the period 1990 through 2050;
2. Identify potential water supply options to meet the needs of the study area;
3. Provide an assessment of the water supply potentials, costs, and environmental advantages and disadvantages of each option; and
4. Provide integrated water supply plans based upon information from the assessment mentioned in objective number three.

In this study, water supply options were identified within the 12-county study area (Figure 1.1-1), and in neighboring basins to the northeast, including the Lavaca River Basin, the Lower Colorado River Basin, the Lower Brazos River Basin, the Lower Guadalupe River Basin, and the Lower San Antonio River Basin. Water demand and supply projections will be presented for the potential supply areas that have options included in the potential water supply plans for the period 1990 through 2050 (Figure 1.1-2). Only those quantities that are projected



TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

12-COUNTY SOUTH CENTRAL STUDY AREA AND 10-COUNTY POTENTIAL SUPPLY AREA

HDR

HDR Engineering, Inc.

FIGURE 1.1-2

to be surplus to the supply area's needs will be considered for transfer to the South Central Trans-Texas area to meet the needs of the Corpus Christi service area.

1.3 Review of Previous Studies

This study of water supply alternatives for the South Central area of the Trans-Texas Water Program has used existing information from agency files and particularly the results of previous studies of potential water supply projects of the Nueces, San Antonio, Guadalupe, Lavaca-Navidad, and Colorado River Basins. Reviews were made of 35 reports that have been prepared since 1965 that pertain to various water supply and water quality topics relevant to the South Central Trans-Texas area.

The most common type of report included in the literature review focuses on the concepts, cost estimates, and feasibility of individual surface water supply options. These reports include studies of individual projects, single basin water supply programs, and interbasin water transfer plans. The authors of these reports include private consulting firms, cities, river authorities, and state and federal agencies. There are also a substantial number of reports which focus on topics ranging from particular hydrological characteristics of basins, to regional water supply issues; from legal responsibilities, to water treatment technologies; from water quality characteristics to interbasin transfer strategies; and from water reuse options to overviews of water supply conditions of individual river basins. In the reviews, any information relevant to the South Central Trans-Texas portion of the Trans-Texas Water program was obtained for use in evaluating water supply options. Since the literature review is voluminous, it is included as Appendix A of this Study Report.

2.0 POPULATION, WATER DEMAND, AND WATER SUPPLY PROJECTIONS

The purpose of this section is to present population, water demand, and water supply projections for the 12-county South Central Trans-Texas Study Area. In addition, population and water demand projections are shown for the Lavaca River Basin and the adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins water supply area. The population and water demand projections presented herein, as specified by the Texas Water Development Board in the Trans-Texas Water Program, are the Texas Water Development Board's (TWDB) April, 1992 high case projections, with conservation.[1] Since the TWDB projections are by decade for the period 1990 through 2040, it was decided to extrapolate projections, as appropriate, from the year 2040 to 2050. The extrapolation to 2050 was at the same rate that was projected for the period of 2030 to 2040.[2]

The water supply projections are from the TWDB's water planning information and recent studies of the Choke Canyon/Lake Corpus Christi (CC/LCC) Reservoir System,[3] and represent the best available estimates of surface and ground water supplies on an annual basis for each area and each projection point in time.

2.1 12-County Study Area Population Projections

For the 60-year period of 1930 to 1990, the population of the 12-county area has grown at a compound annual rate of 1.90 percent, and has increased from 171,206 to 530,878 (Table 2.1-1A). In 1930, 30 percent of the area's population resided in Nueces County, 14 percent resided in San Patricio county, 8 percent resided in each of Atascosa and Bee counties, 7 percent resided in each of Duval, Jim Wells, and Kleberg counties, 5 percent resided in Live Oak county, 4 percent resided in Refugio county, with each of the remaining counties (Aransas, Brooks, and McMullen) having 3 percent or less of the area total.

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[1] Unpublished, "Scope of Work for South Central Texas Study, Trans-Texas Water Program, Corpus Christi Area," Texas Water Development Board, September 17, 1992, Austin, Texas.

[2] Decision at February 10, 1992 Trans-Texas Coordination Meeting.

[3] "Regional Wastewater Planning Study -- Phase II, Nueces Estuary, City of Corpus Christi, Port of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, and Texas Water Development Board, June 1993, Austin, Texas.

Table 2.1-1A
Census Reported Population[1]
Corpus Christi 12-County Study Area
Trans-Texas Water Program

County	1930	1940	Percent[2] Growth 1930-40	1950	Percent[2] Growth 1940-50	1960	Percent[2] Growth 1950-60	1970	Percent[2] Growth 1960-70	1980	Percent[2] Growth 1970-80	1990	Percent[2] Growth 1980-90	Percent Growth 30-90
Aransas	2,219	3,469	(4.56)	4,252	(2.05)	7,006	(5.12)	8,902	(2.42)	14,260	(4.82)	17,892	(2.29)	(3.54)
Atascosa	15,654	19,275	(2.10)	20,048	(0.39)	18,828	(-0.62)	18,696	(-0.07)	25,055	(2.97)	30,533	(1.99)	(1.12)
Bee	15,721	16,481	(0.47)	18,174	(0.98)	23,755	(2.71)	22,737	(-0.44)	26,030	(1.36)	25,135	(-0.35)	(0.78)
Brooks	5,901	6,362	(0.75)	9,195	(3.75)	8,609	(-0.65)	8,005	(-0.72)	8,428	(0.52)	8,204	(-0.27)	(0.55)
Duval	12,191	20,565	(5.36)	15,643	(-2.69)	13,398	(-1.54)	11,772	(-1.28)	12,517	(0.61)	12,918	(0.31)	(0.09)
Jim Wells	13,456	20,239	(4.16)	27,991	(3.29)	34,548	(2.12)	33,032	(-0.45)	36,498	(1.00)	37,679	(0.32)	(1.73)
Kleberg	12,451	13,344	(0.69)	21,991	(5.12)	30,052	(3.17)	33,166	(0.99)	33,358	(0.06)	30,274	(-0.96)	(1.49)
Live Oak	8,956	9,799	(0.90)	9,054	(-0.78)	7,846	(-1.42)	6,697	(-1.57)	9,606	(3.67)	9,556	(-0.05)	(0.11)
McMullen	1,351	1,374	(0.17)	1,178	(-1.53)	1,116	(-0.54)	1,095	(-0.19)	789	(-3.22)	817	(0.35)	(-0.83)
Nueces	51,779	92,661	(5.99)	165,471	(5.96)	221,573	(2.96)	237,544	(0.70)	268,215	(1.22)	291,145	(0.82)	(2.92)
Refugio	7,691	10,383	(3.05)	10,113	(-0.26)	10,975	(0.82)	9,494	(-1.44)	9,289	(-0.22)	7,976	(-1.51)	(0.06)
San Patricio	23,836	28,871	(1.93)	35,842	(2.18)	45,021	(2.30)	47,288	(0.49)	58,013	(2.06)	58,749	(0.13)	(1.51)
Region Total	171,206	242,823	(3.55)	338,952	(3.39)	422,727	(2.23)	438,428	(0.36)	502,058	(1.36)	530,878	(0.56)	(1.90)

[1] U S Bureau of the Census, U S Department of Commerce

[2] Compound annual growth rate

Texas Population 1930: 5,824,715
Texas Population 1990: 16,986,510

Growth Rate: 1.79%

Of the 530,878 population of area in 1990, 54.8 percent resided in Nueces county, with 11.1 percent in San Patricio County, 7.1 percent in Jim Wells County, 5.6 percent in both Kleberg and Atascosa counties, and less than five percent in each of the other seven counties (Table 2.1-1A). Population of the 12-county area is projected to increase at a compound annual rate of 1.47 percent during the decade of the 1990s, at an annual rate of 1.22 percent from 2000 to 2010, and at an annual rate of 0.8 percent from 2030 to 2040. The projections for year 2000 are 614,529, for 2020 are 762,768, and are 975,874 by 2050 (Table 2.1-1B). The distribution of the population among the 12 counties changes slightly during the 60-year projection period, with Nueces County increasing from 54.8 percent to 58 percent and San Patricio County increasing from 11.1 percent to 11.8 percent. The TWDB's projected compound annual growth rate for the 60-year period of 1990 to 2050 for the 12-county area averages 1.02 percent. This is 20 percent less than the projected compound annual growth rate of 1.27 percent for Texas, whose population is projected to increase from 16.98 million in 1990 to 36.31 million in 2050, and is 46.3 percent less than the historic 1930 to 1990 growth rate for the area.

2.2 Corpus Christi Surface Water Service Area Population Projections

Population of the service area which obtained municipal and industrial water supplies from the CC/LCC Reservoir System in 1990 was about 379,293, or 71 percent of the total (Table 2.2-1 and Figure 2.1-1). The Year 2050 projected population of the area which obtains municipal and industrial water from the CC/LCC System is 772,291 (Table 2.2-1 and Figure 2.1-1), which includes 79 percent of the total.

2.3 12-County Study Area Water Demand Projections

The TWDB high case, with conservation, projections of water demands for municipal, industrial, steam-electric power, irrigation, mining, and livestock purposes are tabulated and explained in the following discussion. Projections of total water demand, which are the sum of the projections for all purposes, are also shown. Each type of water use is described on the following pages.

Table 2.1-1B
Population Projections - Corpus Christi 12-County Area
Trans-Texas Water Program

County[1]	Population Projections[4]												
	2000	Percent Growth 90-00	2010	Percent Growth 00-10	2020	Percent Growth 10-20	2030	Percent Growth 20-30	2040	Percent Growth 30-40	2050	Percent Growth 40-50	Percent[5] Growth 90-50
Aransas	21,203	(1.71)	25,158	(1.72)	29,667	(1.66)	34,984	(1.66)	39,888	(1.32)	44,792	(1.17)	(1.54)
Atascosa	37,785	(2.15)	44,108	(1.56)	49,394	(1.14)	54,480	(0.98)	59,580	(0.90)	64,680	(0.82	(1.26)
Bee	28,402	(1.23)	30,519	(0.72)	32,686	(0.69)	35,485	(0.82)	38,532	(0.83)	41,579	(0.76)	(0.84)
Brooks	8,359	(0.19)	9,190	(0.95)	10,008	(0.86)	10,806	(0.77)	11,712	(0.81)	12,618	(0.75)	(0.72)
Duval	14,137	(0.91)	14,599	(0.32)	14,934	(0.23)	15,512	(0.38)	16,230	(0.45)	16,948	(0.43)	(0.45)
Jim Wells	41,411	(0.95)	43,231	(0.43)	43,757	(0.12)	44,314	(0.13)	44,666	(0.08)	45,018	(0.08)	(0.03)
Kleberg	33,370	(0.98)	36,904	(1.01)	39,315	(0.63)	42,324	(0.74)	44,739	(0.55)	47,154	(0.53)	(0.74)
Live Oak	10,579	(1.02)	11,317	(0.68)	11,537	(0.19)	11,674	(0.12)	11,714	(0.03)	11,754	(0.03)	(0.34)
McMullen	998	(2.02)	1,063	(0.63)	1,041	(-.21)	1,030	(-.11)	1,013	(-.17)	996	(-.17)	(0.33)
Nueces	339,413	(1.54)	386,134	(1.30)	427,119	(1.01)	472,085	(1.00)	518,667	(0.94)	565,249	(0.86)	(1.11)
Refugio	7,939	(-.05)	8,415	(0.58)	8,780	(0.42)	9,096	(0.35)	9,278	(0.20)	9,460	(0.19)	(0.28)
San Patricio	70,933	(1.90)	83,176	(1.60)	94,530	(1.29)	103,216	(1.29)	109,421	(0.58)	115,626	(0.55)	(1.13)
Region Total	614,529	(1.47)	693,814	(1.22)	762,768	(0.95)	835,006	(0.91)	905,440	(0.81)	975,874	(0.75)	(1.02)

[1] Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

[2] U.S. Bureau of the Census, U.S. Department of Commerce.

[3] Compound annual growth rate

[4] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - 2040, April 1992, Austin, Texas. Compound annual growth rates for each decade are shown in parentheses.

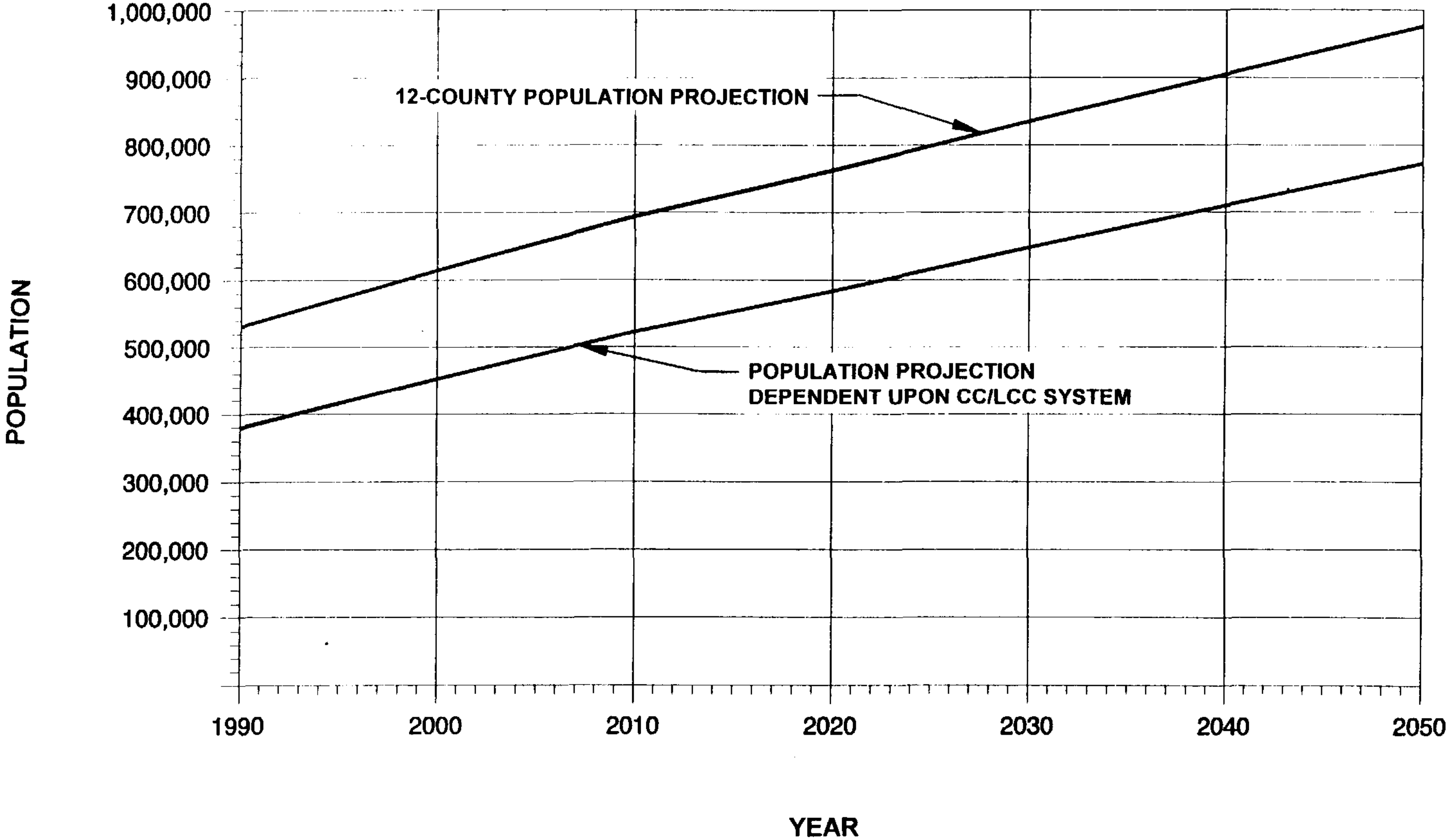
[5] Compound annual growth rate for the 60-year period from 1990 to 2050.

Note: Texas population in 1990 was 16,986,510. TWDB projections of Texas population for 2000 is 20,257,960 and for 2050 is 36,308,602 (1.27%).

Table 2.2-1
Population Projections of Choke Canyon/Lake Corpus Christi Reservoir System Service Area[1]
Trans-Texas Water Program

County	1990 Census	Projections						
		2000	2010	2020	2030	2040	2050	Percent Growth[2]
Aransas	15,764	19,075	23,030	27,539	32,856	37,760	42,664	1.67
Atascosa[3]	0	0	0	0	0	0	0	
Bee	13,623	16,890	19,007	21,174	23,973	27,020	30,067	1.33
Brooks[3]	0	0	0	0	0	0	0	
Duval[3]	0	0	0	0	0	0	0	
Jim Wells	23,046	26,778	28,598	29,124	29,681	30,033	30,385	0.46
Kleberg	2,786	5,882	9,416	11,827	14,836	17,251	19,666	3.31
Live Oak	2,512	3,535	4,273	4,493	4,630	4,670	4,710	1.05
McMullen[3]	0	0	0	0	0	0	0	0
Nueces	277,035	323,944	369,279	409,120	452,831	498,113	543,395	1.13
Refugio[3]	0	0	0	0	0	0	0	
San Patricio	44,527	56,711	68,954	80,308	88,994	95,199	101,404	1.38
TOTAL	379,293	452,815	522,557	583,585	647,801	710,046	772,291	1.19

[1] The number of people within each county that are expected to be supplied with municipal and commercial water (drinking, sanitation, fire protection, landscaping and lawn needs, cooking, bathing, restaurants, car washes, swimming pools, for example) from the Choke Canyon/Lake Corpus Christi System.
[2] Compound annual growth rate for the 60-year period from 1990 to 2050.
[3] Water from the Choke Canyon/Lake Corpus Christi System is not projected to be supplied within these counties.



TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

POPULATION PROJECTION

HDR Engineering, Inc.

FIGURE 2.1-1

Municipal Water Demand

Water that is used by households for drinking, bathing, food preparation, dishwashing, laundry, flushing toilets, lawn watering and landscaping, and for swimming pools and hot tubs plus that which is used by commercial establishments, including restaurants, car washes, hotels, motels, laundries and laundromats, nurseries, and office buildings, plus water used for fire protection, and public recreation and sanitation is referred to as municipal water. This type of water must meet safe drinking water standards as specified by Federal and State laws and regulations.

For purposes of making projections of future municipal water demands, TWDB has conducted an annual survey of cities, and public and private water districts and authorities since the mid-1960's. In the annual survey, each respondent reports the quantities of water that have been obtained from each respective water source and supplied to municipal-type customers. From the water use reports of the cities, TWDB has computed an annual per capita water use, in gallons per person per day, for each city. For the high case projection, the per capita use for the year with the highest computed value of the 1977-1986 period was chosen as the projection starting point (1990) per capita municipal water use rate for the city.

The effects of water conservation were used to adjust the per capita water use rates of each city as follows. In 1991, the Texas Legislature enacted legislation which allows only the sale of low-flow rate plumbing fixtures in Texas after January 1, 1993. TWDB estimated that by 2020, the effects of this legislation will have reduced per capita water use by 18 gallons per person per day. This 18 gallons per person per day was phased into the projection methodology by reducing the computed per capita water use rate of each city by six gallons per decade between 1990 and 2020; i.e., if per capita water use for City A, in 1990, as explained above, was computed at 190 gallons per day, then the rate used for the year 2000 would be 184 gallons per day, the rate used for 2010 would be 178 gallons per day, and the rate used for 2020 and the following decades would be 172 gallons per day. Projections of annual municipal water demand for each city for the 1990-2050 planning period were made by multiplying the projected per capita water use of the city at each decadal point in time, times 365 days, times the number of people projected for that city at the corresponding point in time. This result is then divided by 325,851 (number of gallons in 1 acft) in order to express the quantities in terms of acft/yr.

Similar computations were made for rural areas using data from water use reports of water supply corporations. County and area projections were obtained by summing the projections for cities and rural areas of the counties, respectively.[4]

In 1990, total municipal water use for the 12-county area was 115,473 acft, with 66.3 percent being used in Nueces County (Table 2.3-1). Projected municipal water requirements for the 12-county area are 132,035 acft/yr in 2000, 150,931 acft/yr in 2020, and 186,054 acft/yr in 2050 (Table 2.3-1).

Industrial Water Demand

Water used in the operation of industries, including that used within the industrial processes as well as that used for cooling purposes, is referred to as industrial water use. The major water-using industries of the 12-county study area are petroleum refining, petrochemicals, food processing, primary metals, fabricated metals, and electrical and non-electrical machinery. The total quantity of freshwater used by these industries in 1990 was reported at 43,611 acft, of which 80- percent was used in Nueces County, 17 percent was used in San Patricio County, 2.2 percent was used in Live Oak County, and 0.6 percent was used in Aransas County (Table 2.3-2).[5] The TWDB high case projected industrial water demand, with conservation (recycling, reuse, and technology improvements), at year 2000 is 57,776 acft/yr, at 2030 is 83,145 acft/yr, and at 2050 is 100,231 acft/yr (Table 2.3-2).

It is important to note that the Corpus Christi area has nearly 13 percent of Texas petroleum refining capacity, and that the petroleum refining sector uses nearly 66 percent of total industrial water demand within the Corpus Christi service area. Further, it is important to note that the Corpus Christi area refineries have implemented significant water conservation and water use efficiency improvement programs. For example, Corpus Christi area refineries use

[4] It should be noted that the annual water use reports are in terms of raw water diverted at the source and therefore include losses during treatment, conveyance, and distribution. Thus, the quantities projected may not be the quantities that actually reach the consumers' taps. In the case of the Choke Canyon/Lake Corpus Christi System, which supplies surface water to a large part of the 12-county study area, the quantities are measured at the Calallen Diversion Dam, and do not take into account channel losses between the lakes and the diversion point, nor treatment and leakage losses during conveyance.

[5] Quantities delivered to the plants, and does not include channel losses between Choke Canyon and Lake Corpus Christi and the Calallen River diversion point, nor treatment and leakage losses during conveyance.

Table 2.3-1
Municipal Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County[*]	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	2,614	4,192	4,730	5,347	6,222	7,021	7,820
Atascosa	5,670	6,979	7,657	8,157	8,808	9,465	10,122
Bee	3,569	4,687	4,774	4,855	5,124	5,432	5,740
Brooks	1,150	1,568	1,637	1,694	1,794	1,905	2,016
Duval	2,090	2,426	2,384	2,324	2,358	2,409	2,460
Jim Wells	6,535	9,229	9,287	9,123	9,175	9,133	9,091
Kleberg	6,261	7,383	7,758	7,903	8,305	8,633	8,961
Live Oak	1,796	1,983	2,013	1,961	1,949	1,919	1,889
McMullen	109	217	222	211	211	208	205
Nueces	76,521	81,634	89,206	95,643	104,119	113,094	122,069
Refugio	1,227	1,359	1,372	1,363	1,382	1,380	1,378
San Patricio	7,931	10,378	11,452	12,350	13,175	13,739	14,303
Region Total	115,473	132,035	142,492	150,931	162,622	174,338	186,054

[*] Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

[1] As reported to the Texas Water Development Board. Includes Commercial Use.

[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - to 2040, April 1992, Austin, Texas.

Table 2.3-2
Industrial Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County*	Water Use 1990[2]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	283	416	521	638	771	877	983
Atascosa	0	0	0	0	0	0	0
Bee	1	2	2	3	3	4	5
Brooks	0	0	0	0	0	0	0
Duval	0	0	0	0	0	0	0
Jim Wells	0	0	0	0	0	0	0
Kleberg	0	0	0	0	0	0	0
Live Oak	943	986	959	967	971	974	977
McMullen	0	0	0	0	0	0	0
Nueces	34,949	41,993	44,323	48,143	51,578	55,144	58,710
Refugio	0	0	0	0	0	0	0
San Patricio	7,435	14,379	19,143	24,503	29,822	34,689	39,556
Region Total	43,611	57,776	64,948	74,254	83,145	91,688	100,231

* Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

1 As reported to the Texas Water Development Board.

2 Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - to 2040, April 1992, Austin, Texas.

about 46 gallons of water per barrel of crude petroleum refined while the State average is about 100 gallons per barrel refined.[6]

The industrial water demand projections are based upon information about plans for expansion of the Corpus Christi area industries and projected national growth trends of each major water using industry. In the projections, adjustments have been made for improved water use efficiency through recycling and reuse unique to each industry, in order to obtain a projection of demand for each industry with water conservation effects taken into account. In the case of the Corpus Christi area, the water conservation effect lowers the industrial water demand projections by about five percent.

Although the effects of water conservation have been factored into the industrial water demand projections, the potential effects of the North American Free Trade Agreement (NAFTA) upon the growth rate of the Corpus Christi industries have not been taken into account.

Steam-Electric Power Generation

In the 12-county study area, there are steam-electric power plants located in Atascosa and Nueces counties. The steam-electric power generation process uses water in boilers and for cooling the electric power generating equipment. The usual practice is to use freshwater with a very low concentration of dissolved solids for boiler feed water and to use either freshwater or saline water for powerplant cooling purposes. In the study area, the large electric power generation plants located at Corpus Christi, in Nueces County, use seawater for cooling and freshwater for boiler feed. The steam-electric power plant located in Atascosa County uses freshwater from groundwater sources for both boiler feed and cooling purposes. Thus, the total quantity of freshwater used for steam-electric power generation in the study area is low in relation to the level of electric power generation capacity. In 1990, the reported quantity of freshwater used for steam-electric power generation was 6,026 acft (Table 2.3-3), and is projected to increase to 15,500 acft/yr in 2000, 25,500 acft/yr in 2030, and 35,500 acft/yr in

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[6] "Report of Water Use for Refineries and Selected Cities in Texas, 1976-1987," South Texas Water Authority, Kingsville, Texas, 1990.

Table 2.3-3
Steam Electric Power Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County*	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	0	0	0	0	0	0	0
Atascosa	6,036	12,000	12,000	17,000	22,000	27,000	32,000
Bee	0	0	0	0	0	0	0
Brooks	0	0	0	0	0	0	0
Duval	0	0	0	0	0	0	0
Jim Wells	0	0	0	0	0	0	0
Kleberg	0	0	0	0	0	0	0
Live Oak	0	0	0	0	0	0	0
McMullen	0	0	0	0	0	0	0
Nueces	2,404	3,500	3,500	3,500	3,500	3,500	3,500
Refugio	0	0	0	0	0	0	0
San Patricio	0	0	0	0	0	0	0
Region Total	8,440	15,500	15,500	20,500	25,500	30,500	35,500

* Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

1 As reported to the Texas Water Development Board.

2 Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - 2040, April 1992, Austin, Texas.

2050 (Table 2.3-3). About 96 percent of the increase is due to the projected expansion of electric power generation facilities located in Atascosa County.

Irrigation Water Demand

Irrigated crop production is practiced in small quantities throughout the 12-county area, with the exception of Atascosa County, where irrigation is a major water-using activity. Irrigated crops include grain sorghum, corn, hay, pasture, vegetables, and peanuts. In 1990, irrigation water use was estimated at 61,445 acft, which was 25 percent of total water use within the 12-county area in 1990 (Table 2.3-4). Over 80 percent of irrigation was from groundwater sources. TWDB projected irrigation water use for year 2000 is 65,315 acft/yr, with projections declining to 55,315 acft/yr in 2020, 2030, 2040, and 2050 (Table 2.3-4). By the year 2050, irrigation water use is estimated to be only 14 percent of the total water use within the 12-county area. The projected decline of irrigation water use as a percent of total water use is due to water conservation through increased irrigation efficiencies, and the fact that each of the other uses is projected to increase significantly.

Mining Water Demand

In 1990, 8,300 acft of water was used in the 12-county study area in the mining of sand and gravel and in the production of energy (crude oil and uranium). In 1990, water was used for one or more of these purposes in practically every county of the area, with the largest quantities being used in Atascosa, Duval, Kleberg, and Live Oak counties (Table 2.3-5). The TWDB projections of mining water use are 9,371 acft in 2000, 10,623 acft in 2030, and 12,707 acft in 2050 (Table 2.3-5).

Livestock Water Demand

In the 12-county study area, the principal livestock type is beef cattle, with some dairy herds. In 1990, the estimated quantity of water used by livestock in the 12-county area was 10,735 acft (Table 2.3-6). The TWDB projects that livestock water demand in 2000 will be 13,841 acft, and will remain at this level through the year 2050 (Table 2.3-6). The projections are based upon estimates of the maximum carrying capacity of the range land of the area, and

Table 2.3-4
Irrigation Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County*	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	0	0	0	0	0	0	0
Atascosa	47,208	50,000	42,500	40,000	40,000	40,000	40,000
Bee	3,474	2,250	2,250	2,250	2,250	2,250	2,250
Brooks	350	371	371	371	371	371	371
Duval	2,586	3,095	3,095	3,095	3,095	3,095	3,095
Jim Wells	1,189	1,748	1,748	1,748	1,748	1,748	1,748
Kleberg	461	578	578	578	578	578	578
Live Oak	3,333	2,000	2,000	2,000	2,000	2,000	2,000
McMullen	0	0	0	0	0	0	0
Nueces	1,734	2,632	2,632	2,632	2,632	2,632	2,632
Refugio	0	83	83	83	83	83	83
San Patricio	1,110	2,558	2,558	2,558	2,558	2,558	2,558
Region Total	61,445	65,315	57,815	55,315	55,315	55,315	55,315

* Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

[1] As estimated from "Surveys of Irrigation in Texas--1958, 1964, 1969, 1974, 1979, 1984, and 1989", Texas Water Development Board and Texas State Soil and Water Conservation Board, January, 1991, Austin, Texas.

[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - 2040, April 1992, Austin, Texas.

Table 2.3-5
Mining Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County*	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	0	113	85	57	29	14	0
Atascosa	664	1,444	1,554	2,680	3,806	4,931	6,056
Bee	20	40	30	23	16	12	8
Brooks	145	117	103	88	74	62	50
Duval	3,049	3,036	2,673	2,529	2,494	2,484	2,474
Jim Wells	393	339	238	175	124	94	64
Kleberg	1,221	950	844	739	633	542	451
Live Oak	2,385	2,737	2,794	2,864	2,943	3,027	3,111
McMullen	239	330	358	364	373	382	391
Nueces	50	136	93	57	28	16	4
Refugio	77	28	14	7	4	1	0
San Patricio	57	101	100	100	99	99	99
Region Total	8,300	9,371	8,886	9,683	10,623	11,664	12,708

* Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

[1] As reported to the Texas Water Development Board.

[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - to 2040, April 1992, Austin, Texas.

Table 2.3-6
Livestock Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County*	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	52	93	93	93	93	93	93
Atascosa	1,613	1,945	1,945	1,945	1,945	1,945	1,945
Bee	1,088	1,314	1,314	1,314	1,314	1,314	1,314
Brooks	816	1,133	1,133	1,133	1,133	1,133	1,133
Duval	1,177	2,306	2,306	2,306	2,306	2,306	2,306
Jim Wells	907	1,419	1,419	1,419	1,419	1,419	1,419
Kleberg	1,745	1,470	1,470	1,470	1,470	1,470	1,470
Live Oak	1,170	1,105	1,105	1,105	1,105	1,105	1,105
McMullen	484	1,237	1,237	1,237	1,237	1,237	1,237
Nueces	373	352	352	352	352	352	352
Refugio	563	673	673	673	673	673	673
San Patricio	747	794	794	794	794	794	794
Region Total	10,735	13,841	13,841	13,841	13,841	13,841	13,841

* Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.
1 As estimated by the Texas Water Development Board.
2 Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - 2040, April 1992, Austin, Texas.

the number of gallons of drinking water needed per head of cattle per day. It should be noted that livestock drinking water is obtained from wells, stock watering tanks (small lakes constructed or dug on the ranches especially for these purposes), and streams that flow through the ranches. In effect, for the most part, livestock drinking water is taken directly from the hydrologic cycle of the study area, and although it may affect the quantities available for other purposes, it is not usually included explicitly in water supply plans. The quantities are included here in order to be as complete as possible in the presentation of demands upon the water resources of the study area.

Total Water Demand

In the previous discussion, 1990 water use with projections to 2050 were presented for municipal, industrial, steam-electric power, irrigation, mining, and livestock purposes. The sum of the projections for these six purposes is presented here in order to obtain projections of total water demand for the 12-county study area for the 1990 through 2050 planning period. In 1990, total water use in the area was 245,590 acft (Table 2.3-7). TWDB high case projections, with conservation, are 293,838 acft in 2000, 351,046 acft in 2030, and 403,646 acft in 2050 (Table 2.3-7 and Figure 2.3-1). Of total water use in 1990, in the 12-county study area, 47 percent was for municipal purposes, 18 percent was for industry, 25 percent was for irrigation, and the remaining 11 percent was for steam-electric power generation, mining, and livestock (Table 2.3-8). Throughout the projection period, municipal demand is projected to be 46 percent of the total demand, with the industry proportion increasing from 18 percent to 25 percent and irrigation declining from 25 percent to 14 percent (Table 2.3-8).

2.4 Municipal and Industrial (M&I) Water Demand Projections

Total water use in 1990 in the 12-county area (groundwater plus CC/LCC and other surface water) was 245,590 acft and is projected to increase to 403,646 acft in 2050, with conservation (Table 2.3-8). It is important to note that municipal use is projected to hold steady, as a percent of total use at about 46 percent, while industrial use is projected to increase from 18 percent of the total in 1990 to 25 percent in 2050, and irrigation use is projected to decline

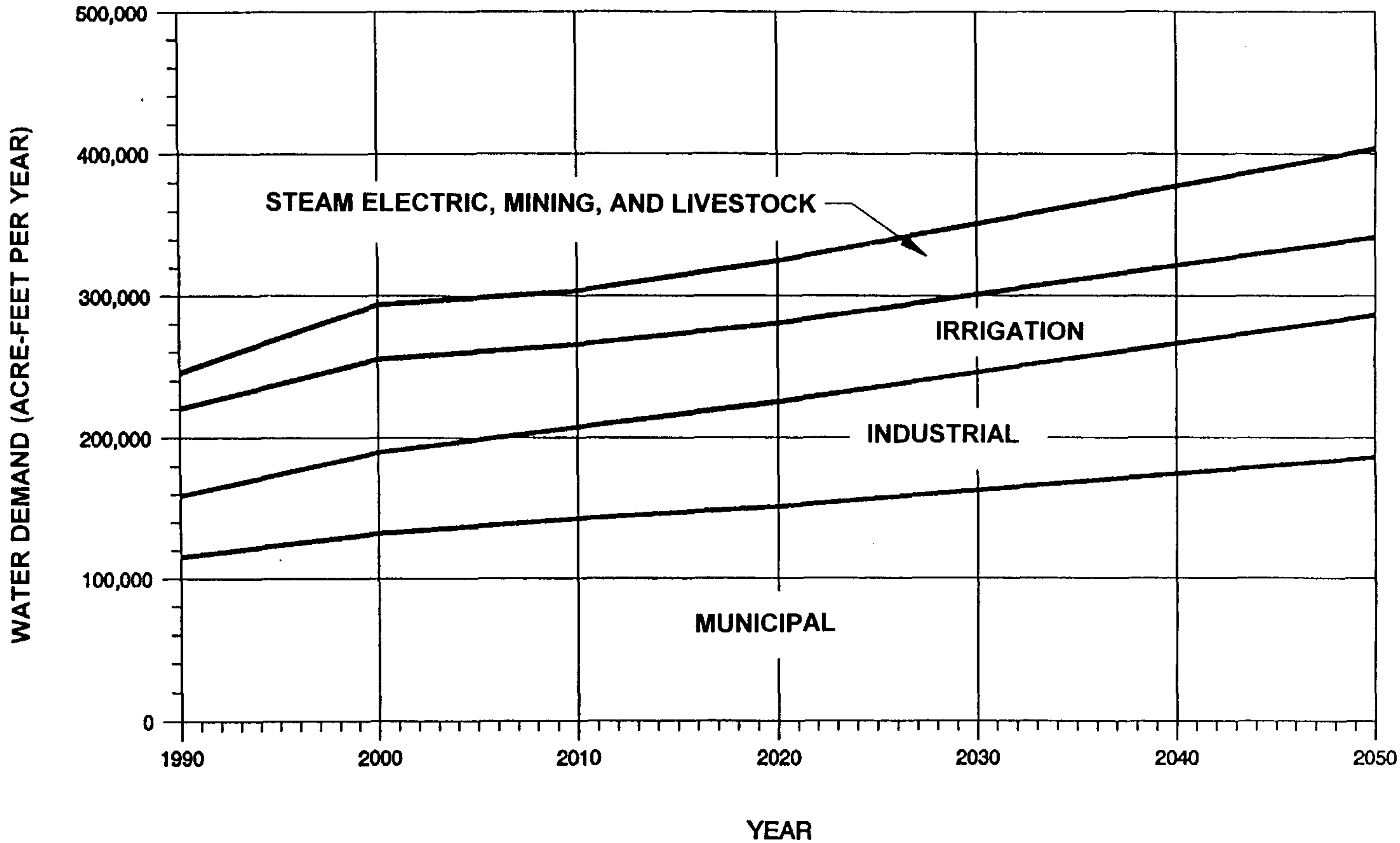
Table 2.3-7
Total Water Demand Projections - Corpus Christi Area
Trans-Texas Water Program

County*	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	2,949	4,814	5,429	6,135	7,115	8,005	8,895
Atascosa	58,777	72,368	65,656	69,782	76,559	83,341	90,123
Bee	8,152	8,293	8,370	8,445	8,707	9,012	9,317
Brooks	2,461	3,189	3,244	3,286	3,372	3,471	3,570
Duval	8,902	10,863	10,458	10,254	10,253	10,294	10,335
Jim Wells	9,024	12,735	12,692	12,465	12,466	12,394	12,322
Kleberg	9,688	10,381	10,650	10,690	10,986	11,223	11,460
Live Oak	9,627	8,811	8,871	8,897	8,968	9,025	9,082
McMullen	832	1,784	1,817	1,812	1,821	1,827	1,833
Nueces	116,031	130,247	140,106	150,327	162,209	174,738	187,267
Refugio	1,867	2,143	2,142	2,126	2,142	2,137	2,132
San Patricio	17,280	28,210	34,047	40,305	46,448	51,879	57,310
Region Total	245,590	293,838	303,482	324,524	351,046	377,346	403,646

* Service area of the Corpus Christi-Nueces River Authority Choke Canyon/Lake Corpus Christi System for municipal and industrial water supply.

[1] As reported to the Texas Water Development Board, for municipal, industrial, steam-electric power and mining, with estimates for irrigation and livestock.

[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 - 2040, April 1992, Austin, Texas.



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TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

WATER DEMAND PROJECTIONS REGION TOTAL

FIGURE 2.3-1

Table 2.3-8 Total Water Demand Projections - Corpus Christi Area Trans-Texas Water Program Distribution by Type of Use								
	1990 Use		2000		2030		2050	
Water Use	Acft	%	Acft	%	Acft	%	Acft	%
Municipal	115,473	47	132,035	45	162,622	46	186,054	46
Industrial	43,611	18	57,776	20	83,145	24	100,231	25
Steam-Electric	6,026	2	15,500	5	25,500	7	35,500	9
Irrigation	61,445	25	65,315	22	55,315	16	55,315	14
Mining	8,300	3	9,371	3	10,623	3	12,707	3
Livestock	10,735	4	13,841	5	13,841	4	13,841	3
TOTAL	245,590	100	293,838	100	351,046	100	403,646	100

from 25 percent of total use in 1990 to 14 percent in 2050. (Note: Irrigation is concentrated in Atascosa County.)

In 1990, municipal water use for the 12-county study area was reported at 115,473 acft, with industrial use at 43,611 (Tables 2.3-1 and 2.3-2). The total of M&I use in 1990 was 159,084 acft (Table 2.4-1). Of the total M&I water use in 1990, 70 percent was in Nueces County, 9.6 percent was in San Patricio County, and the remaining 20.3 percent was in the other 10 counties (Table 2.4-1). For the 12-county study area, M&I water use in 2050 is projected at 286,285 acft, with 63 percent in Nueces County, 18.8 percent in San Patricio County, and the remaining 18.1 percent in the remaining 10 counties (Table 2.4-1). In the following sections, the 12-county regional projections of M&I demands are divided into those dependent upon the CC/LCC surface water system and those that are expected to remain dependent upon local groundwater supplies.

2.4.1 Projections of M&I Water Demands upon Groundwater Supplies of the Study Area

In 1990, groundwater use for M&I purposes in the 12-county study area was reported at 24,569 acft (Table 2.4-2). The projected 2050 M&I demands from groundwater sources are 30,455 acft (Table 2.4-2). (Note: See discussion in Section 2.4.1 for explanation of assumptions used in making projections of M&I water demands from CC/LCC surface water

Table 2.4-1
Municipal and Industrial Water Demand Projections - Corpus Christi Study Area
Trans-Texas Water Program

County	Water Use 1990[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	2,897	4,608	5,251	5,985	6,993	7,898	8,803
Atascosa	5,670	6,979	7,657	8,157	8,808	9,465	10,122
Bee	3,570	4,689	4,776	4,858	5,127	5,436	5,745
Brooks	1,150	1,568	1,637	1,694	1,794	1,905	2,016
Duval	2,090	2,426	2,384	2,324	2,358	2,409	2,460
Jim Wells	6,535	9,229	9,287	9,123	9,175	9,133	9,091
Kleberg	6,261	7,383	7,758	7,903	8,305	8,633	8,961
Live Oak	2,739	2,969	2,972	2,928	2,920	2,893	2,866
McMullen	109	217	222	211	211	208	205
Nueces	111,470	123,627	133,529	143,786	155,697	168,238	180,779
Refugio	1,227	1,359	1,372	1,363	1,382	1,380	1,378
San Patricio	15,366	24,757	30,595	36,853	42,997	48,428	53,859
Region Total	159,084	189,811	207,440	225,185	245,767	266,026	286,285

[1] As reported to the Texas Water Development Board. Includes Commercial Use.

[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030 to 2040, April 1992, Austin, Texas.

Table 2.4-2
Projections of Municipal and Industrial Water Demands, With Conservation, Upon Ground Water Supplies -- Corpus Christi Study Area
Trans-Texas Water Program

County	1990 Reported Water Use[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	447	400	400	400	400	400	400
Atascosa[3]	5,670	6,979	7,657	8,157	8,808	9,465	10,122
Bee	1,637	1,635	1,635	1,635	1,635	1,635	1,635
Brooks[3]	1,150	1,568	1,637	1,694	1,794	1,905	2,016
Duval[3,4]	2,090	2,426	2,384	2,324	2,358	2,409	2,460
Jim Wells[4]	2,538	2,538	2,538	2,538	2,538	2,538	2,538
Kleberg	5,685	5,685	5,685	5,685	5,685	5,685	5,685
Live Oak	1,527	1,527	1,527	1,527	1,527	1,527	1,527
McMullen[3]	109	217	222	211	211	208	205
Nueces	567	567	567	567	567	567	567
Refugio[3]	1,227	1,359	1,372	1,363	1,382	1,380	1,378
San Patricio	1,922	1,922	1,922	1,922	1,922	1,922	1,922
REGION TOTAL	24,569	26,823	27,546	28,023	28,827	29,641	30,455

[1] As reported to the Texas Water Development Board. Includes Commercial Use.

[2] Texas Water Development Board, High Case for 1990 through 2040, with conservation, with extrapolation to 2050 at same rate as projected for 2030 to 2040, April 1992, Austin, Texas.

[3] These counties relied wholly upon groundwater in 1990 and are projected to obtain all of the needed M&I water from groundwater sources through 2050.

[4] In the fall of 1994, studies were initiated to evaluate supplementing groundwater supplies for the Cities of San Diego, Benavides, and Freer with surface water from for the City of Alice which relies in part, on surface water from the CC/LCC system.

system and from groundwater (Aquifers) sources of the area.) Groundwater supply information is presented in a following section (Section 2.5.1) of this report.

2.4.2 Projections of M&I Water Demands Upon the CC/LCC Surface Water System

In 1990, total M&I water use from the Corpus Christi (CC/LCC) System was reported at 132,086 acft. This use is projected to increase to 253,284 acft in 2050 (Table 2.4-3). The projections of future M&I water demands upon the CC/LCC System are based upon conservation programs being continued, and the assumption that communities within the area that were being supplied from groundwater in 1990 would be able to continue using groundwater in the future at the same level as was being used in 1990. In those study area counties which relied wholly upon groundwater in 1990 (Atascosa, Brooks, Duval, McMullen, and Refugio), the projections are based upon the assumption that future needs can continue to be met from groundwater. Groundwater supply information from the Texas Water Development Board (TWDB) indicates adequate quantities of groundwater within these counties to meet their projected M&I water demands. However, in study area counties that are supplied both from groundwater and the CC/LCC System, the projections of future M&I demands are based upon the assumption that historical trends of cities to shift from groundwater to CC/LCC System water will continue, and that although groundwater will continue to be used by some communities to meet a part of their needs, that part needed to supply population and industrial growth after 1990 will be supplied from the CC/LCC System. (Note: The TWDB groundwater supply information indicates adequate quantities of groundwater within each county to meet the 1990 level of groundwater use except in Aransas County (see Section 2.5.1 for groundwater supply information). For Aransas County, the projected use of groundwater was limited to supply available, with the remainder of demand shifted to the CC/LCC System.) It is important to note that poor groundwater quality may hasten the trend to shift to CC/LCC supplies, in which case the projections of demand in 2050 could increase by about 30,000 acft annually. A water supply and demand analysis for the 12-county study area and for the Corpus Christi CC/LCC System is presented in Sections 2.5 and 2.6 below.

Table 2.4-3
Projections of Municipal and Industrial Water Demands, With Conservation, Upon Choke Canyon/Lake Corpus Christi Reservoir System Service Area
Trans-Texas Water Program

County	1990 Reported Water Use[1]	Projections in Acft[2]					
		2000	2010	2020	2030	2040	2050
Aransas	2,450	4,208	4,851	5,585	6,593	7,498	8,403
Atascosa	0	0	0	0	0	0	0
Bee	1,933	3,054	3,141	3,223	3,492	3,801	4,110
Brooks	0	0	0	0	0	0	0
Duval	0	0	0	0	0	0	0
Jim Wells	3,997	6,691	6,749	6,585	6,637	6,595	6,553
Kleberg	576	1,698	2,073	2,218	2,620	2,948	3,276
Live Oak	1,212	1,442	1,445	1,401	1,393	1,366	1,339
McMullen	0	0	0	0	0	0	0
Nueces[3]	108,474	120,959	130,779	141,007	152,792	165,229	177,666
Refugio	0	0	0	0	0	0	0
San Patricio	13,444	22,835	28,673	34,931	41,075	46,506	51,937
REGION TOTAL[3]	132,086	160,887	177,711	194,950	214,602	233,943	253,284
Robstown	2,429	2,101	2,183	2,212	2,338	2,442	2,546

[1] As reported to the Texas Water Development Board. Includes Commercial Use.

[2] Texas Water Development Board, High Case for 1990 through 2040, with conservation, with extrapolation to 2050 at same rate as projected for 2030 to 2040, April 1992, Austin, Texas.

[3] Does not include Robstown M&I Demands since Robstown is supplied from a Nueces Water Control and Improvement District No. 3 permit which is senior to the permit for the CC/LCC System and, at 3,500 acft/yr, is greater than the projected demand for Robstown.

2.5 Water Supply Projections

Water supply projections of the 12-county study area and of the water supply area are presented below. The projections are those that have been developed by the Texas Water Development Board (TWDB) and by previous water supply studies of both the demand and supply areas. Both groundwater and surface water supply projections are included.

2.5.1 Groundwater Supplies of the 12-County Study Area

The Gulf Coast Aquifer is the source of groundwater in all of the counties of the CC/LCC service area except in Atascosa, and northwestern McMullen and Live Oak Counties, where the Carrizo Aquifer is the source of groundwater supplies. Groundwater supplies of the area are limited in relation to total water demand, and quality, particularly in the Gulf Coast Aquifer, is marginal to poor with high concentrations of chlorides, sulfates, and total dissolved solids.

In 1990, total groundwater use for M&I purposes within the 12-county area was 24,569 acft (Table 2.4-3). An additional 71,317 acft of groundwater was used for other purposes, mainly irrigation in Atascosa County, for a total groundwater use from the area's Aquifers of 95,886 acft (Table 2.5-1). Total groundwater supplies for the 12-county area are projected to decline from 184,787 acft in 2000 to 165,237 acft in 2050 (Table 2.5-1).

In the coastal counties of the area (Aransas, San Patricio, Nueces, and Kleberg) the quantities available are 16 percent of projected M&I demands in year 2000, and are 10 percent of projected M&I demands in 2050 (Tables 2.5-1 and 2.4-2).

In the inland counties of Bee, Brooks, Duval, Jim Wells, Live Oak, McMullen, and Refugio, projected county total groundwater supply shows adequate quantities to meet projected M&I water demands within each county (Tables 2.5-1 and 2.4-3). However, groundwater quality is marginal to poor (high chlorides, sulfates, and total dissolved solids) quantities are distributed throughout the counties, requiring extensive well fields and collection systems in order to obtain this supply for M&I uses at centralized locations. In the case of Duval and Jim Wells counties, many communities are currently using abandoned oil wells, which have been retrofitted to serve as public water supply services. These wells are experiencing considerable

Table 2.5-1
Groundwater Supply Projections - Corpus Christi Study Area
Trans-Texas Water Program

County	Reported Use 1990[1]	Supply Projections in Acft						
		2000	2010	2020	2030	2040	2050	Annual Recharge*
Aransas	452	400	400	400	400	400	400	400
Atascosa	57,324	48,280	48,280	48,280	28,730	28,730	28,730	28,730
Bee	5,065	15,661	15,661	15,661	15,661	15,661	15,661	15,661
Brooks	1,726	14,577	14,577	14,577	14,577	14,577	14,577	14,577
Duval	7,842	23,970	23,970	23,970	23,970	23,970	23,970	23,970
Jim Wells	4,210	11,370	11,370	11,370	11,370	11,370	11,370	11,370
Kleberg	7,509	17,088	17,088	17,088	17,088	17,088	17,088	17,088
Live Oak	5,997	11,853	11,853	11,853	11,853	11,853	11,853	11,853
McMullen	396	25,338	25,338	25,338	25,338	25,338	25,338	25,338
Nueces	842	3,254	3,254	3,254	3,254	3,254	3,254	3,254
Refugio	1,360	7,768	7,768	7,768	7,768	7,768	7,768	7,768
San Patricio	3,163	5,228	5,228	5,228	5,228	5,228	5,228	5,228
Region Total	95,886	184,787	184,787	184,787	165,237	165,237	165,237	165,237

* Source: Unpublished county groundwater availability data, Texas Water Development Board, Austin, Texas, 1993.

1 Reported use for municipal, industrial, stream-electric power, and mining, with estimates for irrigation and livestock.

deterioration and reductions in water quality and quantity produced.[7] The City of Freer, of Duval county has experienced static water level declines of over 300 feet since 1961, and two of its municipal water supply wells have gone dry.[8] The groundwater resources of Duval county are high in dissolved solids, chlorides, and hardness and most of the water does not meet drinking water standards for public supply.[9] A regional water supply plan is being developed for Duval and Jim Wells counties to evaluate the possibilities of obtaining surface water supplies for communities of these counties. A potential supplier is the Alice Water Authority, which obtains water from Lake Corpus Christi under a water supply contract with the City of Corpus Christi.[10] In 1990, communities of Duval and Jim Wells counties used 2,959 acft of groundwater for municipal purposes. The projected demands in 2050 are 3,973 acft/yr. Therefore, the projections of water demands on the groundwater supplies as shown in Table 2.4-3 could be overstated, and the projections of surface water demands on the CC/LCC system as shown in Table 2.4-2 could be understated, each by as much as 3,973 acft/yr for 2050 conditions.

In the case of Atascosa County, groundwater use in 1990 was almost twice the estimated annual recharge (57,324 acft vs. 28,730 acft; Table 2.5-1), and although projected Atascosa County supplies exceed projected annual Atascosa County M&I demands (28,730 acft of supply vs. 10,122 acft of M&I demand in 2050; Tables 2.4-3 and 2.5-1) the continued overdrafting of groundwater in Atascosa County, largely for irrigation, could result in local water shortages for M&I purposes within the county. Additional studies on the Carrizo-Wilcox Aquifer system are needed to adequately address the potential groundwater supply in Atascosa County.

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[7] Problem statement from a planning grant application "Regional Water Supply Planning Study for Duval and Jim Wells County, Texas, Nueces River Authority," Texas Water Development Board, Austin, Texas, September, 1994.

[8] Ibid.

[9] "Ground Water Resources of Duval County", Texas Water Development Board, Report 181, Austin, Texas, March 1974.

[10] op.cit.

2.5.2 Surface Water Supplies of the 12-County Study Area

The 12-county study area surface water supplies consist of the firm yield of the Choke Canyon/Lake Corpus Christi (CC/LCC) Reservoir System plus rights to divert and use a small quantity of Nueces River flows at the Calallen Reservoir. The City of Corpus Christi, the Nueces River Authority, and the City of Three Rivers hold TNRCC (TNRCC) permits to the CC/LCC Reservoir System. Corpus Christi operates the system and supplies treated water to its own customers and sells treated and raw water to other water supply utilities that serve customers in neighboring communities. The system also supplies treated and raw water to industries of the area. At the present time, the CC/LCC Reservoir System supplies water for M&I use in seven of the 12 study area counties (Aransas, Bee, Jim Wells, Kleberg, Live Oak, Nueces, and San Patricio).

The Nueces County Water Control and Improvement District No. 3 (Nueces County WCID No. 3) holds TNRCC permits to divert and use Nueces River flows from the Calallen Reservoir. This source supplies municipal water to the City of Robstown and irrigation water to farms within the boundaries of the District. The Nueces County WCID No. 3 permit is for 4,246 acft of water for municipal purposes and 7,300 acft of water for irrigation purposes. Since this permit is for a specific location, and the quantities will meet the projected M&I demands of Robstown, in this study the permitted quantities are set aside for those purposes and will not be given further consideration in the M&I water supply and demand analyses of this section of this report. (However in a subsequent section of this report the potential purchase and use of those permitted rights is addressed.)

The yield of the CC/LCC Reservoir System, as can be realized at the Calallen Reservoir where most of the diversions occur, is the effective surface water supply available for M&I users of the Corpus Christi water system. The yield of the CC/LCC Reservoir System for 1990 sediment conditions, with the Phase II Operation Plan and the Texas Water Commission (TWC; now TNRCC) March 1992 Order for releases to Nueces Bay, was 168,500 acft.[11] The projected 2050 yield, under projected 2050 sediment conditions for the Phase II Operation Plan,

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[11] Computations of CC/LCC System Yield were made using "The Lower Nueces River Basin and Estuary Model (NUBAY4);" the most recent update of the model developed in "Regional Wastewater Planning Study -- Phase II, Nueces Estuary," City of Corpus Christi, Port of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, and Texas Water Development Board, Austin, Texas, June 1993.

with the TNRCC 1992 release order, is 153,000 acft (Table 2.5-2). The yield of the Reservoir System for 1990 sediment conditions, with the Corpus Christi Phase II Operations Plan and the TNRCC April 1995 Order for releases to Nueces Bay in 1990 would have been 181,500 acft (Table 2.5-2).[12] The projected 2050 yield, under projected 2050 sediment conditions for the Phase II Operation Plan, with the TNRCC April 1995 order is 162,500 acft (Table 2.5-2). Since the Operation Plan and Release Order are major factors in the CC/LCC yield calculations, the important points are presented below.

Table 2.5-2
Projected Yield of CC/LCC System

Year	Yield at Calallen (acft/yr)	
	1992 Release Order[1]	1995 Release Order[2]
1990	168,500	181,500
2000	165,500	178,500
2010	163,000	175,000
2020	160,500	172,000
2030	158,000	169,000
2040	155,500	165,500
2050	153,000	162,500

[1] Yield calculations for Phase II Operation Plan with TNRCC Order of March 1992 for releases to Nueces Bay. See text for explanation of Phase II Operation Plan and Release Order. The yield computations take into account channel losses between Choke Canyon and Lake Corpus Christi and between Lake Corpus Christi and Calallen Reservoir. Firm yield calculations rounded to the nearest 500 acft/yr.
[2] Yield calculations for Phase II Operation Plan with TNRCC Order of April 1995.
Note: Robstown supplies meet Robstown demands and are not included here.

The Phase II Operations Plan for the CC/LCC Reservoir System is as follows:

1. A minimum of 2,000 acft per month will be released from Choke Canyon Reservoir to meet conditions of the release agreement between the City of Corpus Christi and the Texas Parks and Wildlife Department.

[12] 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. Texas Natural Resource Conservation Commission, Austin, Texas, April 28, 1995.

2. Whenever Lake Corpus Christi water surface falls to elevation 88 feet and Choke Canyon Reservoir surface elevation is above 204 feet, releases will be made from Choke Canyon Reservoir to maintain Lake Corpus Christi surface at elevation 88 feet.

3. Whenever Lake Corpus Christi water surface is at or below elevation 88 feet and Choke Canyon Reservoir surface elevation is below 204 feet, the Choke Canyon release for the current month is made equal to the Lake Corpus Christi release for the preceding month. This minimizes drawdown at Lake Corpus Christi for recreation purposes and promotes a more constant quality of water by mixing Choke Canyon Reservoir releases with Lake Corpus Christi content."

The TNRCC Agreed Order of April, 1995 specifies that:

"The City of Corpus Christi, as operator of the Choke Canyon/Lake Corpus Christi reservoirs (the "Reservoir System"), shall provide not less than 151,000 acre-feet of water per annum (per calendar year) for the estuaries by a combination of releases and spills from the Reservoir System at Lake Corpus Christi Dam and return flows to Nueces and Corpus Christi Bays and other receiving estuaries (including such credits as may be appropriate for diversion of river flows and/or return flows to the Nueces Delta and/or Nueces Bay),..."

The April, 1995 bay and estuary release order (1995 Agreed Order) effectively provides about the same quantities of water to the bays and estuary as the 1992 Interim Order, but significantly increases the firm yield of the CC/LCC system. The major differences between the new 1995 Agreed Order and the 1992 Interim Order are as follows:

1) The water released from the CC/LCC System to satisfy the TNRCC bay and estuary release requirement in a given month is limited to no more than the inflow to LCC 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 LCC. When the system storage is less than 70 percent, but more than 40 percent, the target schedule is reduced so as to provide 97,000 acft/yr to Nueces Bay/Delta. 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. 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.

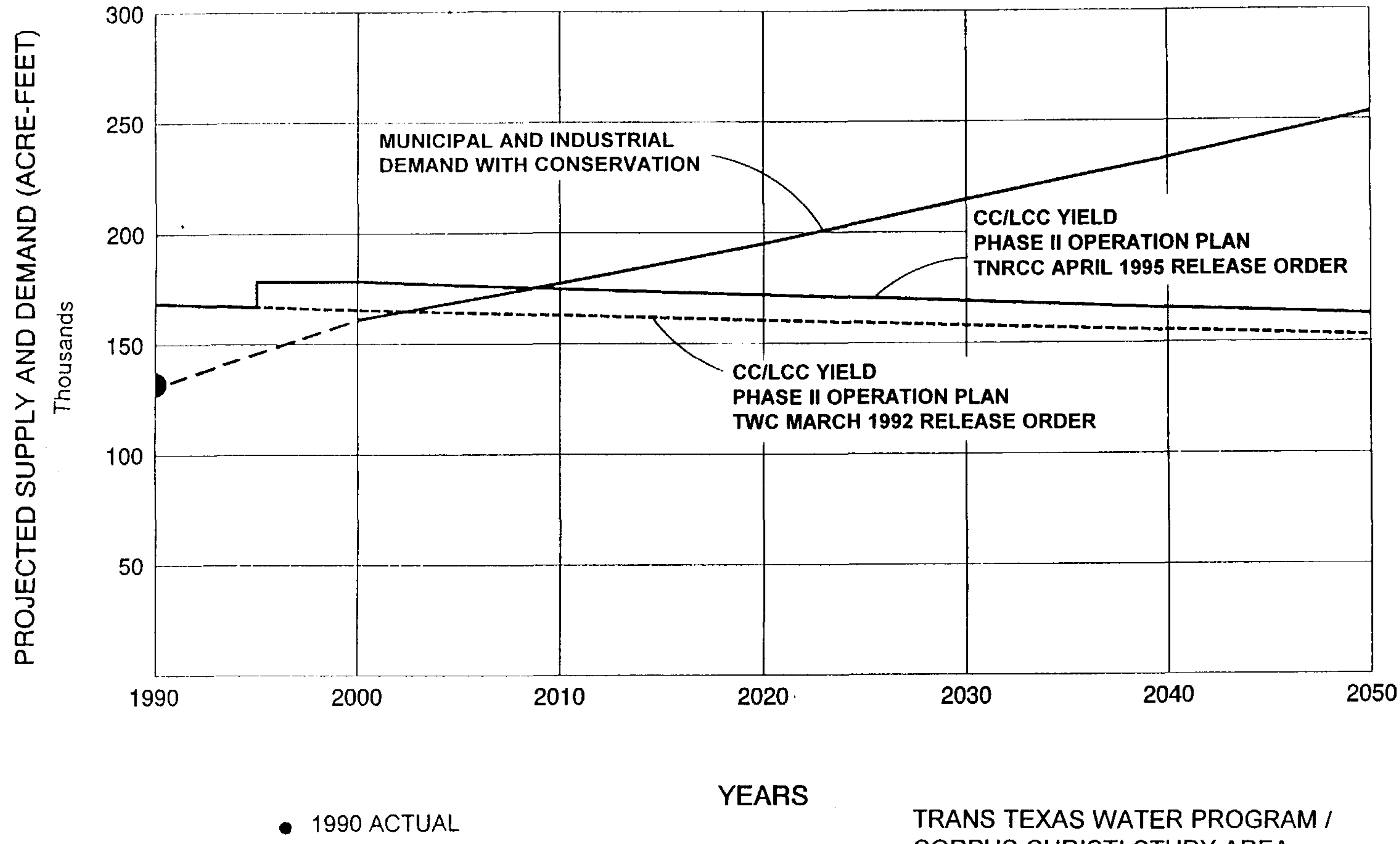
The 1995 Agreed Order provides for relief from bay and estuary release requirements when salinity criteria in Nueces Estuary are met and when spills in the previous month are more than that month's release requirement in the same manner as the 1992 Interim Order.

The limiting of releases to the bays and estuary in the 1995 Agreed Order would have increased the firm yield of the CC/LCC System in 1990 under Phase II Operations Policy by approximately 13,500 acft/yr under 1990 sediment conditions and 9,500 acft/yr in 2050 under 2050 sediment conditions.

2.6 Water Needs of the CC/LCC Service Area

Municipal and industrial water demand and water supply comparisons for the CC/LCC Surface Water Service Area are made in order to estimate the quantity of water needed and the time of need in the Corpus Christi study area. The M&I water demands of the CC/LCC System, with conservation, increase from about 132,000 acft in 1990 to about 253,500 acft in 2050 (Figure 2.6-1 and Table 2.6-1). The CC/LCC System under present operation policies (i.e., Phase II Operation and with the TNRCC Order of April 1995 for release to Nueces Bay) can meet projected M&I demands to about the year 2007 (Figure 2.6-1). An additional 2,500 acft/yr is needed in 2010 to meet projected M&I demands at that time (Table 2.6-1 and Figure 2.6-1), with 45,500 acft needed in 2030, and an additional 91,000 acft needed in 2050.[13] Note: The adoption of the April 1995 TNRCC Release Order is one of the water supply alternatives evaluated in the South Central Trans-Texas Study and meets 9,500 acft of the projected 2050 needs.

[13] If communities of Duval and Jim Wells counties switch from groundwater to surface water, the additional quantities needed in 2050 would total 95,000 acft.



TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI STUDY AREA

HDR Engineering, Inc.

MUNICIPAL AND INDUSTRIAL WATER DEMAND AND WATER SUPPLY PROJECTIONS

CHOKE CANYON/LAKE CORPUS CHRISTI RESERVOIR SYSTEM

FIGURE 2.6-1

Table 2.6-1 Projected Choke Canyon/Lake Corpus Christi Water Supplies and Municipal and Industrial Water Demands, With Conservation, Upon the CC/LCC System Trans-Texas Water Program					
	Projected Yield of CC/LCC System acft/yr[1]		Projected M&I Demands Upon CC/LCC System acft/yr[2]	Surplus or <Shortage> of Supply acft/yr[3]	
Year	1992 Release Order	1995 Release Order		1992 Release Order	1995 Release Order
1990	168,500	---	132,000	36,000	---
2000	165,500	178,500	161,000	4,500	17,500
2010	163,000	175,000	177,500	<14,500>	<2,500>
2020	160,500	172,000	195,000	<34,500>	<23,000>
2030	158,000	169,000	214,500	<56,500>	<45,500>
2040	155,500	165,500	234,000	<78,500>	<68,500>
2050	153,000	162,500	253,500	<100,500>	<91,000>

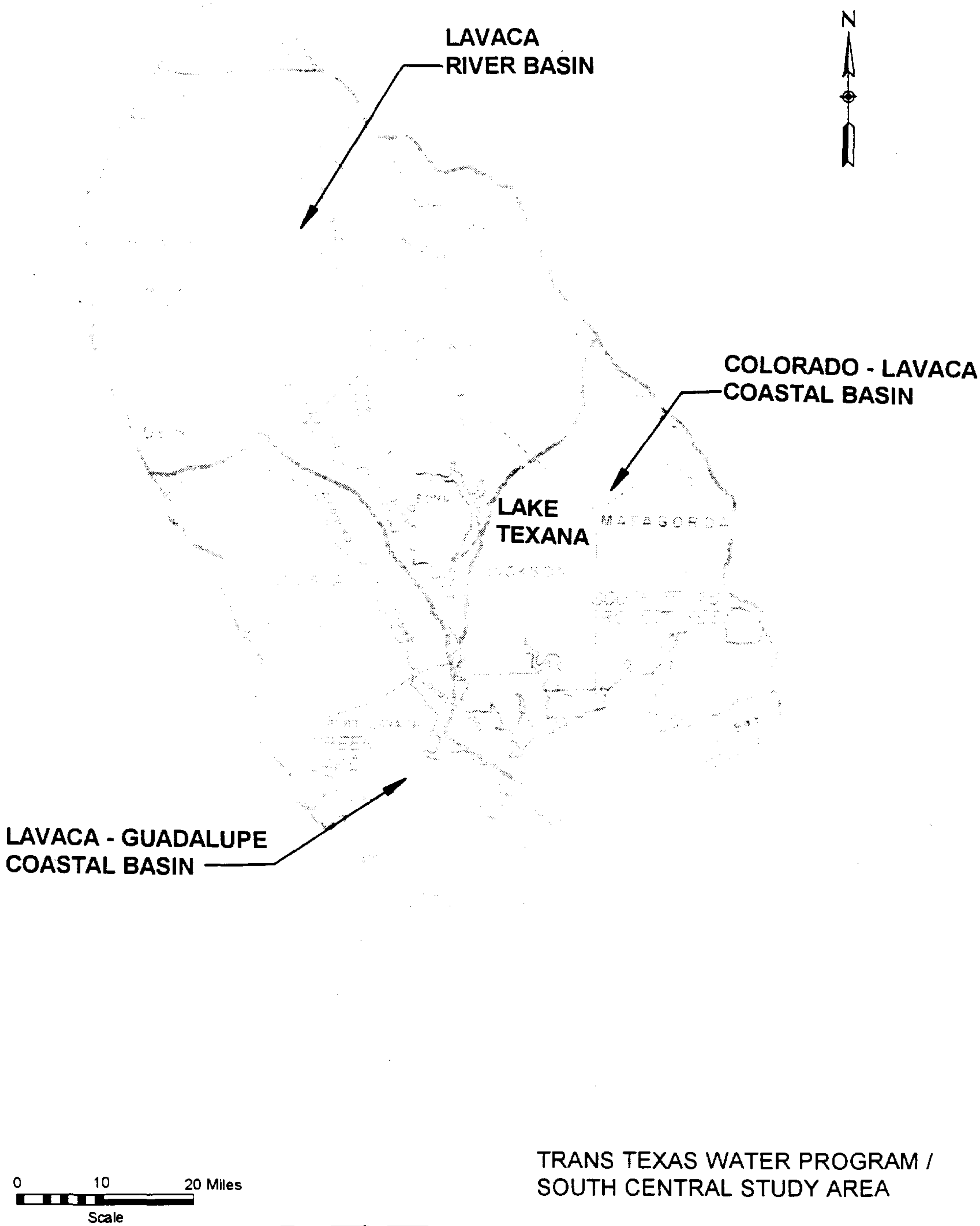
[1] Yield calculations from Table 2.5-2.
[2] Projected M&I demands from Table 2.4-3, rounded to the nearest 500 acft/yr.
[3] CC/LCC yield of column 1 minus projected M&I demands of column 2.

2.7 Population, Water Demand and Water Supply Projections for the Lavaca River Basin Water Supply Area and Adjacent Coastal Basins

Potential water supplies in the Lavaca River Basin which is outside of the South Central Study Area, are alternatives for the Corpus Christi area to meet projected shortages. See Figure 2.7-1 for definition of the area. Projections of water supply and demand in the basin of origin are made to estimate quantities of water surplus to local area needs that could potentially be transferred to Corpus Christi. In this section, projections of water demand and supply are presented for the Lavaca River Basin and adjacent Lavaca-Guadalupe Coastal and Colorado-Lavaca Coastal Basins.

2.7.1 Population Projections

In 1990, the population of the Lavaca River Basin water supply area and adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins was 106,440, with 40.9 percent in the Lavaca Basin, 22.4 percent in the Colorado-Lavaca Coastal Basin, and 36.7 percent in the Lavaca-Guadalupe Coastal Basin (Table 2.7-1). Projected year 2050 population is 169,154 with 34.6 percent in the Lavaca Basin, 22.2 percent in the Colorado-Lavaca Coastal Basin, and 43.2 percent in the Lavaca-Guadalupe Coastal Basin (Table 2.7-1 and Figure 2.7-2).



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TRANS TEXAS WATER PROGRAM /
SOUTH CENTRAL STUDY AREA

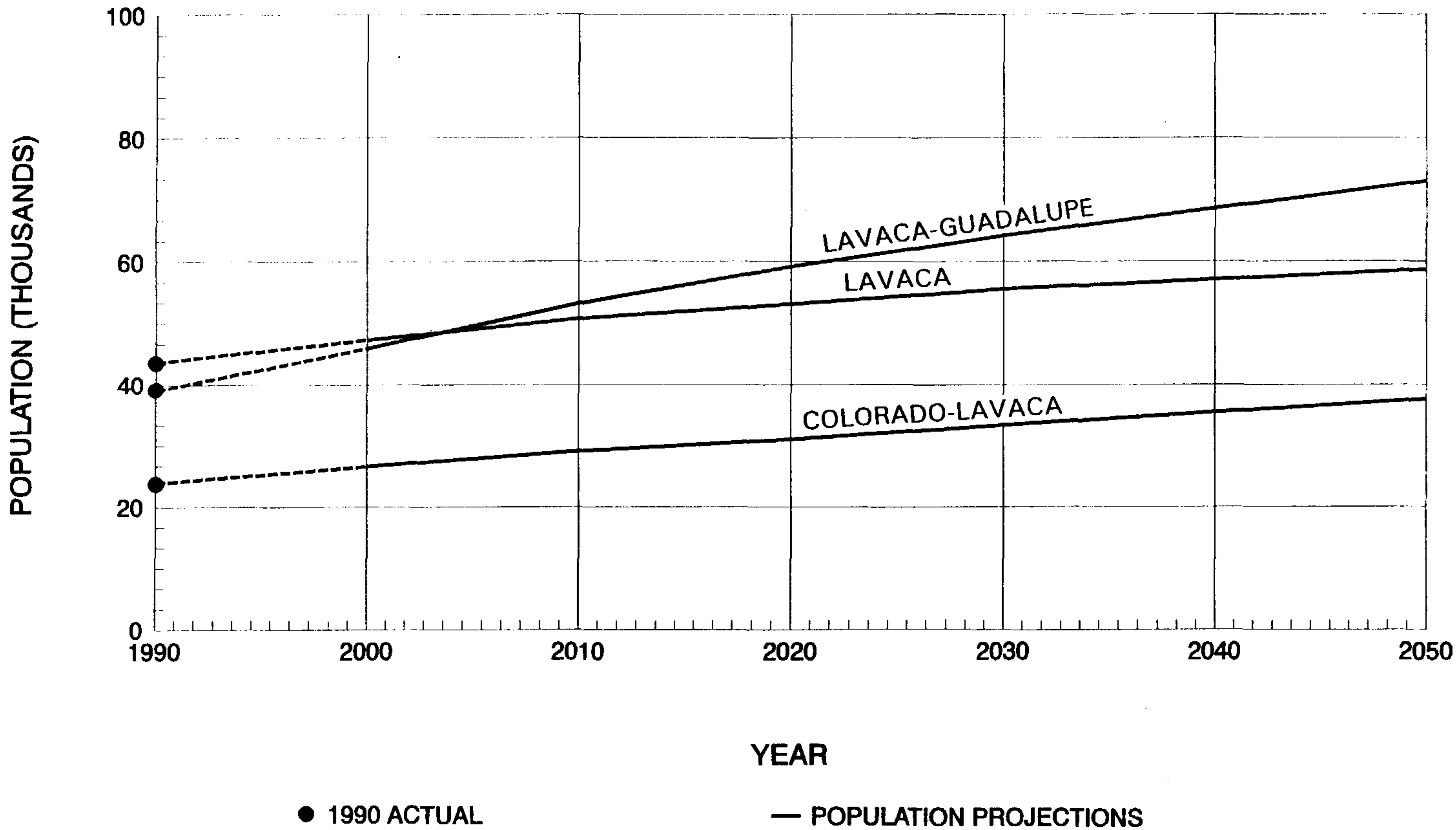
**WATER SUPPLY AREA
LAVACA RIVER BASIN AND
ADJACENT COASTAL BASINS**

FIGURE 2.7-1

Table 2.7-1
Population Projections[1] for the Water Supply Area
(Lavaca River Basin and the Adjacent
Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins)

Area	1990[2] Census	Percent of Total	Projections[3] 2000	Percent of Total	2010	Percent of Total	2020	Percent of Total	2030	Percent of Total	2040	Percent of Total	2050	Percent of Total
Lavaca	43,597	(40.9)	47,268	(39.4)	50,697	(38.1)	53,097	(37.0)	55,519	(36.3)	57,083	(35.4)	58,647	(34.6)
Colorado-Lavaca	23,838	(22.4)	26,551	(22.2)	29,019	(21.8)	31,012	(21.6)	33,292	(21.8)	35,398	(22.0)	37,504	(22.2)
Lavaca-Guadalupe	39,005	(36.7)	45,891	(38.4)	53,180	(40.1)	59,205	(41.4)	64,165	(41.9)	68,584	(42.6)	73,003	(43.2)
Total	106,440		119,710		132,896		143,314		152,976		161,065		169,154	

[1] Texas Water Development Board high case, 1992.
[2] 1990 Census, U.S. Bureau of the Census, U.S. Department of Commerce.
[3] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030-2040, April, 1992, Austin, Texas. Percentages of totals are shown in parentheses.



TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

HDR Engineering, Inc.

POPULATION PROJECTIONS FOR THE WATER SUPPLY AREA
(LAVACA RIVER BASIN AND ADJACENT COLORADO-LAVACA AND LAVACA-GUADALUPE COASTAL BASINS)

FIGURE 2.7-2

2.7.2 Water Demand Projections

Total water use for all purposes (municipal, industrial, irrigation, mining, and livestock water) in the water supply area (Lavaca River Basin and adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins) was 542,382 acft in 1990 (Table 2.7-2). Projected total water demand for all purposes in 2050 in the water supply area is 477,052 acft (Table 2.7-2 and Figure 2.7-3). Municipal and industrial water use in the water supply area was 41,967 acft in 1990, with 28.2 percent in the Lavaca River Basin, 12.9 percent in the Colorado-Lavaca Coastal Basin and 59.0 percent in the Lavaca-Guadalupe Coastal Basin (Table 2.7-3). Projected municipal and industrial water demands in the supply area in 2050 are 151,314 acft, with 42,207 acft (27.9 percent) in the Lavaca River Basin, 27,360 acft (18.1 percent) in the Colorado-Lavaca Coastal Basin, and 81,747 acft (54.1 percent) in the Lavaca-Guadalupe Coastal Basin (Table 2.7-3 and Figure 2.7-4).

2.7.3 Water Supply Projections

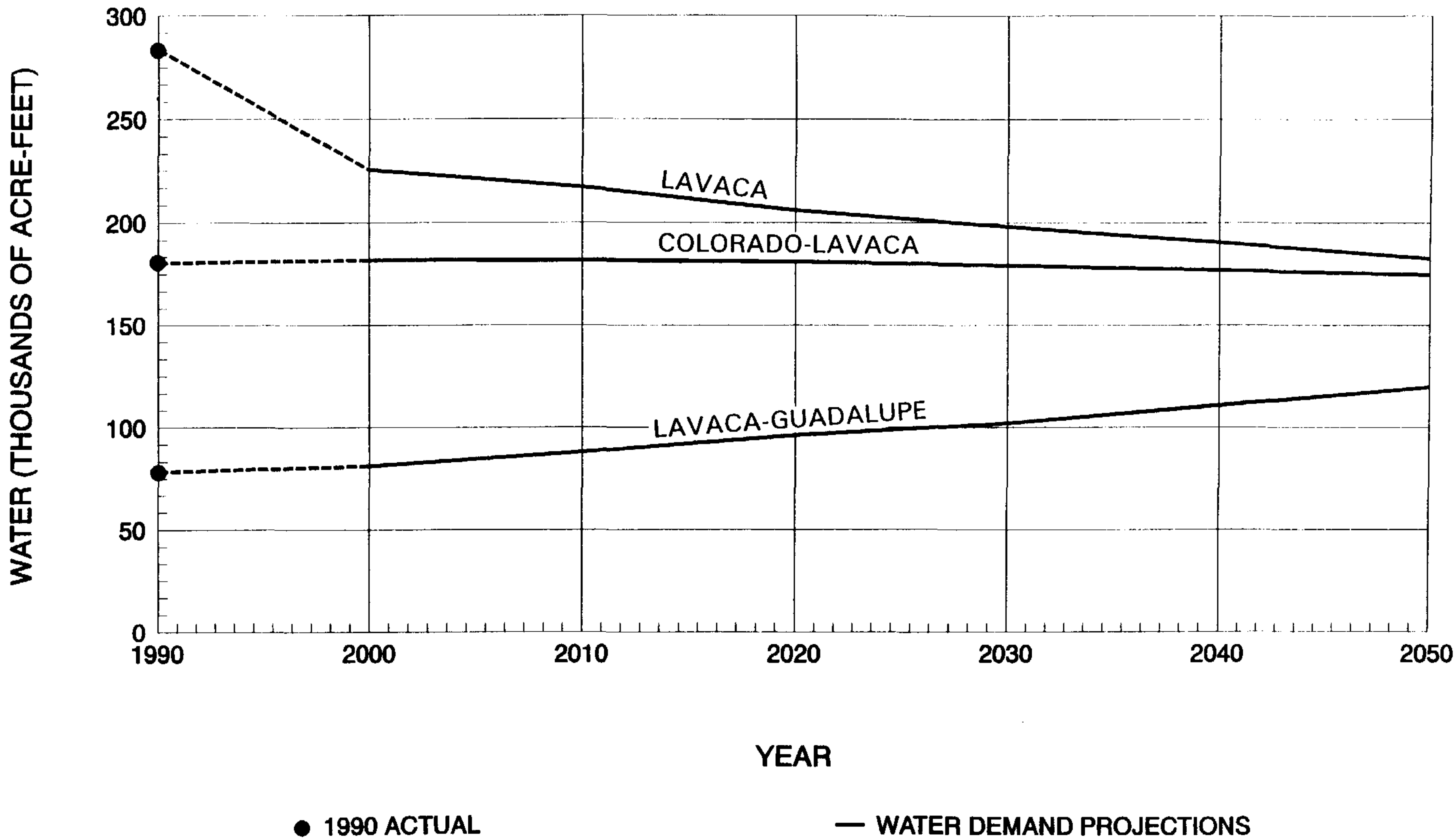
Projected total water supplies of the water supply area (Lavaca River Basin) and adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins in 2050 are 572,869 acft (Table 2.7-4), composed of 184,573 acft (32.2 percent) of in-basin groundwater, 110,166 acft (19.2 percent) of in-basin surface water and 278,130 acft (48.6 percent) of surface water imported from the neighboring Colorado and Guadalupe River Basins. The sources of water of the water supply area are described below.

The Gulf Coast Aquifer has been a major source of water for irrigation and municipal purposes, and underlies all of the water supply area except a small part of the northwestern Lavaca River Basin in Fayette and Lavaca Counties. Water for irrigation is obtained from the Aquifer from beneath the land to which it has been applied. Municipal water supplies have also been obtained from well fields located in or near the respective cities and communities of the water supply area. The TWDB projections indicate that the Gulf Coast Aquifer can continue to supply water throughout the 50 year projection period and that of the total 184,573 acft of groundwater projected to be available in 2050, 102,468 acft (55.5 percent) will be from beneath lands of the Lavaca River Basin, 57,685 acft (31.2 percent) will be from beneath lands of the Colorado-Lavaca Coastal Basin, and 24,420 acft (13.3 percent) will be from beneath lands of

Table 2.7-2
Total Water Demand Projections for Water Supply Area
(Lavaca River Basin and Adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins)

Area	1990 Use[1]	Projections[2]					
		2000	2010	2020	2030	2040	2050
Lavaca River Basin	288,114	257,492	249,127	237,997	230,234	222,448	214,662
Colorado-Lavaca Coastal Basin	175,968	149,980	149,773	149,059	147,287	145,027	142,767
Lavaca-Guadalupe Coastal Basin	78,300	81,251	88,048	96,197	102,157	110,890	119,623
Total	542,382	488,723	486,948	483,253	479,678	478,365	477,052

Source: Texas Water Development Board high case, with conservation, 1992.
[1] As reported to the Texas Water Development Board.
[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030-2040, April, 1992, Austin, Texas. Percentages of totals are shown in parentheses.
[3] New plants put into operation in 1993 with annual water use of 32,000 acft.



TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

HDR Engineering, Inc.

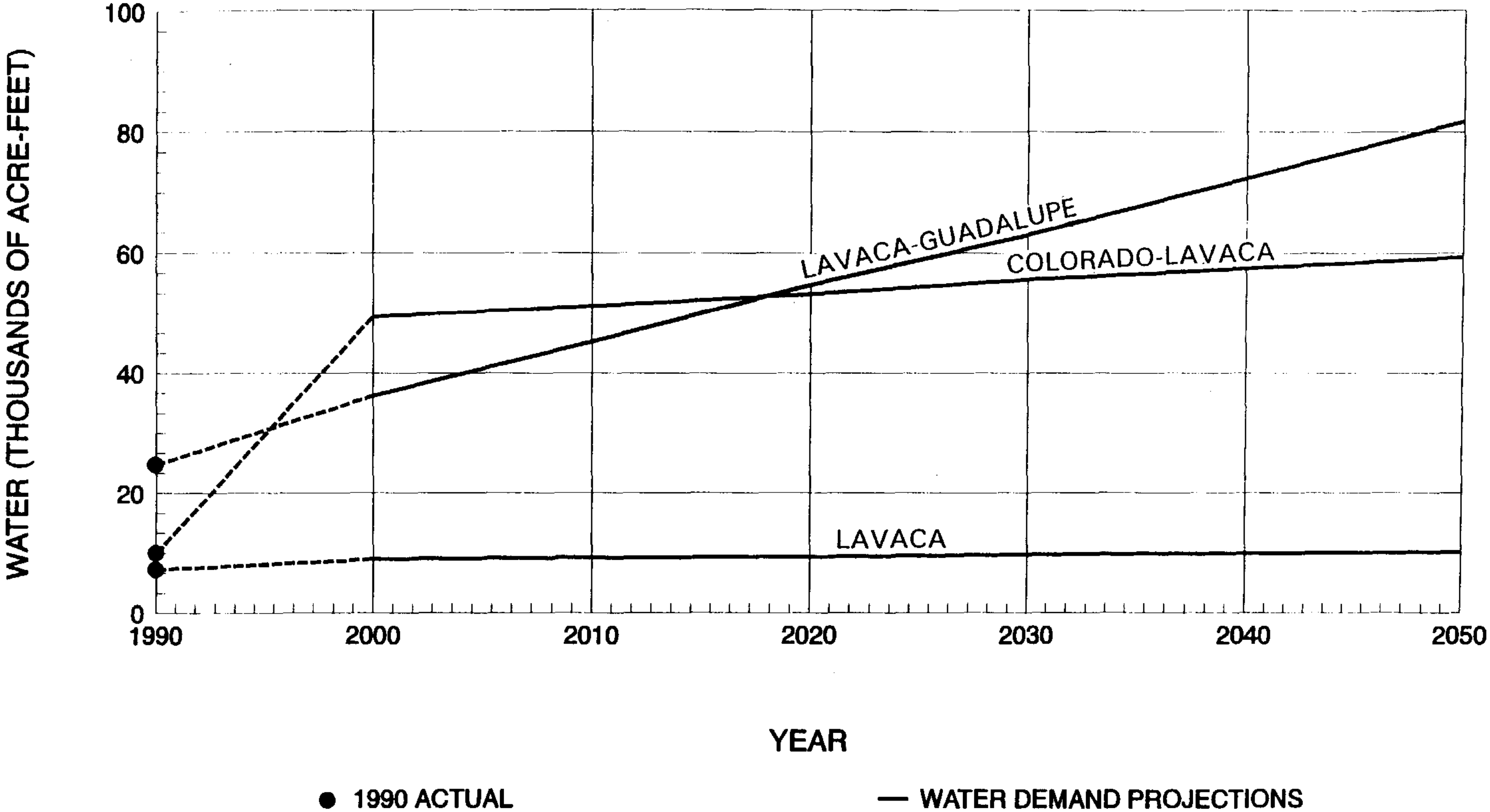
TOTAL WATER DEMAND PROJECTIONS FOR THE WATER SUPPLY AREA
(LAVACA RIVER BASIN AND ADJACENT COLORADO-LAVACA AND LAVACA-GUADALUPE COASTAL BASINS)

FIGURE 2.7-3

Table 2.7-3
Total Municipal and Industrial Water Demand Projections for the Water Supply Area (Lavaca River Basin and the Adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins)

Area	1990 Use[1]	Percent of Total	Projections in Acft[2]											
			2000	Percent of Total	2010	Percent of Total	2020	Percent of Total	2030	Percent of Total	2040	Percent of Total	2050	Percent of Total
Lavaca River Basin	11,814	(28.2)	40,988	(43.3)	41,262	(39.0)	41,364	(35.2)	41,707	(32.5)	41,957	(30.01)	42,207	(27.9)
Colorado-Lavaca Coastal Basin	5,415	(12.9)	17,367	(18.4)	19,172	(18.1)	21,212	(18.4)	23,594	(18.4)	25,477	(18.2)	27,360	(18.1)
Lavaca-Guadalupe Coastal Basin	24,738	(59.0)	36,213	(38.3)	45,232	(42.9)	54,784	(46.7)	62,993	(49.1)	72,370	(51.8)	81,747	(54.1)
Total	41,967		94,568		105,666		117,360		128,294		139,804		151,314	

Source: Texas Water Development Board high case, with conservation, 1992.
[1] As reported to the Texas Water Development Board.
[2] Texas Water Development Board, High Case for 1990 through 2040, with extrapolation to 2050 at same rate as projected for 2030-2040, April, 1992, Austin, Texas. Percentages of totals are shown in parentheses.



TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

HDR Engineering, Inc.

MUNICIPAL AND INDUSTRIAL PROJECTIONS FOR THE WATER SUPPLY AREA
(LAVACA RIVER BASIN AND ADJACENT COLORADO-LAVACA AND LAVACA-GUADALUPE COASTAL BASINS)

FIGURE 2.7-4

Table 2.7-4
Projected 2050 Water Supply of the Water Supply Area (Lavaca River Basin) and the Adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins in Acft

Area	In-Basin		Imports[1]	Total Supply
	Ground Water	Surface Water		
Lavaca River Basin	102,468	88,597[2]	119,414[3]	310,479
Colorado-Lavaca Coastal Basin	57,685	7,986	77,096[4]	142,767
Lavaca-Guadalupe Coastal Basin	24,420	13,583	81,620[5]	119,623
Total	184,573	110,166	278,130	572,869

Source: "Water for Texas, Today and Tomorrow, 1990", Texas Water Development Board, Austin, Texas, December, 1990. Projections for 2040 are extrapolated to 2050.

[1] Imports from neighboring Colorado and Guadalupe Basins.

[2] Permitted diversion of Lake Texana of 74,500 acft for municipal and industrial uses plus 14,097 acft/yr run-of-river permits for irrigation use.

[3] Calculated from Garwood Irrigation Company Certified Filing No. 398 of 124,106 acft, with estimated use in Colorado and Wharton counties in Lavaca River Basin of 96 percent.

[4] Irrigation water from the Colorado River Basin.

[5] Municipal industrial and irrigation water from the Guadalupe River Basin.

NOTE: Total permitted for these purposes is approximately 172,501 acft/yr; quantity of imports is set at quantity needed meet projected demands which exceed projected in-basin supplies.

the Lavaca-Guadalupe Coastal Basin (Table 2.7-4). In the case of groundwater, it is projected that these quantities will be available to meet local irrigation and municipal needs within the water supply area.

Surface water supplies from streams, stockwatering tanks, and Lake Texana are projected at 88,597 acft annually in 2050 (Table 2.7-4). Of this total, 74,500 acft (67.6 percent) is the annual authorized diversion of Lake Texana of the Lavaca River Basin. The Lavaca-Navidad River Authority (LNRA) and the TWDB hold the permit to Lake Texana, with the LNRA having 42.67 percent and the TWDB having 57.33 percent. The purposes for which the Lake Texana diversions are permitted are municipal use (23.76 percent) and industrial use (76.24 percent). The remainder of the surface water supply is largely run-of-river rights for irrigation of tracts adjacent to streams of the area, with 14,097 acft in the Lavaca River Basin, 7,986 acft in the Colorado-Lavaca Coastal Basin, and 13,583 acft in the Lavaca-Guadalupe Coastal Basin (Table 2.7-4). It should be noted that the sum of existing run-of-river surface water permits of the Lavaca River Basin water supply area are greater than the quantities stated above. However, many such permits are for a term of 10 years or less and thus are not included in the totals for year 2050.

Water has been and is projected to continue to be imported into the area from the neighboring Colorado and Guadalupe River Basins in accordance with permits issued by TNRCC and predecessor state regulatory agencies. Water rights permits for these purposes are among the most senior in these basins, with the Garwood Irrigation Company permit (Certificate of Adjudication No. 14-5434) being recognized a right to divert and use 168,000 acft of water annually from the Colorado River for irrigation, with a priority date of November 1, 1900. The irrigation area served by the Garwood Irrigation Company is located in Colorado County, with about 90 percent of the area being located in the Lavaca River Basin, thus its designation as water imported to the water supply area. Annual use of the Garwood Irrigation right has reached about 124,106 acft, of which about 96 percent or 119,414 acft is estimated to have been transferred for use in the Lavaca River Basin (Table 2.7-4). Since this is a senior water right of the Lower Colorado River Basin, it is assumed to be established for the long term, and therefore is included at the 119,414 acre-foot per year level as a part of the water supply of the water supply area in 2050 (Table 2.7-4).

As is the case of projected imports to the Lavaca Basin, projected imports to the Colorado-Lavaca Coastal Basin of 77,096 acft/yr in 2050 would be a continuation of long-term practice of importing water from the Lower Colorado River Basin for irrigation purposes in the Colorado-Lavaca Coastal Basin. In the case of the Lavaca-Guadalupe Coastal Basin, which includes eastern Victoria and western Calhoun Counties, both groundwater and surface water supplies are limited. In order to meet the needs of these areas, beginning in the early 1940's water rights permits were obtained from the agencies predecessor to TNRCC to import and use water from the Guadalupe River Basin for municipal, industrial, and irrigation purposes. The total of these run-of-river permits in 1990 for use in Calhoun County in the Lavaca-Guadalupe

Coastal Basin exceeded 225,000 acft.[14] Thus, the projected 2050 supply of import water for the Lavaca-Guadalupe Coastal Basin from the Guadalupe River Basin is set at 81,620 acft, or the quantity that is projected to be needed to meet the 2050 projected demands of the Lavaca-Guadalupe Coastal Basin that cannot be met from in-basin supplies of groundwater and surface water (projected 2050 water demands are shown in Table 2.7-2).

2.7.4 Water Demand and Supply Comparisons

Projected 2050 water demands of the water supply area (Lavaca River Basin) and adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins are 477,052 acft, of which 151,314 acft are for municipal and industrial purposes (Table 2.7-5). Projected year 2050 water supplies of the area are 572,869 acft, of which 184,573 acft are from in-basin groundwater sources, 110,166 acft are from in-basin surface water sources, and 278,130 acft are imported from the neighboring Colorado and Guadalupe River Basins (Tables 2.7-4 and 2.7-5). The projected water supplies exceed projected water demands in year 2050, resulting in a projected surplus of 95,817 acft/yr at that time (Table 2.7-5).

[14] Files of the Texas Natural Resource Conservation Commission, Austin, Texas, 1990.

Table 2.7-5
Projected 2050 Water Demand and Supply Comparisons for the Water Supply Area (Lavaca River Basin and Adjacent Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins)

Area	Projected Water Demand in 2050 (acft)	Projected Water Supply in 2050 (acft)[3]	Projected Surplus in 2050 (acft)
Total Demand[1]			
Lavaca River Basin	214,662	310,479[4]	95,817
Colorado-Lavaca Coastal Basin	142,767	142,767[4]	0
Lavaca-Guadalupe Coastal Basin	119,623	119,623	0
Total	477,052	572,869[3]	95,817
Municipal & Industrial Demand[2]			
Lavaca River Basin	10,207	N/A[4]	N/A
Colorado-Lavaca Coastal Basin	59,360	N/A[4]	N/A
Lavaca-Guadalupe Coastal Basin	81,747	N/A	N/A
Total	151,314	N/A[3]	N/A

[1] See Table 2.7-2.
[2] See Table 2.7-3.
[3] See Table 2.7-4.
[4] Not applicable.

3.0 IDENTIFICATION OF BASIC WATER SUPPLY ALTERNATIVES

The purposes of this section are to: 1) Identify and describe water supply alternatives to meet the projected water needs of the CC/LCC Service area during the 50-year planning period; and 2) Present cost estimates and identify environmental and implementation issues of each alternative. The supply alternatives are listed below, and a brief description is given of methods used in making cost estimates.

Water Supply Options for the Corpus Christi Area

The following water supply options were studied:

1. Modify Existing Reservoir Operating Policy (N-1);
2. Diversion from Nueces River to Choke Canyon Reservoir (N-2);
3. R&M Reservoir (N-3);
4. Purchase of Existing Water Rights in Nueces Basin (N-4);
5. Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5);
6. Pipeline from Lake Corpus Christi to Calallen Dam (N-6);
7. Industrial Water Use (L-5);
8. Desalination of Seawater (L-1);
9. Local Groundwater - Gulf Coast Aquifer (L-2);
10. Use of Groundwater from Campbellton Wells - Carrizo Aquifer (L-3);
11. Municipal Wastewater Reuse (L-4);
12. Goliad Reservoir (S-1);
13. Diversion from the Guadalupe and San Antonio Rivers (with and without McFaddin Reservoir) (GS-1);
14. Lake Texana Pipeline to Corpus Christi (LN-1);
15. Palmetto Bend (Stage II) Reservoir (LN-2);
16. Diversion from Lavaca River to Lake Texana (LN-3);

17. Purchase and Diversion of Garwood Water Rights to Corpus Christi through Lake Texana (C-1);

18. Accelerated and Additional Municipal Water Conservation (L-6);

19. Groundwater Recharge and Recovery (Carrizo/Wilcox Aquifer) (L-7);

20. Dredging of Lake Corpus Christi (N-7);

21. Purchase of Colorado River Water (C-2); and

22. Purchase of Brazos River Water (B-3).

3.0.1 Cost Estimating Procedures

Introduction

This study includes preparation of construction cost estimates, total project cost estimates, and estimates of operation and maintenance costs for a variety of project elements. Major structural and non-structural cost elements included in the estimates are listed below:

Structural Costs		Non-Structural Costs	
1.	Dams, reservoirs, & appurtenances	1.	Engineering - Design, Bidding and Construction Phase Services, Geotechnical, and Surveying
2.	Pump stations	2.	Legal Services
3.	Pipelines	3.	Contingencies
4.	Relocations	4.	Permits
5.	Water Wells	5.	Environmental - Studies & Mitigation
6.	Recharge Injection Wells	6.	Archaeology - Studies & Mitigation
		7.	Interest During Construction
		8.	Operations and Maintenance
		9.	Land and Rights-of-Way
		10.	Financing

The methods used in estimating costs are as follows:

Structural Costs

1. Dams, reservoirs, and appurtenances. The construction costs for these projects were handled individually. Since each reservoir site is unique, costs were based on the specific requirements of the project for the site. Items included in the estimate consisted of the construction cost and the non-structural costs listed above. Most reservoirs in the Trans-Texas program have been studied in the past and previous cost estimates were

updated to mid-1995 prices, using either the U.S. Bureau of Reclamation Construction Cost Indexes or the ENR Construction Cost Indexes.

2. Pump Stations. Pump stations vary in cost according to the discharge and pumping head requirements and structure requirements for housing the equipment and providing proper flow conditions to the pump suction intake. The costs of pumps, motors, and electrical controls were estimated using a generalized cost data related to station horsepower derived from actual construction costs of equipment previously installed, escalated to mid-1995 prices.

3. Pipeline. Pipeline construction costs are influenced by pipe materials, bedding requirements, geologic conditions, urbanization, terrain, and special crossings. Most pipelines in the present study areas will be constructed in rural areas with subsurface material consisting of soil (non-rock). Table 3.0-1 includes estimated base pipeline costs per foot for pipeline sizes ranging from 18-inch to 120-inch diameter. The table includes costs based on soil construction (without rock) and rural environment. The costs shown represent the minimum cost range for pipelines. Costs for specific applications are estimated by adding the increased cost of installation to the cost per foot shown in the table to compensate for geologic conditions such as rock and urbanization. Both of these items will also increase the time for construction. The cost estimates pertain to installed cost of pipeline and appurtenances, such as markers, valves, thrust restraint system, corrosion monitoring and control equipment, air and vacuum control valves, blow-off valves, revegetation, rights-of-way, fencing, and gates. Costs of special crossings such as railroads, highways, and rivers were estimated on an individual basis.

4. Relocations. Costs to relocate oil wells, utilities, roads, and structures that would be affected by reservoir construction were estimated on a site-specific basis, usually by updating previous studies. In the case that previous studies did not exist or were inadequate, additional estimating work was performed as described in the engineering and cost section for the specific alternative.

5. Water Wells and Recharge Injection Wells. The cost of wells in the Carrizo-Wilcox aquifer were obtained from the report "Phase I Evaluation, Carrizo-Wilcox Aquifer, West Central Study Area, Trans-Texas Water Program", LBG-Guyton Associates, December, 1993. The cost is based on these conditions: (a) a standard 16 x 10-inch underreamed, 30-inch gravel-wall well; (b) well depth is approximately 1,20 ft with 400 ft of stainless steel screen; (c) the pump is a 250-horsepower electric turbine pump; (d) pumping levels would be approximately 400 ft below land surface at the end of 50 years of operation; and (e) well capacity is 1,000 to 1,500 gallons per minute (1,600 to 2,400 acft/yr). The estimated mid-1995 construction cost for the well, pump, motor, site improvements, and one mile of access road is about $575,000 per well.

Table 3.0-1 Pipeline Costs	
Size (inches)	Base Pipeline Cost[1] including Appurtenances ($/LF)
18	35
24	42
30	54
36	73
42	88
48	101
54	117
60	134
66	166
72	199
78	218
84	234
90	246
96	290
102	333
108	376
120	474

[1] Base pipeline cost is for low pressure pipe installed in a soil trench, rural environment. For other conditions (i.e., rock trench, medium or high pressure pipe class, and urban environment) costs were determined for the increased material and installation components, resulting in a cost factor multiplier to be applied to the base pipeline cost. Cost factors ranged from 1.0 to 2.25. Base pipeline costs obtained from Trans-Texas Corpus Christi Service Area Phase I Report, inflated to mid-1995. ENR CCI = 5489.

Construction Cost Indices

Updates of previous cost estimates to mid-1995 price levels and trending of unit costs were preformed using an ENR Construction Cost Index (CCI) of 5489 or a USBR Composite CCI of 209.

Non-Structural Costs

The costs for engineering, administration, legal, environment, land, O&M and interest during construction must be added to the construction costs to obtain the project capital cost. The following guides were used for estimating the costs of non-structural items and are common to all alternatives:

1. Engineering, contingencies, financial and legal services were lumped together and estimated as 30% of total construction costs for pipelines and 35% for all other facilities. Construction costs include only the cost of building the project facilities and any relocations requiring construction contracts including labor and materials. Costs for land and rights-of-way, permits, environmental and archaeological studies, and mitigation were estimated separately.

2. Land costs vary significantly with location and economic factors. Land costs for reservoirs and canals were estimated by using appropriate costs per acre as obtained from local appraisal districts and include costs for legal services, sales commissions, and surveys in the cost per acre used.

3. Land costs for pipelines include a permanent easement plus a temporary construction easement plus rights to enter the easement for maintenance and repairs. For estimating pipeline right-of-way cost, the cost was the full land value per acre based on purchase of the land as determined from discussions with the local appraisal districts plus legal, sales, and surveying costs. This full value was applied to a 40-foot permanent easement width for the length of the pipeline. This cost covers the cost of the permanent and temporary easement.

4. Permits, environmental studies and mitigation, and archaeological studies and mitigation costs were estimated on an individual project basis utilizing information available and judgement of qualified professionals. In the case of reservoir projects, the mitigation costs are based on acreages of inundation times the cost per acre to purchase an equal land area.

5. Debt service and interest during construction. Debt service for all projects was calculated assuming an interest rate of 8% for 25 years (i.e., debt service factor of 0.0937) applied to total estimated project costs including interest during construction. Interest during construction was calculated assuming the total estimated project cost (excluding interest during construction) will be drawn down at a constant rate per month during the construction period. Interest during construction is the total of interest accrued at the end of the construction period using an 8 percent annual interest rate less 4 percent for investment of available funds. Interest during construction was calculated as the average project cost for the construction period times the net annual interest rate of 4 percent times the number of years required to construct the facilities.

6. Operations and maintenance costs (O&M) (not including power costs for pumping). Annual O&M costs were calculated as 1.0 percent of the total estimated construction cost for pipelines, as 2.5 percent of total estimated construction costs for pump stations, and as 1.5 percent of total estimated construction costs for dams. These costs include labor and materials required to maintain the project and regular replacement of equipment. In addition to these costs, power costs were calculated on an annual basis using calculated horsepower

input and applicable existing local power rates obtained from individual power companies.

7. Presentation of Estimates.. Cost estimates were prepared to show annual total cost and annual cost per acft of water supplied by each alternative.

3.0.2 Environmental Overview

Introduction

This section presents methods used to perform the environmental evaluations, general descriptions of characteristics of the 12 county study area and potential interbasin supply areas, and comparisons of the potential environmental effects and mitigation associated with the various water supply alternatives. Additional information and environmental impacts specific to the alternatives are discussed in the separate alternative sections.

General Methods

The need for environmental studies and mitigation activities as part of the alternatives analysis results from the need to obtain state and federal permits. With respect to most of the alternatives considered here, the regulations that will drive environmental compliance standards include the Clean Water Act (33 USC 1344), the Rivers and Harbors Act of 1899 (33 USC 403), the Endangered Species Act (16 USC 1531 et seq), and portions of the Texas Water Code involving water rights permits (TAC chapters 281, 287, 295, 297, 299). Section 404 of the Clean Water Act prohibits the discharge of dredged or fill material into the waters of the United States, including adjacent wetlands, while Section 10 of the Rivers and Harbors Act regulates structural alterations in the navigable waters of the United States. Both regulations are administered by the U.S. Army Corps of Engineers, although the U.S. Environmental Protection Agency can exercise a veto over Section 404 permits. It is expected that all impacts will be mitigated by 1) avoiding the impact, 2) minimizing the impact, and 3) compensating for unavoidable impacts.

Cultural resources protection on public lands in Texas, or lands affected by projects regulated under Department of the Army permits, is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

Land uses, habitat types and values, and wetland occurrences have been identified and evaluated using available literature and a variety of other sources, including the Texas Parks and Wildlife Department, Resource Protection Division's Texas Natural Heritage Program data and mapping files for endangered, protected and sensitive resources, the U.S. Fish and Wildlife Service' National Wetland Inventory (NWI) maps and U.S. Geological Survey (USGS) EROS Data Center black and white and infrared photographs. A records search for cultural resources using existing data of reported cultural resources identified from Texas Archaeological Research Laboratory (TARL) files was performed. This data base, including archaeological sites of record, natural resources, protected species, and potential wetland areas is on 7.5 minute quadrangles maintained at Paul Price Associates, Inc.

Field reconnaissance included in the Trans Texas Phase II scope was performed for several Nueces basin alternatives including N-1, N-2, N-3, L-3, C-1, C-2 and B-3 (see page 3-1 for list of alternatives). Several of the alternatives are dependent on LN-1 including C-1, C-2 and B-3, or would potentially use part of this pipeline route (L-2, S-1, GS-1). A pedestrian survey of selected sites was conducted for the proposed pipeline route from Lake Texana to the O.N. Stevens Water Treatment Plant (LN-1).

The water supply alternatives have been mapped onto the comprehensive environmental data base described above. The proposed construction activities and locations, together with each alternative's operational characteristics were then evaluated with respect to mapped regional environmental resources in order to identify the potential effects of each alternative. Special attention was given to construction activities in or adjacent to ecologically sensitive areas, and to operational characteristics that might result in changes in stream hydrology, bays and estuary inflow regimes, and the distribution and abundance of protected species.

Environmental Setting

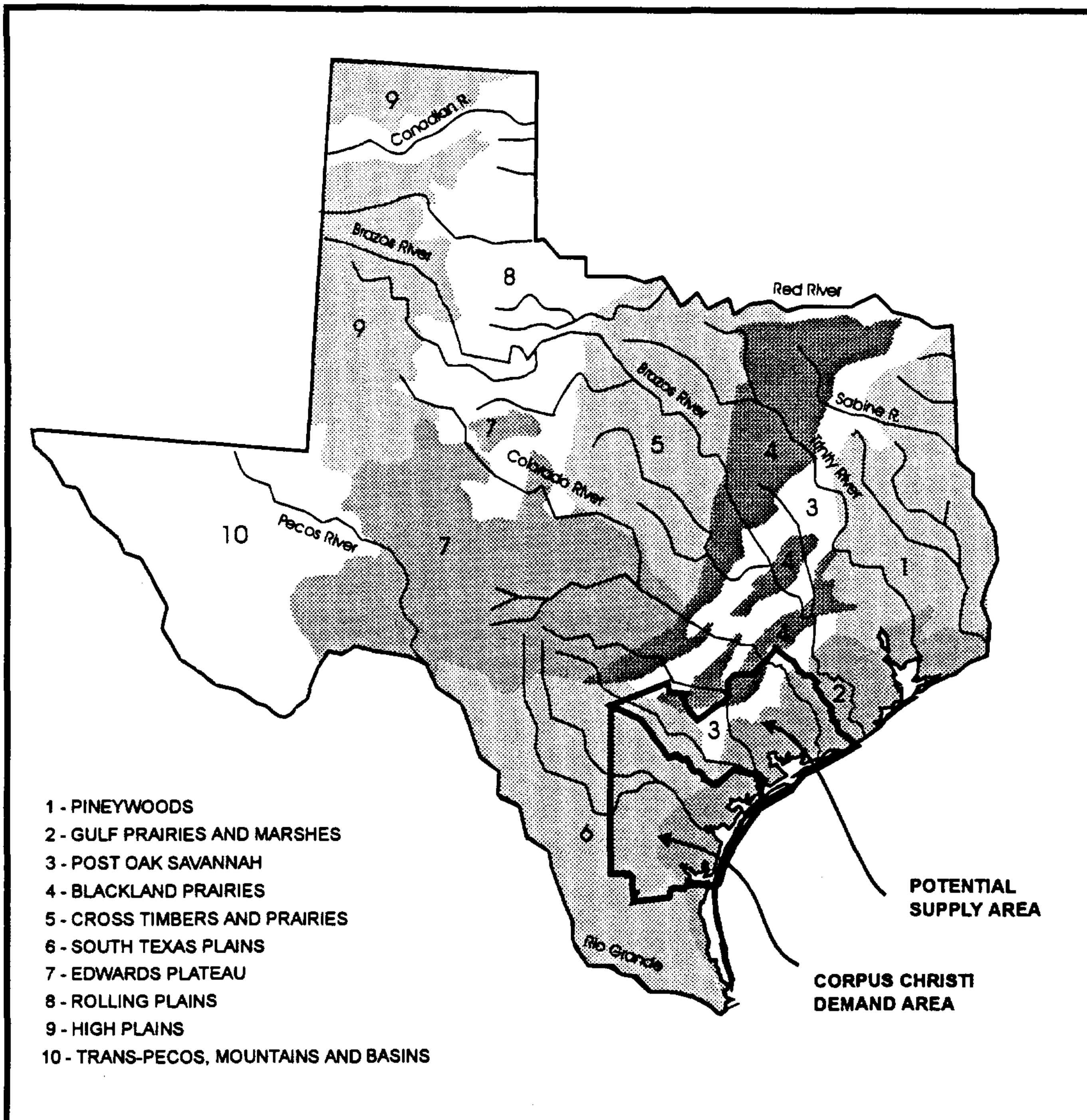
Study Area

Climate and Economy

The study area includes the six counties of Atascosa, Bee, Brooks, Duval, Live Oak and McMullen which lie within a vegetational region termed the South Texas Plains, the four coastal counties of Refugio, San Patricio, Nueces, and Kleberg which are in the Gulf Prairies and Marshes vegetational region, and Jim Wells and Kleberg Counties which are divided by the South Texas Plains to the west and the Gulf Prairies and Marshes to the east (Figure 3.0-1). Winters throughout the region are mild with growing seasons ranging from 282 days for Atascosa County to 314 days for Kleberg County. Average temperatures are higher and the growing seasons are longer for the coastal counties and there is a southerly increasing trend in these factors. The interior counties generally have sunny dry winters, whereas sunny days tend to alternate with cloudy days nearer to the coast. Summers are hot throughout the region and tend to be more humid in the coastal counties. Annual rainfall averages 24.4 inches for McMullen County and 38.8 inches for Refugio County. Generally rainfall is greater in the coastal counties and increases toward the north and east. Most of the rainfall in the interior counties comes in the form of thundershowers during the spring and summer months. The low rainfall inland and the disproportionate contribution made by periodic thunderstorms to total rainfall heavily influence the function of the Nueces River Basin and Estuary.

The terrain in Aransas, Kleberg, Nueces, Refugio and San Patricio counties, which are in a coastal plain broken by streams and bays, is low (a maximum of 150 feet above sea level) and there is little topographical relief. The inland counties are characterized by brushy plains which in the case of Atascosa, McMullen and Live Oak Counties are broken up by the Nueces River and its tributaries. Major tributaries of the Nueces River include the Atascosa and Frio Rivers.

Oil and gas production are important throughout the region. The petrochemical industry is especially important to the economies of Nueces and San Patrico Counties. Agribusiness, including cattle ranching, is important in the region and tourism contributes significantly to the economies of the coastal communities.



Map Source: After Gould, 1962.

200 MILES
300 KILOMETERS

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TRANS TEXAS WATER PROGRAM/
CORPUS CHRISTI STUDY AREA

VEGETATIONAL AREAS OF TEXAS

FIGURE 3.0-1

The City of Corpus Christi and the surrounding metropolitan area represent substantial urban and industrial development adjacent to Nueces Estuary. According to the 1990 census Nueces County (Corpus Christi) had a population of 291,145 (Table 2.1-1A). The population of Nueces County is projected to reach 565,249 by the year 2050 (Table 2.1-1B). San Patricio County, on the north side of the Nueces River and Estuary, had a 1990 population of 58,749 and is expected to grow to 115,626 by the year 2050. Municipal and industrial water needs are supplied primarily by the Choke Canyon Reservoir - Lake Corpus Christi System (CC/LCC System).

Nueces River Basin

The Nueces River headwaters are in northwestern Real County on the Edwards Plateau at an elevation of about 2,400 feet above sea level and the river has a length of about 446 miles. The principal tributaries of the Nueces River are the West Nueces River, entering from the west near the Balcones Escarpment, Elm Creek entering from the west 3 miles south of Crystal City, and the Frio River entering from the North near Three Rivers. In terms of environmental issues, the Nueces River Basin area of greatest concern, with respect to the study area and alternatives considered herein, includes that part of the basin primarily within Atascosa, McMullen, Live Oak and Nueces Counties. This includes Choke Canyon Reservoir on the Frio River, the Frio River downstream of Choke Canyon Reservoir, and the Nueces River downstream of the "braided reach" including Lake Corpus Christi which is formed by Wesley Seale Dam. Descriptions of the Nueces River Basin including the reservoirs was presented in a report published by the Bureau of Reclamation.[1]

Although the extensive brushland of the Nueces basin represents considerable wildlife habitat, the riparian woodlands are most important in terms of plant and animal biomass.[2] The deeper, well-watered soils in the riparian areas serve to increase plant biomass production and support plant species not found in the dry, thinner soils of the upland areas. Because of the meandering nature of the river, riparian woodlands provide considerable edge or ecotonal

[1] Bureau of Reclamation. 1983. Nueces River Basin. U.S. Department of the Interior. Amarillo, Texas.

[2] Ibid.

(transitional) habitats which enhance wildlife productivity. In arid areas like the South Texas Plain, large trees tend to be restricted to riparian areas. These provide resting and feeding areas for migratory woodland birds such as warblers, vireos and woodpeckers.

Although 95% of the Nueces River Basin watershed is considered to be white-tailed deer (*Odocoileus virginianus*) habitat, riparian woodlands are especially important to deer as a source of cover as well as food in the form of mast.[3] Riparian habitats may be critically important to deer during prolonged droughts when herbaceous food plants may be found in abundance only in these areas.

Nueces River Basin water is impounded at Choke Canyon and Lake Corpus Christi reservoirs to supply users in Corpus Christi and surrounding counties. At Calallen, Nueces River flows are diverted from the freshwater pool behind the Calallen Diversion Dam. Below the dam approximately 13 miles of the Nueces River is tidally influenced. Historically, the Nueces River flowed directly into Nueces Bay, however, today, except during floods and salinity maintenance releases, the water is used for municipal and industrial purposes and then returned as treated wastewater. Treated wastewater, which is now approximately half of the inflow to the bay, flows into the estuary at various locations.[4]

The Nueces River Delta includes a system of tidal lakes and fresh to brackish marshes totaling approximately 9,500 acres.[5] Nueces River delta marshes support mixed associations of saltwort (*Batis maritima*), glasswort (*Salicornia* spp.), sea oxeye daisy (*Borrichia frutescens*), smooth cordgrass (*Spartina alterniflora*), salt flat grass, (*Monanthochloe litterolis*), *Iva* sp., gulf cordgrass (*S. spartinae*), saltgrass (*Distichlia spicta*) and locally near ponds and flats, saltmarsh bullrush (*Scirpus maritimus*). Frequently flooded saltwater marshes near the shore tend to be dominated by *S. alterniflora*, *Salicornia* spp. *B. maritima* and *B. frutescens*. Higher, less frequently flooded marshes typically are dominated by *M. littoralis*, *D. spicata* and *S. spartinae*. Oligohaline, brackish conditions farther inland and upriver support common reed *Phragmites*

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[3] Ibid.

[4] TWC. 1991. Choke Canyon/Lake Corpus Christi Technical Advisory Commission - Final Report. August 16, 1991.

[5] Ibid.

australis, cattail (*Typha* sp.), sea myrtle (*Baccharis halimifolia*), *S. spartinae* and marshhay cordgrass in low-lying areas.

Nueces Bay and Estuary

Nueces Bay is a secondary bay in the Nueces Estuary and is located north of Corpus Christi, Texas. In addition to Nueces Bay, Nueces Estuary includes Oso Bay and Corpus Christi Bay which is the largest bay in the estuary. The brackish aquatic systems of the lower Nueces River and Nueces Bay and Estuary have been described.[6] Additional information regarding the geology, hydrography, water quality, nutrient exchange characteristics, and species diversity of Nueces Estuary have been reported previously.[7,8,9,10,11,12,13,14,15,16,17]

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[6] TWC. 1991. Choke Canyon/Lake Corpus Christi Technical Advisory Commission - Final Report. August 16, 1991.

[7] HDR Engineering, Inc. 1980. Studies of Freshwater Needs of Fish and Wildlife Resources in Nueces-Corpus Christi Bay Area, Texas. Phase 4 Report. Presented to the United State Fish and Wildlife Service, August, 1980.

[8] HDR Engineering, Inc. 1993. Regional Wastewater Planning Study - Phase II. Nueces Estuary.

[9] Amos, A.F. 1989. Nitrogen Processes Study (NIPS): Analysis and Synthesis of Data Collected in Nueces/Corpus Christi and San Antonio Bays, Texas, Component 9: Hydrography, Part 1: Methods, Analysis and Discussion. University of Texas Marine Science Institute Technical Report No. TR/89-012.

[10] Fesenmaire, D.R., S. Um, W.S. Roehl, A.S. Mills, T. Ozuna, Jr., L.L. Jones and R. Guajardo. 1987. Nueces and Mission-Aransas Estuary: Economic Impact of Recreational Activity and Commercial Fishing. Report to Texas Water Development Board, by Department of Recreation and Parks, and Department of Agricultural Economics, Texas Agricultural Experiment Station, Texas A&M University System.

[11] Holland, J.S., N.J. Maciolek, R.D. Kalke and C.H. Oppenheimer. 1975. A Benthos and Plankton Study of the Corpus Christi, Copano and Aransas Bay Systems. Report on data collected during the period July 1974-May 1975 and summary of the three-year project: The University of Texas at Port Aransas Marine Science Institute, final report to the Texas Water Development Board.

[12] Jinnette, T.S. 1976. Certain Aspects of Thermal Stratification in Nueces Bay, Texas. Central Power and Light Report to EPA.

[13] Montagna, P.A. and R.D. Kalke. 1989. The Effect of Freshwater Inflow on Meiofaunal and Macrofaunal Populations in San Antonio, Nueces and Corpus Christi Bays, Texas. Report to Texas Water Development Board, by Marine Science Institute, University of Texas at Austin, Port Aransas, Texas.

[14] Morton, R.A. and J.G. Paine. 1984. Historical Shoreline Changes in Corpus Christi, Oso, and Nueces Bays, Texas Gulf Coast. The University of Texas, Bureau of Economic Geology. Austin, Texas. Geological Circular 84-6.

Nueces Estuary is a semiarid estuary commonly subjected to substantial variation in environmental conditions.[18] Nueces Bay receives 28 to 30 inches of rain annually, however, with an annual evaporation of 35 to 45 inches. Average annual freshwater inflow to Nueces Estuary is 491,200 acft/yr based on the 1934-1989 period of record. Median annual freshwater inflow to Nueces Estuary is 300,000 acft/yr based on the 1934-1989 period. The Nueces River is the primary source of inflows to Nueces Bay. Annual median flow of the Nueces River is 266,700 acft/yr at Calallen. Hondo Creek and other small tributaries also contribute to Nueces Estuary inflows.

Biogeography

Approximately two-thirds (4.4 million acres) of the 12 county study area lies within the South Texas Plains Vegetational Area while the remaining third (2.7 million acres) lies within the Gulf Prairies and Marshes Vegetational Area (Figure 3.0-1). The South Texas Plains are also termed the Rio Grande Plains, or Tamaulipan Brushlands.[19] The South Texas Plains Vegetational Area and the Gulf Prairies and Marshes Vegetational Area correspond with the Southern Texas Plains Ecoregion[20] and the Western Gulf Coastal Plain Ecoregion[21] respectively (Figure (3.0-2). The topography is level to rolling, and the land is dissected by

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[15] Stockwell, D.A. 1989. Nitrogen Processes Study (NIPS): Effects of Freshwater Inflow on the Primary Production of a Texas Coastal Bay System. University of Texas Marine Science Institute Technical Report No. TR/19-010.

[16] TDWR. 1981. Nueces and Mission-Aransas Estuaries: A Study of the Influence of Freshwater Inflows. LP-108. Austin, Texas.

[17] Whitledge, T.E. 1989. Nitrogen Processes Study (NIPS): Nutrient Distributions and Dynamics in Lavaca, San Antonio and Nueces/Corpus Christi Bays in Relation to Freshwater Inflow, Part I: Results and Discussion. University of Texas Marine Science Institute Technical Report No. TR/89-007.

[18] Ibid.

[19] Correll, D. S. and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. The University of Texas at Dallas.

[20] Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1):pp. 118-125.

[21] Ibid.

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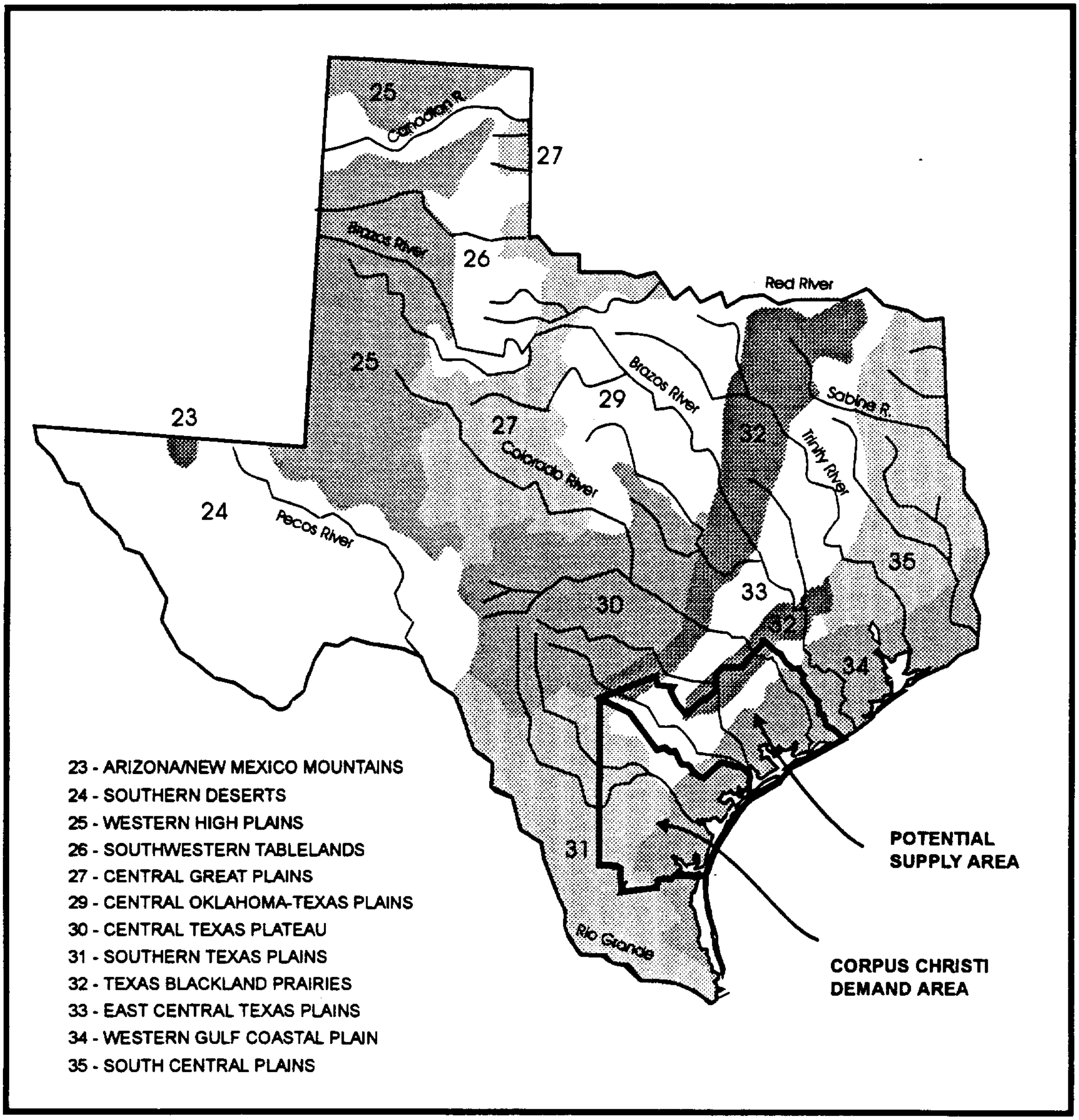

Map Source: After Omernik, 1986

200 MILES
300 KILOMETERS
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ECOREGIONS OF TEXAS

FIGURE 3.0-2

arroyos or by streams flowing into the Rio Grande and Gulf of Mexico. It is characterized by open prairies and a growth of mesquite (*Prosopis glandulosa*), grangeno (*Celtis pallida*), cacti, clepe (*Ziziphus obtusifolia*), coyotillo (*Karwinskia Humboldtiana*), guayacan (*Porlieria angustifolia*), white brush (*Aloysia gratissima*), brasil (*Condalia Hookeri*), bisbirinda (*Castela texana*), cenizo (*Leucophyllum* spp.), huisache (*Acacia Farnesiana*), catclaw (*A. greggii*), black brush (*A. rigidula*), guajillo (*A. Berlandieri*) and other small trees and shrubs which are found in varying degrees of abundance and composition.[22] Although historically the area was grassland or savanna type climax vegetation, long-continued heavy grazing and other factors have resulted in a general change to a cover of shrubs and low trees. Among the several species of shrubs and trees that have made dramatic increases are mesquite, live oak (*Quercus virginiana*), post oak (*Q. stellata*), *Opuntia* spp. and *Acacia* spp.[23] The South Texas Plains corresponds geographically with Blair's[24] Tamaulipan Biotic Province (Figure 3.0-3). He described the Tamaulipan province of Texas as being characterized by predominantly thorny brush vegetation. This brushland stretches from the Balcones fault line southward into Mexico. A few species of plants account for the bulk of the brush vegetation and give it a characteristic aspect throughout the Tamaulipan Biotic Province of Texas. The most important of these include: mesquite, lignum vitae (*Porliera angustifolia*), cenizo (*L. texanum*), white brush (*A. gratissima*), prickly pear (*O. lindheimeri*), tasajillo (*O. leptocaulis*), and *Condalia* sp. and *Castela* sp. The brush on sandy soils differs in species and aspect from that on clay soils. Mesquite, in an open stand and mixed with various grasses, is characteristic of sandy areas. Clay soils usually have all of the species listed above, including mesquite. Although rangeland predominates throughout the South Texas Plains/Tamaulipan Brushland, land use also includes significant acreages in croplands.

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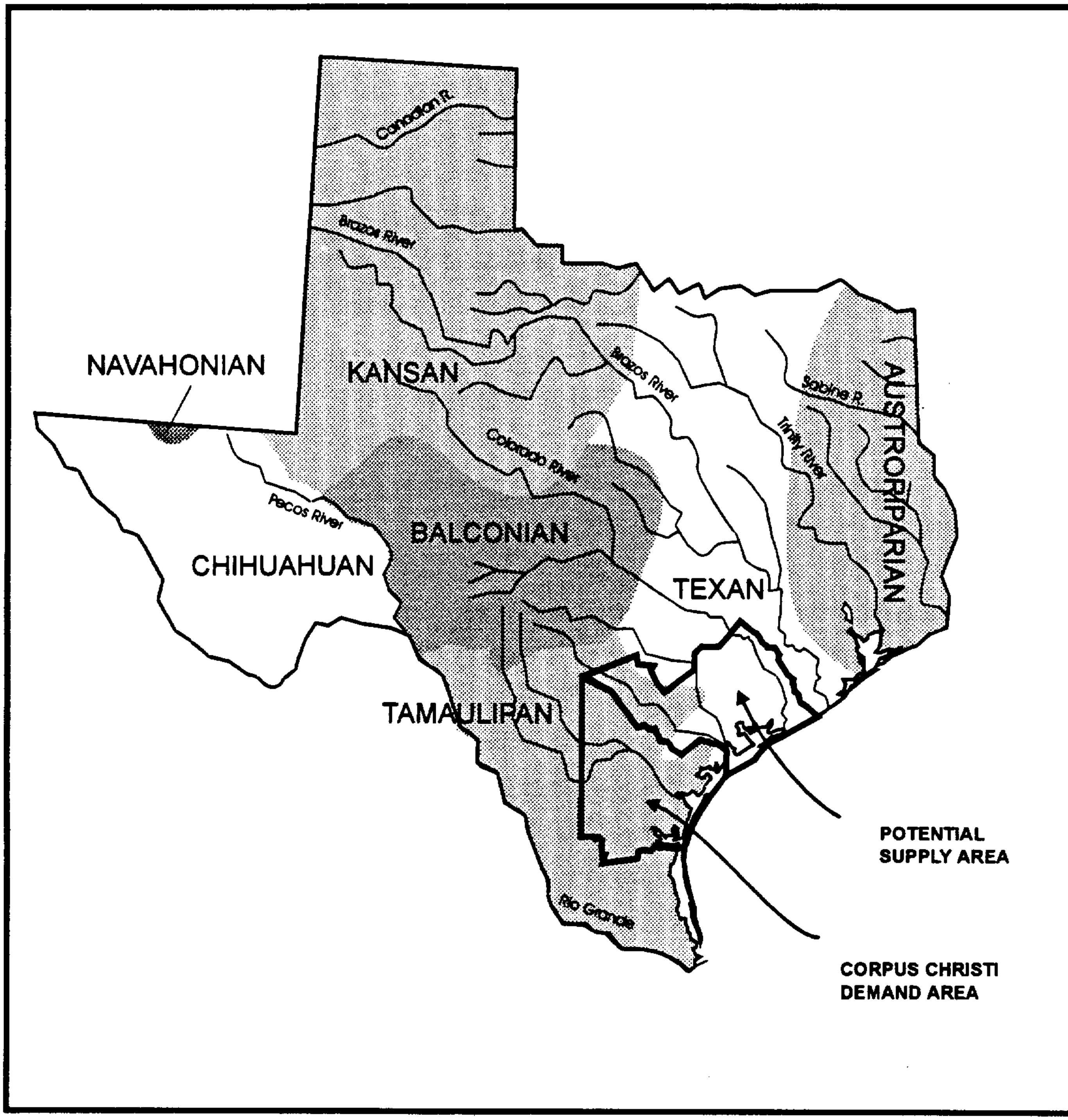
[22] Correll, D. S. and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. The University of Texas at Dallas.

[23] Gould, F. W. 1975. The Grasses of Texas. Texas A&M University Press.

[24] Blair, F.W. 1950. The Biotic Provinces of Texas. The Texas Journal of Science. 2:93-117.



Map Source: After W. Frank Blair, 1950.

200 MILES
300 KILOMETERS

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BIOTIC PROVINCES OF TEXAS

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FIGURE 3.0-3

The Gulf Prairies and Marshes Vegetational area[25] corresponds to the Western Gulf Coastal Plain Ecoregion[26] (Figures 3.0-1, 3.0-2) and is about 9.5 million acres of nearly level prairie characterized by level grasslands, low flat woodlands along the streams and freshwater marshes including cypress swamps and canebrakes. About 28 percent (2.7 million acres) of the Gulf Prairies and Marshes Vegetational area is located within the central Trans-Texas study area. The alternatives involving the interbasin transfer of water also are in this vegetational area/ecoregion; S-1, GS-1, LN-1, LN-2, LN-3, C-1, C-2, B-3. The native prairies have been largely replaced by agricultural land used primarily as pasture for cattle and cropland. Woodlands are limited primarily to the margins of rivers and larger creeks.[27]

The climax vegetation of the Gulf Prairies vegetational area is tall grass prairie such as big bluestem (*Andropogon gerardi*), seacoast bluestem (*Schizachyrium scoparium* var. *littoralis*), Indian grass (*Sorghastrum avenaceum*), gulf muhly (*Muhlenbergia capillaris*) over acid sands, sandy loams and clays; or post oak savanna with little bluestem (*Schizachyrium scoparium* var. *frequens*) , indian grass, switchgrass (*Panicum virgatum*), wintergrass (*Stipa leucotricha*) with post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) on sandy acidic loam soils. Brushland occurs primarily as a result of overgrazing and fire suppression.[28,29]

In improved pastures of the area, typical grass species include bermudagrass (*Cynodon dactylon*), Johnsongrass (*Sorghum halepense*), Kleingrass (*P. coloratum*), and King Ranch bluestem (*Bothriochloa ischaemum*). Native grasses which typically occur in grasslands in the reservoir site include little bluestem (*Schizachyrium scoparium*), silver bluestem (*B. laguroides torreyana*), pinhole bluestem (*B. barbinodis* var. *perforata*), windmill grasses (*Chloris* spp.),

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[25] Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, College Station, Texas.

[26] Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1):pp.118-125.

[27] U.S. Department of Interior, Fish and Wildlife Service (FWS). (Various dates.) National Wetland Inventory maps. U.S. Department of Interior, U.S. Geological Survey (USGS). (Various dates.) 7.5' topographic quadrangle maps.

[28] Correll, D.S. and M.C. Johnston. 1979. Manual of the Vascular Plants of Texas. Second Printing, University of Texas at Dallas, Richardson, Texas.

[29] Schmidly, D.J. 1983. Texas Mammals East of the Balcones Fault Zone. Texas A&M University Press, College Station, Texas.

plains bristlegrass (*Setaria macrostachya*), sideoats grama (*Bouteloua curtipendula*), plains lovegrass (*Eragrostis intermedia*), Arizona cottontop (*Trichachne californica*) and switchgrass (*P. virgatum*). Grazing and other disturbance factors cause these species to decrease and less favorable species, such as Texas wintergrass (*Stipa leucotricha*), buffalo grass (*Buchloe dactyloides*), dropseeds (*Sporobolus* spp.), common curlymesquite grass (*Hilaria belangeri*), threeawns (*Aristida* sp.), gramas, and lovegrasses to increase.[30, 31, 32, 33]

Important habitats within the coastal plains are associated with streams and freshwater floodplains where grazing or agricultural crop activities have not altered river terraces or removed bottomland forests. In these forested bottomlands black willow (*Salix nigra*), green ash (*Fraxinus pennsylvanica*), eastern cottonwood (*Populus deltoides*), pecan (*Carya illinoinensis*), bald cypress (*Taxodium distichum*), American elm (*Ulmus americana*), boxelder (*Acer negundo*), and red mulberry (*Morus rubra*) occur on the lowest river terraces. Pecan along with cedar elm (*Ulmus crassifloria*), Texas sugarberry (*Celtis laevigata*), common honeylocust (*Gleditsia triacanthos*), and hawthornes (*Crataegus* spp.) are common dominates on second terraces. Important vines in the understory include greenbriar (*Smilax* spp.), trumpet creeper (*Campsis radicans*), poison ivy (*Rhus toxicodendron*), southern dewberry (*Rubus trivialis*), and Virginia creeper (*Parthenocissus quinquefolia*). Shrubs such as possumhaw (*Ilex decidua*), roughleaf dogwood (*Cornus drummondii*), drummond sesbania (*Sesbania drummondii*), common buttonbush (*Cephalanthus occidentalis*) and herbaceous species including inland seaoats (*Chasmanthium latifolium*), giant ragweed (*Ambrosia trifida*), marsh-elder (*Iva frutescens*) and asters (*Aster* sp.) are common.[34,35]

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[30] Correll, D.S. and M.C. Johnston. 1979. Manual of the Vascular Plants of Texas. Second Printing, University of Texas at Dallas, Richardson, Texas.

[31] U.S. Department of Agriculture, Soil Conservation Service (SCS). Soil Survey of Nueces County, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A&M University, College Station.

[32] U.S. Department of Agriculture, Soil Conservation Service (SCS). Soil Survey of Victoria County, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A&M University, College Station.

[33] U.S. Department of Agriculture, Soil Conservation Service (SCS). Soil Survey of San Patricio and Aransas Counties, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A&M University, College Station.

[34] Correll, D.S. and M.C. Johnston. 1979. Manual of the Vascular Plants of Texas. Second Printing, University of Texas at Dallas, Richardson, Texas.

Wetland, meadow and prairie species occur within and around moist and water-filled depressions, borrow pits, and stock ponds. Although generally small, this habitat type is important because of its distribution and prevalence throughout the gulf plains. A typical vegetation list is difficult to develop since there is great variation between depressions, and the assemblage depends on the length of inundation. Where standing water is present, species such as water hyacinth (*Eichhornia crassipes*), cattails, arrow-arum (*Peltandra virginica*) may occur with rabbitfoot grass (*Polygonum monspeliensis*), while drier areas may have rose-mallow (*Hibiscus* spp.), bushy broomsedge (*Andropogon glomeratus*), asters (*Aster spinosus*, *A. subulatus*) and common reed (*Phragmites australis*).[36,37]

Interbasin Supply Area

River Basins

The majority of the interbasin supply alternatives involve the Lavaca and Navidad Rivers, particularly Lake Texana (LN-1, LN-2, and LN-3), and the Colorado River (C-1 and C-2), all of which flow into the Lavaca-Colorado Estuary. Also, the Colorado River alternatives involve transferring water through Lake Texana on the Navidad River. Thus, a general overview of the lower Lavaca Basin and the Lavaca-Colorado Estuary is presented here. Background information relative to S-1, GS-1, and B3 is presented in the respective sections where each option is discussed.

The Lavaca River Basin includes Lake Texana which was formed on the Navidad River by Palmetto Bend Dam approximately 4 miles upstream of the Navidad's confluence with the Lavaca River. The portions of the Navidad and Lavaca rivers below Palmetto Bend Dam are tidally influenced and have bottom elevations below sea level.[38] Except during periods of high

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[35] White, W.A., T.R. Calnan, R.A. Morton, R.S. Kimble, T.G. Littleton, J.H. McGowen, and H.S. Nance. 1989. Submerged Lands of Texas, Port Lavaca Area: Sediments, Geochemistry, Benthic Macroinvertebrates, and Associated Wetlands. Bureau of Economic Geology, University of Texas at Austin, Austin, Texas.

[36] U.S. Department of Interior, Fish and Wildlife Service (FWS). (Various dates.) National Wetland Inventory maps.

[37] Ibid.

[38] Paul Price Associates, Inc. 1989. Environmental Assessment Report: Lavaca-Navidad River Authority Proposed Water Supply System Expansion.

freshwater flow they are commonly brackish, at least near the bottom. Water quality, in terms of nutrient loads, fecal coliform counts, oxygen demanding materials and pesticides originating in the Lavaca Navidad basin is generally good. However, as a result of salinity stratification, dissolved oxygen levels may become depleted in bottom waters. These riverine segments are transitional zones, alternately dominated by freshwater or saltwater species depending on conditions of freshwater flows and tidal regimes.

The floodplain of the lower Lavaca River, grading into the Lavaca Delta, contains a system of brackish tidal lakes and fresh to brackish marshes that total about 15,000 acres.[39,40,41] These delta marshes tend to be dominated by smooth cordgrass, particularly at the edges of the tidal channels, but substantial areas of marshhay cordgrass (*S. patens*), sea oxeye daisy, saltgrass, glasswort, saltwort (*B. maritima*) and algal mats also are present depending on local topography and inundation regime. The delta marshes are believed to be important both as nurseries for juvenile shell and finfish, and as sources of particulate organic material that support the largely detrital food chains of the open bay waters. Live oyster reefs in this system are concentrated in Lavaca Bay.

Bays and Estuaries

Lavaca-Colorado

The Lavaca-Colorado Estuary consists of Lavaca Bay, which is a secondary bay, and Matagorda Bay. The Lavaca-Colorado Estuary and the brackish aquatic systems of the lower Navidad and Lavaca Rivers are described in the Palmetto Bend Final EIS.[42] Additional

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[39] BOR. 1974. Palmetto Bend Project - Texas Final Environmental Impact Statement. Bureau of Reclamation, U.S. Department of the Interior.

[40] BOR. 1990. Draft Environmental Assessment, Lavaca-Navidad River Authority Pipeline Permit.

[41] Paul Price Associates, Inc. 1989. Environmental Assessment Report: Lavaca-Navidad River Authority Proposed Water Supply System Expansion.

[42] BOR. 1974. Palmetto Bend Project - Texas Final Environmental Impact Statement. Bureau of Reclamation, U.S. Department of the Interior.

descriptions of the hydrography, water quality, nutrient exchange characteristics, and species assemblages of the estuary have been reported.[43,44,45,46,47,48,49,50,51,52,53,54]

In addition to the Lavaca River, Lavaca Bay receives inflows from Garcitas Creek, Chocolate Bayou, and numerous small, local drainages that contribute an annual average of approximately 190,000 acft, and direct precipitation amounting to an average of 156,000 acft/yr. The Lavaca-Colorado Estuary also receives inflows from Huisache Creek, Keller Creek, Carancahua Creek and Tres Palacios Creek. These smaller drainages provide annual average inflows of approximately 360,000 acft.

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[43] R.J. Brandes Company and M. Sullivan and Assoc. 1991. Evaluation of the Effects of Proposed Release Operation Plans for Lake Texana on Lavaca Bay Salinities. Prepared for Texas Parks and Wildlife Department, Austin, Texas.

[44] Espey, Huston & Associates, Inc. 1977. Marsh Biology and Nutrient Exchange in Three Texas Estuaries. Espey Huston and Associates, Inc., Austin Texas, Doc. No. 7687.

[45] Gilmore, G., M. Dailey, M. Garcia, N. Hannebaum and J. Means. 1976. A Study of the Effects of Fresh Water on the Plankton, Benthos, and Nekton Assemblages of the Lavaca Bay System, Texas. Texas Parks and Wildlife Department, Austin, Texas.

[46] TDWR. 1980 cited in PPA EA.

[47] TDWR. 1985. Investigation of the Effects of Releases of Water from Lake Texana, Lavaca River Basin, on August 31-September 7, 1984. Texas Department of Water Resources, Austin, Texas.

[48] Jones, R.S. 1986. Studies of Freshwater Inflow Effect on the Lavaca Delta and Lavaca Bay, Texas. The University of Texas Marine Science Institute, Technical Report No. TR/86-006.

[49] Mueller, A.J. and G.A. Matthews. 1987. Freshwater inflow needs of the Matagorda system with focus on penaid shrimp. NOAA Technical Memorandom NMFS-SEFC-189, National Marine Fisheries Service, Galveston, Texas.

[50] Britton, J.C. and Brian Morton. 1989. Shore Ecology of the Gulf of Mexico. University of Texas Press, Austin, Texas.

[51] Paul Price Associates, Inc. 1989. Environmental Assessment Report: Lavaca-Navidad River Authority Proposed Water Supply System Expansion.

[52] BOR. 1974. Palmetto Bend Project - Texas Final Environmental Impact Statement. Bureau of Reclamation, U.S. Department of the Interior.

[53] BOR. 1990. Draft Environmental Assessment, Lavaca-Navidad River Authority Pipeline Permit.

[54] Espey, Huston and Associates, Inc. 1982. Matagorda Bay: A Management Plan. In Cooperation with University of Texas, Austin, Texas.

As a result of catastrophic delta progradation during the 1930's, the Colorado River flowed directly into the Gulf of Mexico until recently when the U.S. Corps of Engineers cut a channel to divert water from the Colorado River into Matagorda Bay, the lower bay in the Lavaca Colorado Estuary. The Colorado River contribution has been variously estimated to be in the range of 500,000 to 1,000,000 acft/yr, primarily as flood flows into the lower portion of Matagorda Bay. Currently, nearly all Colorado River flows enter Matagorda Bay. Direct precipitation amounts to an additional 550,000 acft/yr.

Total annual average freshwater inflow to the Lavaca-Colorado Estuary, excluding the Colorado River is approximately 1,241,902 acft for the 1941-1987 period of record.[55] However, there are large fluctuations in inflows both from month-to-month within years and from year-to-year.[56] For example, total annual flows to the Lavaca and Matagorda Bays excluding the Colorado River have ranged from a minimum of 38,169 acft in 1956 to 3,245,480 acft in 1973.[57]

Significant development has occurred around the Lavaca-Colorado Estuary in the Port Lavaca-Point Comfort area, and includes the Formosa Plastics plant, the Alcoa plant, and the E.S. Joslin Electrical Generating Facility on Cox's Bay. Additionally, the estuary has an extensive network of navigation channels that extend up to the confluence of the Lavaca and Navidad Rivers.

Biogeography

Of the supply area alternatives, only L-7 involving Wilson and Bexar Counties, and S-1 involving Goliad County, are within the South Texas Plain. The southern margin of Colorado County and Wharton, Jackson, Victoria, and Calhoun Counties are within the Western Gulf Coastal Plain ecoregion/Gulf Prairies and Marshes Vegetational Area. However, midway between the Guadalupe and the San Antonio rivers, soils change from pedalfers to the northeast to pedocals to the southwest. This boundary corresponds to the divide between Blair's Texan

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[55] TWDB. 1990. Water for Texas. Today and Tomorrow.

[56] Mueller, A.J. and G.A. Matthews. 1987. Freshwater inflow needs of the Matagorda system with focus on penaid shrimp. NOAA Technical Memorandum NMFS-SEFC-189, National Marine Fisheries Service, Galveston, Texas.

[57] TWDB. 1990. Water for Texas. Today and Tomorrow.

Biotic Province and the Tamaulipan Biotic Province (Figure 3.0-3).[58] The pedalfer soils exhibit profiles in which calcium carbonates in the same or lower proportions are in the underlaying formations. These are acid soils which may hold an excess of moisture and support a vegetational mixture of alternating wooded savannas, tall-grass prairies, and associated ecotones.[59] Pedocal soils contain a greater amount of calcium carbonate than is present in the underlaying parent material beneath. These alkaline soils tend to support the development of grassland or prairie communities. The Texan Biotic Province characteristically receives higher rainfall and most soils are brown acid clays over clay and soft limestone. The Tamaulipan Biotic Province is drier and soils are sandier. Due to the proximity to the Gulf of Mexico, the transition along the gulf coastal plain from one biotic province to another is more gradual than inland. Blair recognized the Texan Biotic Province as an ecotone between eastern forests of the Austroriparian and the grasslands of the southwestern plains while the Tamaulipan is a Neotropical province with a strong dilution of Sonoran and Austroriparian species. Dispersal between provinces occurs in favorable environments such as stream floodplains and the coastal prairies. Differences in the physical environment comparing between the Texan and Tamaulipan provinces correspond to changes in the assemblages of animal and plant species.

Ground cover is occasionally thick in grasslands, thus providing good cover for a variety of rodent species which in turn provide food for carnivores such as the coyote (*Canis latrans*), northern harrier (*Circus cyaneus*,) and common barn-owl (*Tyto alba*). A variety of reptiles, mammals, and birds also use grassland habitats for food and cover. Although species dependent on native prairie have almost disappeared, as for example, the Attwater's greater prairie chicken (*Tympanicus cupido Attwateri*), other prairie species like the scissor-tailed flycatcher (*Tyrannus forficatus*), white-tailed hawk (*Buteo albicaudatus*), Swainson's hawk (*Buteo swainsoni*), long billed curlew (*Numenius americanus*) and sandhill crane (*Grus canadensis*) now utilize the pastures and croplands that replaced native prairies.

Woody species in the grassland habitats are either sparse or absent. Bottomland forests provide habitat for a multitude of migrating songbirds, waterfowl, and hawks. Nesting

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[58] Schmidly, D.J. 1983. Texas Mammals East of the Balcones Fault Zone. Texas A&M University Press, College Station, Texas.

[59] Ibid.

residences may include species such as wood duck (*Aix sponsa*), fish crow (*Corvus ossifragus*), ringed kingfisher (*Ceryle torquata*), and Swainson's warbler (*Limnothlypis swainsonii*). The thick nature of the brushland vegetation of the Texan Biotic Province makes this an excellent nesting habitat for a variety of bird species. It also provides ample food and cover for a number of rodent and other mammalian species, including the white-tailed deer and collared peccary (*Tayassu tajacu*). The protected Texas tortoise (*Gopherus berlandieri*) utilizes brush habitats for cover, and for food in the form of cacti and herbaceous undergrowth.[60]

Environmental Issues

Comparison of the Alternatives

A summary of the water alternatives being considered in Phase II is provided in Appendix C, Table 22. Alternatives involving the diversion of Lake Texana water through a pipeline to Corpus Christi hold the greatest promise for supplying the needed quantities of water at a reasonable price and with minimal environmental impact; Lake Texana Pipeline to Corpus Christi (LN-1), Purchase and Diversion of Garwood Water Rights to Corpus Christi through Lake Texana (C-1), Purchase of Colorado River Water (C-2), and Purchase of Brazos River Water (B-3). Several alternatives each would supply in excess of 20,000 acft/yr; R&M Reservoir (N-3), Goliad Reservoir (S-1), Lake Texana Pipeline to Corpus Christi (LN-1), Purchase and Diversion of Garwood Water Rights to Corpus Christi through Lake Texana (C-1), Palmetto Bend (Stage II) Reseroir (LN-2) and Desalination (L-1). Alternatives involving new reservoir construction or diverting large quantities of freshwater from Nueces Estuary are expected to be least desirable in terms of environmental impact. For example, The Palmetto Bend (Stage II) Reservoir (LN-2) would impact 6,000 acres more than the Lake Texana to Corpus Christi Pipeline (LN-1), and R&M Reservoir (N-3) and Goliad Reservoir (S-1) each would impact at least 28,000 acres more than LN-1. Furthermore, relative to building a new reservoir, the potential impact of pipeline construction and operation can be easily avoided or minimized by judicious placement of the pipeline easement and good construction practices. R&M Reservoir (N-3), which would have a high impact in terms of acres affected, would also reduce Nueces inflows considerably.

[60] Davis, W.B. 1978. The Mammals of Texas. *Texas Parks and Wildlife Dept. Bulletin 41*, Austin, Texas.

With respect to water supply strategies, and the extent and types of possible impacts, the alternatives can be generally categorized as water budget alternatives (defined below), desalination, interbasin transfers, new reservoir construction, and groundwater supplies. Issues relevant to an alternative may involve several categories. These are briefly considered below.

Water Budget Alternatives

Several alternatives involve management and operation of existing water resrouces and the potential to obtain enhanced yield. These alternatives would include Modification of Choke Canyon/Lake Corpus Christi (CC/LCC) Reservoir Operating Policy (N-1), the Purchase of Existing Water Rights in Nueces Basin (N-4), Industrial Water Use Evaluation (L-5), Municipal Wastewater Reuse (L-4), and Accelerated Municipal Water Conservation (L-6). Issues generally associated with increased conservation concern the disposal of reclaimed wastewater. For example, an environmental cost of conservation measures depending on water reuse can be the production of environmentally undesirable wastewater requiring special and expensive permitting, handling, and processing. This is especially of concern with respect to the reuse of initially poor quality water.

Desalination

In terms of construction, the most significant impact of this alternative is the construction of a pipeline from the plant, across the barrier island and seabed, and out into the Gulf of Mexico. The more significant effects would be in the environmental impact of energy generation to supply the desalination plant, maintenance requirements (e.g., equipment cleaning), and brine disposal.

Interbasin Transfers

Several alternatives consider the interbasin transfer of water; Lake Texana Pipeline to Corpus Christi (LN-1), Palmetto Bend (Stage II) Reservoir (LN-2), Diversion from Lavaca River to Lake Texana (LN-3), Purchase and Diversion of Garwood Water Rights to Corpus Christi through Lake Texana (C-1), Purchase of Colorado River Water (C-2), and the Purchase of Brazos River Water (B-3). Important environmental considerations with respect to these alternatives, in addition to pipeline construction which is noted below, include the potential interbasin transfer of organisms. The issue of the interbasin transfer of organisms in general, is currently under investigation.[61] However, under the proposed alternative of transferring Colorado River water to Lake Texana and then by transferring Lake Texana and Colorado River water by pipeline to the O.N. Stevens Water Treatment Plant, greatly reduces the likelihood of transferring organisms to the Nueces River. The close proximity of the lower Colorado River and the Lavaca-Navidad River Basin to each other and the estuary, plus the fact that Colorado River water has been transferred to the Lavaca Basin annually since the early 1900's makes it highly unlikely that species inhabiting either basin are geographically isolated from the other basin. Also, human activities and extreme storm conditions such as hurricanes which reduce salinity in the estuary provide a corridor for organism exchange between the Colorado and Lavaca Rivers. In any case, intake design and placement, and the treatment of water at the source could be implemented to greatly reduce the likelihood of transferring organisms to the Nueces or intervening basins.

New Reservoir Construction

Several alternatives consider the construction of major new water storage reservoirs; R&M Reservoir (N-3), Goliad Reservior (S-1), Diversion from the Guadalupe and San Antonio Rivers (Includes McFaddin Reservoir) (GS-1), and Palmetto Bend (Stage II) Reservoir (LN-2). Because of the large number of acres inundated, these types of projects result in considerable impact to property, terrestrial wildlife habit, and riverine habitats. Additional impacts to estuaries in terms of diminished freshwater inflows must also be considered.

Groundwater

Several alternatives involve the development of groundwater supplies; Local Groundwater - Gulf Coast Aquifer (L-2), Use of Groundwater from Campbellton Wells - Carrizo Aquifer (L-3), and Groundwater Recharge and Recovery (Carrrizo/Wilcox) (L-7). Generally, environmental issues of concern with respect to these alternatives involve the quality of the water

[61] U.S. Army Corps of Engineers, Technical Memorandum, Potential Ecological Effects of Two Proposed Interbasin Transfers in the South Central Study Area, 1995.

and the quantity that can be withdrawn while maintaining the integrity of the supply and the aquifer. Potential subsidence of the land and saltwater intrusion are significant concerns related to groundwater use along the Texas coast.

Underground Pipeline Construction

Implementing the majority of alternatives would depend on pipeline construction to transport water into the Corpus Christi metropolitan area (N-2, N-3, N-5, N-6, L-2, L-3, S-1, GS-1, LN-1, LN-2, LN-3, C-1, C-2, B-3). Environmental issues arise from the construction of diversion facilities, pump stations, and installation and maintenance of the pipeline. These issues include trenching through property, which may have environmentally sensitive terrestrial wildlife habitats, and wetlands. Compared to well and reservoir construction, pipeline construction allows greater flexibility in terms of route selection. This can be used to minimize impact. Maintenance of a pipeline ROW requires about one-third the acreage initially impacted during construction. The remaining acreage can be returned to its original condition. Additionally, those portions of an underground pipeline ROW passing through pasture and farmland can be returned to these uses following construction.

The installation of pipelines below ground would use the following process:

1) A corridor of the appropriate width (approximately 140 feet wide for most of the pipelines considered in this report) would be cleared of brush and small trees. If possible, trees larger than six inches in diameter would be avoided by adjusting the pipeline route within the permanent 40 foot easement;
2) Pipe and stockpiles of sand and gravel for bedding and embedment would be placed within the 140 foot wide easement prior to construction;
3) The ditch would be excavated by a backhoe or ditching machine in two steps. First, topsoil, usually the top 12 to 18 inches of soil, would be removed and stockpiled on one side of the ditch. Second, the remainder of the ditch would be excavated to the bottom and the excavated material would be placed on the opposite side of the ditch to ensure it is not mixed with the topsoil;
4) Four to six inches of bedding (sand or gravel) would be placed in the bottom of the ditch and leveled to the appropriate grade;
5) The pipe would be placed in the trench and embedment (sand or gravel) would be placed around the pipe and up to six inches above the top of the pipe;
6) The ditch would be backfilled with appropriate layers of compacted material excavated from the ditch, but not topsoil, to within 12 to 18 inches of the surface;
7) The topsoil would be replaced and compacted lightly;
8) Exess material would be removed from the job site;

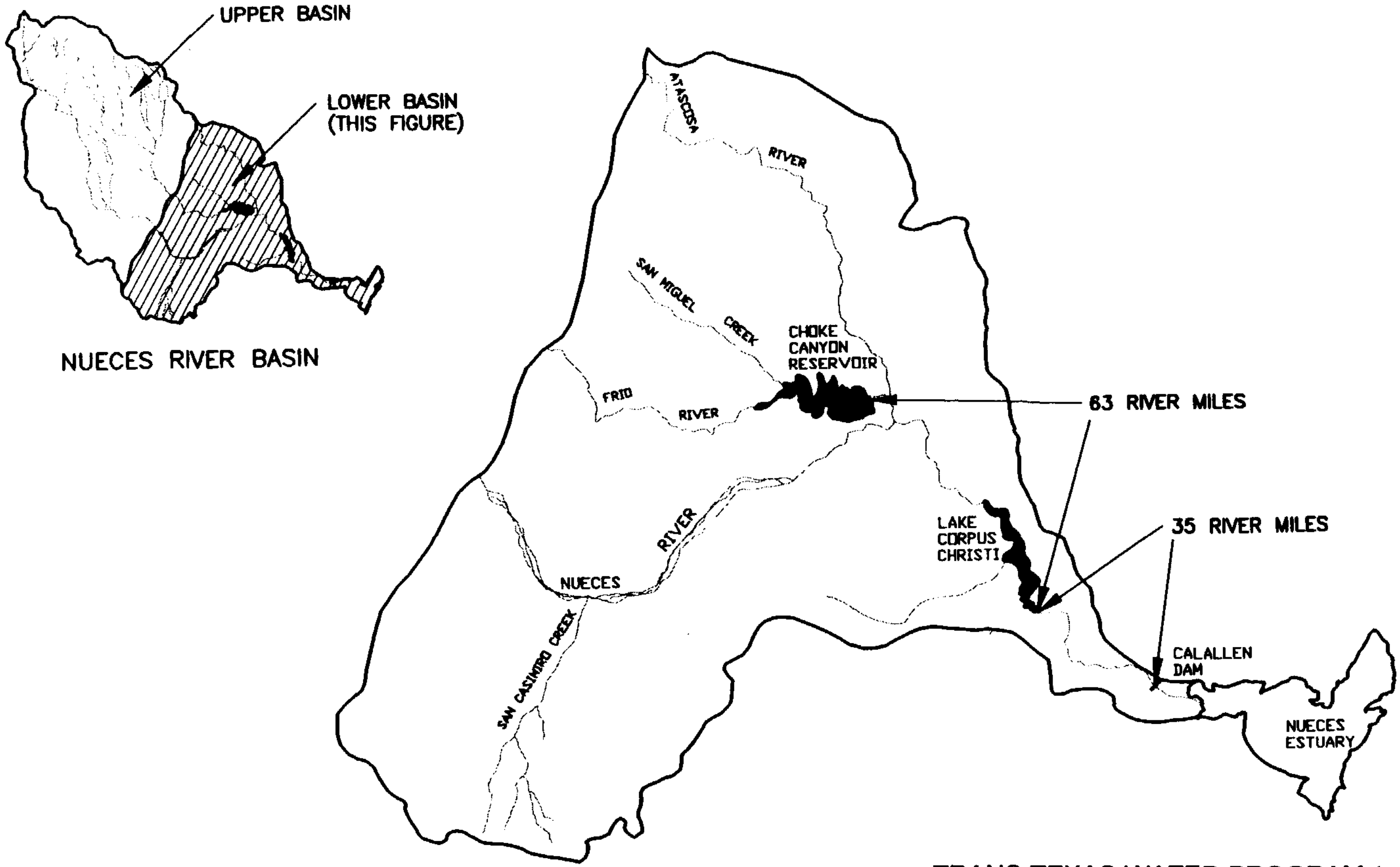
9) Disturbed portions of the easement would be graded, if required, and the area would be reseeded in accordance with construction specifications.

3.1 Modify Existing Reservoir Operating Policy (N-1)

3.1.1 Description of Alternative

In the late 1800's, 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 3.5 feet mean sea level (ft-msl) and a capacity of about 1,175 acft. The City continued to expand and in 1934, Mathis 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 Mathis Dam, and the new Lake Corpus Christi (LCC) was formed which engulfed the old dam and reservoir and expanded storage to about 302,000 acft (see Figure 3.1-1). In the late 1960's, following an extreme drought which occurred from 1961-1963, planning was begun 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, and following considerable debate, Choke Canyon Reservoir (CCR), located on the Frio River, 63.3 river miles upstream of LCC, was constructed. Choke Canyon Dam was constructed by the United States Bureau of Reclamation (USBR). The dam was completed in 1982, and the reservoir was filled in 1987. Choke Canyon Reservoir contains approximately 690,000 acft of conservation storage based on original USBR estimates. A recent volumetric survey performed by the TWDB reported the capacity of Choke Canyon Reservoir to be 695,262 acft. Today, the City operates these three reservoirs (Calallen, LCC, and CCR) as a system to supply water for municipal and industrial users of the South Central Trans-Texas Region.

A summary of physical and hydrologic data for the three reservoirs and two river reaches which affect the delivery of raw water to the City and their customers is shown in Table 3.1-1. As indicated in this table, approximately 94 percent of the demand occurs at the Calallen Reservoir Pool, while 74 percent of the stored water is located some 98 river miles upstream at Choke Canyon Reservoir with the remaining 26 percent of the stored water being located 35 miles upstream in Lake Corpus Christi. Water stored in the Choke Canyon Reservoir is released



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LOCATION OF LOWER NUECES RIVER WATERSHED AND THREE RESERVOIRS - ALTERNATIVE N-1

FIGURE 3.1-1

into the river channel and released from Lake Corpus Christi. Water is then released from Lake Coprus 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 indicated that a significant portion of the water that is released from Choke Canyon 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 3.1-1
Summary of Physical and Hydrologic Data for Three Reservoirs and Two River Reaches

Reservoir or River Reach	1990 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	689,314	74%	3.26	---	---	1%
River Reach Between CCR & LCC	---	---	---	63.3	29*	
Lake Corpus Christi	239,473	25.9%	2.85	---	---	
River Reach Between LCC & Calallen	---	---	---	35	7**	4%
Calallen Reservoir	1,175	0.1%	2.85	---	---	94%
Total	929,962	100%	---	98.3	---	100%

* Includes losses from Lake Corpus Christi to local aquifer and represents maximum percentage lost.
** Represents average percentage lost.

[1] Bureau of Reclamation, "Nueces River Basin: A Special Report for the Texas Basins Project," U.S. Dept. of the Interior, December, 1983.

[2] U.S. Dept. of the Interior, "Nueces River Project, Texas: Feasibility Report," July, 1971.

[3] HDR Engineering, Inc. and Geraghty and Miller, Inc., "Regional Water Supply Planning Study - Phase I: Nueces River Basin. Volume I, Executive Summary," for the Nueces River Authority, City of Corpus Christi, Edwards Underground Water District, South Texas Water Authority, and Texas Water Development Board, May, 1991.

[4] Rauschuber and Associates, Inc., "Potential for Development of Additional Water Supply from the Nueces River Between Simmons and Calallen Diversion Dam," for Subcommittee on Additional Water Supply from the Nueces River Watershed, December, 1985.

[5] United States Geological Survey, "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 3.1-1, losses from Choke Canyon Reservoir downstream to (and including losses from) Lake Corpus Christi can be as high as 29 percent and losses downstream of LCC to the Calallen pool average about 7 percent. In addition, under a recent order from the Texas Natural Resource Conservation Commission (TNRCC), 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 productivity of the Nueces Estuary (see Appendix O). All of the above items are significant factors which must be taken into account in the operation of the reservoir system.

The City of Corpus Christi has a four-phased operation plan for the Choke Canyon/Lake Corpus Christi (CC/LCC) reservoir system. The objective of each phase is 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 TNRCC 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 operation plan consists of four phases, with the first phase (Phase I) having been applicable to the initial filling of Choke Canyon Reservoir. In 1987, Choke Canyon Reservoir officially filled and the operating policy shifted to Phase II. The Phase II policy is the current operating policy and it applies to the CC/LCC System until water user demand is more than 150,000 acft/yr. The operational guidelines under this policy are as follows:

1) A minimum of 2,000 acft per month is to be released from Choke Canyon Reservoir to meet the release agreement between the City of Corpus Christi and Texas Parks and Wildlife Department (TPWD);

2) 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 is above 204 ft-msl, releases will be made from Choke Canyon to maintain the water surface elevation at Lake Corpus Christi at 88 ft-msl; and

3) When Lake Corpus Christi's water surface elevation is at or below 88 ft-msl and Choke Canyon's water surface elevation is below 204 ft-msl, the Choke Canyon 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 releases with the stored water in Lake Corpus Christi, but also for recreation considerations.

The third operational policy (Phase III) applies 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, 2,000 acft per month is the minimum release from Choke Canyon, and 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 applies to the system after water user demand exceeds 200,000 acft annually. Under this policy, the system is operated as follows:

1) A minimum of 2,000 acft per month is to be released from Choke Canyon Reservoir to meet the release agreement between the City of Corpus Christi and TPWD;

2) 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 to maintain Lake Corpus Christi at 76 ft-msl; and

3) When Lake Corpus Christi's water surface elevation is at or below 76 ft-msl and Choke Canyon's water surface elevation is below 155 ft-msl, Lake Corpus Christi is allowed to draw down to its minimum elevation and Choke Canyon releases are made only to meet water supply shortages.

For many of the alternatives evaluated in this study, both the Phase II (i.e., present operating policy) and the Phase IV (i.e., maximum yield policy) Operation Policies were considered. Since the Phase II policy is the current operating policy, the Phase II policy was generally used as a baseline condition.

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. This model operates on a monthly timestep over the 1934-89 period of record, which includes significant droughts in the 1950's, 1960's, and 1980's. Computations in the model simulate evaporation losses in the reservoirs as well as channel losses in the rivers associated with water delivery from CCR to LCC, and from LCC to the City's water supply intake at the Calallen diversion dam. In addition, due to sediment deposition in CCR and LCC, the model allows for a variety of sediment conditions ranging from the 1990 storage volumes in the lakes to the projected 2050 system storage capacities.

3.1.2 Available Yield

In 1992, in response to requirements in the water rights permit for CCR (Certificate of Adjudication No. 21-3214) and as a result of concerns from the environmental community about the health of the Nueces Estuary, a Technical Advisory Committee chaired by the TNRCC established a set of operational guidelines and desired monthly flows to ensure that at least 97,000 acft of water per year would be provided to Nueces Bay through wastewater return flows, natural runoff downstream of the CC/LCC system, and spills and releases from the two-reservoir system. This order, commonly referred to as the 1992 Interim Order, provided for relief from bay and estuary release requirements when certain salinity criteria were met in the upper Nueces Bay and when the previous month's spills from the reservoir system exceeded that month's release requirement. In Tran-Texas Phase I studies, the operational requirements of the 1992 Order were included in the Lower Nueces River Basin and Estuary model and were used to determine the firm yield of the reservoir system under the Phase II operating policy. Given these operating rules, the CC/LCC System was simulated assuming 1990 and 2050 reservoir sedimentation conditions. The resulting firm yields from these simulations indicate a 1990 firm yield of 168,000 acft/yr decreasing to a 2050 firm yield of 153,000 acft/yr, due to sedimentation (Table 3.1-2).

In April, 1995, a new bay and estuary release order (1995 Agreed Order) was adopted governing fresh water release requirements to the Nueces Estuary that effectively provides about the same quantities of water to the bays and estuary, but significantly increases the firm yield of the CC/LCC system (see Appendix O). The major differences between the new 1995 Agreed Order and the 1992 Interim Order are as follows:

Table 3.1-2 Summary of CC/LCC System Firm Yields Under the Phase II Operating Policy and 1992 TNRCC Interim Release Order[1]	
Reservoir Sedimentation Year	**Firm Yield Under Phase II Policy (acft/yr)**
1990	168,000
2050	153,000

[1] See text fro description of Phase II Operating Policy and 1992 TNRCC Interim Release Order.

1) The water released from the CC/LCC System to satisfy the TNRCC bay and estuary release requirement in a given month is limited to no more than the inflow to LCC 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 LCC. When the system storage is less than 70 percent, but more than 40 percent, the target schedule is reduced so as to provide 97,000 acft/yr to Nueces Bay/Delta. 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 may be suspended when the City and its customers implement Condition III of the Plan.

The 1995 Agreed Order provides for relief from bay and estuary release requirements when salinity criteria in Nueces Estuary are met and when spills in the previous month are more than that month's release requirement in the same manner as the 1992 Interim Order.

The limiting of releases to the bays and estuary in the 1995 Agreed Order increases the firm yield of the CC/LCC System under Phase II Operations Policy by approximately 13,500 acft/yr under 1990 sediment conditions and 9,500 acft/yr under 2050 sediment conditions. A comparison of the firm yields between the 1992 Interim Order and the 1995 Agreed Order is provided in Table 3.1-3.

Table 3.1-3
Comparison of CC/LCC System Firm Yields
Under the 1992 and 1995 TNRCC Release Orders

Reservoir Sedimentation Year	1992 Interim Order Firm Yield Under Phase II Policy (acft/yr)	1995 Agreed Order Firm Yield Under Phase II Policy (acft/yr)	Increase in Firm Yield Due to New Release Order (acft/yr)
1990	168,000	181,500	13,500
2050	153,000	162,500	9,500

3.1.3 Phase IV Operational Policy Constraints

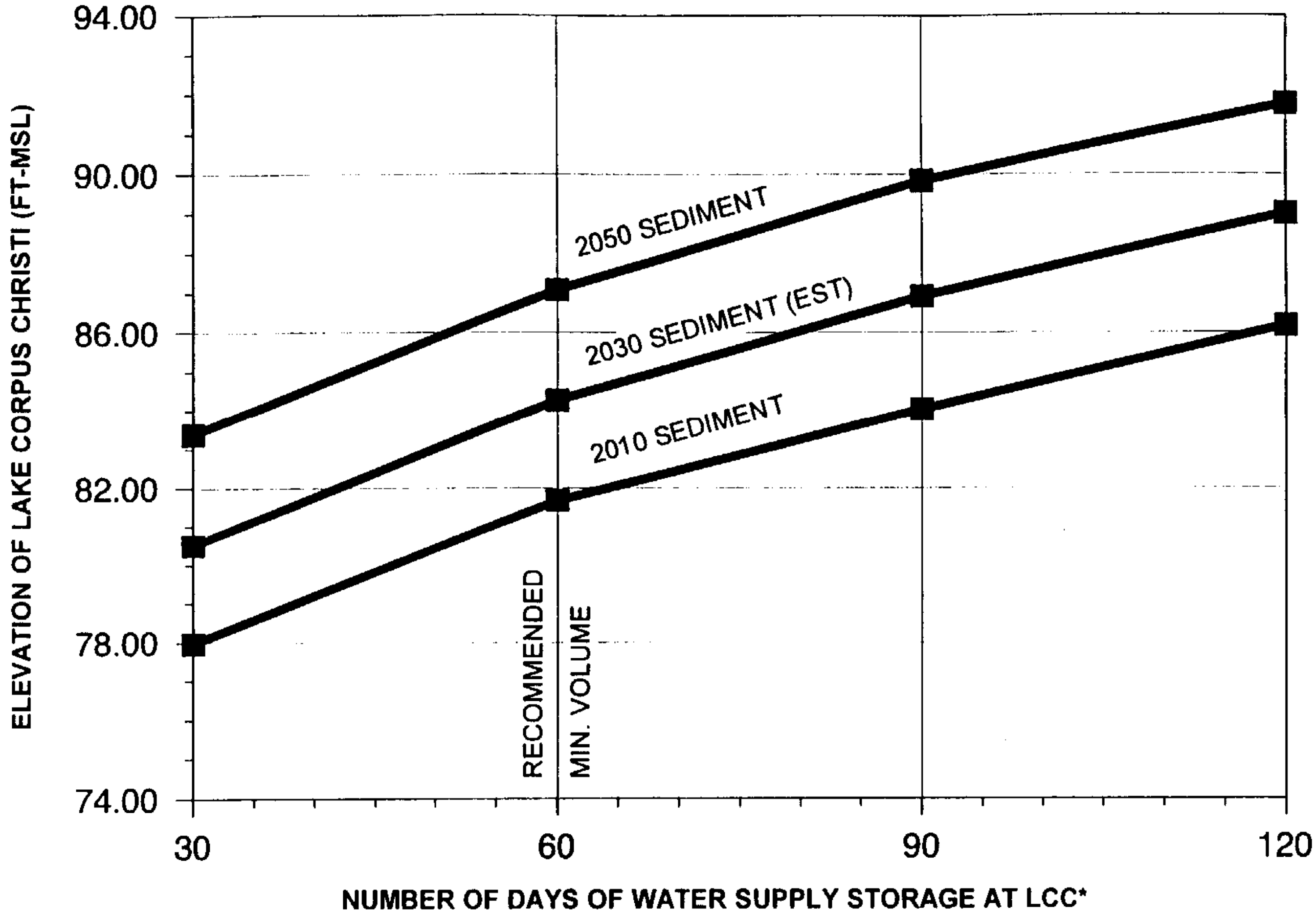
As shown in Trans-Texas Phase I studies, changing the City's system operations policy from Phase II to Phase IV, without regard to water supply delivery constraints, produces an increase in system yield of 22,900 acft/yr under 2050 sediment conditions. Implementation of the Phase IV Operations Policy, as written, allows LCC to draw down to 76 ft-msl, as opposed to 88 ft-msl under current Phase II operations, before significant releases occur from Choke Canyon Reservoir to maintain water surface elevations at LCC.

Updated sedimentation data, which has become available since the initial operating plans were developed, shows that at elevation 76 ft-msl there is only a 20 day supply of water in LCC under 2010 sediment conditions and only a 4 day supply of water under 2050 conditions. Additionally, if a 76 ft-msl target level were used to operate LCC, some raw water customers of the City would be adversely affected. The City currently supplies raw water from the LCC pool to the cities of Alice, Beeville, and Mathis. According to the operators of the raw water intakes for these municipalities, the lowest water surface at which each City's intake can perform properly is about 84 ft-msl. At this elevation, minor modifications would still be necessary to ensure proper operation of the intakes for the cities of Beeville and Mathis. Section 3.1.7 contains a more detailed description of these intake structures and a summary of the costs to ensure the operation of Beeville's and Mathis' intake facilities at a water surface elevation of 84 ft-msl in LCC.

Figure 3.1-2 shows a graph of number of days of water supply storage in Lake Corpus Christi versus water surface elevation. The curves in this figure show that as the reservoir accumulates sediment and water demands on the system increase, the number of days storage at a given elevation decreases. For instance, at elevation 84 ft-msl, in 2010 there are approximately 90 days of water supply storage; however, in 2050 after 40 more years of sediment has been deposited in LCC and demands have increased, at elevation 84 ft-msl, there are only 35 days of water supply stored in LCC. The volume of water in storage in LCC can have a significant effect on stabilizing the water quality in the reservoir. This topic is discussed in more detail in Section 3.1.6 and Appendix D, but the more water there is in LCC to blend with water from CCR, the more stable the quality of the water delivered to the City's O.N. Stevens Water Treatment Plant at Calallen. A 60-day supply would be a reasonable minimum volume to ensure adequate blending.

Considering the above concerns, a target water surface elevation of 84 ft-msl in Lake Corpus Christi may be the minimum reasonable operating target at LCC during the next several decades. This level will avoid major water supply improvement costs for the cities of Alice, Beeville, Mathis, and Corpus Christi, and ensure a reasonable volume of water to stabilize water quality until about the year 2030. After that timeframe, a target level of about 87 ft-msl will be needed to ensure a minimum 60-day supply until year 2050 sediment conditions occur.

Figure 3.1-3 shows the effect of changing the LCC target elevation on system firm yield. As shown in this figure, if the target water surface elevation in LCC is decreased, the firm yield increases. For example, if the existing target were raised 4 ft to elevation 92 ft-msl, the yield of the system would decrease by 34,000 acft/yr. If the target level were lowered to 84 ft-msl, the yield would increase by 14,000 acft/yr (Figure 3.1-2) and if the target level were lowered to 87 ft-msl the yield would increase by 4,000 acft/yr.. Effects on system yield resulting from changing the LCC target elevation are about the same for 2050 sediment conditions as for 2010 conditions. However, the number of days of water in storage in LCC below a given trigger level changes significantly with time as sedimentation occurs.



* BASED ON PEAK MONTHLY DEMANDS

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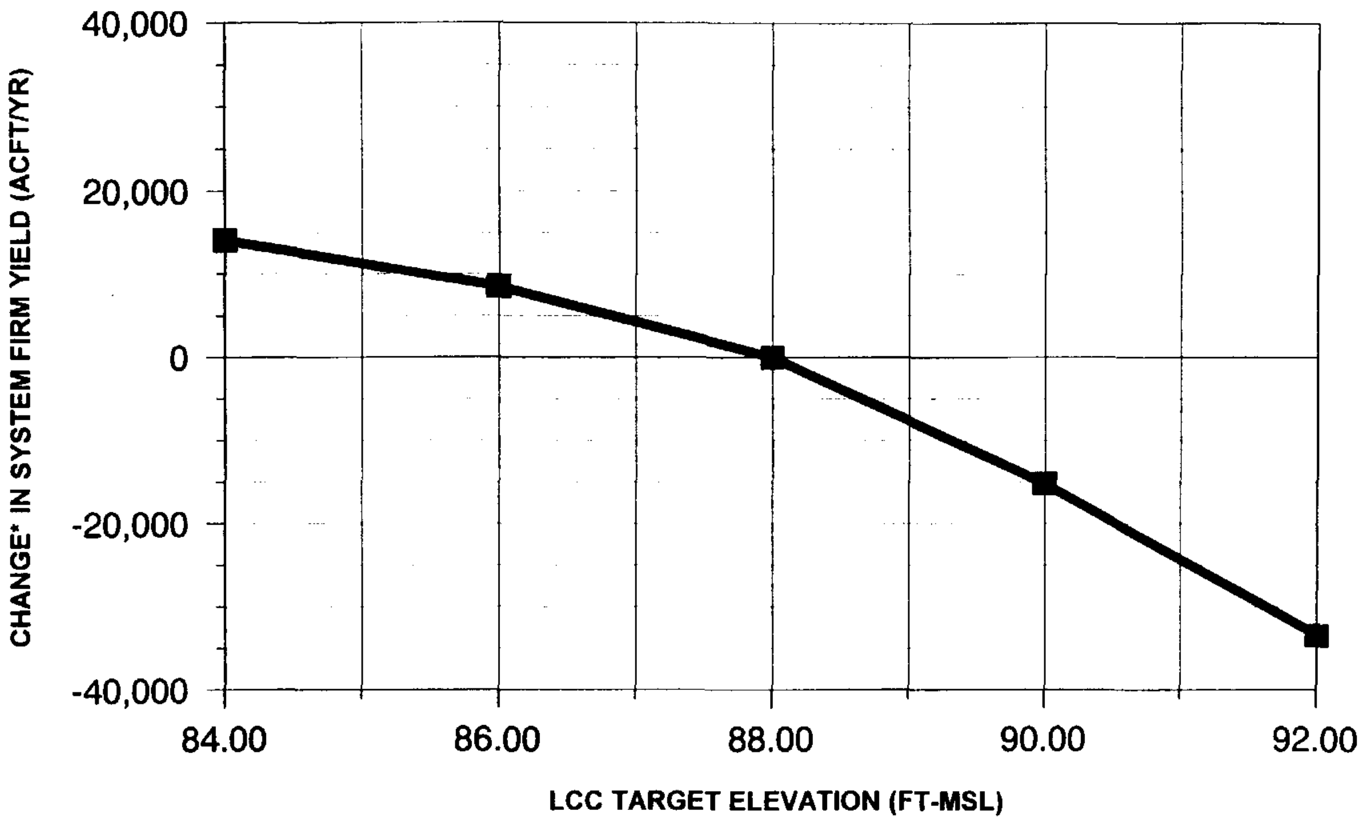
NUMBER OF DAYS OF WATER SUPPLY STORAGE IN LAKE CORPUS CHRISTI ALTERNATIVE N-1

FIGURE 3.1-2



NOTES:
* CHANGE IN SYSTEM YIELD BASED ON COMPARISON WITH YIELD UNDER EXISTING PHASE II POLICY

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CHANGE IN SYSTEM YIELD FOR VARIOUS LAKE CORPUS CHRISTI TARGET ELEVATIONS-ALTERNATIVE N-1

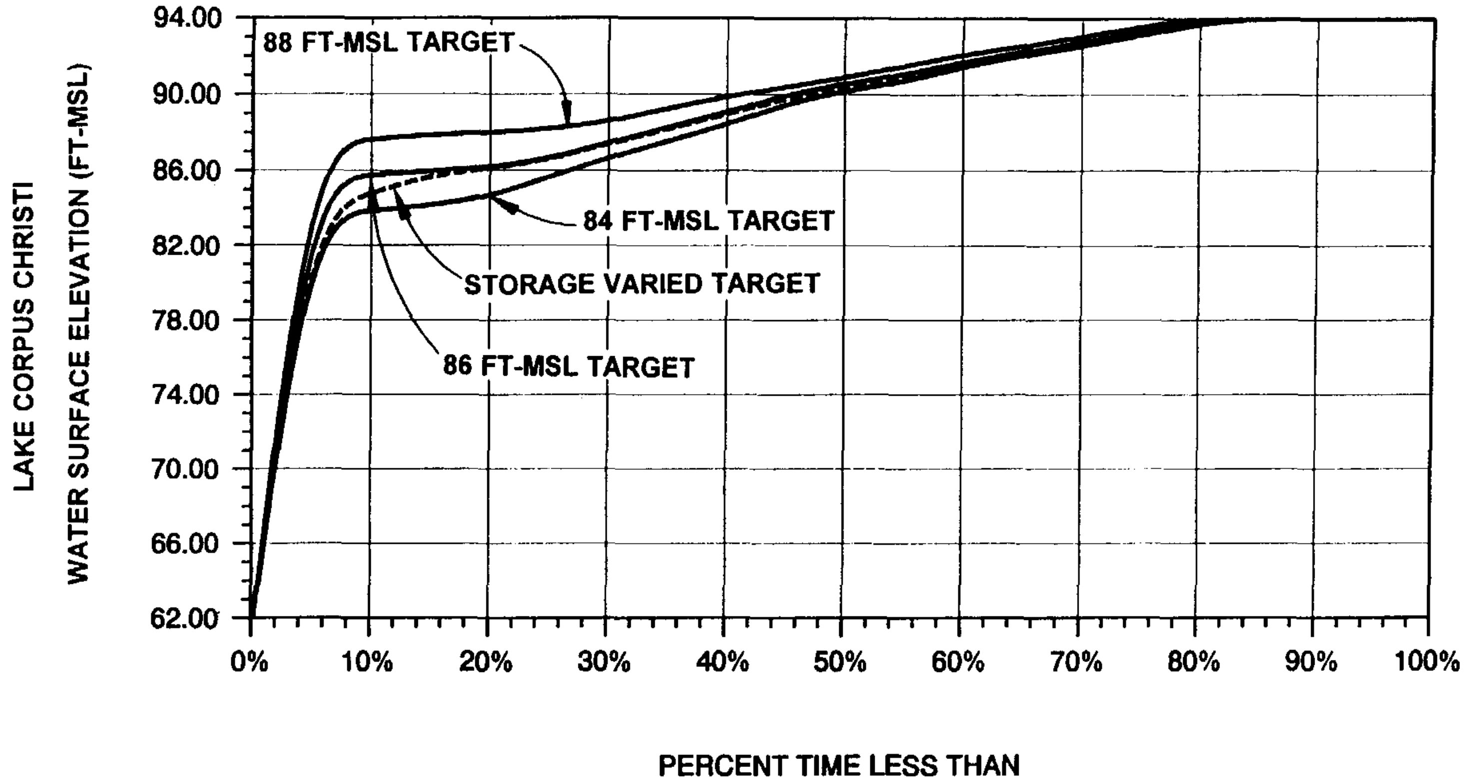
FIGURE 3.1-3

As shown in Figure 3.1-4, as the LCC target elevation is decreased, the median water surface elevations in LCC decrease as well. For example, if the water surface target in LCC is reduced from the current elevation of 88 ft-msl to 84 ft-msl, the median water surface elevation in Lake Corpus Christi is reduced by 0.67 feet from 90.87 ft-msl to 90.20 ft-msl. Raw water intakes at 84 ft-msl would be inoperable about 12 percent of the time as opposed to about 5 percent of the time at 88 ft-msl. The data plotted with solid lines represents a fixed target level for all months and storage conditions, however, alternative operating policies have been explored which consider variable target levels. These alternative operating policies are presented in the following section.

3.1.4 Alternative Reservoir Operating Policies

The first alternative reservoir operating policy explored uses a seasonally variable target elevation for LCC. Under this policy, a target elevation of 88 ft-msl was assumed for the summer months (May through August) and a lower target was used in the remaining months of the year (September through April). This target allows a higher level for increased recreational opportunities during the summer from Memorial Day in late May to Labor Day in early September. The firm yield gains using this policy, however, are modest at best. In the best case, where a summer target elevation of 88 ft-msl and a winter target of 84 ft-msl are used the system yield increase is only about 500 acft/yr. One favorable item of note regarding this policy is that the median percent system storage increases approximately 3 percent under the seasonal operation policy (compared to the baseline case of 88 ft-msl target year round). This indicates that the reliability of the reservoir system could be slightly greater if the seasonal operating policy were used.

A second alternative operation policy evaluated considers stepped reductions in the LCC target level as system storage becomes depleted during drought. This is similar to the 1995 Agreed Order, in which Nueces Bay inflow requirements are reduced as system storage is depleted. A series of model runs were made varying the system storage at which the target elevation in LCC was reduced from 88 ft-msl (when storage is high), to 86 ft-msl (when storage is in some intermediate zone), and finally to 84 ft-msl (when storage is low and drought contingency measures are required). Two choices for the lower storage trigger transition (i.e.,



NOTES:

2010 SEDIMENT CONDITIONS

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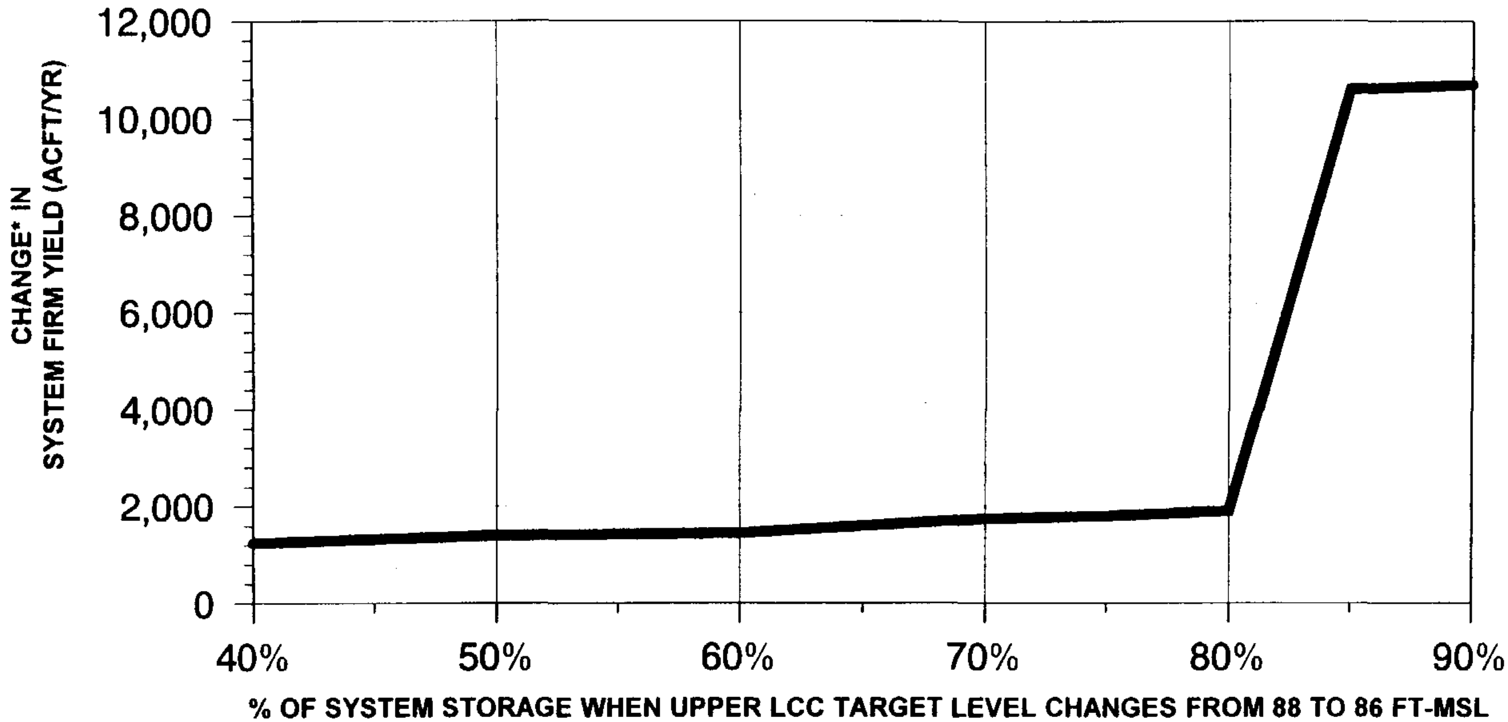
LAKE CORPUS CHRISTI STAGE FREQUENCY CURVES FOR VARIOUS LCC TARGET ELEVATIONS - ALTERNATIVE N-1

FIGURE 3.1-4

changing from a LCC target elevation of 86 ft-msl to 84 ft-msl) were either 40 percent or 30 percent of system storage since these percentages are also triggers in the 1995 Agreed Order. A series of firm yield calculations were made to compare the two choices and the results indicated that the 40 percent trigger will maximize the yield increase. Reducing the target in LCC at 30 percent storage appears to be too late to effectively increase the firm yield of the system.

The next step involved an evaluation of the upper storage trigger transition (i.e., changing from a target elevation of 88 ft-msl to 86 ft-msl). Figure 3.1-5 shows how system firm yield varies as the upper storage trigger changes with system storage. As can be seen in this figure, the maximum gain in yield is obtained by setting the percentage of system storage trigger to 85 percent. Raising the trigger above 85 percent does not increase yield substantially, but does decrease median lake levels in LCC. Therefore, it does not appear to be advantageous to raise the upper trigger to above 85 percent. A plot of the water surface elevation frequencies under this system operation policy is shown in Figure 3.1-4 (dashed line). Figure 3.1-4 shows that 80 percent of the time, under this operating policy, Lake Corpus Christi would be above 86 ft-msl. The frequency plots for this storage-varied target option and a constant target of 86 ft-msl are very similar. The storage-varied target option increases system yield by 11,000 acft/yr which is 29 percent greater than the yield gained under the constant target of 86 ft-msl option which increases yield by 8,500 acft/yr.

Table 3.1-4 summarizes the reservoir system operating policy options evaluated and lists key results for each. Before a new policy is adopted, several outstanding questions regarding the system need to be further evaluated. First, the impending sediment survey of Lake Corpus Christi needs to be completed. This will provide more accurate estimates of the rate of sedimentation accumulation in the lake, which will in turn increase confidence in the estimates of future reservoir capacities. As shown by the decreasing yield of the system over time, the capacities of the lakes play an important role in the firm yield of the system. In addition, channel loss studies on the Frio and Nueces River reaches between CCR and LCC and between LCC and Calallen Dam need to be completed to determine if losses vary significantly with the time of year and the magnitude of the releases. Results may show that losses on reservoir releases from CCR are lower in one season than another and/or that losses vary with the rate



NOTES:
* CHANGE IN SYSTEM YIELD BASED ON COMPARISON WITH YIELD UNDER EXISTING PHASE II POLICY

2010 SEDIMENT CONDITIONS

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CHANGE IN SYSTEM YIELD FOR VARIOUS UPPER TARGET LEVEL TRIGGERS - ALTERNATIVE N-1

FIGURE 3.1-5

Table 3.1-4
Summary of CC/LCC Alternative Operating Policies

Policy	LCC Target Elevation (ft-msl)	2010 Yield Increase[1] (acft/yr)	Percent of Time LCC at or below:		Change in Median Lake Level Compared to Existing Phase II Policy	
			Elevation 88 (ft-msl)	Elevation 84 (ft-msl)	Lake Corpus Christi (ft-msl)	Choke Canyon Reservoir (ft-msl)
Uniform LCC Target	88 All Year 86 All Year 84 All Year	-0- 8,500 14,000	20% 33% 37%	5% 5% 12%	0 -0.31 -0.67	0 +1.58 +2.86
Seasonal LCC Target[2]	84 Winter 88 Summer	500	26%	6%	-0.06	+1.33
Variable LCC Target[3]	88 if storage ≥ 85% 86 if storage ≥ 40% 84 if storage < 40%	11,000	33%	6%	-0.48	+1.50

[1] Yield Increases for all cases based on comparison to baseline case considering Phase II operating policy (88 ft-msl target), 2010 sediment conditions, and 1995 Agreed Order.

[2] Summer months in simulation were May--August, and winter months were September--April.

[3] LCC Target varied based on system storage percentages.

of release. This information combined with the variable LCC target elevation could lead to an improved operation policy which will maximize the yield of the CC/LCC System and minimize, to the extent possible, impacts to recreational users.

3.1.5 Environmental Issues

Introduction

Methods used to develop this section, including mapping, searches of available literature and databases, and a reconnaissance level survey of the Choke Canyon Reservoir and Lake Corpus Christi system, are described in the Environmental Overview (Section 3.0.2). The lakes and river are in or bordered by McMullen, Live Oak, Jim Wells and Nueces Counties. General descriptions of the regional environment, Nueces River Basin, and Nueces Estuary also are provided in the environmental overview.

Habitats of greatest concern with respect to altering operations of Choke Canyon Reservoir and Lake Corpus Christi include those in the lakes, streams and river, as well as those along the lake edges and the riparian strips. Protected and sensitive species of the region are listed in Appendix C, Tables 11, 14, 15, 16.

Impact Assessment

Reducing target levels for Lake Corpus Christi from 88 to 87 ft-msl would result in median levels decreasing at Lake Corpus Christi about 2 inches and increases in median levels at Choke Canyon Reservoir of about 9 inches. Reducing target levels for Lake Corpus Christi from 88 to 84 ft-msl would result in median levels decreasing less than one foot with respect to the uniform target, seasonal target, and variable target policies considered here (Table 3.1-4). Choke Canyon Reservoir levels would increase by 1.3 to 1.6 ft except in the case of a uniform target of 84 ft-msl for Lake Corpus Christi, which would increase lake levels by 2.9 ft. Furthermore, the most pronounced decreases in the level of Lake Corpus Christi would occur less than 40 percent of the time and would occur during periods of low rainfall (Figure 3.1-4). During the 10 to 20 percent of driest times, target reduction from 88 to 87 ft-msl would reduce Lake Corpus Christi levels about 1 ft and reduction from 88 to 84 ft-msl would reduce Lake

Corpus Christi levels about 4 ft. In terms of lake levels, the storage varied option is nearly equivalent to the uniform target of 86 ft-msl.

why only Centrarchid spp considered. No references for 'severe' criteria. Effect on nesting success.

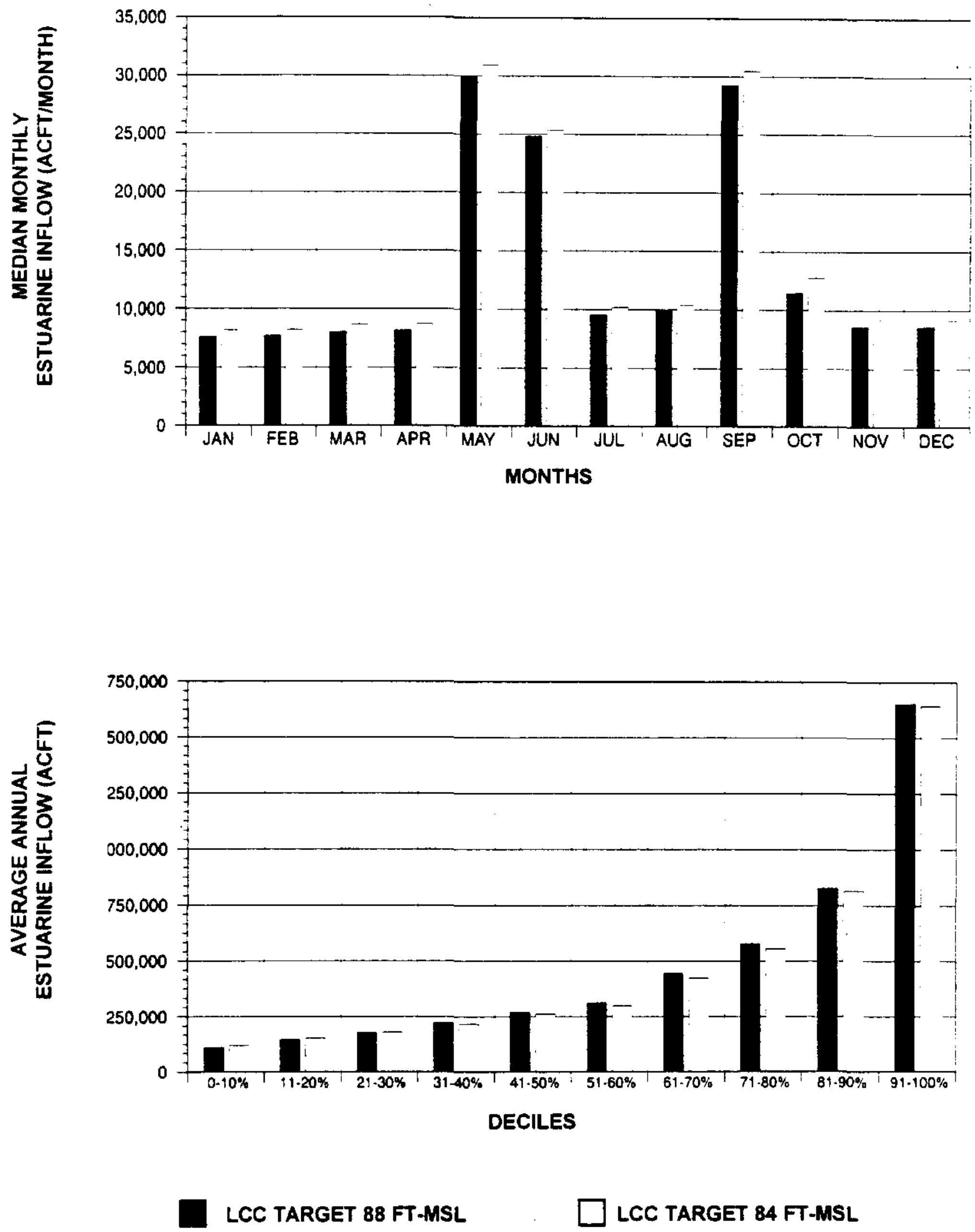
Water level fluctuations in both reservoirs might be expected to adversely affect nesting success in Centrarchid game fish only if severe (>1 meter/month), prolonged fluctuations occur during the spawning period (March-September). Long-term changes in lake hydrology would be expected to exhibit effects in terms of the distribution of aquatic vegetation and its inhabitants, however, the existence of vegetative habitats should not be affected. The effects of lowering the target 88 to 84 ft-msl would appear to be minor compared to lake level reductions that occur during a severe drought. For example, five percent of the time Lake Corpus Christi would be projected to be 80 ft-msl or lower regardless of operating policies. Nueces River flows would continue to be maintained by mandated releases (2,000 acft/month) from Choke Canyon Reservoir. Aquatic habitat in the Nueces River is not expected to be adversely affected.

Approximately 47 percent of the water diverted for use in Corpus Christi can be expected to be returned to Nueces Estuary as treated wastewater. Decreasing the Lake Corpus Christi target from 88 ft-msl to 84 ft-msl would slightly increase median monthly inflows (Figure 3.1-6). Average annual inflows would be reduced from periods of historically high flow and increased from periods of low flow with a slight reduction in median monthly salinity in Nueces Bay (Figure 3.1-7).

3.1.6 Water Quality and Treatability

Historically, the water quality at O.N. Stevens Water Treatment Plant (Stevens) near Calallen is in compliance with the TWC Secondary Drinking Water Standards. However, there is no information available on the potential effects of the CC/LCC reservoir operating policy on the water quality within Lake Corpus Christi and ultimately at Stevens. A reduced volume of water within Lake Corpus Christ as well as reduced releases from Choke Canyon Reservoir brings into question how water quality at Stevens could be affected as a result of a modification in the reservoir operating policy.

A comparison of water quality with respect to chlorides and total dissolved solids (TDS) for Choke Canyon Reservoir and Lake Corpus Christi (for the 1991 and 1992 timeframe)



NOTES:

PHASE 2 RESERVOIR OPERATING POLICY
2010 SEDIMENT CONDITIONS

TRANS TEXAS WATER PROGRAM /
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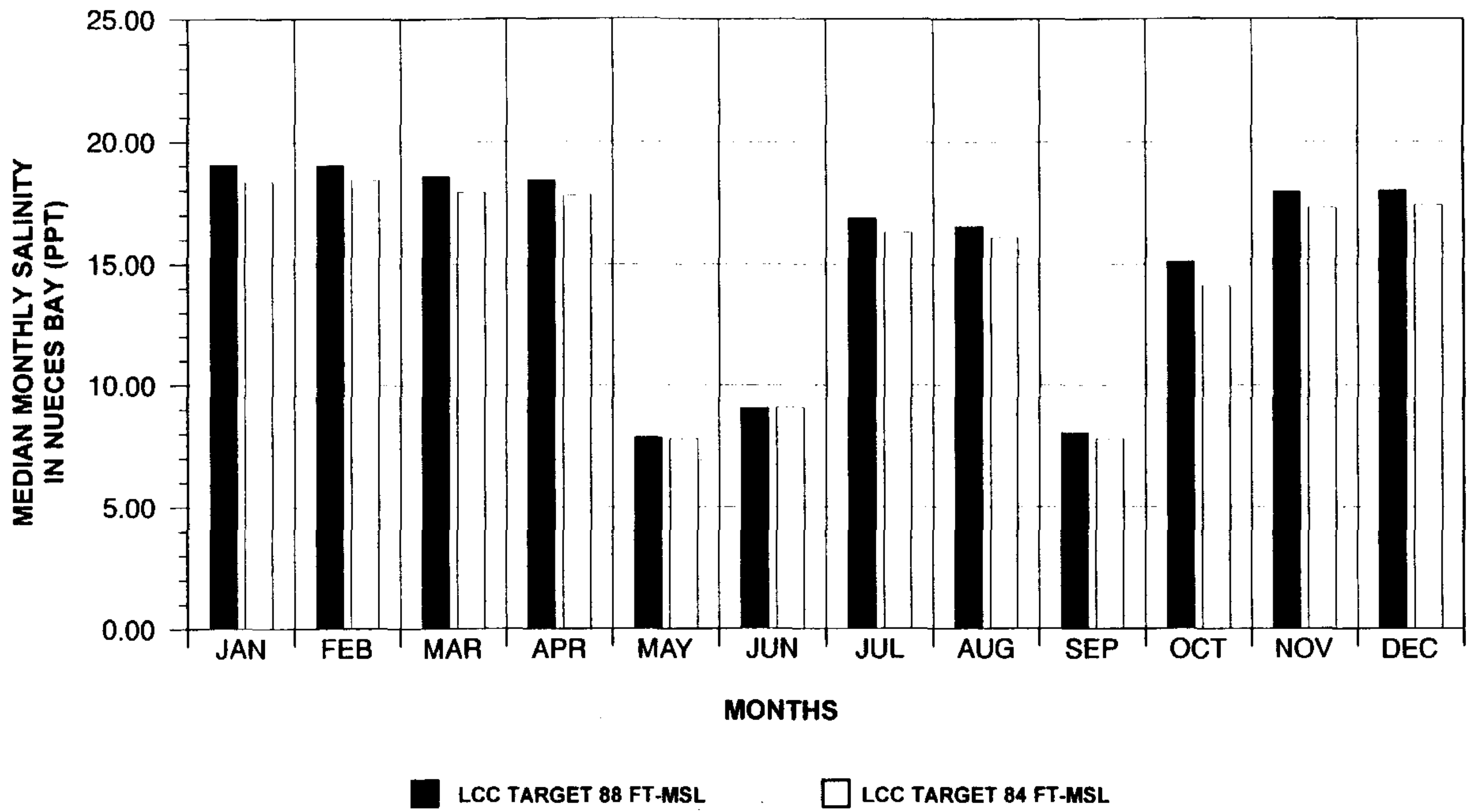
CHANGES IN NUECES ESTUARY INFLOWS ALTERNATIVE N-1

FIGURE 3.1-6



NOTES
1995 AGREED ORDER
2010 SEDIMENT CONDITIONS

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

CHANGES IN NUECES BAY SALINITY ALTERNATIVE N-1

FIGURE 3.1-7

indicates that chloride levels in Lake Corpus Christi were 48 percent lower than in Choke Canyon and that TDS were about 16 percent lower in Lake Corpus Christi. These data suggest that a change in reservoir operation policy that reduces releases from Choke Canyon may have some small positive effect on the quality of water in Lake Corpus Christi. However, water quality data for Lake Corpus Christi during the early 1980's, when Choke Canyon was filling, shows elevated chloride levels (see Figure D-3 in Appendix D). Since releases from Choke Canyon were minimal during filling, it is unclear if the rise in chlorides at LCC during this period had anything to do with Choke Canyon Reservoir or if it was strictly related to the concurrent drought conditions.

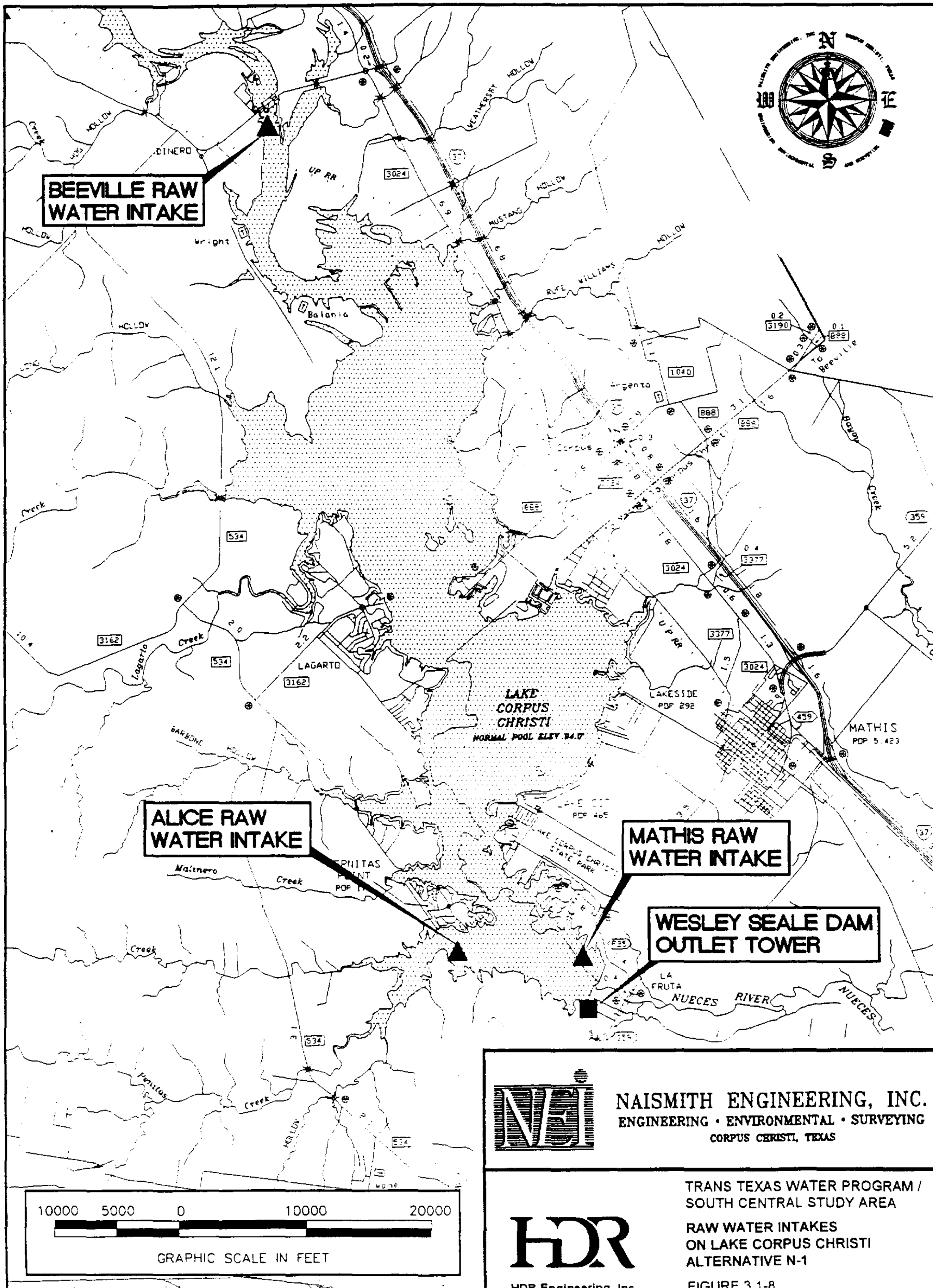
If a modification of the reservoir system operating policy is to be considered prior to the development of other, better-quality water supply options which could be used for blending purposes, then it is recommended that a more detailed study be made of the effects of changing the reservoir operation policy on the water quality at Stevens. However, from the analysis in Appendix D, it is evident that if an alternate good-quality source were available prior to changing the operating policy, the buffering effects of blending better quality water with the Nueces River water will allow an adequate margin to absorb possible adverse effects which could result from a change in reservoir system operating policy (See Table D-2 and Figures D-10, D-11, and D-12 in Appendix D).

3.1.7 Engineering and Costing

A lower operating level in Lake Corpus Christi would affect the hydraulics of the existing raw water intake structures in the lake and, potentially, the outlet tower at Wesley Seale Dam. Preliminary information on modifying existing intake structures to facilitate diversions with lake levels down to 84 was obtained from the three affected cities and their engineering consultants. Figure 3.1-8 shows the locations of the existing raw water intake facilities for the cities of Alice, Beeville, and Mathis, as well as the Wesley Seale Dam outlet tower.

City of Alice

The City of Alice raw water intake is located approximately 10,000 ft west of the outlet tower at the dam, as shown in Figure 3.1-8. The pump station includes 4 vertical turbine pumps



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RAW WATER INTAKES ON LAKE CORPUS CHRISTI ALTERNATIVE N-1

FIGURE 3.1-8

mounted on an inlet tower that is approximately 150 ft from the lake shoreline. The lake bottom below the tower was originally excavated to elevation 58 ft-msl. The bottoms of screens on the pump suction tubes are set at elevation 63 ft-msl and extend up to elevations ranging from 69 to 72 ft-msl.

Due to pump suction limits, 83 ft-msl is presently the lowest lake water surface elevation which would allow operation of the existing pumps. Level controls are set to automatically prevent operation of the pumps at elevations lower than 83 ft-msl. Minor pump station modifications would be necessary to operate the pumps between 83 and 80 ft-msl. Major modifications or construction of a new intake structure and pump station would be required if the lake operating level is lowered below 80 ft-msl.

City of Beeville

The City of Beeville's raw water intake is located near the old channel of the Nueces River approximately 14 miles north-northwest of Wesley Seale Dam, and approximately 200 ft south of the FM 534 Nueces River bridge, as shown in Figure 3.1-8. The pumps are located in a separate structure about 300 ft northeast of the intake. The intake tower was placed into operation in 1985 and was originally capable of diverting water at three levels (88.0, 79.5, and 71.0 ft-msl). However, as a result of sedimentation problems at the intake, a steel plate has been welded over the lowest intake and it is no longer functional. The City presently operates out of the middle intake at 79.5 ft-msl.

The pump station consists of 4 vertical turbine pumps mounted above a sheet pile wet well. The capacities of the existing pumps would be substantially reduced if they were operated at lake elevations below 88 ft-msl and new pumps would be required in order to operate at lake levels as low as 84 ft-msl. A review of the most recent lake bottom topographic maps indicate the Beeville intake is located in an isolated depression in the lake bottom which becomes separated from the main body of the lake when the reservoir level drops to about 83 to 84 ft-msl. It is estimated that the Beeville intake would function adequately at a lake level as low as 84 ft-msl until additional sedimentation occurs. With maintenance channel dredging, the intake could continue to function at 84 ft-msl if new pumps were installed. Table 3.1-5 presents a

Table 3.1-5
Cost Estimate for
Modifications to Existing Raw Water Intake Facilities*

Item	Estimated Cost
Capital Cost	
Beeville Intake Structure & Pump Station Modifications	$ 1,800,000
Mathis Pump Station Modifications	100,000
Subtotal	$ 1,900,000
Contingencies and Engineering (35%)	$ 665,000
Total Project Capital Cost	$ 2,565,000
Annual Cost	
Annual Debt Service	$ 240,000

* Costs include items necessary to allow operation of the intakes at Lake Corpus Christi elevations as low as 84 ft-msl.

conceptual budget estimate for new Beeville pumps that would allow operation at a minimum water level of 84.0.

City of Mathis

The City of Mathis raw water intake is located near Sunrise Beach, approximately 3,500 ft north of the Wesley Seale Dam outlet structure as shown on Figure 3.1-8. The pump station is constructed on the old Mathis dam structure in one of the deepest portions of the lake, and the station includes 2 vertical turbine pumps. Due to existing pump suction limits, operation of the intake at lake elevations as low as 84 ft-msl would require that new pumps be installed, with pump intake bowls set at lower elevations. Table 3.1-5 presents a conceptual budget estimate for modification to the pump station that would allow operation at a minimum water level of 84 ft-msl.

Outlet at Wesley Seale Dam

The outlet works at Wesley Seale Dam consist of a concrete outlet tower with 3 exterior sluice gates which control the level at which water is withdrawn from the lake into the tower, and 3 interior sluice gates and a 48-inch cylinder valve (Bunger Valve) which control the rate of release from the tower. The sizes and elevations of the 3 exterior sluice gates are indicated below.

Sluice Gate Designation	Top Elevation	Size
A	92.0	60" x 72"
B	79.0	60" x 72"
C	62.5	72" x 84"

Due to the current normal lake operating level of 88.0 ft, only gates B and C are normally used to release water into the intake tower. Normal releases from the intake tower are made through the Bunger Valve, which has opening settings to control the amount of flow that is discharged. The Bunger Valve is normally not operated at high settings due to the potential for excessive wear and operational problems that may be caused at extremely high velocities. For release rates in excess of the Bunger Valve capacity, three interior sluice gates are used to control releases. These sluice gates are 30" (H) x 48" (V) in size and have a top elevation of 59.5 ft-msl.

The interior sluice gates are occasionally opened to release the higher flow rates required by the 1995 Agreed Order. Sluice gates are normally operated in the fully open or closed position. During operation of the sluice gates, the Bunger Valve setting is lowered or closed altogether. The streamflow gaging station at the La Fruta Bridge, located approximately 3,000 ft downstream from the dam, is used to confirm the flow that is released through the sluice gates. The elevations of outlet tower gates show that the existing outlet tower can be used to make releases at lake levels as low as elevation 62.5 ft-msl.

3.1.8 Implementation Issues

The following items need to be addressed prior to implementation of this alternative:

- The impending sediment survey of Lake Corpus Christi needs to be completed. This will provide more accurate estimates of the sedimentation rate in the lake, which will result in better estimates of future reservoir capacities. The capacities of the lakes play an important role in the firm yield of the system. If the results of the sedimentation surveys indicate that reservoir sedimentation is continuing at historical rates, then a large percentage of the increases in yield presented herein (estimated for 2010 sediment conditions) are only temporary gains. For example, by the year 2050 a yield increase of 4,000 acft/yr is possible while still maintaining a 60-day minimum blending volume in Lake Corpus Christi.

- Following the results of the sediment survey, reservoir system yield should be re-computed for both 2010 and 2050 conditions.

- Additional channel loss studies on the river reaches between CCR and LCC and between LCC and Calallen Dam need to be completed to determine if losses vary significantly with the time of year and the magnitude of the release rates. Any new operating policy must consider losses from all sources in order to fully maximize the yield of the reservoir system while attempting, to the extent possible, to minimize impacts to recreational users and to maintain an adequate blending volume for water quality purposes.

- If an alternative reservoir operating policy is implemented prior to an alternative water source with better water quality becoming available, a detailed analysis of water quality should be undertaken to determine the degree and extent of water quality changes at Stevens as a result of less frequent water supply releases occurring from Choke Canyon Reservoir.

- Consideration of lower target levels at Lake Corpus Christi should address the need to modify water supply intakes in and around Lake Corpus Christi.

- Presently there are no known permits required to implement this alternative.

- As demands increase, modification of the current City Ordinance describing the implementation of operation policy phases will be necessary if alternative operating policies are implemented.

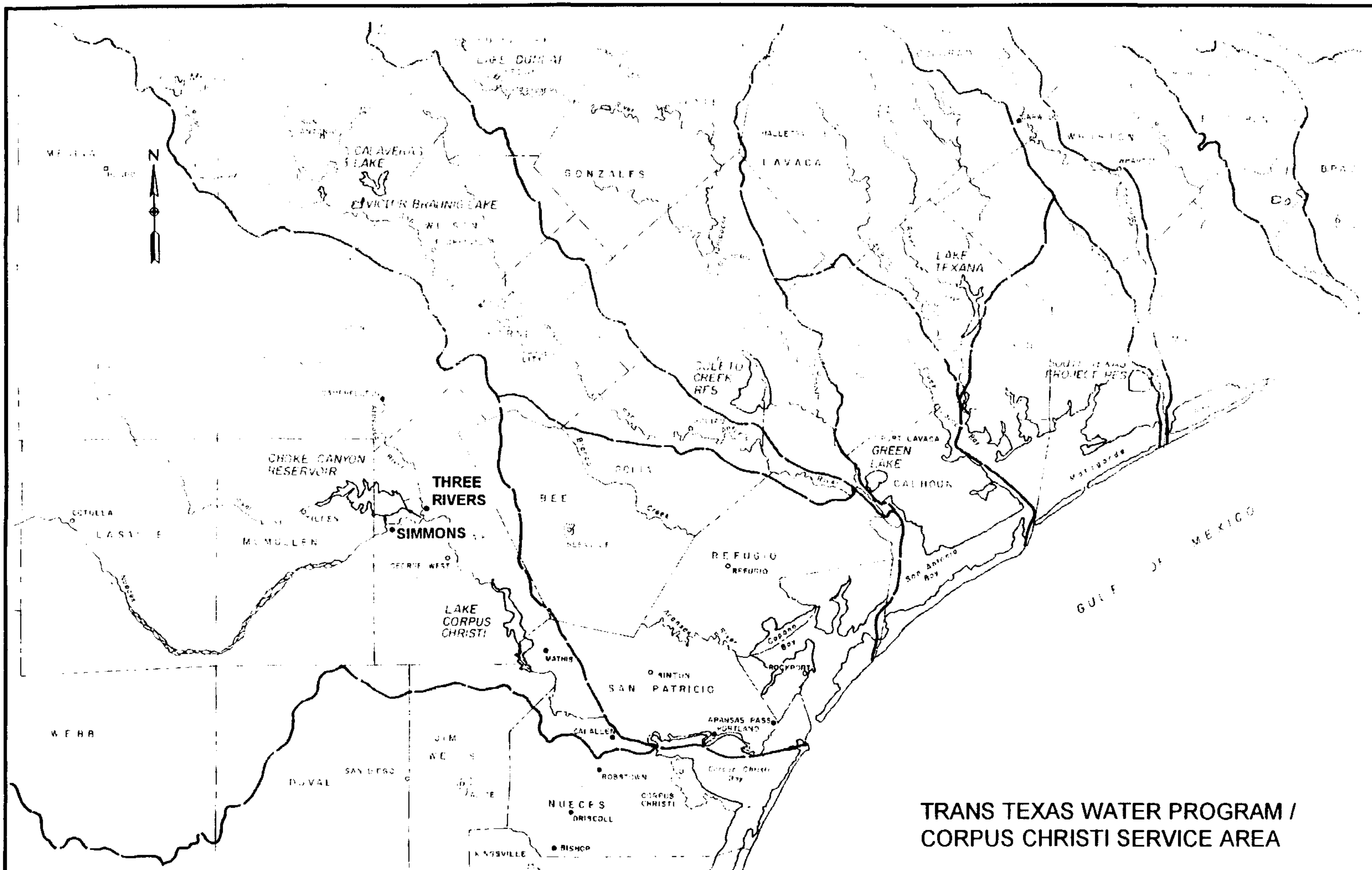
3.2 Diversion from Nueces River to Choke Canyon Reservoir (N-2)

3.2.1 Description of Alternative

Several previous studies have considered the concept of increasing the yield of the CC/LCC System by either constructing a new reservoir on the Nueces River or by diverting water from the Nueces River, under certain conditions, into Choke Canyon Reservoir. The most important factor driving the consideration of these potential alternatives is the relative proximity of the Nueces River to Choke Canyon Reservoir. The Nueces River comes within two miles of the Reservoir just north of Simmons, Texas as shown in Figure 3.2-1.

The idea that increased surface water supply could be developed in the Lower Nueces River Basin was introduced in a 1982 study entitled "Report on Availability of Additional Surface Water Supply from the Nueces River Between Uvalde and Three Rivers" (Freese & Nichols, Inc.). The Simmons Reservoir, one of the projects reviewed in the 1982 report, involved the construction of a dam and reservoir on the Nueces River near Simmons, Texas. The reservoir would inundate some 26,400 acres of land, creating 450,000 acft of total storage. In the 1982 study, firm yield volumes were calculated for two operating scenarios. In the first operating scenario, all inflows to the Simmons reservoir were captured and held, producing a firm yield of 124,900 acft/yr. However, under this scenario, the CC/LCC System yield was reduced by 120,000 acft/yr. The net increase in firm yield due to the Simmons reservoir was small (4,900 acft/yr), and the study estimated the gain would probably be lost in transferring the water downstream to the City's diversion location where it is needed. In the second operating scenario, the Simmons Reservoir only impounded those waters that would have spilled at Lake Corpus Christi had they been allowed to flow downstream. This scenario produced a larger 14,400 acft/yr firm yield increase at the Simmons Reservoir. However, the study concluded that from a system impact perspective, the lack of substantial yield would not justify such a large project.

In a 1985 report entitled "Potential for Development of Additional Water Supply from the Nueces River Between Simmons and Calallen Diversion Dam", D.G. Rauschuber and Associates proposed a pump facility rather than a reservoir at Simmons. The pump option would make use of the proximity of the Nueces River near Simmons to Choke Canyon Reservoir by taking water from the Nueces River and pumping it into Choke Canyon Reservoir.



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DIVERSION FROM NUECES RIVER TO CHOKE CANYON ALTERNATIVE N-2

FIGURE 3.2-1

The Simmons Pump Station was analyzed under two operating scenarios: 1) Operate the pumps only when Lake Corpus Christi was spilling, and 2) Operate the pumps when the water surface elevation in Choke Canyon Reservoir was more than one foot below its normal pool elevation of 220.5 feet-msl. Under the first scenario, Rauschuber estimated that 6,000 acft/yr of firm yield would be added to the CC/LCC System; however, the pumping capacity needed to achieve this increase was calculated to be 2,228 cfs or about 1400 mgd. Under the second scenario, the yield was estimated to increase by 14,000 acre-feet per year.

With previous studies providing a background for supplemental water diversions into Choke Canyon Reservoir, this study initially considered the following potential options: 1) Diverting water from the Nueces River at Three Rivers, Texas (i.e., downstream of the Frio and Atascosa Rivers), and, depending on the results of option 1), 2) Diverting water from the Nueces River at Simmons, Texas (i.e., upstream of the confluence with the Frio River).

3.2.2 Available Yield

For evaluation of this alternative, the NUBAY2 Model[1] was modified by adding a subroutine to simulate the diversion of water from the Nueces River. Diversions from the Three Rivers location were investigated first, as this option included the combined waters of the Atascosa, Frio, and Nueces Rivers. The diversions at Three Rivers were simulated with the following assumptions: 1) The minimum instream flow requirements of the Trans-Texas Environmental Criteria (i.e., 60 percent of the monthly median flows in March through September and 40 percent of the monthly median flows in October through February) were left in the river at Three Rivers and only the quantities of water in the Nueces River above these monthly volumes could be diverted into Choke Canyon; 2) Lake Corpus Christi must have a water surface above a specified cut-off elevation in order for the diversion pumps at Three Rivers to engage; 3) Choke Canyon Reservoir must have sufficient capacity to hold the diverted water; and 4) No releases above the minimum monthly release of 2,000 acre-feet are made from

[1] "Nueces Estuary Regional Wastewater Planning Study, Phase II", HDR Engineering, Inc., prepared for City of Corpus Christi, et al. March, 1993.

Choke Canyon when the pumps at Three Rivers are operating. In addition, it was assumed that the TNRCC 1992 Interim Release Order would control the releases made to Nueces Bay.

The firm yield of a reservoir system is the quantity of water that can be diverted throughout the entire historical period simulated without a shortage. In the analysis performed here, the historical period of record was 1934 to 1989 (which included the significant droughts of the 1940's, 1950's, 1960's, and early 1980's), and the firm yield of the system was calculated assuming the City of Corpus Christi's Phase IV Operations Plan and the TNRCC's 1992 Interim Release Order[2] guidelines for releases from the CC/LCC System to the bay and estuary. The City's Phase IV policy requires a minimum release of 2,000 acre-feet per month from Choke Canyon Reservoir. If the water surface at Lake Corpus Christi drops below 76 feet-msl, Choke Canyon releases are increased, based on water supply requirements at Lake Corpus Christi and downstream at Calallen, until the level of Lake Corpus Christi is returned to 76 feet-msl. Delivery losses between Choke Canyon, Lake Corpus Christi, and downstream to Calallen are accounted for in the computation of system firm yield.

Given these assumptions and operating rules, three alternative diversion cut-off levels at Lake Corpus Christi were simulated: 94 feet-msl (the elevation at which Lake Corpus Christi starts to spill), 88 feet-msl, and 80 feet-msl. The firm yield computations for these three alternatives, as well as the no pumping baseline firm yield, are shown in Table 3.2-1, for 1990 and 2050 reservoir sedimentation conditions.

As shown in Table 3.2-1, the increases in firm yield from diversions at Three Rivers are modest at best (700 to 900 acft/yr). The reason these increases are small is illustrated in Figure 3.2-2. In this figure, the bars on the vertical axis represent the volumes of water that can be diverted at Three Rivers and pumped into Choke Canyon Reservoir during the critical drought. The critical drought is the most severe drought encountered in the simulation, and the critical

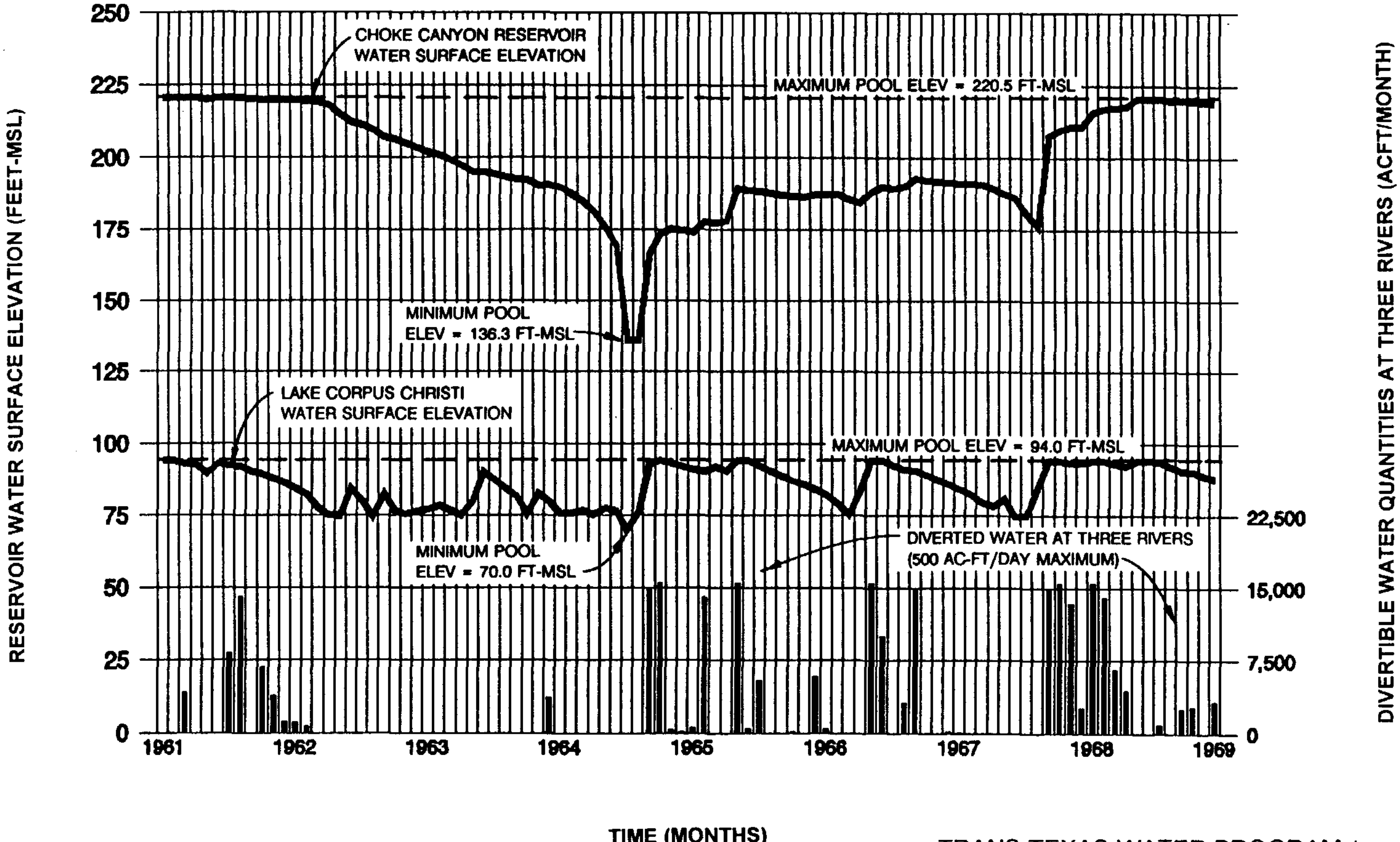
[2] On April 28, 1995, the TNRCC issued an Agreed Order superseding the 1992 Interim Order used in this study. One of the most significant differences between the Interim and Agreed Order is the CC/LCC System is not required to release stored water to satisfy monthly Nueces Bay inflow requirements under the Agreed Order. If the Diversion from Nueces Rivers to Choke Canyon Reservoir were analyzed under the 1995 Agreed Order, it is likely that the firm yield would still be very low since the critical drawdown is the same under both operating orders. Under the 1995 Agreed Order, the average annual yield would likely be unaffected.

LCC Target Elevation (No Pumping Below This Level) (ft-msl)	Firm Yield Under 1990 Conditions (acft/yr)	Increase in 1990 Firm Yield Due to Diversions (acft/yr)	Firm Yield Under 2050 Conditions (acft/yr)	Increase in 2050 Firm Yield Due to Diversions (acft\yr)
No Pumping	191,800	***	176,000	***
94.0	191,800	0	176,000	0
88.0	192,000	200	176,700	700
80.0	192,200	400	176,900	900

Table 3.2-1
Summary of CC/LCC System Firm Yields with Diversions at Three-Rivers

period for this simulation was from February, 1961 through July, 1964. As shown in Figure 3.2-2, during the critical period, only minor quantities of water are available for diversion. The reasons for this are twofold: 1) Lake Corpus Christi did not maintain a water surface elevation at or above the pump cut-off elevation of 80 feet-msl, so pumping could not be utilized; and 2) since the system was experiencing a drought, the quantities passing Three Rivers had to remain in the river to meet the instream flow requirements. As shown in the figure, only after the lakes start to refill, in August, 1964, would water have been available in the system to allow pumping at Three Rivers. However, this pumpage would have been after the critical period and, therefore, would have had no effect on the firm yield.

As shown in Table 3.2-1, the diversions at Three Rivers into Choke Canyon Reservoir gain only minor increases in firm yield, and in the scenario where waters are diverted at Three Rivers only when Lake Corpus Christi is spilling (i.e. LCC target elevation of 94 ft-msl), there is no increase in the firm yield. Therefore, as a source of firm water supply, this option is not effective. However, analysis was done to evaluate the river diversion at Three Rivers on an annual average basis. A review of the Nueces River flows indicates that on the average approximately 15,300 acft is available for diversion into Choke Canyon Reservoir (from Nueces River at Three Rivers). If channel losses to deliver this water from Choke Canyon to the City's



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CRITICAL DROUGHT PERIOD WITH LCC PUMPAGE CUT-OFF ELEVATION = 80 FT-MSL

HDR Engineering, Inc.

FIGURE 3.2-2

water supply intake are estimated at about 30%, the available water supply increase in an average year would be 10,700 acft/yr at Calallen. These volumes of water were computed using a Lake Corpus Christi target elevation of 94 ft-msl to begin pumping at Three Rivers and 2050 sediment conditions in the lakes.

The increases in firm yield and average water supply were computed using a monthly computation interval and would likely be even smaller in real time operation. For example, the simulation model operates on a monthly time step, and the model assumes that all divertable water can be captured and pumped to Choke Canyon. In actual real time operation, this would not normally be the case. The time step used in the model averages the flood flows over a month, and these flood volumes are the major source of water for diversion. During real storm events, the duration of the high flows is a matter of days or weeks rather than an entire month. Using a monthly time step, a maximum diversion rate of 15,000 acre-feet per month (i.e., 250 cubic feet per second) was used in the model. This would require a pipeline with a 90-inch diameter to transfer the water. Under daily operations, the divertable high flows pass Three Rivers in a few weeks rather than a month and the pumping requirements necessary to capture the flows could easily be three or four times the above rate.

In any case, the firm yield available from diverting the excess flows at Three Rivers to Choke Canyon Reservoir is relatively small. Based on the results of diverting water at Three Rivers, it was decided that an evaluation of diverting water at the Simmons location (where only Nueces River water is available) would not be practical since it has significantly less flow than the Three Rivers location and would provide even less water. As concluded in Phase I, the Simmons diversion alternative was not studied.

3.2.3 Environmental Issues

Introduction

Environmental issues related to diverting water from the Nueces River to Choke Canyon Reservoir include the following:

- Effects related to Nueces River flows and freshwater inflows to Nueces Estuary; and
- Effects related to pipeline construction and maintenance.

Methods used to develop this section, including mapping, searches of available literature and data searches are described in the Environmental Overview (Section 3.0.2). A reconnaissance level survey of the proposed pipeline route was performed. This alternative lies entirely within Live Oak County, which is in the South Texas Plains. The South Texas Plains, Nueces River Basin, and Nueces Estuary are described in the Environmental Overview.

Impact Assessment

Proposed Pipeline Route

The diversion of Nueces River water at Three Rivers, Texas to Choke Canyon Reservoir would include an intake, outfall, and relatively short pipeline of about 5 miles in length. Installation of the pipeline would impact 88 acres during construction and would require a 25 acre maintenance ROW for the life of the project. The region between Three Rivers, Texas and Choke Canyon Reservoir has been characterized as cropland, while that surrounding Choke Canyon Reservoir is characterized by mesquite-blackbrush brushlands[3]. The pipeline corridor between Three Rivers and Choke Canyon would cross primarily cropland (approximately 96 percent of the ROW) with the remaining area consisting of pasture (approximately 2 percent of the ROW) and riparian woodland (approximately 2 percent of the ROW).[4] Cropland and pasture would be restored to its original use following pipeline installation. The intake site on the Nueces River is in a wetland area classified as lower perennial riverine. The outfall site would be on the margin of Choke Canyon Reservoir. Less than an acre of wetland would be affected by intake and outfall construction and maintenance access to the structures.

Protected species known to this area of Live Oak and Nueces County are listed in Appendix C Tables 14 and 16. The habitat for the endangered Jaguarundi (*Felis yagouaroundi*) and Coati (*Nasua nasua*) may be within the pipeline corridor. The presence of mesquite-blackbrush, pasture, and water provide habitat for the following State protected species: the Northern Cat-eyed Snake (*Leptodeira s. septentrionalis*), Indigo Snake (*Drymarchon corais*

[3] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The vegetation types of Texas including cropland. Texas Parks and Wildlife Department.

[4] Paul Price Associates, based upon aerial photography and field reconnaissance.

erebennus), Specked Racer (*Drymobius margaritiferus*), Black-spotted Newt (*Notophthalmus meridionalis),* Rio Grande Lesser Siren (*Siren intermedia texana),* Sheep Frog (*Hypopachus variolosus),* Reticulated Collared Lizard (*Crotaphytus reticulatus),* and the Texas Horned Lizard (*Phrynosoma cornutum*).

For operation on a firm yield basis, this alternative produces only 900 acft/yr of additional water supply which would be unlikely to have an adverse impact in terms of aquatic issues. Approximately 423 acft/yr (0.2 percent of total inflow) would be returned to Nueces Estuary as wastewater. The difference of 477 acft/yr represents decreased inflows to Nueces Estuary of approximately 0.2 percent. This alternative considered alone would not produce a detectable change in the Nueces River and its Estuary.

For operation on an average annual basis, about 15,300 acft/yr would be diverted from the river reach below Choke Canyon Reservoir and stored for later release. Because these diversions occur during high river flows (when Lake Corpus Christi is spilling), instream flows will be reduced slightly and instream flows during dry periods will be increased slightly when stored water is released. If this operational scenario is chosen to be pursued in later phases, further analysis of in-stream flow effects should be performed.

Some cultural resources have been found in the vicinity of the pipeline corridor. A systematic pedestrian survey of the entire corridor will be required to search for surface indications of cultural deposits. There is one National Historic Register site in the vicinity of the project area near Calliham (Pagan site 41LK58).

3.2.4 Water Quality and Treatability

Since this project would function as part of the CC/LCC System and all increase in system yield would come from the Nueces River, no significant impacts to water quality or treatability are anticipated.

3.2.5 Engineering and Costing

Diversion of the Nueces River at Three Rivers into Choke Canyon Reservoir results in minor increases in firm yield. As a source of firm water supply, this option only provides about 900 acft of firm yield. However, on an annual average basis it produces about 10,700 acft/yr of additional water supply at Calallen. For costing of this scenario, a diversion dam and pump station would be constructed downstream of the confluence of the Nueces and Atascosa rivers to capture a portion of high flows when Lake Corpus Christi is spilling. The major facilities required to implement this alternative are:

Diversion Dam
Intake and Pump Station
Transmission Pipeline
Stilling Basin at Choke Canyon Reservoir

The intake and pump station would be sized to deliver 500 acft/day (250 cfs) through a 90-inch diameter pipeline. The operating cost was determined for an annual average water delivery of 15,300 acft. Estimated project costs are summarized in Table 3.2-2. The estimated construction cost totals $16,720,000. For a construction period of one year, a uniform disbursement of construction funds, and an 8% annual interest rate, interest during construction totals $460,000. Financing the project over 25 years at an 8% annual interest rate results in an annual expense of $2,130,000. Operation and maintenance costs total $290,000. Annual costs, including construction costs, interest, and operation and maintenance, would total $3,140,000. Cost of water would be $293 per acft for Alternative N-2 based on year 2050 estimated average annual water supply of 10,700 acft. Cost of water would be about $3,400 per acft based on the 900 acft of firm yield developed.

3.2.6 Implementation Issues

On a firm yield basis, very little water is available from this alternative and the resulting high unit cost renders the project not feasible. However, if implemented, this project could produce about 10,700 acft/yr on average (some years would be much lower) and the annual cost of this water would be about $293 per acft. Although this cost cannot be compared directly to the cost of firm yield water of other alternatives, it can be compared to the operational cost of other projects which approximates the cost for pumping non-firm water when available. For instance, the incremental cost to pump water in the Texana Pipeline is about $73 per acft to pay for electricity, and cost of non-firm water for Alternative N-2 (this alternative) is about 4 times as expensive.

Table 3.2-2
Cost Estimate for Diversion from Nueces River To Choke Canyon Reservoir (Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Diversion Dam	$1,750,000
Intake and Pump Station	6,520,000
Pipeline	8,450,000
Subtotal	$16,720,000
Engineering, Legal and Contingencies	5,370,000
Environmental Studies and Mitigation	150,000
Land Acquisition	50,000
Subtotal	$22,290,000
Interest During Construction	460,000
Total Project Cost	$22,750,000
Annual Cost	
Annual Debt Service	$2,130,000
Annual Operation and Maintenance (excl. power)	290,000
Annual Power Cost	720,000
Total Annual Cost	$3,140,000
Average Water Supply (acft/yr)	10,700
Annual Cost of Water (Average Conditions)	$293 per acft
Firm Yield Developed (acft/yr)	900
Annual Cost of Water (Firm Yield)	$3,488 per acft

1. It will be necessary to obtain these permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD Sand, Gravel, and Marl permit.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highway and railroads.
   b. Creeks and rivers.
   c. Other utilities.

Other Considerations

If Alternative N-2 is chosen to be pursued in later phases of the Trans-Texas program, then conjunctive implementation of Alternative N-5 (Pipeline from Choke Canyon to Lake Corpus Christi) should be studied. Under this combined option, the short pipeline from the Nueces River to Choke Canyon Reservoir (N-2) would be designed to flow either direction. When Lake Corpus Christi is below spillway elevation, water would be diverted from Choke Canyon to Lake Corpus Christi. When Lake Corpus Christi is spilling, then water would be diverted from the Nueces River and pumped to Choke Canyon Reservoir.

3.3 R&M Reservoir (N-3)

3.3.1 Description of Alternative

R&M Reservoir was proposed in 1965 by Reagan and McCaughan Consultants[1] as an alternative to the Bureau of Reclamation's Choke Canyon Reservoir to provide a future water supply source for the City of Corpus Christi. At the time R&M was introduced, Choke Canyon was considered the preferred of the two projects due to its lower unit cost for water. Since the two alternatives were supported by various local interests, the TWDB elected to support either of the proposals if the decision were based on the plans of the local government and business interests.

The Bureau completed a comparative analysis of the two reservoirs in 1969. On the basis of this report, the City held a referendum in which R&M was preferred by the voters. After the referendum, the Bureau published the "Nueces River Project, Texas: Feasibility Report" in July, 1971, recommending R&M despite significant decreases in freshwater inflows to the bays and estuaries associated with the project. The report states that these shortages would be essentially unavoidable and that the only way to mitigate the problem would be either to cancel the project or import water from the east. Debate over the two alternatives continued until 1975 when Choke Canyon was again selected as the favored water supply project and was subsequently constructed.

R&M Reservoir was again considered as a possible water supply source in the 1985 Rauschuber and Associates, Inc. report, "Potential for Development of Additional Water Supply from the Nueces River Between Simmons and Calallen Diversion Dam". R&M was analyzed as part of a three-reservoir system with Choke Canyon and Lake Corpus Christi and was found to increase the system yield by 68,300 acft/yr under year 2010 sediment conditions. The cost of water from R&M was estimated in 1985 to be $355 per acft/yr. Inflows to the bays and estuaries were expected to decrease by 81 percent upon construction of R&M. The report mentions the possibility of mitigation by increased return flows and nutrient flows entering the estuarine system, however, specific flow rates were not presented.

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[1] "Engineering Report, Dam and Reservoir Sites on the Nueces River Below Lake Corpus Christi", Reagan and McCaughan Consultants, prepared for TWDB, 1965.

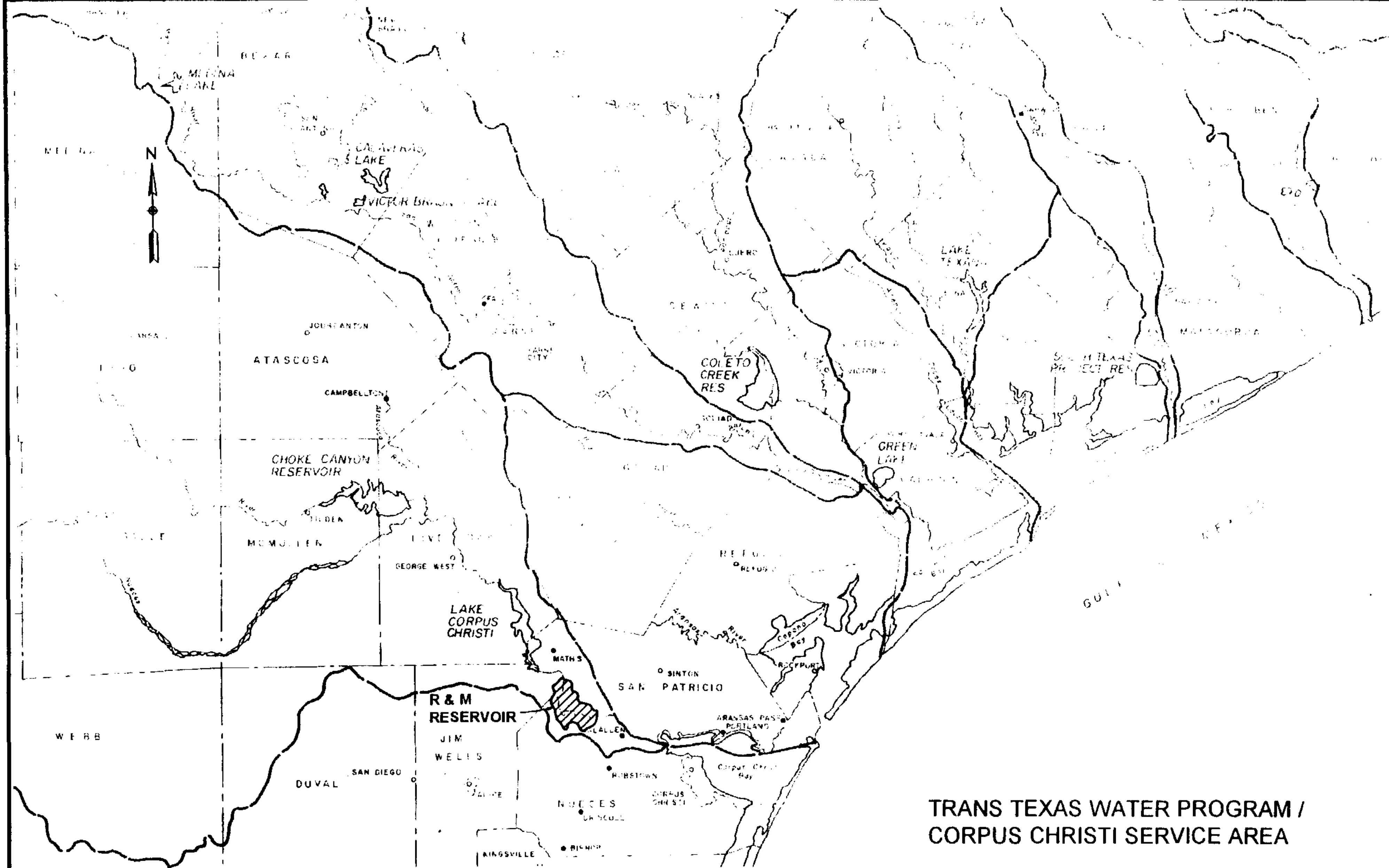
The R&M Reservoir described by Rauschuber had an earth-fill dam and a concrete spillway located approximately 22 river miles above the mouth of the Nueces River (see Figure 3.3-1). The reservoir, at a conservation pool level of 70 feet-msl, extended 25 river miles upstream to the toe of the Wesley Seale Dam, had a conservation capacity of 986,600 acre-feet, and a surface area of 31,340 acres. The estimated construction cost was stated as $236.3 million and the annual cost estimated at $24.4 million.

3.3.2 Available Yield

The yield of the R&M Reservoir alternative was analyzed in two different ways for this report. For Alternative N-3A, the R&M Reservoir was treated as a third reservoir in the existing CC/LCC System and operated according to the 1992 TNRCC Interim Order governing the releases for Nueces Estuary. This is how the reservoir was considered in the Phase 1 study. For Alternative N-3B, R&M Reservoir was modeled as a new reservoir under Trans-Texas Environmental Criteria for New Reservoirs. The assumptions and modeling techniques used to analyze these two options are described below.

<u>Alternative N-3A</u>

To determine the yield available under this alternative, the Lower Nueces River Basin and Estuary Model was modified to simulate the operation of R&M Reservoir as part of the existing CC/LCC System. A version of the model was created to operate the three-reservoir system (including Choke Canyon Reservoir, Lake Corpus Christi, and R&M Reservoir) subject to the following assumptions: 1) Releases for water supply and for the Nueces Estuary were made from R&M first and supplemented by releases from Lake Corpus Christi and/or Choke Canyon Reservoir when R&M lacked sufficient storage to meet the requirements and; 2) Releases to meet the bay and estuary flow requirements were made from the three-reservoir system in accordance with the TNRCC Interim Order of March 9, 1992. It was assumed that the freshwater needs of the Nueces Estuary were adequately defined by studies for the Technical Advisory Committee formed by the Texas Water Commission on which the 1992 Order is based. Freshwater inflows as called for in the 1992 Interim Order were assumed to preclude the need for central tendency estimates of freshwater inflows as referenced in the Trans-Texas



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R & M RESERVOIR ALTERNATIVE N-3

FIGURE 3.3-1

Environmental Criteria. The resulting yield developed by R&M under this alternative operating plan ranged from 86,000 acft/yr for 1990 sediment conditions to 92,000 acft/yr for 2050 conditions as shown in Table 3.3-1.

Table 3.3-1
Summary of System Firm Yields with and without R&M Reservoir

Alternative N-3A			
Reservoir Sedimentation Year	**Firm Yield[1] Without R&M Reservoir (acft/yr)**	**Firm Yield[1] With R&M Reservoir (acft/yr)**	**Increase in Firm Yield[1] Due to R&M Reservoir (acft/yr)**
1990	192,000	278,000	86,000
2050	176,000	268,000	92,000

[1] Firm yields are based on Phase IV operating policy and 1992 TNRCC Interim Order. Trans-Texas Environmental Criteria not applied.

Alternative N-3B

To determine yield available under Alternative N-3B, the firm yield of the R&M Reservoir was computed using a model (RESSIM) specifically written to simulate reservoir operations subject to the Trans-Texas Environmental Criteria for New Reservoirs. These criteria include: 1) Passage of reservoir inflows up to the mean or median natural streamflow in each month to maintain instream flows and provide freshwater inflows to the bays and estuaries when reservoir storage exceeds the capacity threshold for drought contingency operations; and 2) Passage of reservoir inflows up to the median daily flow of the stream observed during the historical drought of record when the reservoir storage drops below the capacity threshold for drought contingency operations. The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operation under the Trans-Texas Environmental Criteria for new reservoirs and threshold triggers of 40 percent, 60 percent, and 80 percent storage were modeled. Inflows used in the simulation of R&M Reservoir under this alternative included LCC releases and spills as well as runoff from the intervening drainage area upstream of the proposed R&M dam site and downstream of LCC.

R&M was allowed to impound only LCC spills and intervening runoff in excess of the higher of either the Trans-Texas Environmental Criteria inflow passage requirements or the Nueces Bay inflow requirements as stated in the 1992 TNRCC Interim Order.

The resulting firm yields of R&M Reservoir under this alternative operating plan are shown in Table 3.3-2. For a 60 percent capacity threshold, the yields ranged from a low of 43,500 acft/yr for 1990 sediment conditions to a high of 57,500 acft/yr for 2050 sediment conditions. At an 80 percent capacity threshold, the increase in firm yield due to R&M Reservoir was found to be 47,500 acft/yr and 62,000 acft/yr under 1990 and 2050 sediment conditions, respectively. This represents less than a 10 percent increase when compared to yields with a 60 percent capacity threshold. At a 40 percent capacity threshold, the increase in firm yield due to R&M Reservoir was found to be 42,500 acft/yr and 53,500 acft/yr under 1990 and 2050 sediment conditions, respectively. These yields represent 1,000 acft/yr (2.4 percent) and 4,000 acft/yr (7 percent) decreases in the 1990 and 2050 firm yields compared to the yields resulting from a 60 percent capacity threshold.

Table 3.3-2
Summary of System Firm Yields with and without R&M Reservoir

Alternative N-3B

Reservoir Sedimentation Year	Reservoir Capacity Threshold[2]	Firm Yield[1] Without R&M Reservoir (acft/yr)	Firm Yield[1] With R&M Reservoir (acft/yr)	Increase in Firm Yield[1] Due to R&M Reservoir (acft/yr)
1990	60%	192,000	235,500	43,500
2050	60%	176,000	233,500	57,500
1990	80%	192,000	239,500	47,500
2050	80%	176,000	238,000	62,000
1990	40%	192,000	234,500	42,500
2050	40%	176,000	229,500	53,500

[1] Firm yields are based on Phase IV operating policy and 1992 TNRCC Interim Order.
[2] The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

When R&M is treated as a new Trans-Texas reservoir (Alternative N-3B), the increases in yield attributable to R&M are significantly less than under Alternative N-3A. This is because Alternative N-3A only considers Nueces Bay inflow requirements under the 1992 TNRCC Interim Order, whereas Alternative N-3B considers the higher of the 1992 TNRCC Interim Order or the Trans-Texas Environmental Criteria. Freshwater inflow requirements for Nueces Bay under the 1992 TNRCC Interim Order were based on maintenance/maximization of expected harvest of selected species in the Nueces Estuary. These requirements were typically significantly less than the monthly mean or median flows required to be passed under Trans-Texas Environmental Criteria in those months when R&M storage exceeded the capacity threshold for drought contingency operation. In both cases the firm yield attributable to R&M increases in the year 2050 because most of the sediment accumulation occurs in Lake Corpus Christi and R&M is able to capture the resulting additional spills.

On April 28, 1995, the TNRCC issued an Agreed Order superseding the 1992 Interim Order used in this study. One of the most significant differences between the Interim and the Agreed Order is that the CC/LCC System is not required to release stored water to satisfy monthly Nueces Bay inflow requirements under the Agreed Order. If R&M were analyzed under the 1995 Agreed Order, it is likely that the yield attributable to R&M would decrease because the baseline yield of the existing CC/LCC System increases by about 13,000 acft/yr, while the yield of the three reservoir system would not likely increase to the same extent.

3.3.3 Environmental Issues

Introduction

Environmental issues related to the construction of R&M Reservoir can be categorized as follows:

- Effects related to the construction and maintenance of R&M Reservoir;
- Effects related to Nueces River downstream from the dam and;
- Effects related to Nueces Bay and Estuary.

Methods used to develop this section, including mapping, searches of existing literature and databases, and field reconnaissance are described in the Environmental Overview (Section 3.0.2). R&M Reservoir would involve land usage in portions of Nueces, San Patricio and the northeast corner of Jim Wells counties. Descriptions of the regional environment are presented in the Environmental Overview.

The environmental and cultural resources mitigation items discussed by the Bureau of Reclamation in the Nueces River Project Feasibility Report (BOR, 1971) are not included as part of this analysis, although they are used as a guide to areas of concern, and as indicators of probable impact liability.

Impact Assessment

The R&M dam would be an earth embankment 3.1 miles in length, having a footprint of about 160 acres, and with concrete service and emergency spillways. The dam would span the Nueces River valley about 22 miles above the river mouth in Nueces Bay, where it would intercept runoff from the 168 square mile drainage area below Lake Corpus Christi. At a conservation pool elevation of 70 feet MSL and a conservation capacity of 986,600 acft, R&M Reservoir would back water up to Wesley Seale Dam, inundate 31,340 acres, and provide a firm yield (incremental to the existing Choke Canyon - Lake Corpus Christi system yield) of between 92,000 acft /yr and 53,500 acft/yr (2050 conditions) depending on operational procedures (N-3A and N-3B respectively). Except for the borrow areas, construction impacts would occur on less than 200 acres, and would be partially compensated for by development of vegetation cover on the dam. Sediment loading would need to be minimized by engineering practices during dam construction to prevent large scale movement and deposition in the river channel. Small, temporary increases in sediment load are not expected to have significant impacts to the biological community of the Nueces River reach between the proposed dam site and the Calallen Diversion Dam. The lower Nueces River water is characteristically mildly turbid, and the biological community is presumably adapted to those conditions.

Direct operational effects of the R&M alternative will include permanent inundation of 31,340 acres in the conservation pool, changes in the streamflow regime below the dam, and reductions in inflows to Nueces Bay equal to the amount of water diverted and not returned to Nueces Bay, plus the net increase in evaporation resulting from impoundment. Indirect impacts would include land use changes in the areas surrounding the reservoir, and in mitigation areas that may be required to compensate for losses of terrestrial habitat.

The 31,340 acres to be disturbed by dam construction or inundation includes about 446 acres (1.4 percent) of wetlands, primarily Nueces River channel and vegetated wetlands on the floodplain, nearly 13,000 acres (41 percent) of woods, brush and shrubland, and about 16,000 acres (52 percent) of grass and cropland. The remainder of the R&M site (1854 acres, 6 percent) is occupied by developed areas. Dominant vegetation in the region containing the reservoir site consists of mesquite-blackbrush brushland which has been extensively modified by agricultural activity, oil and gas extraction, and suburban/rural residential development (TPWD, 1984). Agricultural activity on the Nueces River floodplain is not as intense as in the surrounding uplands where little woody plant cover persists. Woodlands on the reservoir generally occur as riparian strips and more extensive floodplain stands, while the brush and shrub communities often occur as scattered, overgrown pastures or abandoned cultivated fields partially or wholly surrounded by cultivated land. The wood and brushland on the Nueces River floodplain and its tributaries appears to be the largest area of contiguous wildlife habitat in Nueces and San Patricio Counties, which have experienced much more agricultural modification than the more arid brushlands to the west.

Plant and animal species listed as endangered or threatened by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department are listed for Nueces, San Patricio and Jim Wells Counties, respectively, in Tables 16, 18, and 11, of Appendix C. Although the Texas Natural Heritage Program has not reported any endangered species occurrences from the R&M site, a number of those listed for these three counties have habitat requirements or preferences that indicate that they could be present within the reservoir site (Table 3.3-3), and several marine endangered species may be considered affected by this alternative. The reservoir site will have to be surveyed for the occurrence of endangered species or designated critical habitat, and any project applicant will likely have to support endangered species consultation among the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service or National Marine Fisheries Service (depending on the species involved). Operation of the R&M alternative will reduce stream flow in the approximately 5 mile reach of the Nueces River between the dam site and the salt water barrier at Calallen by an amount equal to the net increase in evaporation resulting from impoundment. It will continue the controlled flow regime now in place on the lower

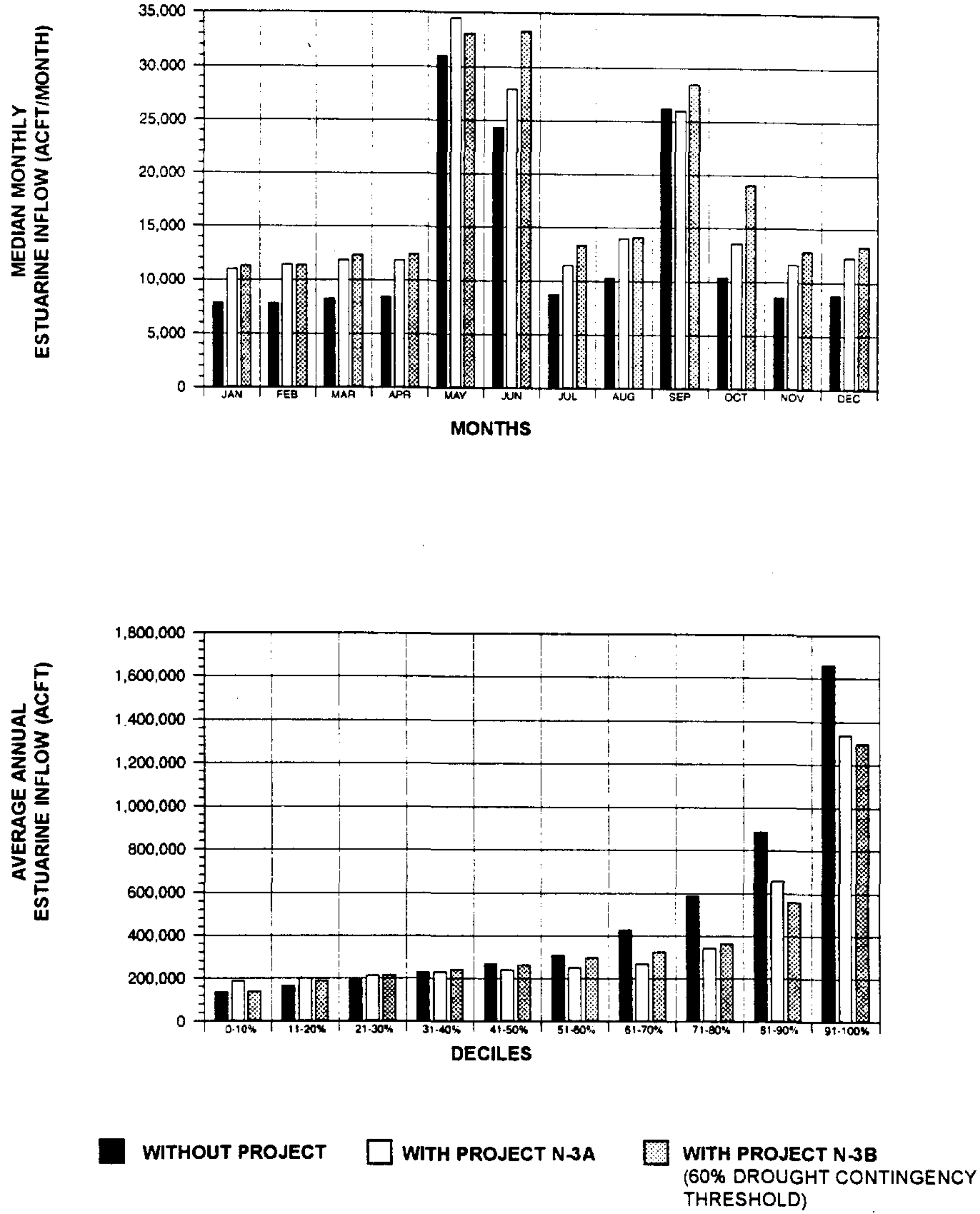
Table 3.3-3
Important Species With Habitat in the Vicinity of the Proposed Project (GS-1)

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	Listing Agency TPWD
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E
Jaguarundi	*Felis yagourarundi*	South Texas thick brushlands, favors area near water	E	E
Ocelot	*Felis pardalis*	Dense Chaparral thickets, mesquite-thorn scrubland, live oak mottes; primarily extreme south Texas	E	E
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporarily wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E
Indigo Snake	*Drymarchon coralis*	Grassland Prairie to coastal sand hills; prefers woodland and mesquite savannah of Coastal Plain	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks	C2	T
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions	NL	T
Northern Cat-eyed Snake	*Leptodeira septentrionalis septentrionalis*	Coastal Thorn thicket; principal microhabitat is dense vegetation bordering ponds and watercourses	NL	E
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T
Black Lace Cactus	*Echinocereus reichenbacnii albertii*	Grows in extremely heavy brush and very localized	E	E
Slender Rush-pea	*Hoffmannseggia tenella*	Gulf Coast Prairies and marshes; clay soils near creeks with buffalo grass, spear grass, mesquite and prickly pear cactus	E	E

Sources: Texas Parks and Wildlife Department. Unpublished data, December 1993. Texas Natural Heritage Program Files; TPWD, Endangered Resources Annual Status Report (E.R.A.S.R.) Appendix G Special Plant List; and TPWD, Unpublished May 1988 species data list by county.

Nueces as water will continue to be released downstream for diversion at Calallen. However, the operation of R&M will reduce estuarine inflows by an amount equal to the net increase in evaporation resulting from impoundment and by the amount diverted and not returned to the Nueces Delta.

Combined inflows to Nueces Estuary were modeled without R&M reservoir and with the reservoir (N-3A and N-3B) as part of the Nueces Basin reservoir system by HDR Engineering using a 1934-1989 period of record. The "without R&M" scenario assumed 1990 reservoir capacities, 1990 water demands and return flows, continuation of the present maintenance inflow regime for the Nueces Estuary required by the TNRCC, and all return flows delivered to Nueces Bay. The "with R&M" scenarios (N-3A and N-3B) were similar except that 2050 reservoir capacities, water demands and return flows were assumed. The inflows to Nueces Bay presently required by the Texas Water Commission (N-3A) were significantly less than the releases required to comply with the Trans-Texas guidelines for new reservoirs (N-3B). The analysis indicated that the incremental system yield with the R&M Alternative N-3A in place would be 86,000 acft/yr under 1990 conditions and 92,000 acft/yr under 2050 conditions (Table 3.3-1). Using Trans-Texas guidelines for new reservoirs would reduce the additional system yield attributable to R&M Reservoir to 43,500 acft/yr under 1990 conditions and 57,500 acft/yr under 2050 conditions with a 60 percent reservoir capacity threshold (Table 3.3-2). With respect to Alternative N-3A, adding R&M operation increased monthly median estuary inflows from the Nueces River by an average 3,055 acft (31 percent; Figure 3.3-2). Similarly modeling R&M under Alternative N-3B increased monthly median estuary inflows from the Nueces River by an average of 4526 acft (43 percent). Conversely, in terms of 2050 conditions, R&M Reservoir decreased median annual inflows from 290,373 acft to 247,612 acft (14.7 percent) and 272,266 acft (6.2 percent) for N-3A and N-3B respectively. The pattern of increased median monthly inflows concomitant with decreased median annual inflows reflects the nature of system operation. Low flows typical of the Nueces River are increased and maintained at more constant levels by inflow maintenance requirements and return flows of treated wastewater. Conversely, higher flows are captured and diverted for human use. The average annual inflow presented in Figure 3.3-2 illustrates the projected small increases in the lowest 20 percent of Nueces Bay inflows and the large decreases (about 20 percent or greater) in the highest flows, with respect to either operational alternative involving R&M. Changes of this magnitude in the high range inflows, particularly when coupled with the additional sediment trapping capability of R&M Reservoir, are expected to result in further reductions in nutrient and sediment delivery to the Nueces Estuary.



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CHANGES IN STREAMFLOW
R & M RESERVOIR
ALTERNATIVE N-3

FIGURE 3.3-2

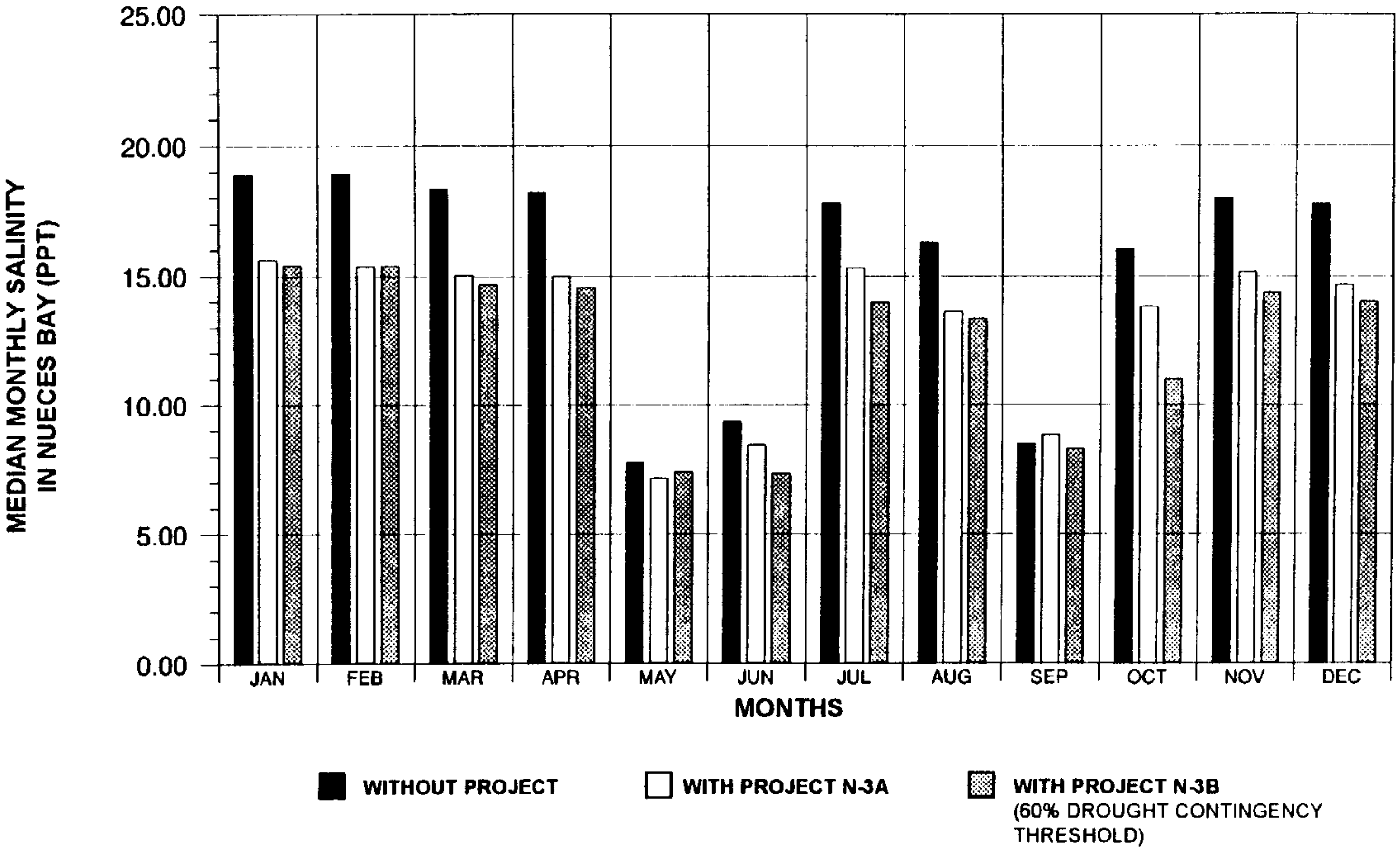
Upper bay salinity changes exhibited a pattern similar to those for freshwater inflows (Figure 3.3-3). Although monthly median salinities decreased under both alternatives involving R&M, the number of upper bound and lower bound violations decreased (Tables 3.3-4 and 3.3-5). This resulted from reservoir operation characterized by increasing flow during periods of low flow and diverting water during periods of high inflow.

With regard to cultural resources, at least one site on the National Register of Historic Places (the McGloin Homestead) is present within the area that would be inundated. Other known sites, including a small state park, that have already been recommended for additional study and would be affected by implementation of the R&M Alternative, are present at the town of San Patricio and at Fort Lipantitlan. In addition to mitigating impacts to these sites, at least one cemetery is present within the reservoir footprint, and numerous grave relocations may have to be accomplished. A systematic pedestrian survey of the entire reservoir site will be required to search for surface indications of cultural deposits, while a geomorphologic study to evaluate the potential for buried deposits is also a likely requirement. Sites located will have to be tested for archaeological or historical significance, eligibility for listing on the National Register, and the need for additional study, salvage, or other mitigation determined.

Mitigation costs for the R&M Reservoir Alternative will vary depending on the price and availability of land together with the acreage required to generate the necessary habitat value. Because of the proximity of the area to Corpus Christi, considerable development such as weekend homes and small farms exist in the reservoir area.[2] This development can be expected to continue and to increase project costs. Required acreages are unlikely to be less than the combined area of the uncultivated lands impacted, including wetlands, woods, brush, shrub, and some fraction of the grasslands (about 15,000 acres), and may be much higher, possibly equal to the entire reservoir area. It is the policy of Texas Parks and Wildlife Department to request mitigation for all wildlife impacts. The extensive brushland of the Nueces basin represents considerable wildlife habitat.[3] Even habitat heavily modified for pasture or crop production has

[2] Paul Price Associates, Inc., 1995. Reconnaissance Survey.

[3] Ibid.



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CHANGES IN UPPER NUECES BAY SALINITY ALTERNATIVE N-3

FIGURE 3.3-3

Table 3.3-4
Comparison of Monthly Lower Salinity Bound Violations in Upper Nueces Bay with and without R&M Reservoir (Alternative N-3)

Month	Interim Order Monthly Lower Salinity Bound (ppm)	Reduction in Lower Bound Violations w/ R&M Reservoir Option N-3A	Additional Lower Bound Violations w/ R&M Reservoir Option N-3B
JAN	5	1	1
FEB	5	1	1
MAR	5	0	0
APR	5	1	1
MAY	1	1	1
JUN	1	3	3
JUL	2	2	2
AUG	2	2	2
SEP	5	5	3
OCT	5	6	3
NOV	5	4	5
DEC	5	0	1
SUM		26	23

Analysis based on Phase 4 CC/LCC Operating Policy, the 1992 TNRCC Interim Release Order, and 2050 sediment conditions.

Reductions based on comparison with CC/LCC System without R&M Reservoir.

Table 3.3-5
Comparison of Monthly Upper Salinity Bound Violations
in Upper Nueces Bay
with and without R&M Reservoir (Alternative N-3)

Month	Interim Order Monthly Lower Salinity Bound (ppm)	Reduction in Upper Bound Violations w/ R&M Reservoir Option N-3A	Reduction in Upper Bound Violations w/ R&M Reservoir Option N-3B
JAN	5	0	0
FEB	5	0	0
MAR	5	0	0
APR	5	0	0
MAY	1	2	2
JUN	1	3	3
JUL	2	0	0
AUG	2	0	0
SEP	5	2	2
OCT	5	0	0
NOV	5	0	0
DEC	5	0	0
SUM		7	7

Analysis based on Phase 4 CC/LCC Operating Policy, the 1992 TNRCC Interim Release Order, and 2050 sediment conditions.

Reductions based on comparison with CC/LCC System without R&M Reservoir.

some wildlife value. For example, 95 percent of the Nueces River Basin watershed is considered to be white-tailed deer (*Odocoileus virginianus*) habitat.[4] Mitigation area management costs can be expected to average $5-10 per acre per year over the life of the project. Ownership and management responsibility for the mitigation site may be retained by the owner of the R&M Alternative or transferred to a resource agency (typically Texas Parks and Wildlife Department) agreeable to the parties involved.

Although it is recognized that reservoir construction and operation will affect the aquatic community of the impounded stream reach, there is currently no practical way of mitigating the consequences of converting 105 acres of flowing stream habitat into 31,000 acres of lentic (lake) environment. There is also some controversy as to whether these changes should be regarded as beneficial or adverse.

Compensation for unavoidable impacts to wetland and terrestrial wildlife habitats will likely be requested by U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department. However, decisions on the actual extent of required mitigation are made by the permitting agencies, the TNRCC in the case of a water rights permit, and the U.S. Army Corps of Engineers for a permit under Section 404 of the Clean Water Act. Compensation is generally accomplished by acquisition of an appropriate tract(s) of land, together with development, funding, and implementation of a vegetation/wildlife management plan that will generate enough new habitat value over the life of the project to compensate for that lost as a result of reservoir construction and operation. Acreage requirements should be based on replacement of habitat value lost during the life of the project (50-100 years), and may be determined by one of several formal evaluation procedures (e.g., the U.S. Fish and Wildlife Service Habitat Evaluation Procedure), or by more informal agreements among the parties.

3.3.4 Water Quality and Treatability

Since the R&M Reservoir would function as part of the CC/LCC System and all increase in system yield would come from the Nueces River, no significant impacts to water quality or treatability are anticipated. Water quality data, particularly for chlorides, currently shows

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[4] Ibid.

significant degradation between Lake Corpus Christi and Calallen Dam. Construction of the R&M Reservoir would very likely improve this situation. However, the increased evaporation would have a tendency to increase the dissolved mineral concentrations and degrade the water quality. Overall, the net effect on water quality of the R&M reservoir is not anticipated to be significant; however, if this alternative is pursued, possible effects on water quality should be further investigated.

3.3.5 Engineering and Costing

The cost estimate for R&M Dam and Reservoir is an update of a previous cost estimate performed by Rauschuber and Associates, Inc.[5] with some refinements for consideration of additional known waste disposal sites and mineral rights. The 1985 Rauschuber cost estimate was updated by multiplying the individual cost components of the estimate by the ratio of the relevant Bureau of Reclamation Construction Cost Indexes (Bureau of Reclamation, 1995). Additionally, in this Phase II study, cost estimates for the removal of waste disposal sites and payments for additional oil and gas mineral rights which could affect project costs were included.

Waste Disposal Sites

A preliminary screening was conducted for waste disposal sites within or in proximity to the proposed R&M Reservoir site, which could potentially contribute to contamination of the reservoir. Information contained in various state and federal agency databases was reviewed through us of the GRID Report obtained from Agency Information Consultants, Inc. This report provides information on sites within an area and is a commonly accepted tool for investigating the presence of known waste sites. A summary listing of sites identified in the GRID Report are included in Table 3.3-6.

The 17 sites identified in Table 3.3-6 are sites which may require some remediation and/or relocation cost if R&M Reservoir is constructed. The facilities and potential waste sites

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[5] "Potential for Development of Additional Water Supply from the Nueces River Between Simmons and Calallen Diversion Dam", Donald G. Rauschuber & Associates, Inc., submitted to The Subcommittee on Additional Water Supply from the Nueces River Watershed, December, 1985.

Table 3.3-6
Potential Waste Sites to be Removed at R&M Reservoir

FACILITY ID CODE	DATABASE	FACILITY NAME	FACILITY ADDRESS	ZIP CODE
	CERCLIS[1]	No Sites Indicated in Project Vicinity		
	NPL[2]	No Sites Indicated in Project Vicinity		
	RCRIS[3]	No Sites Indicated in Project Vicinity		
	RCVIOL[4]	No Sites Indicated in Project Vicinity		
TX0001712	RST[5]	Old San Patricio Store	P.O. Box 45	78368
TX0032081	RST	San Patricio Ranch	P.O. Box 77B	78368
TX0059859	RST	Person Farms	P.O. Box 107	78368
TX0060062	RST	Schneider Farms	P.O. Box 147	78368
TX0061647	RST	Hollon Farm	P.O. Box 42B	78368
TX0062009	RST	Clarence C. Chopelas	P.O. Box 174B-15	78368
TX0028527	RST	Parkside Drive Inn	FM 1068 @ P25	78368
TX0051077	RST	Waste Products	CO RD 44	78380
TX0046767	RST	Crossroads Drive In Grocery	Corner County Road 61 &	78380
TX0021974	RST	Pepper Rendering	CO RD No 40	78380
TX0027435	RST	Stop N Shop #18	Hwy 624 and FM 73	78380
TX0065619	RST	Lake Vista Comm Improve. Assoc.	Arrowhead Sub, Ranger Rd	78383
TX0036999	RST	Arrowhead Airstrip	FM 3162 Lagarto Commu	78383
TX097288	LRST[6]	Mr. Reds	2 Miles W. of Hwy 624 & F.M. 1889	78380
TXD988045209	FINDS[7] (FATES)	Helena Chemical Co.	112 County RD 73	78380
TXD988066718	FINDS (RCRIS)	Hoerbiger Svc Inc.	County RD 73	78380
TXD988068458	FINDS (AFS/AIRS)	Natural Gas Pipeline	FM 624 at La Rose	78380

[1] **CERCLIS**: The Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) is a compilation of records for federal Superfund facilities where actual releases have occurred or facilities which are suspected of having a release.
[2] **NPL**: The National Priorities List contains sites from which uncontrolled releases of hazardous substances have occurred, prioritized for long-term remedial evaluation/response.
[3] **RCRIS**: The RCRA Notifiers list is a database of those facilities which generate, treat, store, transport or dispose of hazardous and/or solid waste and who have made proper notification of these activities.
[4] **RCVIOL**: The RCRA Violators lists is maintained by the EPA and contains records for sites which have been found to be in violation of the Resource Conservation and Recovery Act.
[5] **RST**: Registered Storage Tanks are contained in this database which includes records of tank registry for underground and aboveground storage tanks containing regulated substances.
[6] **LRST**: The Leaking Registered Storage Tank database augments the RST list and contains those tanks from which releases have occurred
[7] **FINDS**: The Facility Index System contains a master list of facilities with permits or enforcement actions in any of 17 different EPA maintained databases.

State Superfund: Database containing sites which are contaminated and have been determined to meet the criteria for inclusion on a state's list under individual state superfund laws.

listed are either within or in close proximity to the project area, however, the exact physical location of some sites were not identified in the records.

The range of costs for remedial waste removal or equipment relocation activities at these types of facilities can have a broad range. Listed below is a preliminary cost estimate based on generalized cost information.

TYPE OF SITE (see Table 3.3-6)	ESTIMATED COST
RST (relocation cost per site)	$20,000 to $60,000
RST (removal only, per site)	$3,000 to $15,000
LRST (full remediation)	$40,000 to $300,000
FINDS (AFS/AIRS, FATES, RCRIS)	Highly Variable / Cost Unknown

The RST sites would be the least costly to relocate unless they were found to be leaking and then the higher cost shown for a leaking tank (i.e., LRST), which also involve costs for remediation, would apply. A leaking tank site may take several years to fully remediate depending upon the degree of contamination and chemical and physical characteristics of the contaminants. The FINDS data are commercial or industrial facilities that could involve significant relocation costs. It has been assumed that relocation costs for these facilities were included in previous cost estimates.

Using the average cost range for RST removal and relocation costs combined ($49,000) the total cost to remove and relocate all RST tanks is estimated to be approximately $637,000. Assuming $150,000 to remediate the one known leaking tank and assuming 25 percent of the remaining tanks are leaking (four), the total cost for remediating or relocating waste sites is estimated to be approximately $1,387,000. There were no known major hazardous waste sites nor Federal or State Superfund sites identified in the project site using the GRID Report data. In addition, follow-up with the Region 14 offices of the TNRCC, also indicated there were no known major State or Federal Superfund sites or other major hazardous waste disposal sites in the proposed reservoir site. In addition to the above listed sites there may be contaminated sites resulting from oil and gas exploration and extraction. These sites are regulated by the Texas Railroad Commission (TRRC) and exempted from hazardous waste regulation by the EPA and TNRCC. These sites are typically not listed on any of the above referenced databases. Although a review of TRRC data indicated there are a number of abandoned wells and related waste sites that potentially occur in the reservoir pool, there is strong likelihood the TRRC would use State funds for these cleanups. Therefore no clean-up costs have been included for the TRRC sites.

Mineral Resources

A review of oil and gas holdings in the project area was conducted to determine the potential for additional mineral right costs. Maps showing well locations (including dry and abandoned locations) were obtained from Tobin Data Graphics. These maps were current as of April 25, 1994. The approximate boundary of the reservoir was located and wells inside this boundary were tabulated as follows:

TYPE OF WELL	ESTIMATED NUMBER OF WELLS*
Producing Oil Wells	91
Producing Gas Wells	60
Wet Gas or Condensate Well	4
Producing Oil & Gas	1
Dry & Abandoned Wells	169
TOTAL	325

* Specific types of well symbols were difficult to distinguish on the maps provided by Tobin

Excluding the dry and abandoned wells, there were reported to be 173 wells which were capable of producing oil, gas, or both as of 1994. When compared to the original number of wells identified in 1971 by the USBR in the R&M Reservoir site (i.e., 73 wells), there are now an additional one hundred (100) wells. These wells are located within eighteen (18) well fields, whose boundaries extend into the project area.

For purposes of this study an estimate of the value of these mineral rights was obtained by developing a cost escalation factor based on a comparison of the estimated Choke Canyon Reservoir land and rights cost with the "actual" land and rights cost experienced during construction of Choke Canyon Reservoir.

The cost escalation factor developed by comparing the estimated 1971 Choke Canyon Reservoir land and rights costs to actual costs for land and rights showed the actual cost (approximately $74,000,000) is about 2.3 times the original 1971 USBR Report cost of $32,540,000. Using this multiplier of 2.3 and considering the 1985 preliminary cost estimate by Rauschuber for oil and gas reserves ($15,634,000), the cost for R&M Reservoir mineral reserves are estimated to be approximately $36,000,000. [Note: Using the 1985 estimated costs rather than the 1971 costs, results in a somewhat conservative estimate of cost. However, based on recent Texas experiences of new reservoir development cost for minerals, this conservative approach is considered to be reasonable.]

Summary of Costs for R&M

The updated construction cost estimate for R&M Reservoir totals $326,970,000, as summarized in Table 3.3-7, assuming mitigation costs will be about equal to costs of project land. For a construction period of four years, a uniform disbursement of construction funds, and an 8 percent annual interest rate, the accumulated interest during construction totals $24,220,000. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $30,640,000. Operation and maintenance costs total $1,380,000. Annual costs, including construction costs, interest, and operation and maintenance, would total $32,020,000. Cost of water would be $348 per acft for Alternative N-3A[6] based on year 2050 estimated yield of 92,000 acft/yr and would be $557 per acft for Alternative N-3B[7] based on year 2050 estimated yield of 57,500 acft/yr.

3.3.6 Implementation Issues

R&M Reservoir

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval.
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit.

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6 Phase IV operating policy and 1992 TNRCC Interim Order. Trans-Texas Environmental Criteria not applied.

7 Phase IV operating policy and 1992 TNRCC Interim Order with Trans-Texas Environmental Criteria Reservoir Capacity Threshold of 60%.

Table 3.3-7
Cost Estimate for R&M Reservoir
(Mid-1995 Prices)

Item		Estimated Cost
Capital Cost		
Dam Construction		$ 77,980,000
Reservoir Clearing		1,950,000
Relocation of Cemeteries		1,940,000
Protection of Wesley E. Seale Dam		530,000
Relocation of Highways, Pipelines, etc.		46,720,000
Subtotal		$ 129,120,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)		45,780,000
Subtotal		$ 174,900,000
Environmental, Environmental Mitigation		32,550,000
Land Acquisition		33,680,000
House and Cabin Relocation		21,600,000
Field Cost for Acquisitions		1,100,000
Moving Expense		430,000
Waste Disposal Sites		1,390,000
Oil and Gas Reserves		36,000,000
Existing Easements		1,100,000
Subtotal		$ 302,750,000
Interest During Construction		24,220,000
Total Project Cost		$ 326,970,000
Annual Cost		
Annual Debt Service		$ 30,640,000
Annual Operation and Maintenance		1,380,000
Total Annual Cost		$ 32,020,000
	Alt. N-3A	Alt. N-3B
Annual Project Yield (year 2050)	92,000 acft/yr	57,500 acft/yr
Annual Cost of Water	$ 348 per acft	$ 557 per acft

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary flow impact.
   b. Habitat migration plan.
   c. Environmental studies.
   d. Cultural resource studies.

3. Land and Mineral Rights will need to be acquired either through negotiations or condemnation.

4. Relocations for the reservoir include:
   a. Highways and railroads.
   b. Other utilities.
   c. Waste disposal sites.

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3.4 Purchase of Existing Water Rights in Nueces Basin (N-4)

3.4.1 Description of Alternative

The opportunity exists to increase the firm yield of the Choke Canyon/Lake Corpus Christi System (i.e., CC/LCC System) by the purchase of existing water rights. Two potential purchase scenarios considering the purchase of water rights within the Nueces River Basin have been studied. The first scenario (called "Lower Basin Water Rights Purchase") consisted of a review of water rights in the lower Nueces River Basin (below Lake Corpus Christi) to determine if there were any unutilized or underutilized water rights. The second scenario (called "Upper Basin Water Rights Purchase") considered the purchase of a portion of water rights located upstream of Lake Corpus Christi. Figure 3.4-1 shows all water rights in the Nueces River Basin with authorized annual diversion or storage rights greater than 1,000 acft/yr.

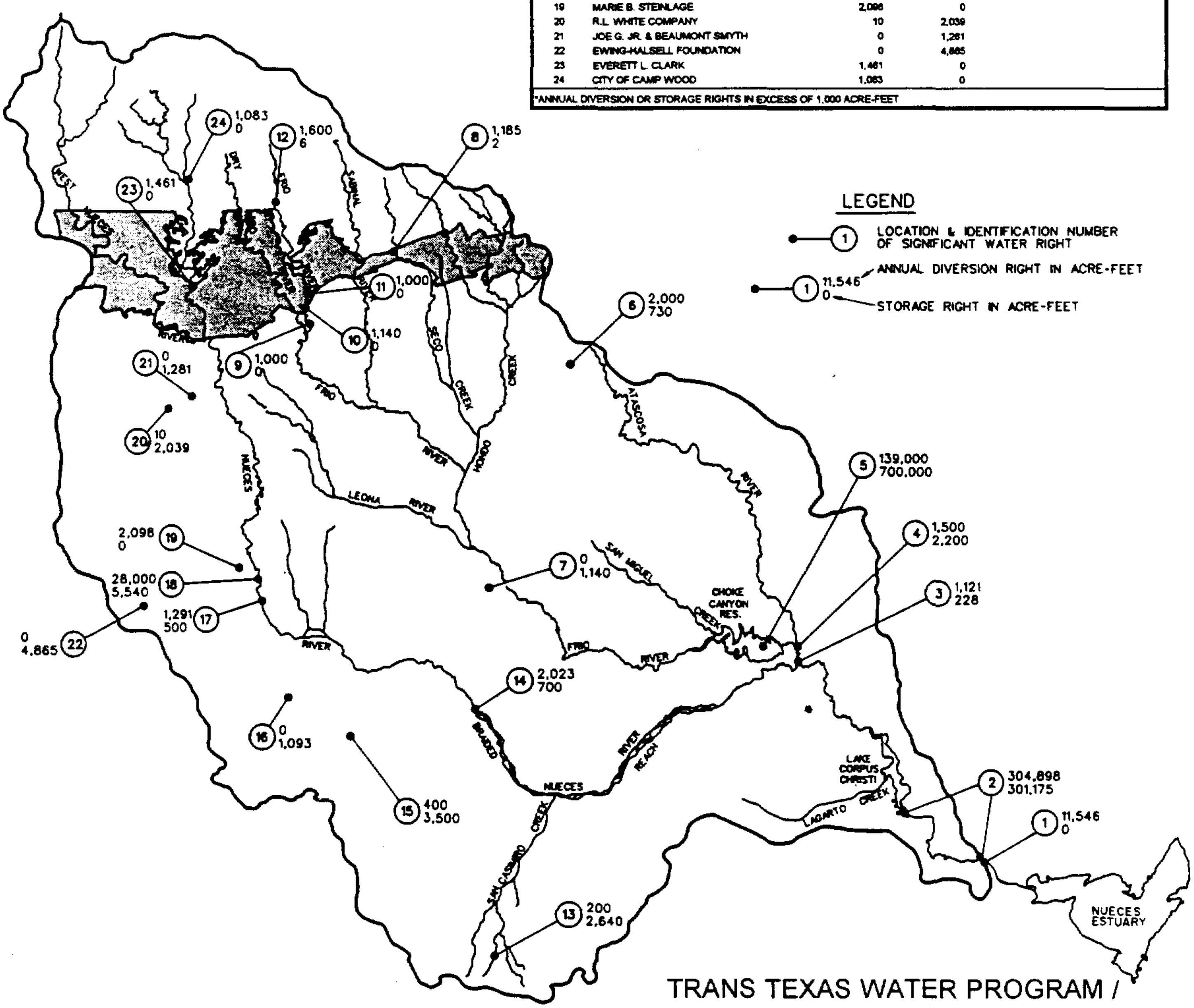
Summaries of water rights for adjacent coastal basins were prepared by the TNRCC and are included in Appendix N. These include both the San Antonio-Nueces Coastal Basin and the Nueces-Rio Grande Coastal Basin. While there are a considerable number of water rights in existence, the potential purchase of these water rights was not considered to be a viable means of economically increasing the firm water supply of the Corpus Christi Service Area for several reasons. First, freshwater availability to these rights is extremely limited during drought conditions due to the limited size of contributing watersheds and lack of storage reservoirs. Secondly, transfer of water on an intermittent basis would require large diversion rates and large capacity pump stations and pipelines. The net result is that the combined costs of the water rights, the large transfer facilities and the limited volume of drought water, would result in a very uneconomical water supply source. For these reasons, only the two options referenced above, which consider the potential purchase of water rights located within the Nueces River Basin, were considered.

<u>Lower Basin Water Rights Purchase</u>

A review of Figure 3.4-1 shows that there is only one significant water rights permit (other than the City's permit) located in the lower portion of the basin. This is the permit (Certificate of Adjudication: 21-2466) held by the Nueces County Water Control and Improvement District No. 3 located in Robstown, Texas (Robstown District). The Robstown

SIGNIFICANT WATER RIGHTS*				
NO.	OWNER	DIVERSION RIGHTS (ACFT/YR)	STORAGE RIGHTS (ACFT/YR)	NOTES
1	NUECES COUNTY WCID #3	11,546	0	LAKE CORPUS CHRISTI
2	CITY OF CORPUS CHRISTI	304,898	300,000	CALALLEN RESERVOIR
			1,175	
3	DIAMOND SHAMROCK REFINING	1,121	228	
4	CITY OF THREE RIVERS	1,500	2,200	
5	CITY OF CORPUS CHRISTI	139,000	700,000	CHOKE CANYON RESERVOIR
6	BEXAR-MEDINA-ATASCOSA WCID #1	2,000	730	
7	T.E. BURNS ET. AL.	0	1,140	
8	EDWARDS UNDERGROUND WATER DIST.	1,185	2	SECO CREEK RECHARGE DAM
9	ALVIN M. RIMKUS	1,000	0	
10	A.C. SANDERLIN ET. AL.	1,140	0	
11	THOMAS & GRETEL EKBAUM	1,000	0	
12	LOMBARDY IRRIGATION CO. LTD.	1,600	6	
13	VAQUILLAS RANCH CO. LTD.	200	2,640	
14	HOLLAND TEXAS DAM & IRRIGATION CO.	2,023	700	
15	R.W. BRIGGS, JR.	400	3,500	
16	J.R. MARMION, JR.	0	1,093	
17	MARRIS McLEAN BOWMAN ET. AL.	1,291	500	
18	ZAVALA-DIMMIT CO. WCID #1	28,000	5,540	
19	MARIE B. STEINLAGE	2,098	0	
20	R.L. WHITE COMPANY	10	2,039	
21	JOE G. JR. & BEAUMONT SMYTH	0	1,281	
22	EWING-HALSELL FOUNDATION	0	4,865	
23	EVERETT L. CLARK	1,461	0	
24	CITY OF CAMP WOOD	1,083	0	

*ANNUAL DIVERSION OR STORAGE RIGHTS IN EXCESS OF 1,000 ACRE-FEET



TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

SIGNIFICANT WATER RIGHTS LOCATION MAP

HDR

HDR Engineering, Inc.

FIGURE 3.4-1

District has the right to divert water from the Calallen Reservoir pool under two sets of rights authorized by their certificate. The first set of rights has a priority date of February 7, 1909 and is senior (i.e., senior in time) to all of the City's rights. These rights include the right to divert up to 3,500 acft/yr for municipal use and up to 5,106 acft/yr for irrigation use for a total right of 8,606 acft/yr. The next set of rights carries a priority date of January 28, 1921 and is junior to a portion of the City's rights (i.e., 4,729 acft/year), but senior to the remainder of the City's diversion rights of 300,169 acft/yr. Table 3.4-1 shows a summary of the Robstown District's water rights.

Table 3.4-1
WCID #3 Water Rights in the Nueces River at the Calallen Reservoir

Owner	Priority Date	Diversion Right (acft/yr)	Type of Use
WCID #3	Feb. 7, 1909	3,500	Municipal
CF 70		5,106	Irrigation
WCID #3	Jan. 28, 1921	746	Municipal
PN 529		2,194	Irrigation
Total WCID #3	---	4,246	Municipal
Rights		7,300	Irrigation

Water use records furnished by the Robstown District to the TNRCC and predecessor agencies were available for the seven-year period from 1983 through 1989. These records are summarized in Table 3.4-2 and show the most water used during that timeframe was 5,737 acft/yr in 1989. This represents about 50 percent of the District's total authorized use of 11,546 acft/yr. TWDB water demand projections for municipal and industrial purposes in the Robstown District increase from 2,429 acft/yr in 1990 to 2,546 acft/yr in 2050. Since the District is utilizing only a portion of their water rights, it is possible that they might be interested in selling some of their rights to the City. This study considered the possibility of the City purchasing a part of their rights. Three options were studied and these include a purchase of 25, 34, and 43 percent of the Robstown District's rights, as explained below in Section 3.4.2.

Table 3.4-2 Actual Water Right Diversion Reported by WCID #3 Under Certificate of Adjudication No. 21-2466				
Year	**Municipal Diversion (acft/yr)**	**Irrigation Diversion (acft/yr)**	**Total Diversion (acft/yr)**	**Percent of Total Diversion to Total Rights**
1983	2,744	994	3,738	32%
1984	2,450	1,078	3,528	31%
1985	2,174	238	2,412	21%
1986	2,334	879	3,213	28%
1987	2,246	522	2,768	24%
1988	2,348	2,092	4,440	38%
1989	2,588	3,149	5,737	50%

Upper Basin Water Rights Purchase

Water rights in the Nueces River Basin above Three Rivers, exclusive of the rights of the City of Corpus Christi (et.al.), total about 68,000 acft/yr based on 1991 TNRCC records. More than 90 percent of these rights are irrigation rights. Firm yield estimates of the CC/LCC System assume these rights are attempting to divert their full authorized amount each year. If a portion of these rights could be purchased, the potential exists to increase the yield of the CC/LCC System. This study considers the potential to increase the yield of the CC/LCC System by purchase and conversion of up to 50 percent of the upper basin water rights for a potential purchase of 34,000 acft/yr.

3.4.2 Available Yield

Lower Basin Water Rights Purchase

Three options involving the purchase of a part of the Robstown District's water rights were evaluated using the 1990 conditions of the CC/LCC System. For all options, the rights of the District are honored to the extent the water was available in the river. The results of this modeling are summarized in Table 3.4-3.

Table 3.4-3 Summary of CC/LCC 1990 System Firm Yield Under Various Water Purchase Options Involving WCID #3		
Description of Purchase Option	**CC/LCC System Firm Yield Increase (acft/yr)**	**Firm Yield as a Percent of Quantity Purchased**
Option 1 Purchase 2,940 acft/yr of WCID #3's junior diversion right	1,848	62.9%
Option 2 Purchase 2,940 acft/yr of WCID #3's junior diversion right & 1,000 acft/yr of WCID #3's senior diversion right	2,554	64.8%
Option 3 Purchase 2,940 acft/yr of WCID #3's junior diversion right and 2,000 acft/yr of WCID #3's senior diversion right	3,261	66.0%

Under Option 1, it was assumed that the City would purchase all 2,940 acft/yr of the District's junior diversion right (Permit No. 529). Under this scenario, the City's 1990 firm yield would increase by 1,848 acft/yr. This results in a recovery of 62.9 percent of the water right purchased. The second option simulated involved the purchase of the District's 2,940 acft/yr junior right (Permit No. 529) and 1,000 acft/yr of the District's senior right (CF 70). This alternative would increase the City's firm yield by 2,554 acft/yr, and would result in the recovery of 64.8 percent of the rights purchased. The third alternative studied involved the purchase of all 2,940 acft/yr of Permit No. 529 and 2,000 acft/yr of CF 70. This would increase the firm yield of the City's system by 3,261 acft/yr, and would result in a 66 percent recovery of the purchased right.

Upper Basin Water Rights Purchase

A comparison of CC/LCC System yield was made, considering all water rights above Three Rivers were diverted at their full permit amounts, and compared to the yield with upstream rights limited to 50 percent of their permitted amounts (i.e., 34,000 acft/yr). The results of this comparison indicated an increase in system yield of approximately 3,500 acft/yr under the 1995 TNRCC Agreed Order and 1990 sediment conditions. This increase in yield represents about 10 percent of the purchased water rights. This is a much lower percentage than calculated for the Robstown District purchase options. The reason for the lower percentage is because most of the irrigation rights are located a large distance from the reservoir which results in large channel losses between the rights and the reservoir. Additionally, only limited run-of-the-river flows are available to those upstream water rights during droughts.

3.4.3 Environmental Issues

Water for the purchase of existing water rights, either in the lower or upper Nueces River Basin would be diverted from the Calallen Reservoir to the city's existing water system with no additional facilities needed to be constructed.

Lower Basin Water Rights Purchase

The Lower Basin Water Rights Purchase would utilize water from the Nueces County Water Control and Improvement District Number Three located in Robstown, Texas, that is not presently diverted to Robstown or any other user (Table 3.4-2). Inflows to the Corpus Christi Bay system would decrease by an amount equal to the increase in diversion, and be partially offset by increased wastewater flows returned to the bay. The result of this would be a net decrease on the order of 1,000 to 1,500 acft/yr, (return flow rate of about 47 percent), depending on the amount purchased (Table 3.4-3). Relative to current estuary inflows and return flows, a change of this magnitude would not be expected to have a detectable impact on the Nueces Estuary.

Upper Basin Water Rights Purchase

The Upper Basin Water Rights Purchase would include up to 50 percent of existing water rights above Choke Canyon Reservoir. Water rights in the upper basin are largely used for irrigation, and although historical use has averaged only about 50 percent of the 68,000 acft/yr right, the largest proportional uses tend to occur during the driest years.

The upper basin purchase of about 34,000 acft/yr involves a more complicated hydrologic analysis. The baseline (without project analysis) assumes utilization of existing water rights to the fullest extent possible. Although this might eventually occur, only about half of the irrigation rights in the upper basin are being used at the present time. The hydrologic analysis assumed that only the firm yield amount available from the purchase of water rights (about 3,500 acft/yr) would be diverted. This assumption is reasonable because the entire right would be available for diversion during wet years even though it would not be needed in those years. When the hydrologic consequences of full utilization of upstream water rights (baseline condition) are compared with purchase of 50 percent of those rights and diversion of only the firm yield amount; higher reservoir water levels are predicted to increase the frequency and volume of spills, resulting in slightly higher instream flows and Nueces Bay inflows. For example, results of analysis indicate that minimum monthly inflows to Nueces Bay would increase about 0.8 percent, and median monthly inflows would increase by 0.5 to 2.7 percent under Phase 2 operation, 1990 sediment conditions, and the 1992 TNRCC operating order. Changes of similar magnitude would be expected under the new 1995 TNRCC Agreed Order.

Because of the small amounts of water involved, the Nueces Basin Model does not predict any significant change in the existing bay inflow regime as a result of implementing the Upper Basin Water Rights Purchase. Application of the TWDB inflow-salinity regression equation for Nueces Bay likewise reveals little change. For example, salinity lower bound violations in Nueces Bay decreased by one event (out of 64 for the period of record) under Phase 2 operation, 1990 sediment conditions, and increased by one (from 65 baseline events) under Phase 4 operation, 2050 sediment conditions (based on the 1992 TNRCC operating order). Salinity upper bound violations were projected to decrease under either operational phase/sediment condition scenario, however, the decrease is probably not a great enough change to result in any perceptible biological change. With the 1995 TNRCC Agreed Order in place, increased inflow to the bay is anticipated, but this increase is unlikely to be of sufficient magnitude to result in any meaningful change.

The listed endangered or threatened species (Appendix C - Tables 17 and 19) in the Corpus Christi Bay system include marine mammals, marine turtles, and birds nesting or wintering on coastal islands. It seems unlikely that inflow alterations and salinity changes of the magnitudes involved in the water purchase alternatives would result in either direct or indirect (food web mediated) impacts to those species. Likewise no impacts to other marine species, fish and invertebrates, and waterfowl that utilize Nueces Bay would be expected from the small changes in Bay salinity that are projected to result from implementation of this alternative.

There are several recorded cultural resource sites in the Calallen reservoir area. Since there would be no construction required for this alternative, no impacts to cultural resources are expected.

3.4.4 Water Quality and Treatability

Since the water to be potentially purchased under this alternative would be diverted from the same reservoir pool (i.e., Calallen Reservoir) as the City's existing diversion location, there would be no change in water quality.

3.4.5 Engineering and Costing

The only costs associated with obtaining the additional raw river water under this alternative would include the purchase price of the water rights as well as the cost of legal and engineering services associated with purchase negotiations. A determination of the value of these rights is beyond the scope of this study. However, for information purposes only, an estimated cost has been prepared assuming the City would pay the same amount per acft as contained in their option contract for water from the Colorado River from the Garwood Irrigation Company (assuming purchase would occur in July, 1995). Cost estimates were prepared on the basis of a one-time purchase price of $430 per acft with 10 percent added to cover legal and engineering fees associated with contract negotiations and permit amendments at the TNRCC. Annual costs were calculated based on the purchase price being financed at an 8 percent interest rate for 25 years. Costs for purchase of the Robstown District water rights varied from a high of $70 per acft per year for Option 1 to a low of $67 per acft per year for Option 3 (Table 3.4-4). Costs for the purchase of up to one-half of the irrigation rights in the upper basin, which yielded 3,500 acft/yr, resulted in a unit cost of water at $431 per acft per year as shown in Table 3.4-4.

Table 3.4-4 Summary of Costs for Potential Purchase of Nueces River Basin Water Rights				
Amount Purchased (acft/yr)	**One-Time Purchase Price & Fees***	**Annual Costs** ($/yr)**	**System Yield Increase (acft/yr)**	**Unit Cost of Water ($/acft/yr)**
Lower Basin Water Rights Purchase				
Option 1 2,940	$1,391,000	$130,000	1,848	$70
Option 2 3,940	$1,864,000	$175,000	2,554	$69
Option 3 4,940	$2,337,000	$219,000	3,261	$67
Upper Basin Water Rights Purchase				
34,000	$16,082,000	$1,507,000	3,500	$431

*Based on $430/acft plus 10% for legal and engineering.
**Based on financing at 8% interest for 25 years.

3.4.6 Implementation Issues

The major issues involved with the purchase of water rights within the Nueces River Basin by Corpus Christi include the willingness of the various water rights owners to sell their rights as well as the ability to obtain the necessary water rights permit amendments from the TNRCC. Often times there is a reluctance by water rights owners to sell all, or even a portion of, their senior water rights.

For the purchase of water rights from Nueces County WCID No. 3, the City of Corpus Christi could consider discussions to either: 1) purchase that part of Nueces County WCID No. 3's water right which is not needed for WCID No. 3's future uses or, 2) obtain a first right of refusal to purchase WCID No. 3's surplus.

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3.5 Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5) and Pipeline from Lake Corpus Christi to Calallen Dam (N-6)

3.5.1 Description of Alternative

Channel losses in streams that deliver water from Choke Canyon Reservoir to Lake Corpus Christi and on to the City of Corpus Christi's intake located near the Saltwater Barrier and Calallen are often large. Previous studies indicate that channel losses in the 10-mile reach of the Frio River downstream of Choke Canyon to the confluence with the Nueces and Atascosa Rivers near Three Rivers, Texas, fluctuate widely and can reach as high as 5 percent. Additionally, channel losses in the 53-mile reach of the Nueces River from Three Rivers to Lake Corpus Christi which include seepage losses within Lake Corpus Christi can be as high as 26 percent. Combined channel and reservoir seepage losses at Lake Corpus Christi and in upstream reaches result in potential losses as high as 29.7 percent. Downstream of Lake Corpus Christi, investigations by the TWDB and USGS as well as observations of reservoir operators indicate channel losses of about 7 percent.

Since the majority of the water supply for the City of Corpus Christi and its customers is delivered to the diversion at Calallen, the yield of the system is affected by these losses. However, water delivered by pipelines that bypass the stream channels would not be subjected to these losses and could potentially keep more water in storage. This alternative considers two projects that could be implemented individually or jointly to reduce losses in the CC/LCC System.

<u>Alternative N-5: Pipeline from Choke Canyon Reservoir to Lake Corpus Christi</u>

Previous investigations[1] have shown that under the worst case conditions, about 30 percent of the releases from Choke Canyon are lost to channel losses before reaching Lake Corpus Christi, although on the average a much higher percentage of the water is delivered. Since the losses in the reach between the two reservoirs in the CC/LCC System are potentially large, a pipeline between the two lakes would relieve some of the channel losses and provide

[1] "Regional Water Supply Planning Study - Phase I - Nueces River Basin" HDR Engineering, Inc., Austin, Texas, May 1991.

an increase in the firm yield. This alternative evaluates a 30-mile, 96-inch diameter pipeline which would deliver water from Choke Canyon Reservoir to the deeper portion of Lake Corpus Christi. The location of the pipeline is shown in Figure 3.5-1

Alternative N-6: Pipeline from Lake Corpus Christi to Calallen Dam (N-6)

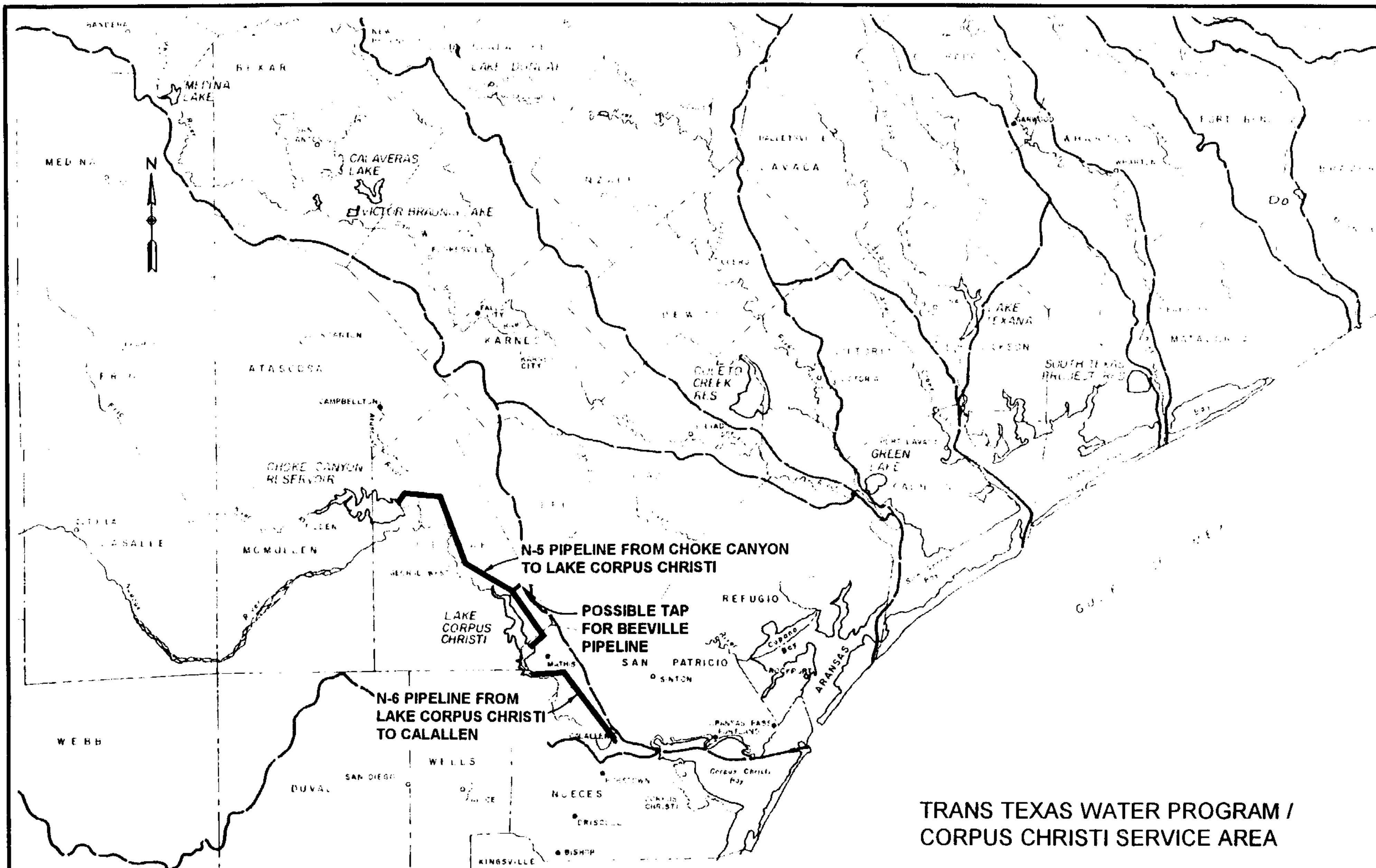
Delivery of water by pipeline from Lake Corpus Christi to the O.N. Stevens WTP could potentially increase the firm yield of the CC/LCC System by as much as 7 percent of the volume delivered by the pipeline. In this alternative, a 23 mile-long, 66-inch diameter pipeline is evaluated between Lake Corpus Christi and the O.N. Stevens WTP near Calallen. The location of the potential pipeline is shown in Figure 3.5-1.

3.5.2 Available Yield

For this alternative, separate yield analyses were performed to simulate each pipeline. The yield available from the individual pipeline projects is presented below.

Available Yield for Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5)

Yield analyses were performed in which Choke Canyon Reservoir and the pipeline were operated in the following manner: 1) A minimum 2,000 acft/month was released from Choke Canyon Reservoir, as specified in the existing permit; 2) When required water supply releases at Choke Canyon are larger than 2,000 acft in any month, the quantity of water over 2,000 acft is delivered through the pipeline between the two reservoirs up to the capacity of the pipeline; and 3) When required monthly releases at Choke Canyon are larger than 2,000 acft plus the capacity of the pipeline, the remaining portion of the release is delivered via the rivers. This release policy assumes that the instream flow requirements downstream of Choke Canyon Reservoir are met by the 2,000 acft/month (33 cfs) minimum release requirement in the existing permit, and that this instream flow volume together with flows in excess of the pipeline capacity would fully satisfy instream flow requirements in the reach between the two reservoirs. Additional water is also released from Choke Canyon to satisfy senior water rights located on the reach between Choke Canyon and Lake Corpus Christi. Releases needed to meet the full



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N-5 PIPELINE-CHOKE CANYON TO LAKE CORPUS CHRISTI AND N-6 PIPELINE - LAKE CORPUS CHRISTI TO CALALLEN

HDR Engineering, Inc.

FIGURE 3.5-1

diversion rights of these senior rights are in excess of the 2,000 acft/month minimum release and are added to releases to the river. Information on how river flows at Three Rivers would be altered under this operation are included in the following subsection.

Simulations were made for the historical period from 1934 to 1989, using the City of Corpus Christi's Phase IV Operations Plan and the 1992 TNRCC Release Order. (For an explanation of these operating rules, see Section 3.1.2.) Given these assumptions and operating rules, several different pipeline sizes were studied, and a pipeline with a capacity of 500 acft/day (250 cfs) was determined to be the most economical size. The 500 acft/day pipeline system was simulated assuming 1990 and 2050 reservoir sedimentation conditions.

For modeling purposes, it was assumed that the same channel loss and reservoir seepage functions would apply to the water released into the stream system. For the portion of the water delivered to Lake Corpus Christi by pipeline, it was assumed that 10 percent of this water would continue to be lost to seepage from the reservoir into the Goliad Sands. The resulting firm yields from these simulations as well as baseline yields of the CC/LCC System without the pipeline are shown in Table 3.5-1.

Table 3.5-1
Summary of System Firm Yields with and without a Pipeline Linking Choke Canyon and Lake Corpus Christi

Reservoir Sedimentation Year	CC/LCC Firm Yield Without the Pipeline (acft/yr)	CC/LCC Firm Yield with the Pipeline (acft/yr)	Increase in Firm Yield Due to the Pipeline (acft/yr)
1990	192,000	208,000	16,000
2050	176,000	194,000	18,000

Although reservoir operation simulations using the 1995 TNRCC Release Order were not performed, it is estimated that about the same results would have been obtained. If this alternative is pursued in later phases of the program, additional yield analysis should be performed to more closely define the potential enhanced yields.

Available Yield for Pipeline from Lake Corpus Christi to Calallen Dam (N-6)

Additional reservoir operation analyses were performed to simulate yields of the CC/LCC System with a pipeline between Lake Corpus Christi and Calallen. A pipeline with a capacity of 250 acft/day (126 cfs) was chosen because it delivers approximately 50 percent of the simulated year 2050 (Phase IV Operating Policy and 1992 TNRCC Release Order) system firm yield of 176,000 acft/yr, leaving the other 50 percent of the water to flow down the Nueces River. This keeps the river habitat downstream of Lake Corpus Christi supplied with water. In the model, it was assumed that the pipeline would run full over the entire simulation.

Simulations were made for the historical period from 1934 to 1989, using the City of Corpus Christi's Phase IV Operations Plan and the 1992 TNRCC Release Order. Given these assumptions and operating rules, the CC/LCC System was simulated assuming 1990 and 2050 reservoir sedimentation conditions. The increase in the system firm yield is about 6,500 acft/yr based on 2050 sediment conditions (Table 3.5-2).

Table 3.5-2
Summary of System Firm Yields with and without a Pipeline Linking Lake Corpus Christi and Calallen

Reservoir Sedimentation Year	CC/LCC Firm Yield Without the Pipeline (acft/yr)	CC/LCC Firm Yield with the Pipeline (acft/yr)	Increase in Firm Yield Due to the Pipeline (acft/yr)
1990	192,000	198,000	6,000
2050	176,000	182,500	6,500

Although reservoir operation simulations using the 1995 TNRCC Release Order were not performed, it is estimated that about the same results would have been obtained. If this alternative is pursued in later phases of the program, additional yield analysis should be performed to more closely define the potential enhanced yields.

3.5.3 Environmental Issues

Introduction

Environmental issues related to transferring water by pipelines from Choke Canyon Reservoir to Lake Corpus Christi and from Lake Corpus Christi to Calallen can be categorized as follows:

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

Methods used to develop this section, including mapping, searches of available literature and databases, and field reconnaissance are described in the Environmental Overview (Section 3.0.2). The project area involves the CC/LCC System which also is described in the Environmental Overview.

Impact Assessment

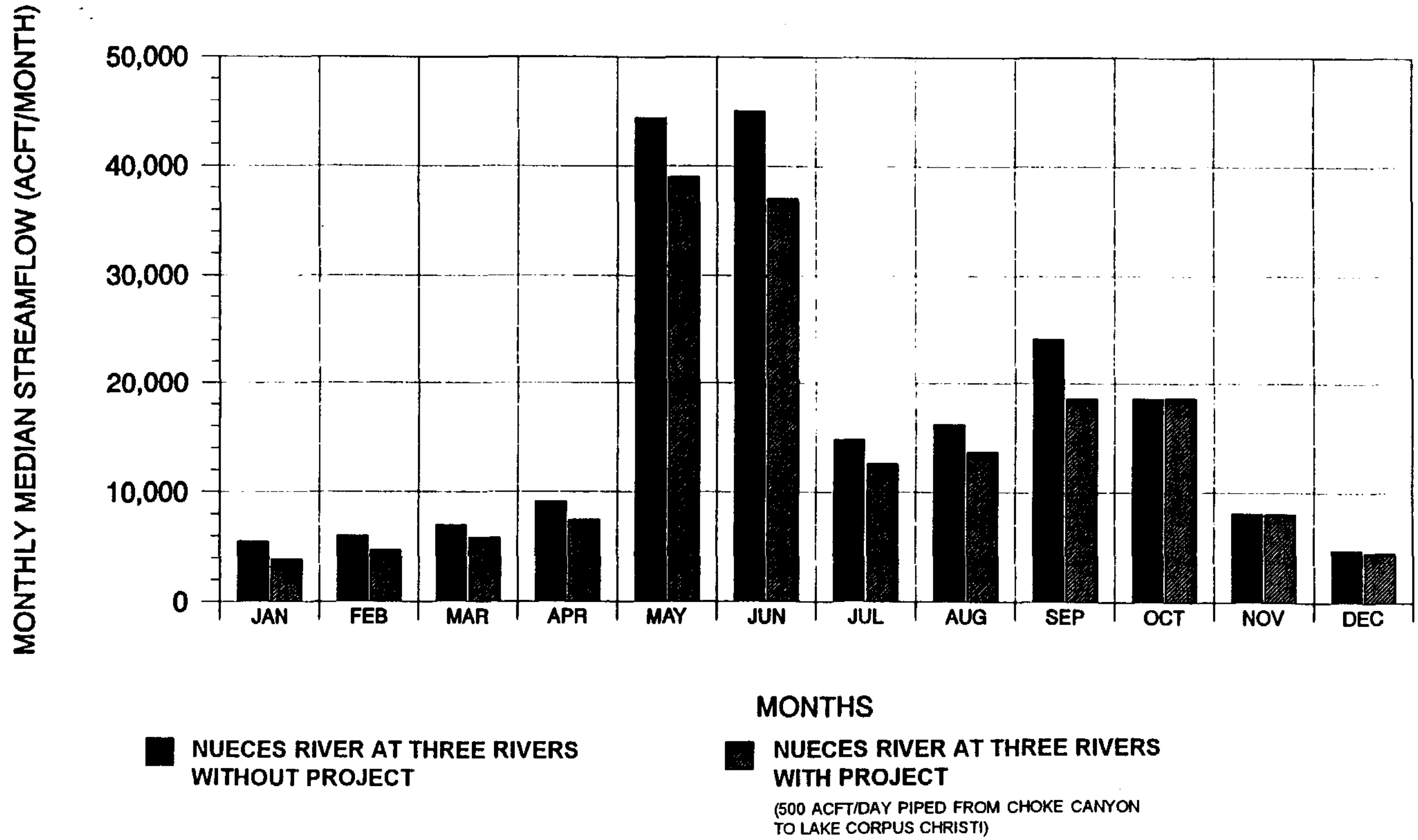
The proposed pipeline corridors would be within Live Oak and Nueces Counties. These pipelines are intended to transfer water without using the bed and banks of the Nueces River, as is presently the case. The 18,000 and 6,500 acft/yr of additional system yield respectively for the N-5 and N-6 pipeline takes advantage of the fact that water is lost to seepage and evaporation during transport down the Nueces River between Choke Canyon and Lake Corpus Christi, and following release from Lake Corpus Christi.

Endangered species occurring in the counties associated with the project (Jim Wells, Live Oak, McMullen, Nueces, and San Patricio) are listed in Appendix C, Tables 11, 14, 15, 16 and 18, respectively. With respect to Choke Canyon Reservoir to Lake Corpus Christi pipeline, construction impacts would result from soil and vegetation disturbance within the approximately 509-acre pipeline construction corridor. Longer term terrestrial impacts would be confined to the 145-acre maintained ROW. In Live Oak County, the Jaguarundi (*Felis yagouaroundi*), listed as endangered, has been reported to occur within the proposed pipeline corridor and habitat for several state protected species may be present. Temporarily wet areas or drainages in uplands and in wetland portions of the pipeline corridor may provide habitat for several state protected amphibians. The black-spotted newt (*Notophthalmus meridionalis*) and Rio Grande lesser siren (*Siren intermedia texana*) are found in wet or temporally wet arroyos, canals, ditches or shallow depressions. During dry periods, they aestivate underground. The sheep frog (*Hypopachus variolosus*) inhabits wet areas and freshwater marshes in the Rio Grande Valley, lower South Texas Plains, and Southern Coastal Prairie. The Mathis spiderling *(Boerhavia mathisiana)* was a possibly extinct plant that has been proposed for protection to USFWS. It inhabits open thorn shrublands with shallow sandy to gravely soils over limestone or on bare limestone or caliche outcrops. The Mathis spiderling was once found in the vicinity of Lake Corpus Christi in San Patricio County.

Several sites on or eligible for inclusion on the National Register of Historic Places are known from the vicinity of the pipeline corridor, and other types of cultural resource sites may be present, although none are known to be located within the corridor.

The construction corridor of the proposed Lake Corpus Christi to O.N. Stevens WTP pipeline (N-6) includes about 390 acres of brush, grass and cropland, all in Nueces County. A ROW totaling about 113 acres would be maintained free of woody species for the lifetime of the project. No protected species or National Register sites have been reported from the proposed corridor, but such resources are present in nearby areas.

Use of pipeline transport will reduce river flows between Choke Canyon Reservoir and Lake Corpus Christi (N-5). The presently required maintenance releases of 2,000 acft per month would be continued. However, historical monthly median flows generally will be reduced by 15 to 25 percent under 1990 sediment conditions and somewhat more under 2050 conditions (See Figures 3.5-2 and 3.5-3). In contrast to the reduction in river flows, estuarine inflows would be affected only slightly. This effect of reduced flow in the river, and relatively unaffected estuarine inflows, results from the additional water being produced by the reduction of losses to evaporation and seepage in the reach between the two reservoirs. Although median annual inflows to the Nueces Estuary would increase by 2 to 3 percent under the 1990 and 2050 sediment conditions, average annual inflows would decrease by 2,490 acft (0.5 percent) under



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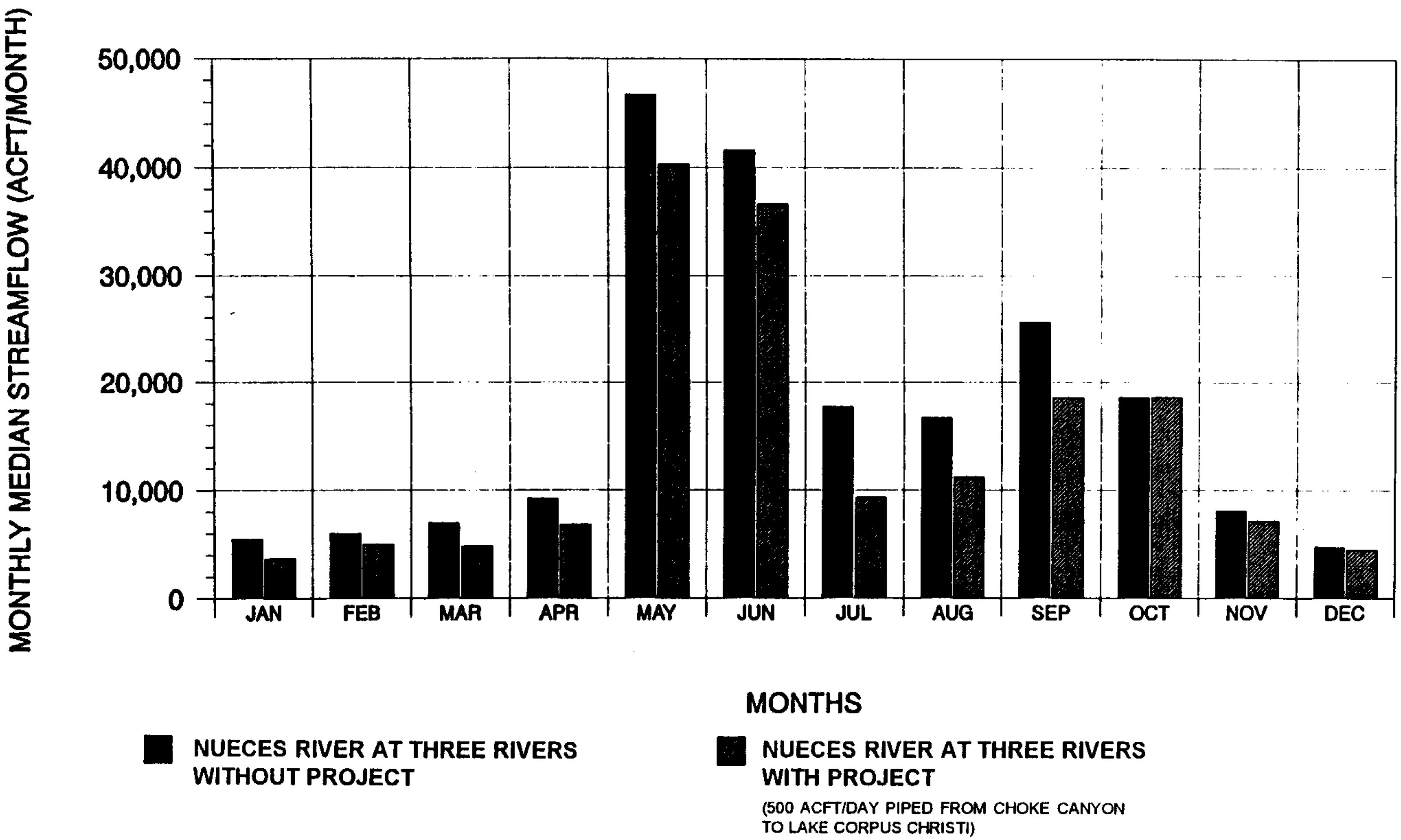
CHANGE IN MONTHLY FLOW OF NUECES RIVER AT THREE RIVERS FOR N-5 FOR 1990 CONDITIONS

FIGURE 3.5-2



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CHANGE IN MONTHLY FLOW OF NUECES RIVER AT THREE RIVERS FOR N-5 FOR 2050 CONDITIONS

FIGURE 3.5-3

1990 conditions, and by only 641 acft (0.1 percent) under 2050 conditions (Figures 3.5-4 and 3.5-5, respectively).

The operational effects of Alternative N-6 are similar to those of Alternative N-5. With respect to flows in the Nueces River, percentage reductions in median monthly spills and releases generally would be in the range of 20 to 40 percent under 1990 and 2050 sediment conditions (Figures 3.5-6 and 3.5-7). Inflows to the Nueces Delta would increase slightly under both sediment conditions (Figures 3.5-8 and 3.5-9, respectively).

3.5.4 Water Quality and Treatability

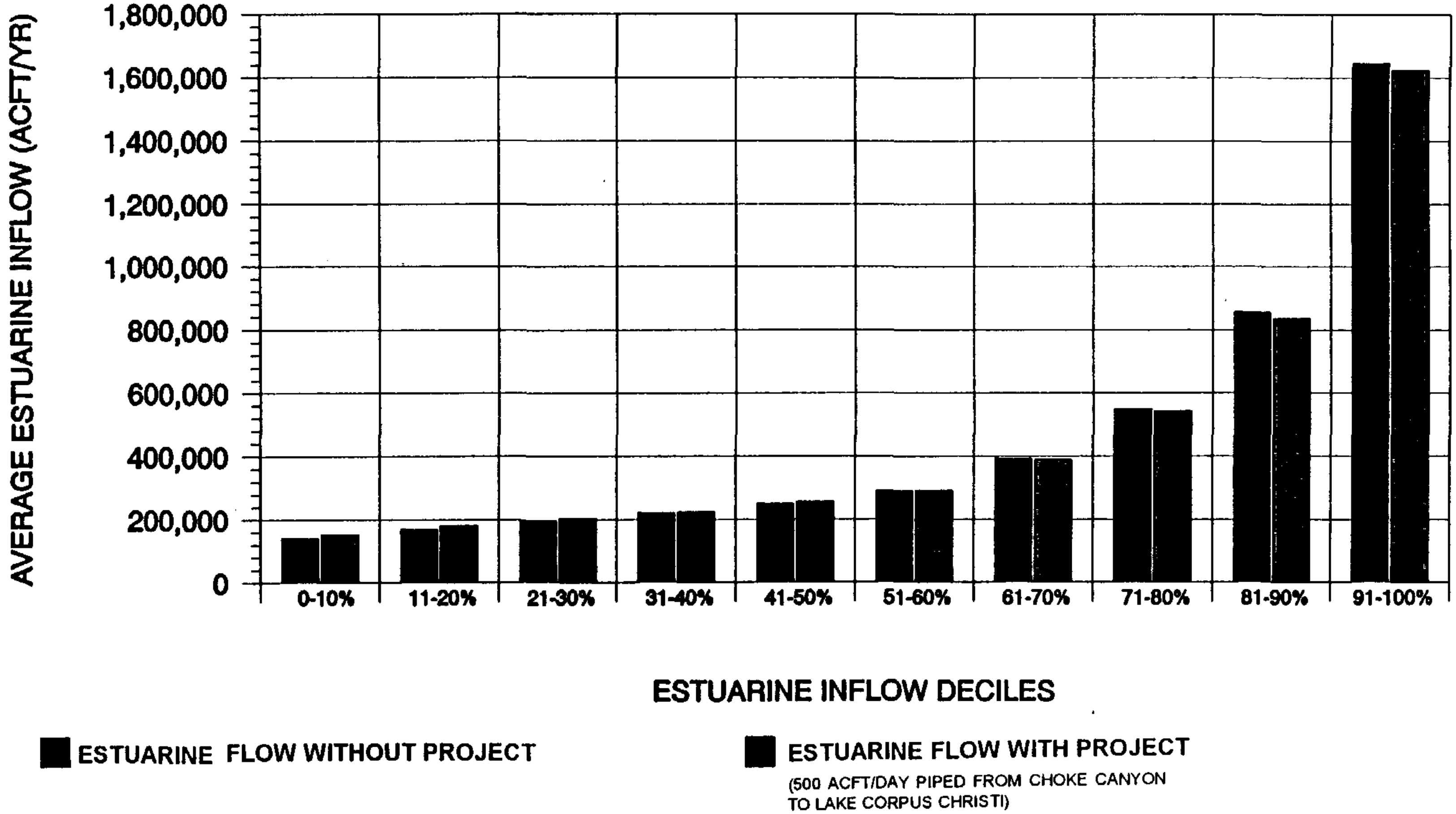
Although significant changes in water quality and treatability are not anticipated for this alternative, there could actually be some improvement in the quality of water delivered to the O.N. Stevens WTP by the Lake Corpus Christi to Calallen pipeline (Alt. N-6). The improvement results from the portion of water delivered by pipeline not being blended with the higher chloride water present in the lower Nueces River as indicated in Appendix D.

3.5.5 Engineering and Costing

Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5)

The estimated cost for constructing and operating the pipeline from Choke Canyon Reservoir to Lake Corpus Christi is an update of the cost estimate contained in the Phase I report which was calculated using 1993 unit costs and estimated quantities for materials, labor, and easements. The 96-inch pipeline size was determined based on a flow rate of 500 acft per day (i.e., 252 cfs or 163 MGD) and the pumping head created by pipe friction and the ground profile along the proposed route.

The total project cost for the pipeline from Choke Canyon Reservoir to Lake Corpus Christi is estimated to be $92,600,000 (Table 3.5-3). A construction period of approximately one and one-half years was assumed along with a uniform disbursement of construction funds. The interest expense during construction totals $2,760,000. Financing for the project was assumed to be for 25 years at an 8 percent annual interest rate. The annual debt service payment was calculated to be $8,680,000. Operation and maintenance costs, including annual power costs, total $2,710,000. The total annual cost for the pipeline, including construction



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CHANGE IN ESTUARINE INFLOWS FOR N-5 FOR 1990 CONDITIONS

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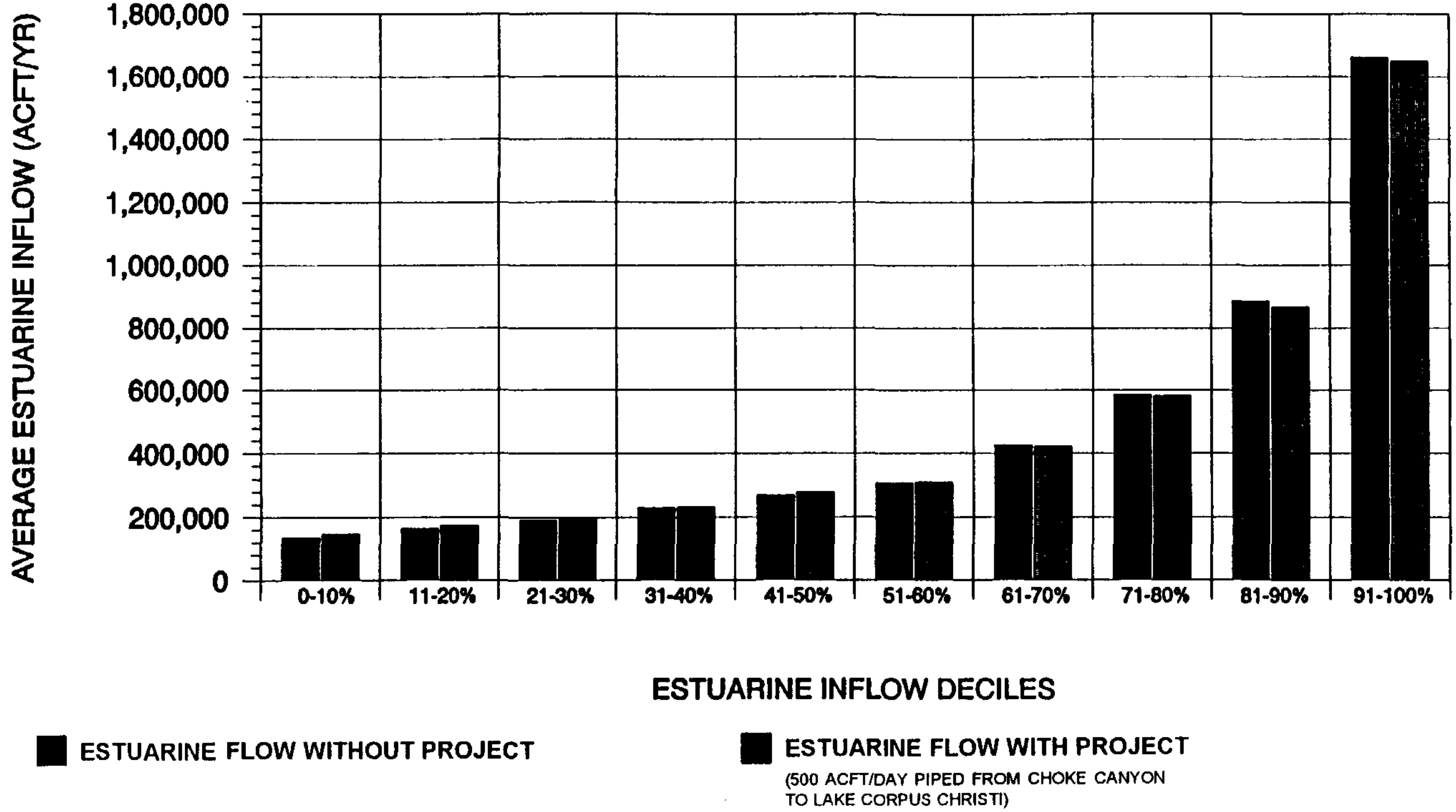
FIGURE 3.5-4



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CHANGE IN ESTAURINE INFLOWS FOR N-5 FOR 2050 CONDITIONS

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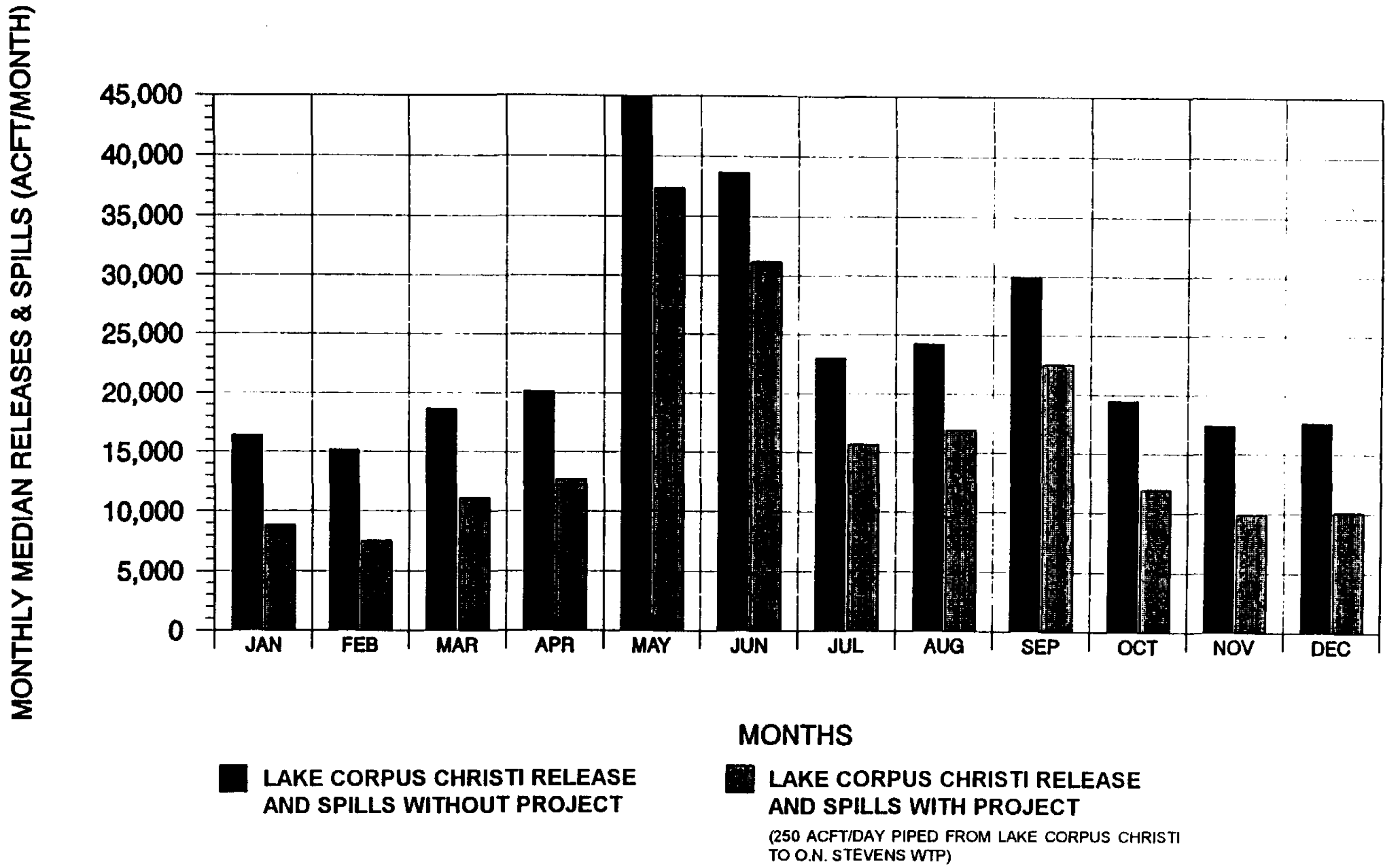
FIGURE 3.5-5



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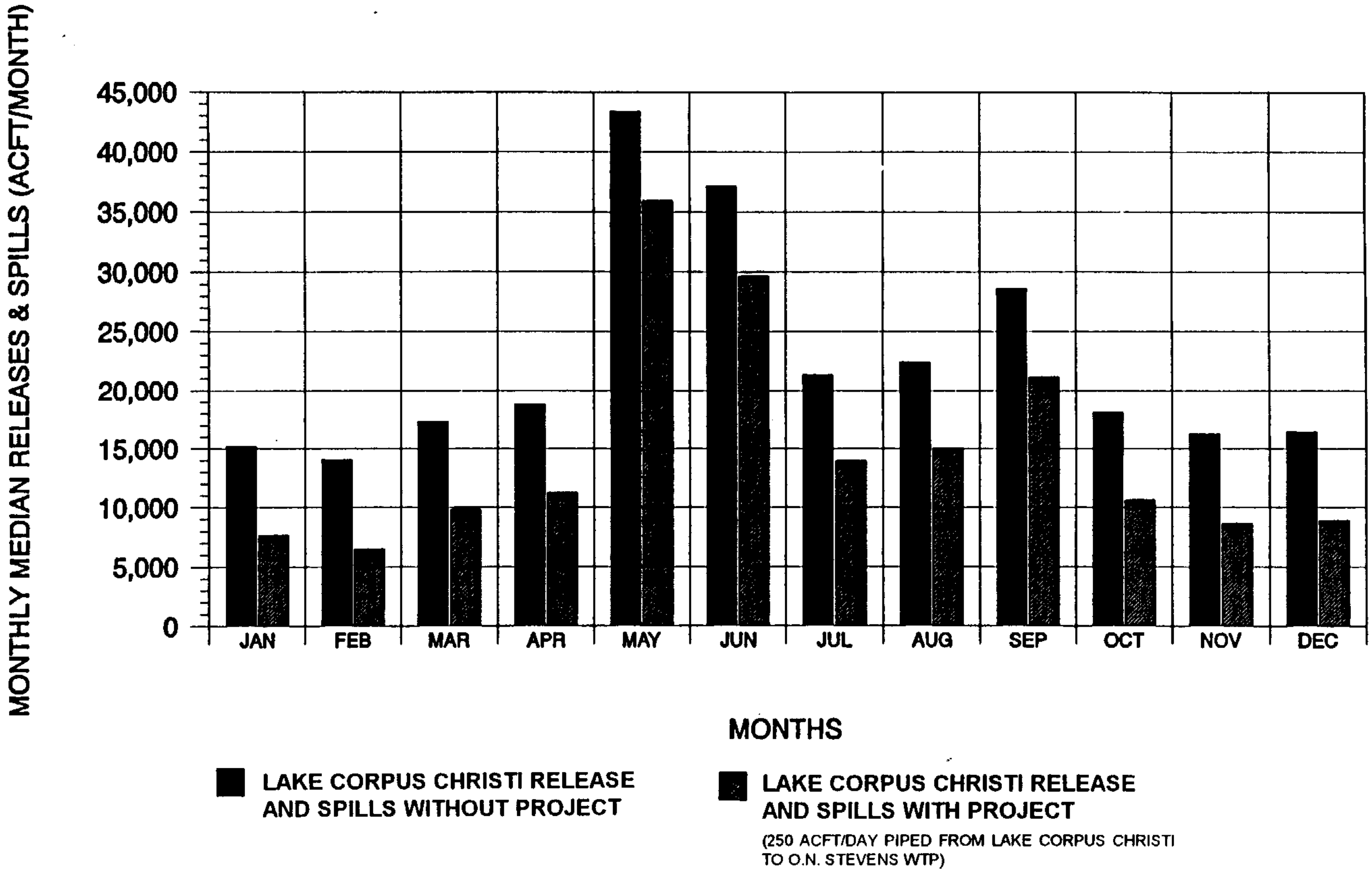
CHANGE IN MONTHLY FLOW OF NUECES RIVER ABOVE CALALLEN FOR N-6 FOR 1990 CONDITIONS

FIGURE 3.5-6



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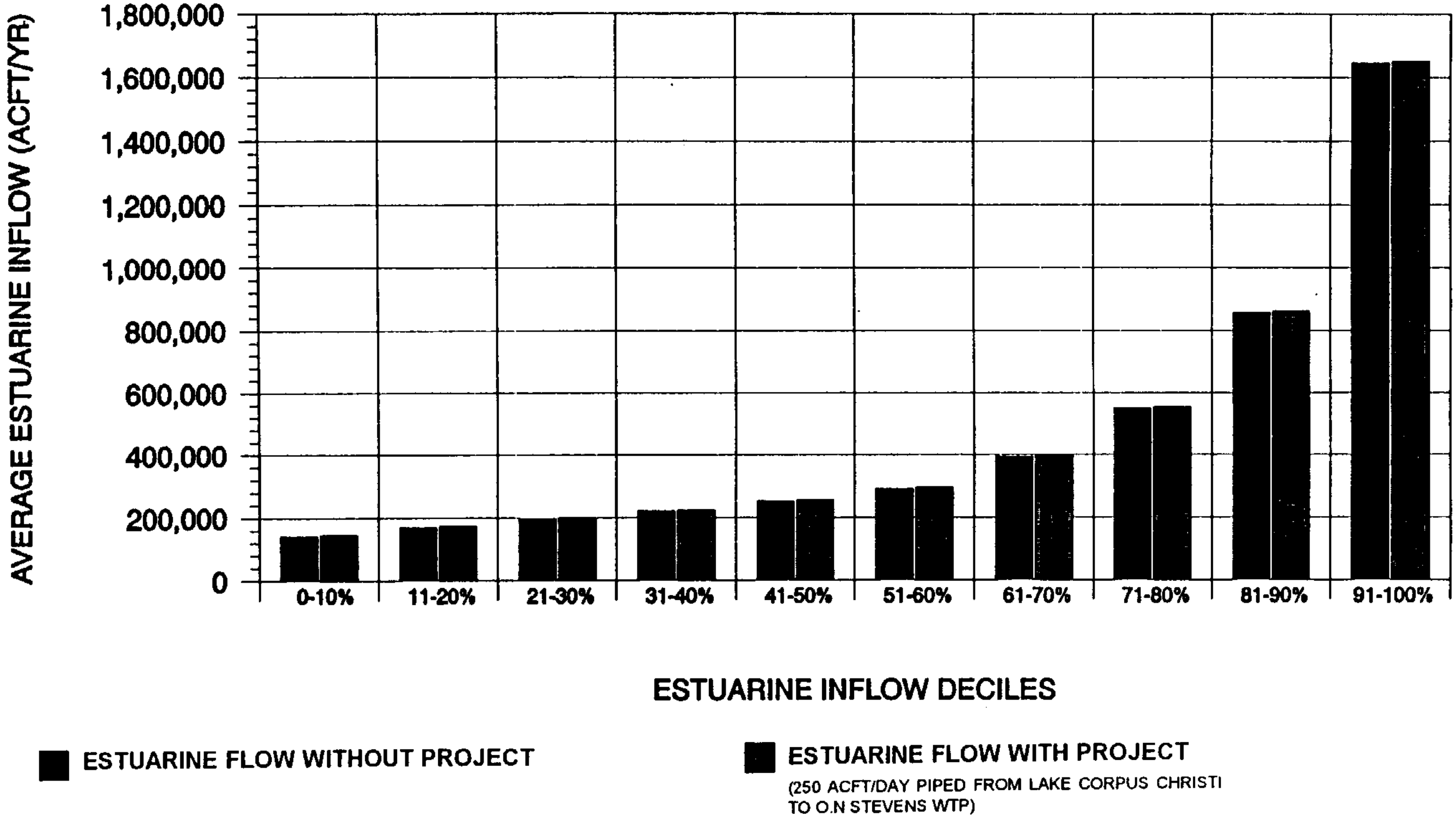
CHANGE IN MONTHLY FLOW OF NUECES RIVER ABOVE CALALLEN FOR N-6 FOR 2050 CONDITIONS

FIGURE 3.5-7



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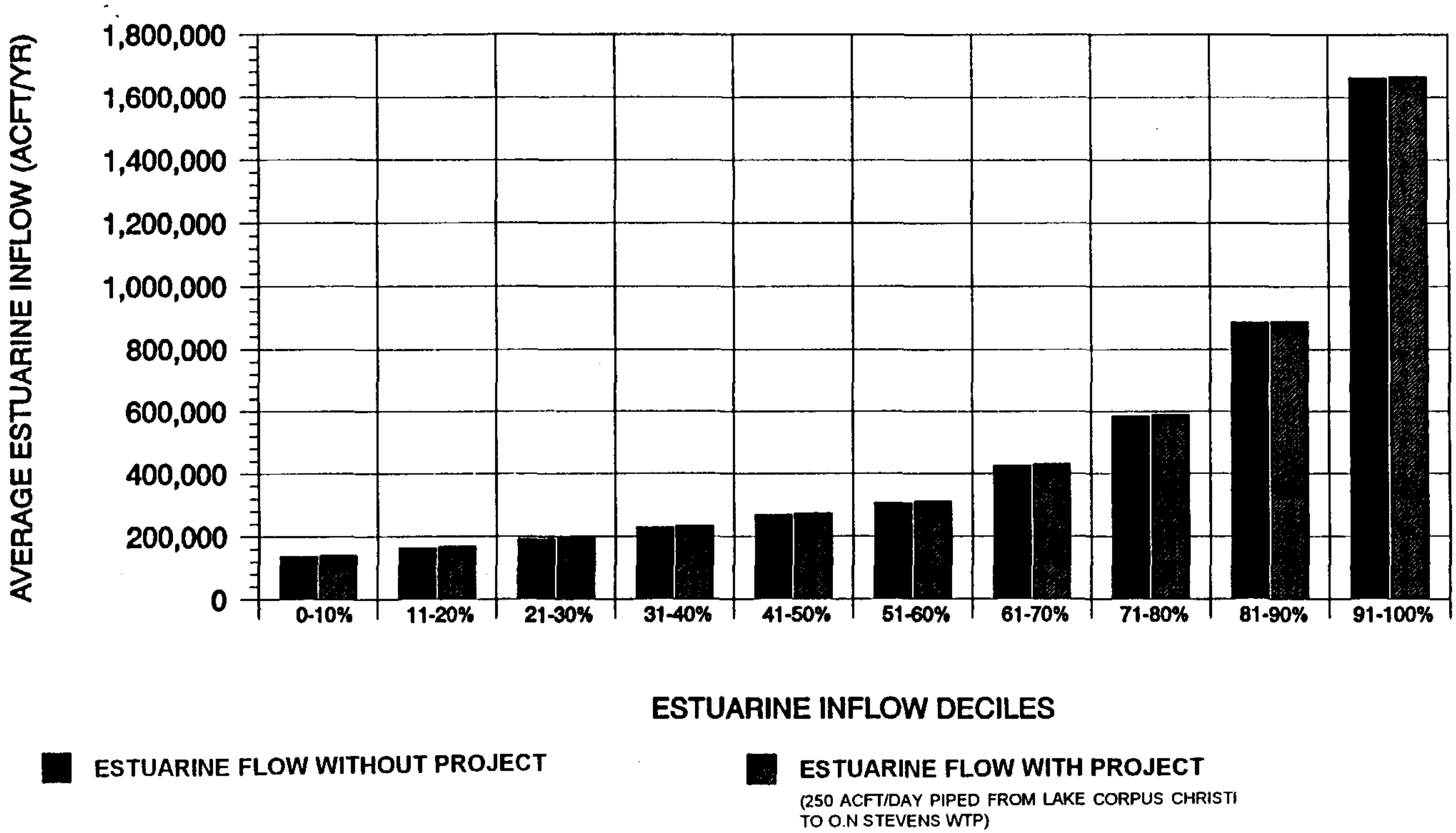
CHANGE IN ESTUARINE INFLOWS FOR N-6 FOR 1990 CONDITIONS

FIGURE 3.5-8



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CHANGE IN ESTAURINE INFLOWS FOR N-6 FOR 2050 CONDITIONS

FIGURE 3.5-9

Table 3.5-3
Cost Estimate for Pipeline from Choke Canyon to Lake Corpus Christi (N-5) and Pipeline from Lake Corpus Christi to Calallen Dam (N-6) (Mid-1995 Prices)

Item	Choke Canyon to LCC (N-5)	LCC to Calallen (N-6)
Capital Cost		
Pump Station	$ 5,900,000	$ 3,370,000
Pipeline	62,630,000	20,250,000
Engineering, Legal and Contingencies	20,860,000	7,260,000
Environmental Studies & Mitigation	240,000	130,000
Land Easements	210,000	120,000
Subtotal	$ 89,840,000	$ 31,130,000
Interest During Construction	2,760,000	930,000
Total Project Cost	$ 92,600,000	$ 32,060,000
Annual Cost		
Annual Debt Service	$ 8,680,000	$ 3,000,000
Annual Operation & Maintenance (Excluding Power)	910,000	340,000
Annual Power	1,800,000	1,120,000
Total Annual Cost	$ 11,390,000	$ 4,460,000
Annual Project Yield (acft/yr)	18,000	6,500
Annual Cost of Water	$633 per acft	$686 per acft

costs, interest, interest during construction, environmental mitigation, and operation and maintenance, is $11,390,000.

Given a net increase in the 2050 yield of the CC/LCC System of 18,000 acft per year, water recovered by eliminating channel losses through the implementation of the pipeline would cost approximately $633 per acre-foot.

Pipeline from Lake Corpus Christi to Calallen (N-6)

The estimated cost for constructing and operating the pipeline from Lake Corpus Christi to Lake Calallen Dam is an update of the cost estimate contained in the Phase I report which was calculated using 1993 unit costs and estimated quantities for materials, labor, and easements. The 66-inch pipeline size was determined based on a flow rate of 250 acft per day (i.e., 126 cfs or 82 MGD) and the pumping head created by pipe friction and the ground profile along the proposed route.

The total project cost for the pipeline from Lake Corpus Christi to Calallen Dam is estimated to be $32,060,000 (Table 3.5-3). A construction period of approximately one and one-half years was assumed along with a uniform disbursement of construction funds. The interest expense during construction totals $930,000. Financing for the project was assumed to be for 25 years at an 8 percent annual interest rate. The annual debt service payment was calculated to be $3,000,000. Operation and maintenance costs, including annual power costs, total $1,460,000. The total annual cost for the pipeline, including construction costs, interest, interest during construction, environmental mitigation, and operation and maintenance, is $4,460,000.

Given a net increase in the 2050 yield of the CC/LCC System of 6,500 acft per year, water recovered by eliminating channel losses through the implementation of the pipeline would cost approximately $686 per acft.

3.5.6 Implementation Issues

The primary implementation issue which would need to be addressed with either of these pipeline alternatives would be the impact of the reduced flows in the Nueces River downstream of Choke Canyon Reservoir or downstream of Lake Corpus Christi. A detailed evaluation of the impacts of reduced flows on the river habitat would have to be undertaken to fully investigate the consequences of implementing this alternative. In addition, the TNRCC permits may need to be amended depending on changes in locations of diversions. Additionally, before a significant expenditure of funds would be considered for either of these alternatives, detailed long-term investigations of channel losses should be under taken to fully understand the seasonality and variability of channel losses which occur in these two river reaches.

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.
   d. TPWD Sand, Gravel, and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

Other Considerations

If Alternative N-5 (Pipeline from Choke Canyon to Lake Corpus Christi) is chosen to be pursued in later phases of the Trans-Texas program, then at least two optional components could offer advantages and should be studied. First, the City of Beeville operates a raw water intake and pipeline from Lake Corpus Christi to Beeville and the route of the potential pipeline crosses the existing Beeville pipeline. The existing Beeville intake on Lake Corpus Christi can only draw water when Lake Corpus Christi is above elevation 84 ft msl, which limits their water supply. If the pipeline were to be constructed, Beeville may consider installing a tap on the pipeline, which would provide an alternate source of raw water.

A second option that may deserve further study would be to combine the Choke Canyon to Lake Corpus Christi pipeline with Alternative N-2, Diversion from Nueces River to Choke Canyon Reservoir. Under this combined option, the short pipeline from the Nueces River to Choke Canyon Reservoir would be designed to flow either direction and a new pipeline alignment from Choke Canyon to Lake Corpus Christi would need to be found. When Lake Corpus Christi is below spillway elevation, water would be diverted from Choke Canyon to Lake Corpus Christi. When Lake Corpus Christi is spilling, then water would be diverted from the Nueces River and pumped to Choke Canyon.

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3.6 Industrial Water Use (L-5)

The major water using industries of the South Central study area include petroleum refining, chemicals, and steam-electric power generation. In these industries, freshwater is used within the production processes as well as for cooling, boiler feed, cleaning, and sanitation. In steam-electric power generation, freshwater is used for boiler feed to generate steam and for some condenser cooling, however, most of the area's steam-electric power cooling is done with seawater.

During the Phase I South Central Trans-Texas Study, the Texas Water Development Board high case, with conservation, industrial water demand projections were presented for the 12-county study area (Table 2.3-2)[1]. Industrial water use in 1990 was reported at 43,611 acft per year. Industrial water use in the study area is projected to increase to 100,231 acft per year in 2050 (Table 2.3-2). As is shown in Section 3.6.4 (Industrial Water Conservation), Corpus Christi area industries are among the most efficient water using industries of Texas.

In this Phase II study, an industrial water use evaluation will: (1) Describe and characterize industrial water use by major industries of the Corpus Christi water service area, including summaries of raw and treated water consumption, internal reuse, and National Pollution Discharge Elimination System (NPDES) wastewater discharges; (2) Quantify water quality and quantity constraints for the different categories of industrial water use, such as cooling, boiler feed, process, and potable; (3) Describe industrial water conservation that occurred during the 1984 drought and in recent years, and describe potential industrial plant modifications or changes in technology which could be used to further reduce water use by study area industries; (4) Describe economic and technical constraints and environmental effects that study area industries would encounter under a range of qualities of water; and (5) Consider environmental effects of industrial water conservation, reuse, or use of brackish water. The sources of information used in these analyses include water use data and industrial water conservation studies by the Texas Water Development Board, the Texas Natural Resource

[1] Water use and projected future water demands are for freshwater, only, and do not include seawater used in steam-electric power generation.

Conservation Commission, a special 1994 survey of industries of the study area, and individual industry water conservation and drought contingency plans.

3.6.1 Fresh Water Use by Major Industries

The major fresh water using industries of the study area are petroleum refining, chemical manufacturing, and steam-electric power generation (Table 3.6-1 and Figure 3.6-1). The sources of supply of fresh water used by industry in the study area are surface water from the Choke Canyon/Lake Corpus Christi Reservoir System (CC/LCC) and groundwater, with 88 percent from the CC/LCC System and 12 percent from groundwater. Of the surface water used by industry, 31 percent is raw water and 69 percent is treated water that is obtained from the City of Corpus Christi water treatment plant. Groundwater use by industry in the study area is for electric power generation in Atascosa County and chemicals manufacturing in Live Oak County.

Between 1985 and 1992, annual industrial water use fluctuated from a low of 38,838 acft in 1985 to a high of 50,248 acft in 1989 (Table 3.6-1). During this period, fresh water consumption for steam-electric power generation ranged from a low of 7,291 acft in 1987 to a high of 9,377 acft in 1991 (Table 3.6-1). Leading factors and changes that affected industrial and steam-electric power water use in the study area during the 1980's and early 1990's are as follows:

- During 1984-85, a portion of refinery production was off-line, which primarily accounts for the lower water use during this period;
- During 1984 to 1986, the Reynolds Aluminum Plant discontinued their smelting operation, which resulted in a reduction in water use. The remainder of Reynolds Aluminum operation is accounted for in the chemical products category;
- Reductions in water use within the steam electric generating category during 1987, and then increases in water use during 1991 were the result of generating units being brought off-line around 1987, then back on-line during 1991;

Table 3.6-1
Industrial Fresh Water Use; 1980-1992 (acft)
Corpus Christi Service Area
Trans Texas Water Program[1]

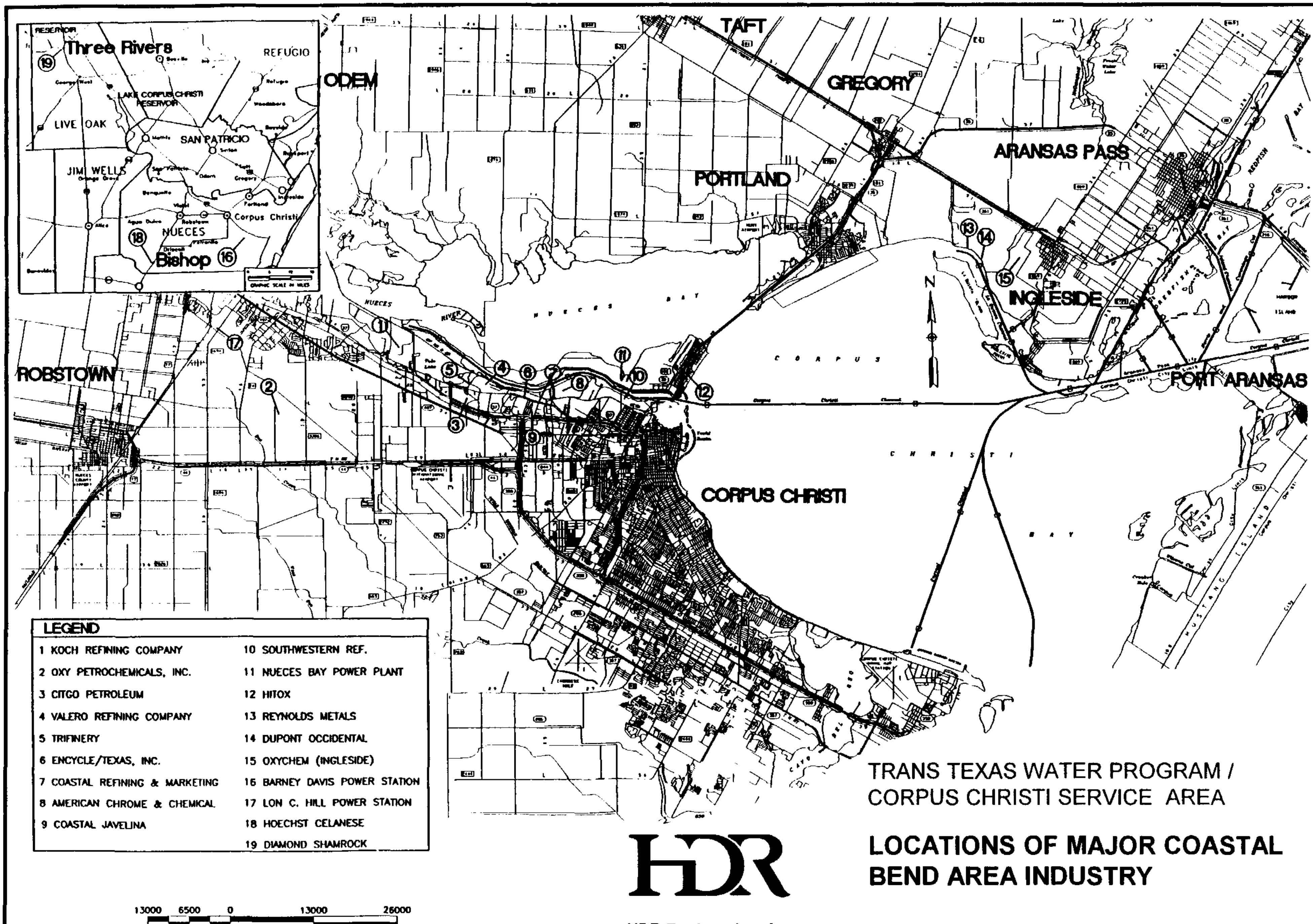
Industry	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Petroleum Refining	18,901	22,541	23,577	26,428	26,264	23,679	26,741	32,446	28,095	31,964	27,683	29,863	30,519
Chemicals	13,096	11,410	10,812	10,578	10,063	9,760	12,895	13,064	14,248	16,609	14,207	16,633	15,847
Other[3]	10,837	8,328	7,067	5,279	9,409	5,399	2,223	1,498	1,437	1,675	1,721	1,952	1,395
Total Industrial Use	42,834	42,279	41,456	42,285	45,736	38,838	41,859	47,008	43,780	50,248	43,611	48,448	47,761
Steam-Electric Power	3,553	2,921	6,981	8,080	8,999	9,069	8,486	7,291	8,562	8,024	8,440	9,377	8,465

Source: Unpublished water use reports, Texas Water Development Board; 88 percent is surface water from the CC/LCC system, and 12 percent is groundwater mostly from the Carrizo Aquifer in Atascosa County.

[1] Data for counties of the study area in which industries are located (Atascosa, Aransas, Live Oak, Nueces, and San Patricio).

[2] Includes consumptive use of freshwater for steam-electric power plants located in Atascosa (groundwater supplied) and Nueces (Nueces River Water supplied) Counties.

[3] Includes food processing, cement and concrete, and metals manufacturing.



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TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

LOCATIONS OF MAJOR COASTAL BEND AREA INDUSTRY

FIGURE 3.6-1

- The increase in industrial water use during 1989 was partially a result of increased production at refineries. However, in 1990, crude oil refining decreased from the 1989 level, resulting in reduced water use by refineries in 1990. Industry water use increased during 1991 and 1992 as a result of increased chemical plant production and increased refinery production. However, due to water conservation practices in the 1990's, water use increased at a slower rate than it would have without conservation;

- During the 1984 drought period, water use increased within the "Other Industry" category in San Patricio County as a result of the drought and lack of available on-site stormwater at Reynolds Metals for tailings bed dust control. For this purpose, Reynolds Metals purchased additional surface water from San Patricio Municipal Utility District; and

- Chemical plant start-ups in 1988, 1991, and 1993.

The reasons for the annual fluctuations in industrial and steam-electric power generation water use include the severe economic recession in the mid to late 1980's which caused a reduction in petroleum refining and petrochemicals production. The recession also resulted in reduced demand for electricity. However, during the late 1980's, the petroleum refining and petrochemical sectors expanded production capacity in the area. As the economy recovered in the early 1990's, production of these industries and the electric power industry have increased, resulting in increased water use (Table 3.6-1). Although annual industrial water use within the study area has fluctuated, the trend of use is upward from an average of approximately 42,200 acft per year for the four years from 1980 thru 1983 to an average of approximately 47,500 acft per year for the four year period from 1989 through 1992 (Table 3.6-1).

3.6.2 Industrial Water Using Processes

In order to understand the water demands of industry, of the study area, as well as the opportunities and constraints to conserve water, it is important to understand the primary industrial processes which utilize water, and whether these processes can use wastewater effluent or other water sources to reduce the demand on the area's present water supplies. Industrial water use within the study area is described below.

In most study area industries, cooling 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 plants that use very large volumes of seawater to cool the steam (for reuse) used to turn turbines for electric power generation. The predominant cooling system used by the petroleum refining and chemical processing industry, however, is cooling towers which use freshwater from the CC/LCC System. Cooling towers work by blowing air into the tower while water cascades down from the top. Air is brought through the sides or bottom of the tower, while water is pumped to the top of the tower. The water is broken into droplets and then brought into contact with the upflowing air, which causes a portion of the water to evaporate. The cooled water droplets collect at the bottom of the tower and the water is recirculated for additional cooling cycles. However, in order to prevent unacceptable build-up of minerals and salts, a portion of the recirculating water is discharged. Thus, a continuous supply of new water (make-up) is required. This process is more fully described later.

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 use of freshwater 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.

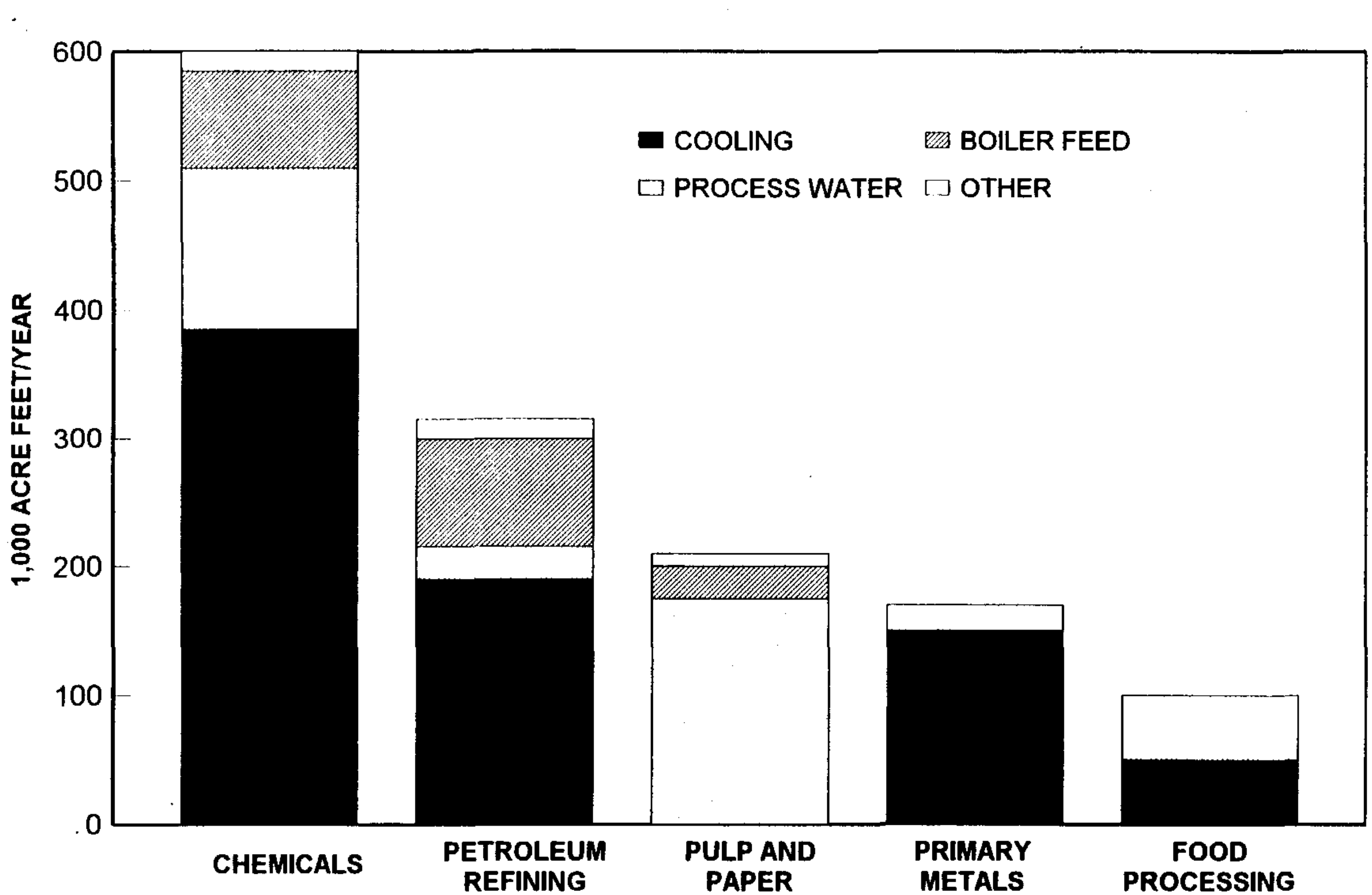
In Texas, 52 percent of industrial freshwater use (including chemicals, refining, primary metals, and food processing) is for cooling purposes, while process water and boiler feed account for 28 percent and 16 percent respectively. The remaining 4 percent is for employee sanitation and drinking water. The industries in the study area utilize water primarily for cooling (Figure 3.6-2). For most chemical and refining plants in the study area, cooling accounted for 60 percent of the water use, boiler water use accounted for 30 percent, process water accounted for 9 percent, and potable or sanitary use accounted for 1 percent (Figure 3.6-2). Chemical plants typically utilize more water in their process streams and in their products, and those refineries which produce steam for electrical generation utilize more water for boiler use.

The use of seawater is primarily at steam-electric generating plants in Nueces County, where about 921,000 acft per year (based on 1991 TWDB reported data) of saltwater is used for once-through cooling of condensers. In addition, a small amount of saltwater once-through cooling capability is used at a chemical plant in Nueces County, which accounts for about 10,046 acft per year (based on 1992 data reported to TWDB) of saltwater use.

3.6.3 Factors Influencing Industrial Water Use and Industrial Water Conservation

Water is used by study area industries for cooling, boiler feed, and process purposes (Figure 3.6-2). Of the total amount of water used by industry in the study area, 88 percent is obtained from the City of Corpus Christi's Choke Canyon/Lake Corpus Christi System. Various factors influence both present water use, the potential for industrial water conservation, and the potential for study area industries to use alternative sources of water, including treated municipal wastewater, brackish groundwater, and seawater. The list of important factors includes the following:

- 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 age of each industrial plant and the types and positioning of pipes and structures of the plant, i.e., the technology of existing plant and equipment.
- Increasingly stringent wastewater discharge permit conditions, such as biomonitoring requirements, and increasing regulatory pressures to minimize waste from the process control standpoint.



SOURCE: SOUTH TEXAS WATER DEVELOPMENT BOARD, 1992

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CORPUS CHRISTI SERVICE AREA

INDUSTRIAL WATER USE IN TEXAS BY MAJOR PROCESS (1990)

FIGURE 3.6-2

The nature of a particular industry, whether refining different types of crude oil, producing reformulated gas, producing different chemical products or pharmaceuticals, or extracting compounds from ore to produce metal products, affects water use, and presents differing opportunities to conserve and reuse water. In addition, the age of an industrial plant and the history of piping and structures above and below ground can also significantly affect the cost/effectiveness of a particular plant being able to re-route internal waste streams for reuse, or the use of alternative lower quality water supplies.

At the time of expansion of an existing facility or the construction of a new facility there are opportunities to install some water conservation measures, whereas, the retro-fit of an existing facility with water conserving equipment or re-routing and segregating internal waste streams for reuse, usually involves significant costs to relocate and replace equipment and piping. All of these factors are weighed by industry under an umbrella of changing market conditions, changing technologies and environmental regulations.

A reliable source of adequate quantities of suitable quality water is essential to industrial existence in the study area. The larger plants require between 1.0 million and 2.0 million gallons per day of freshwater. Each of the once-through seawater cooled electric generating plants require between 500 million and 600 million gallons per day of seawater. In general, major refineries and chemical plants in the study area, and the steam electric power plants that utilize freshwater cooling towers, require between 3,000 and 6,000 acft per year of freshwater at each plant location. Projected industrial water demand for the study area increases from 43,611 acft in 1990 to 100,231 acft in 2050 (Table 3.6-2). When these totals are expressed in terms of types of use within the industrial water use category (cooling, boiler, process, and potable), the quantities of cooling water demand increase from 34,666 acft per year in year 2000 to 60,139 acft per year in 2050 (Table 3.6-2). The projected quantity of boiler feed water increases from 17,333 acft per year in year 2000 to 30,069 acft per year in 2050 (Table 3.6-2). Projected industrial process water demand increases from 5,199 acft per year in 2000 to 9,020 acft per year in 2050 (Table 3.6-2). Projected industrial wastewater return flows increase from 27,489 acft per year in 2000 to 43,223 acft per year in 2050 (Table 3.6-2).

Table 3.6-2 Industrial Water Demand Projections, By Type of Use--Corpus Christi Area Trans-Texas Water Program						
	Projections in Acre Feet					
Year	Total[1]	Cooling[2]	Boiler[2]	Process[2]	Potable[2]	Return Flows[3]
1990 Use	43,611	26,166	13,083	3,925	436	17,683
2000	57,776	34,666	17,333	5,199	578	27,489
2010	64,948	38,969	19,484	5,845	649	30,360
2020	74,254	44,552	22,276	6,683	742	33,306
2030	83,145	49,887	29,932	7,483	831	36,663
2040	91,688	55,013	27,506	8,252	917	39,968
2050	100,231	60,139	30,069	9,020	1,002	43,223

[1] Table 2.3-2 of this report. Note: Based on estimates of water use from TNRCC water use reports, industry water conservation plans, and Naismith Engineering Survey; freshwater use by industries of the study area in 1994 was 55,155 acft, with 1994 return flows of about 19,585 acft.
[2] Survey of water use by Corpus Christi area industries, Naismith Engineering, Inc., 1994 (cooling water use at 60%; Boiler water use at 30%; Process water use at 9%; and Potable water use at 1%).
[3] From Table 3.10-2.

The water quality requirements of industry in the study 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. In particular, because cooling tower make-up can utilize water of poorer quality as compared to the high purity water required in a boiler, the reuse of water in cooling towers and the use of alternative lower quality water supplies in cooling towers, appear to be among the better opportunities for using alternative water supplies within study area industry.

Without proper control of water quality, industrial process equipment can degrade, cooling efficiency can be reduced, heath and safety problems can develop, and permitted wastewater discharge limits can be exceeded. 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 may affect the costs of handling and disposal, triggering new regulatory requirements, and may affect waste minimization programs.

In order to control water quality parameters and prevent the unacceptable build-up of contaminants due to evaporation, in particular various minerals and salts, a portion of the recirculating water is discharged or blowndown. To make-up for this blowdown of wastewater, a continuous supply of water input to the cooling towers or boilers (make-up) is required. Make-up water must be of good quality since any contaminants in the water are concentrated. Cooling water criteria representing the feedwater or make-up water quality for water going to the cooling system (i.e., cooling tower) and water quality criteria for the water being recirculated within the cooling system are shown in Table 3.6-3. The recirculating cooling water criteria represents the maximum concentrations which can be achieved for certain parameters before blowing down (discharging) water must be done. The feedwater has a variable range, since the quality of water being recirculated can be controlled to some extent by changing the cycle of water being recirculated, by changing the amount of blowdown, and by changing water treatment techniques.

Water quality criteria for boiler feedwater and water within the boiler are shown in Table 3.6-4. The high degree of purity required for boiler water is critical because boiler water is used to make steam and if 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 turbine and superheaters. Water sources which have higher concentrations of minerals, for example, have a greater potential for requiring costly pre-treatment.

In addition to considering internal industry wastewater as a source of cooling and boiler feed water, groundwater, seawater, and other surface waters are potential sources. Only industries in Live Oak and Atascosa Counties have been able to access usable groundwater in suitable quantities. Groundwater resources for industries located in San Patricio and Nueces

Table 3.6-3
Cooling Water Criteria for Recirculating Systems[1]
Trans-Texas Water Program

Parameter	Recirculated Water[1] (mg/L)	Feedwater Make-Up[2] (mg/L)	Feedwater Make-up[3] (mg/L)
Cl	2500	100-500	500
TDS	---	500-1650	1000
Hardness ($CaCO_3$)	---	50-650	850
Alkalinity ($CaCO_3$)	---	20-350	500
pH (Std. Units)	6.8-7.5	6.9-9.0	Preferably 3.5-9.1
COD	---	75	100
TSS	---	25-100	15,000
Turbidity	---	50	3.5-9.1
BOD	---	25	---
Organics: Methylene blue active substances	---	1-2	1.3
NH_4	---	4	---
PO_4	20	1	5
SiO_2	200	50	150
Conductivity	15,000	---	---
Fe	---	0.5	80
Mn	---	0.5	10
Ca	1400	50	500
Mg	500	0.5/**	---
HCO_3	---	24	600
SO_4	4500	200	680

[1] From Betz, Water Managemment Group. "Maximum" cooling tower specifications for water treated under environmentally acceptble corrosion and scale control program. Maximum levels cannot normally be achieved for all parameters at the same time. Based on Betz experience with numerous industries in the United States area (1994).
[2] Recommended cooling water make-up limits are from literature summarized in Guidlines for Water Reuse, U. S. EPA, 1994.
[3] Federal Water Pollution Control Administration, Water Quality Criteria, 1968. Water quality characteristics of surface waters used as cooling water make-up for recycling. Values are maximums. No one water will have all the maximum values shown.

Table 3.6-4 Industrial Boiler Water Quality Criteria Trans-Texas Water Program			
Parameter	Feedwater to Boiler[1] (mg/L)	Feedwater to Boiler[2] (mg/L)	Water in Boiler[2] (mg/L)
Silica (SiO_2)	0.7-30	---	1.0 - 150
Aluminum (Al)	0.01-5	---	---
Iron (Fe)	0.05-1	0.01-0.1	---
Manganese (Mn)	0.01-0.3	---	---
Calcium (Ca)	0.01-0.4	---	---
Magnesium (Mg)	0.01-0.25	---	---
Ammonia (NH_4)	0.1	---	---
Bicarbonate (HCO_3)	48 - 170	---	---
Sulfate (SO_4)	****	---	---
Chloride (Cl)	****	---	---
Dissolved Solids (TDS)	200-700	---	---
Copper (Cu)	0.05-0.5	0.01-0.5	---
Zinc (Zn)	0.01****	0.05-0.3	---
Hardness ($CaCO_3$)	0.07-350	---	---
Alkalinity ($CaC0_3$)	40-350	---	100-350
pH, units	7.0-10.0	7.5-10.0	---
Organics:			---
Methylene blue active substances	0.5-1	---	---
Carbon tetrachloride extract	1	---	---
Specific Conductance	1	---	---
Suspended Solids	0.5	---	---

[1] Guidelines for Water Reuse, U. S. EPA. Recommended limits in mg/l except for pH (units) and temperature (degrees Fahrenheit). Parameter concentration is dependent on whether the boiler is low, medium, or high pressure.
[2] Betz Water Management Group, Internal Water Treatment for Industrial Steam Plats Suggested Water Quality Limits for Feedwater to Boiler and Boiler Water. Parameter concentration is dependent on whether low, medium or high pressure boiler.

**** In low pressure boilers, accepted as received (if meeting other limiting values); has never been a problem at concentrations encountered.

Counties would have to be obtained from either the Gulf Coast Aquifer or the Carrizo Aquifer. As discussed in Section 3.8 of this report, most of the groundwater of the local Corpus Christi area Gulf Coast Aquifer is slightly to moderately saline, (1,000 mg/L to 2,000 mg/L of TDS), with chlorides in the range of 150 mg/L to 700 mg/L and sulfates in the range of 150 mg/L to 850 mg/L, and would require costly treatment for industrial use unless blended with significant quantities of better quality surface water. The added cost of constructing and maintaining well fields, collection pipelines and brine disposal pipelines when demineralization is required, and the potential impacts associated with subsidence and potential salt water intrusion problems, render a stand alone, long-term groundwater supply from the Gulf Coast Aquifer around Corpus Christi inadequate for industrial applications. However, the potential exists for use of limited quantities of local groundwater, provided sufficient quantities of good quality surface water are available for purposes of blending to maintain water quality. Alternatives for use of local groundwater are discussed in more detail in Section 3.8 of this report.

The Carrizo Aquifer, however, does have more suitable groundwater quality (TDS=500 to 900 mg/L) with chloride and sulfate concentrations in the range of 50 to 60 mg/L. This water quality compares favorably with the quality of current surface water supplies, however, the Carrizo Aquifer is located 100 miles from the industries of San Patricio and Nueces Counties. The significant cost of piping water from the Carrizo Aquifer, including the costs of a well field, storage impoundments, and operation and maintenance costs are major disadvantages to pursuing groundwater resources in the Carrizo Aquifer area for water supplies for industries located in San Patricio and Nueces Counties. The potential for use of the Carrizo Aquifer to supplement inflows to Choke Canyon Reservoir and the yield of the CC/LCC system are discussed in more detail in Section 3.9 of this report.

Parameters which to some extent control the use of water for industrial cooling and boiler feed are chlorides, hardness, sulfates and total dissolved solids. The concentrations of these constituents for the different major sources of water available to industries of the study area are shown in Table 3.6-5. For example, total dissolved solids (TDS) range from 35,300 mg/L in Corpus Christi Bay, to 3,000 mg/L for brackish groundwater, to 859 mg/L for Nueces River water at Mathis. Lake Texana water had a median TDS of 132 mg/L, with a maximum value of 403 mg/L (Table 3.6-5).

Table 3.6-5
Water Quality of Potential Water Sources
Trans-Texas Water Program

Location		Chloride (mg/L)	Hardness (mg/L)	Sulfate (mg/L)	TDS (mg/L)
Nueces River @ Stevens*	Max	338	312	---	---
	Med	162	219	124[E]	498[E]
	Min	67	138	---	---
Nueces River @ Mathis*	Max	370	360	100	859
	Med	73	180	43	341
	Min	11	93	12	164
Corpus Christi Bay**	Max	20,000	----	2,300	35,300
	Min	16,000	----	1,800	28,600
Lake Texana*	Max	96	216	27	403
	Med	21	75	10	132
	Min	1	37	6	59
Groundwater @ Corpus Christi***	Med	500	----	----	1,350
Groundwater North of Sinton***	Med	250	----	----	1,000
Groundwater @ Bishop*	Range	300-500	----	200-850	1,000-2,000
Brackish Groundwater**	Max	1,300	----	630	3,000
	Min	300	----	165	1,000
Oso Municipal Wastewater**	Med	318	----	125	900
Broadway Municipal Wastewater**	Range	850-1,270	----	202-290	2,360-_____
Refinery Wastewater*****	Ave.	900	800	1,500	4,000
City of Corpus Christi Potable Water****	Ave.	168	219	124	498

*Taken from Appendix D.
**Desalinization and Wastewater Reuse Report (November, 1984).
***Trans-Texas Phase II Groundwater Studies (1995).
****City of Corpus Christi Water Division (1989-90 Average). TDS data from State Health Department 10/30/89 Anaysis.
*****Betz Personal Communications (1994).
[E]Estimated based on potable water analysis.

In addition to the above water quality parameters, the following parameters and contaminants affect the use of water for industrial purposes:

- Free chlorine and oil and grease can affect reverse osmosis membranes and water treatment/processes;
- Biochemical and chemical oxygen demand, hydrocarbons, phosphates, and ammonia provide nutrients favorable to organisms which foul cooling towers;
- The dissolved oxygen in boiler feedwater can cause metal failures; and,
- Calcium, magnesium, iron, and other feedwater contaminants can lead to boiler deposition and tube failures, as well as cooling tower problems.

As was stated above, water quality constituents are concentrated in the cooling towers and boiler water and the water is then blown down, with additional feedwater added to control the water quality. With regard to cooling tower water, the amount of recycling and the degree of blowdown is a function of the water quality of the feedwater source and the concentrations of minerals and other contaminants. Cooling system constituent levels at various cycles of concentration are shown in Table 3.6-6. The water quality of the alternative water source directly affects the amount of water needed as feedwater, the degree of cycling, the extent of water treatment necessary, and the amount of blowdown (discharge). Most study area industries cycle their towers at 3-5 cycles. From strictly a water quality perspective, the water sources shown in Table 3.6-5, with the lower concentrations of Chloride, Hardness, Sulfate, and TDS would be preferred by industry.

3.6.4 Industrial Water Conservation

Corpus Christi area industries have developed and adopted water conservation methods in response to water shortages during times of drought, and in order to control costs of operations. Results of water conservation surveys of Corpus Christi area industries are presented below.[2]

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[2] TNRCC Survey of Industrial Water Use, Austin, Texas 1994; Texas Water Development Board Industrial Water Use Efficiency Study, Austin, Texas, October, 1993; Unpublished Water Conservation Plans of selected Corpus Christi industries; and Naismith Engineering, Inc., Survey of Corpus Christi Industries, 1994.

Table 3.6-6 Cooling System Constituent Levels at Various Cycles of Concentration Trans-Texas Water Program				
CYCLES	**Ca, as $CaCO_3$, mg/L**	**Mg, as $CaCO_3$, mg/L**	**SiO_2, mg/L**	**CONDUCTIVITY, μmhos**
Make-up	24	12	16	799
2.0	48	24	32	1,598
4.0	96	49	64	3,196
6.0	144	73	96	4,794
7.0	168	85	112	5,593
8.0	192	98	128	6,392
Source: Betz Water Management Group (February, 1994).				

During the 1984 drought, Corpus Christi requested its industrial water customers to minimize water use from the CC/LCC System without seriously jeopardizing production. Industry representatives responded by carefully studying ways to reduce water demands through increased efficiency of use of existing supplies, reuse of available supplies, and development and use of alternatives water supplies. In response to water shortages during the drought of 1984, concerns about rising costs of water, increased regulation, rising costs of wastewater treatment and disposal, and public interest in water conservation, Corpus Christi area industries have implemented water conservation and water reuse measures that have significantly reduced the quantities of water needed per unit of production. For example, Corpus Christi area petroleum refineries use 35 gallons of water per barrel of crude oil refined, while refineries in Houston use 91 gallons, and refineries in Beaumont use 96 gallons (Table 3.6-7).[3] According to surveys of Corpus Christi area industries, the leading industrial water conservation measures that have been implemented are as follows:

[3] The study area industrial water demand projections presented in Section 2.0, Table 2.3-2 are based upon the industrial water use data of the study area. Therefore, the more efficient technology and industrial water conservation measures of the Corpus Christi industries have been taken into account in the industrial water demand projections.

- Recycling Cooling Tower and Boiler Blowdown;
- Improved Control Systems;
- Dry Cooling;
- More Efficient Drift Eliminators;
- Changed Washdown Procedures;
- Automatic Cooling Tower Blowdown;
- Leak Detection/Repair;
- Steam Condensate Recovery;
- Reuse of Wastewater Treatment Effluent for Firewater and Cooling Tower Make-up;
- Cycling-Up Cooling Towers;
- On-Site Collection and Use of Stormwater;
- Seawater for Area Washdown;
- Seawater Lubrication of Circulating Water Feed Pumps;
- Reverse Osmosis with Demineralization for very select plant uses;
- Voluntary Water Conservation Planning; and
- Regulatory Requirement to Consider Reuse.

Table 3.6-7
Water Consumption in Texas Refineries[1]
Trans-Texas Water Program

Principal Location	Number of Refineries	Water Usage Gallons/BBL[2]
Beaumont	4	96
Houston	9	91
Corpus Christi	7	35
All Other	8	49

[1] Texas Water Development Board, Industrial Water Use Efficiency Study, 1993.
[2] Gallons of water used per barrel of crude oil refined.

In addition to the water conservation measures listed above, that have already been adopted, Corpus Christi area industries are considering the following list of potential water conservation measures:

- Increased Evaluation of Alternative Water Sources to Replace Treated Water from the City of Corpus Christi;
- Additional Application of Reverse Osmosis Treatment for very select plant uses;
- Increased Wastewater Treatment Plant Effluent Reuse;
- Possible Side-Streaming Softening;
- New Process Changes;

- Additional Steam Leak Repair;
- New Chemical Treatment Technology;
- Increased Water Audits by Industry;
- Possible Water Conservation Incentives;
- Possible Regulatory or Local Government Water Conservation Planning Goals;
- Increased Water Conservation Research and Education; and
- Additional Industry Pursuing Water Conservation Measures.[4]

In the recent surveys of Corpus Christi industries, information about efforts to conserve water was obtained from: (1) Koch Refinery; (2) Valero; (3) Citgo Refinery; (4) Reynolds Metals; and (5) Occidental Chemical Company. The water conservation efforts of each respondent are described below.

As of 1993, Koch Refinery, an establishment which uses large quantities of water, has expanded its Corpus Christi Refinery from a capacity to process 130,000 barrels of crude oil per day to 180,000 barrels per day. The plant expansion also included expansion of the wastewater treatment plant and construction of a new raw water line. This allows the refinery to utilize one hundred percent (100%) raw water in its processes (about 6.0 MGD of which 1.0 MGD will be reused treated wastewater for cooling tower make-up water). The refinery will continue to purchase treated water from the City of Corpus Christi for potable use.

Koch's water conservation and reuse program includes the use of air cooling, increased operating cycles of boilers and cooling tower reuse of process wash water, on-site collection and use of rainwater and reuse of treated wastewater. In Koch's recently expanded wastewater treatment plant, cooling tower and process water are segregated. This segregation of flow may provide options for diverting the blowdown water into the Nueces Estuary. With the conservation program described above, the demand for water at the expanded refinery is about one-half what it would have been without the conservation and reuse program; i.e., the program reduces raw water demand from the CC/LCC system by about 2.0 MGD.

Since Koch acquired the refinery in 1981, about 6.7 million gallons per day or 7,500 acft per year of water has been conserved. Koch Refining has invested over $60 million dollars on water related projects including: $7.7 million for the new raw water pump station, pipeline, and

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[4] Op. cit.

clarifier; $4.8 million for new boiler feedwater pretreatment equipment; $2.5 million on a stormwater drainage and collection system; $43 million on a major modification of the wastewater treatment plant; and several million dollars have been invested on wastewater sewer segregation systems in new process units. In addition, Koch Refinery has various water reuse/minimization projects under consideration over the next 1-5 years, including recycling stormwater, and treating cooling tower blowdown and boiler blowdown to recycle 100 percent of cooling tower and boiler blowdown. The total projected additional water savings are estimated to be 3,293 acft per year.

In addition to the conservation and reuse described above, Koch considered using groundwater and desalination to supplement the current water source. However, these alternatives were not implemented due to their extremely high cost. Koch is also reviewing various alternatives for reducing the amount of evaporation occurring in the cooling towers.

Information from Valero indicates that Valero has almost tripled refinery production from 54,000 barrels per day in 1984, to 145,000 barrels per day in 1994. Since 1992, Valero's expansion has increased water consumption 1.0 MGD. Valero has implemented various water conservation measures to reduce demands on water purchased from the CC/LCC system, such as reuse of stripped sour water, recovery of condensate, maximize cycling of cooling towers, monitoring water balances daily, use of internal steam condensing turbines for power generation which enhances condensate recovery and reduces water make-up, and reusing boiler blowdown as cooling tower make-up. These measures reduced water use by Valero by about 199 acft in 1992 and 160 acft in 1993. Valero estimates that its water conservation programs will reduce water use by about 546 acft/yr. In addition, Valero is investigating reverse osmosis technology to optimize demineralization plant operation for selected applications, and is considering routing more blowdown to the cooling towers. Valero is also considering reuse of wastewater as cooling tower make-up, and reusing cooling tower blowdown as scrubber and firewater make-up.

Citgo Refining personnel stated that Citgo is reviewing the possibility of installing a reverse osmosis unit to reduce demineralization costs required to treat a portion of the incoming CC/LCC system water prior to its use in the Citgo facility.

Currently, Reynolds Metals has the ability to use up to 6.0 MGD of CC/LCC system raw water pumped by the San Patricio Municipal Water District (SPMWD) W.A. Edwards Pump

Station at Nueces River at Calallen. At the present time, Reynolds Metals uses 1.0 MGD from this source. In addition, Reynolds has a TNRCC permit to pump 5,500 acft per year of sea water from Port Bay for dust control, as necessary. In addition, Reynolds is currently studying the possibility of accepting wastewater sludge from area municipalities as a means of dust control on a part of the bauxite tailings beds at the facility; the permitting for this project is currently being reviewed by the TNRCC.

Reynolds Metals of San Patricio County is investigating the acquisition of lower quality water, particularly municipal and possibly industrial wastewater effluents for use in their processes. It will be possible for Reynolds to use municipal wastewater that is treated to a lesser degree than is currently required for discharge from municipal WWTP's in the area. This alternative was evaluated in 1994 through the "Northshore Regional Wastewater Reuse, Water Supply and Flood Control Planning Study," funded in part by the TWDB. The scope of the Regional Northshore study included an evaluation of an option to collect and treat the wastewaters from area municipalities, including Portland, Gregory, and the Northshore Country Club with use of the reclaimed water by Reynolds Metals for dust control.[5] The study showed that reuse of this municipal wastewater by Reynolds Metals could result in making 612 acft per year of CC/LCC yield available for uses other than those now exercised by Reynolds Metals. In addition, Reynolds is considering the possibility of reusing effluent from the industrial facilities of the neighboring Occidental Chemical and DuPont plants. Occidental and DuPont currently discharge about 1.0 MGD and 1.4 MGD, respectively. Reynolds' substitution of this lower quality water for the CC/LCC raw water now used for dust control would free up the raw water for other uses, and increase the effective water supply of the area.

The Reynolds facility has achieved "zero discharge" and current plans call for the use of wastewater instead of the use of raw and treated CC/LCC surface water from the SPMWD. Reynolds plans call for an innovative program to reuse neighboring cities' municipal wastewater treatment plant effluent, increased reuse of internal wastewater and process streams effluent, reducing water consumption by eliminating cooling towers and moving towards a cooling lagoon

[5] "Northshore Regional Wastewater Reuse, Water Supply and Flood Control Planning Study", San Patricio Municipal Water District, et. al., Ingleside, Texas, July, 1994.

system, use of nearby industry wastewater effluent, and increasing the capture of stormwater runoff (about 1.0 billion gallons or 3,100 acft of stormwater per year). Under a test program with the TNRCC, Reynolds is accepting wastewater sludge from area municipalities as a means of dust control on the bauxite tailings beds at the facility, thereby reducing the need for freshwater dust control.

Occidental Chemical Plant stared operating in 1988 and expanded significantly in 1990, 1991, and 1992. Production increased from 392,851 tons in 1988 to 2.2 million tons in 1993. Water use during this period increased from 177 million gallons (543 acft) per year in 1988 to 1.2 billion gallons (3,683 acft) per year in 1993. Occidental Chemical has implemented various water conservation measures, such as recycling steam condensate, reusing cooling tower blowdown for outfall pump cooling water, using utility water as coolant, and increasing cycles on cooling towers. In addition, the facility generates its own electric power, using steam turbines that recover steam condensate, which has saved about 433 million gallons (1,329 acft) per year since 1988. The Occidental Chemical facility also participated in the Northshore Regional Wastewater Reuse, Water Supply and Flood Control Planning Study and is investigating scrubber make-up water control valves to further reduce water consumption.

Information from Corpus Christi industrial water users, as described above, indicates that water reuse is being addressed within individual establishments, and that the major industrial reuse plans are for internal reuse of one's own wastewater. Additionally, Reynolds Metals is planning to reuse its own wastewater and site rainfall runoff, as well as acquiring municipal wastewater from neighboring cities for reuse at its facilities, to replace a part of the raw water now being obtained from the CC/LCC surface water system. However, since water use efficiency improvements (recirculation and technology improvements) were estimated and applied in the industrial water demand projections, these water conservation and reuse potentials, have already been appropriately taken into account in the water demand projections (Table 2.3-2); i.e., without the water conservation and reuse programs described for Koch, Valero, Reynolds Metals, Oxychem Petrochemicals, and others, the industrial water demand projections would be higher than those shown in Table 2.3-2 of this report.

Drought contingency plans have been prepared by the majority of Corpus Christi area industry. These plans include actions which will be undertaken in the event that Corpus Christi

Drought Management Phase I Alert, Phase II Voluntary Curtailments, or Phase III Mandatory Curtailments are triggered due to drought conditions. Corpus Christi industry has designated water conservation teams within the individual plants that are responsible for implementing their respective plans. A summary of typical drought contingency plan measures which will be initiated by industries follows:

Phase I Alert

- Encourage employee water conservation awareness
- Water use audits, increase cycling of towers and boiler system
- Water conservation team increases planning
- Landfarm irrigation is reduced
- Increase leak identification and repair schedule
- Evaluate unit shutdown or overhaul schedule
- Minimize potable water use
- Reaccess priority of water conservation projects
- Plans for Phase II

Phase II Curtailments (Voluntary)

- Reassess schedule for biological effluent recycling
- Temporarily curtail unit washdowns
- Increased planning by water conservation team
- Daily monitoring of plant operations by the conservation team to curtail unnecessary water use
- Implement water conservation plans that will not deteriorate equipment or create water quality problems
- Reschedule major turn-arounds
- Plan for Phase III

Phase III (Mandatory)

- Install temporary filtration and oxidation to treat bioeffluent
- Piping modifications to return wastewater effluent to utility/firewater system
- Monitor cooling towers
- Contingency plans for reducing plant loads
- Recycle wastewater effluent to the cooling tower, reaccess cooling tower blowdown as scrubber quench water
- Reuse cooling tower blowdown water as firewater make-up

3.6.5 Technical and Economic Constraints and Environmental Effects of Industrial Use of Different Qualities of Water

The processes and equipment of study area industries have been planned and designed to use freshwater from the CC/LCC system. In order to use lower quality water, such as seawater or brackish groundwater, it will be necessary to replace existing water pipes and heat exchange equipment with pipes and equipment manufactured with corrosion resistant metals, such as stainless steel.[6] However, in the case of structures, pressure treated wood should be used instead of steel if seawater or brackish groundwater is to be used.

The use of municipal effluent (reclaimed CC/LCC water) in existing industrial processes, although not necessarily requiring pipe and equipment replacement, would require some technical changes to internal processes to handle biological factors, for example, that are not present in CC/LCC water. Both types of plant modifications (plumbing and equipment to handle higher salinities and minerals, and treatment to handle nutrients and biological components of reclaimed water) will result in higher costs to industry and can potentially yield a lower quality of wastewater for discharge, and could increase solid waste concentrations. The latter would require modifications to existing wastewater discharge and solid waste permits, which in turn will result in increased wastewater treatment and solid waste disposal costs. The technical changes, costs and environmental effects of industrial use of seawater and reclaimed water are presented and discussed below. The potential use of brackish groundwater is addressed in Section 3.8 of this report.

3.6.5.1 Industrial Use of Seawater

Seawater has been used in the study area for steam-electric power generation at two major power plants (Nueces Bay and Barney Davis Power Stations) since the plants were constructed. The process used is once-through cooling, in which very large quantities of seawater are passed by the condensers and then discharged into the receiving waters (Nueces Bay and Upper Oso Bay, respectively) in accordance with requirements of the respective wastewater

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[6] An alternative to direct use of brackish groundwater or seawater would be to demineralize such water (desalt) to bring it to the quality of CC/LCC system water, and then use it in present industrial processes. These alternatives are evaluated in Section 3.7, Desalinization.

discharge permits. It is estimated that the once-through cooling technology used for electric-power generation in the study area in the early 1990's uses about 822 MGD (921 thousand acft per year) of seawater. If these electric power plants had been operated with freshwater, 9,521 acft per year would have been consumed through evaporation. This avenue of industrial water conservation has already been implemented in large applications where it has made economic sense.

The petroleum refining and chemical manufacturing plants of the study area use freshwater for cooling, boiler feed, process, and potable purposes. Of these four types of water use, cooling is the only purpose for which seawater or brackish groundwater could potentially be used (Note: Reclaimed water perhaps could be used for cooling or boiler feed with sufficient treatment and will be discussed below.) The projected quantities of freshwater needed to meet cooling water demands in the study area increase from 26,166 acft per year in 1990 to 60,139 acft per year in 2050 (Table 3.6-2). In order to replace these quantities of freshwater with seawater, it would be necessary to completely replace existing plant cooling systems with new systems made from metals, wood, plastics, or ceramics, that are capable of withstanding the corrosion of seawater. In addition, it would be necessary to obtain modifications to existing waste discharge permits to allow the disposal of the resulting wastewater. The cost and permitting factors are discussed below.

The corrosive nature of seawater requires different and more costly metal alloys and corrosion resistant materials in the cooling system than cooling towers using freshwater. The costs of these stainless and titanium steels, the construction costs of retrofitting existing freshwater cooling systems to use seawater, and associated operational and maintenance costs are prohibitively expensive. Typical Corpus Christi Bay water contains 28,000-35,000 mg/L total dissolved solids, chlorides of 16,000 to 20,000 mg/L, sulfates of 1,800 to 2,300 mg/L, calcium of 370 to 410 mg/L, and magnesium of 1,000 to 1,200 mg/L. The use of this water in a cooling tower would concentrate these salts and dissolved solids, requiring significant costs of treatment prior to discharge of any blowdown. Therefore, the preferred alternative for utilizing seawater for cooling has traditionally been once-through cooling; i.e., there are very few saltwater cooling towers in operation in the United States. Once-through cooling using seawater is common and is discussed further below.

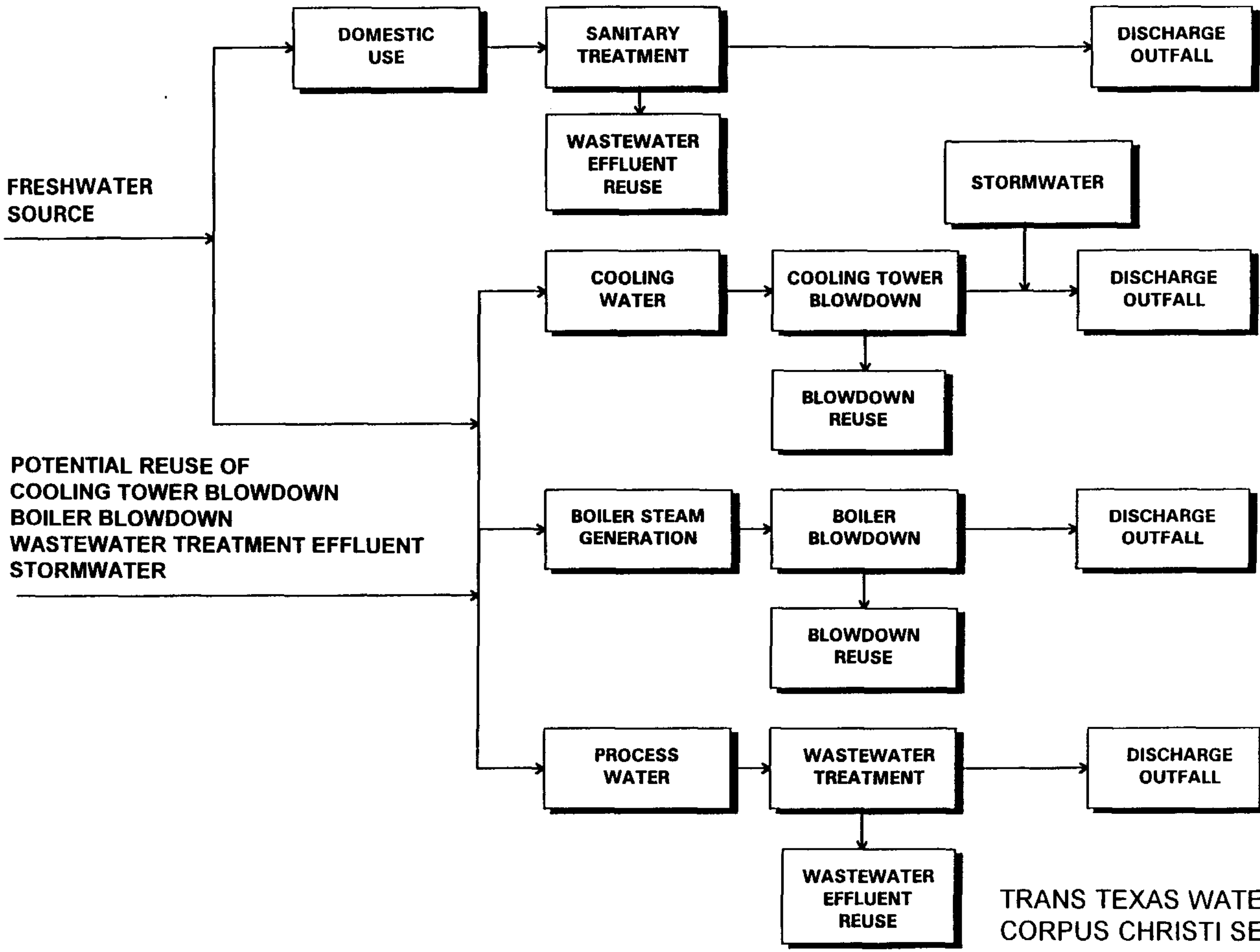
In addition to the replacement of present freshwater cooling towers with once-through systems made from corrosion resistant materials, it would be necessary to construct large impoundments to cool the water prior to discharge of the return flows into the study area estuaries. Direct discharge of thermal water presents potentially significant permitting issues, especially for the retrofit of study area industries' existing freshwater cooling towers with such alternatives. For example, the waste discharge permit conditions for the Barney Davis Steam-Electric Power Plant requires 1,300 acres of cooling impoundments for its present 540 million gallons per day of cooling water discharge. As an alternative to such a system, acceptable locations for thermal discharges could be required to be located in Corpus Christi bay or in Gulf waters, with the associated pumping and piping of such discharges (if acceptable from a permitting standpoint) would be expensive. The concern for maintaining freshwater inflows in area bay systems would also influence the source of such large quantities of seawater, as well as the receiving body of water. Moving more seawater from one bay system to a bay system where freshwater inflows are of concern, would be a major permitting and environmental issue.

3.6.5.2 Industrial Use of Brackish Groundwater

The potential to develop an economical source of brackish groundwater is addressed in Section 3.8 of this report.

3.6.5.3 Industrial Use of Reclaimed Water

Water reclamation and wastewater reuse has been practiced for many years throughout Texas, and is being done at an increasing rate by industry within the South Central Trans-Texas Study area. The use of internal plant wastewater effluent (biological effluent, boiler blowdown, cooling tower blowdown, and process wastewater streams), is presently the most attractive option that study area industry is investigating as a substitute for existing CC/LCC water supplies. Also, on site stormwater storage presents an additional source of freshwater for in-plant use (Figure 3.6-3). However, the reuse by industry of treated municipal effluent is not as attractive as internal plant wastewater reuse. This is primarily due to the increased costs of piping and pumping from present WWTPs to industry and problems with the salt content of treated municipal effluent that would significantly increase treatment costs.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

INDUSTRIAL WATER BALANCE FLOW DIAGRAM SHOWING OPPORTUNITY FOR WASTEWATER REUSE

FIGURE 3.6-3

The concept of "zero discharge" which can only be accomplished through 100 percent wastewater reuse is a planning goal which a few industries have identified in their long-term plans. Currently, the Reynolds Metals Plant in San Patricio County is zero discharge and the San Miguel Electric Plant in Atascosa County is basically zero discharge, except for certain plant stormwater runoff.

The economic and technical factors influencing industries' internal wastewater reuse include the cost and technology of segregating and re-piping certain internal wastestreams (wastestreams with low salt content are preferred in order to reduce additional treatment costs), the capital and operating costs of different treatment technologies, and the additional costs of equipment maintenance and repair, which result from reusing wastestreams in cooling towers and boilers. Cost factors include increased costs of chemicals, acid, caustics, chlorine, costs associated with changes of materials in construction of heat exchangers, wastewater treatment plant design changes, and equipment operational changes to reflect changes in water quality. The better the quality of water, the less the cost of treatment and the less chance for problems developing in cooling towers or boilers from using reclaimed water. However, as water becomes more expensive, as the costs of chemicals increase, and as the environmental wastewater permit requirements become more restrictive (i.e., biomonitoring), the costs of wastewater reuse becomes more attractive.

The cost of chemical treatment increases when using wastewater as make-up as compared to a freshwater source. This accounts for why many industries are focusing on utilizing only a portion of their "biological effluent" from their wastewater treatment plant. Many study area industries are expecting to be able to use biological effluent for 10-25 percent of their cooling tower make-up over the next 5-10 years. The largest treatment chemical increase would be for microbial control, antifoulants, scale inhibitors, and antifoams.

There are various types of treatment technologies which may be used to treat wastewater to make such water suitable for use. A list of water quality parameters in refinery waste streams and the treatment equipment system options typically used to control these parameters is shown in Table 3.6-8. Wastewater treatment processes and costs for different water treatment process typically used to treat wastewaters are shown in Table 3.6-9. These guidelines are intended to identify the approximate range of costs attributed to these water treatment technologies.

Table 3.6-8
Petroleum Refining Water Quality Parameters and Their Treatment Options*
Trans-Texas Water Program

Parameter	Treatment Options	Notes
Aldehydes	A, K	
Aluminum	B, C, G, I, J	B - requires pH adjustment
Amine	K	
Ammonia	F, K, I	
Arsenic	B, C, F, H, J	B - requires pH adjustment
Barium	E, G, I, J	I - possible membrane fouling
BOD	A, B, D, F, H, I	pre-filter
Calcium	E, G, I	
Chlorides	H, I, J	
Chlorine - residual		feed sulfite
COD	A, F, H, I	
Conductivity	G + H, I, J	
Copper	B, C, E, I, J	B - requires pH adjustment
Cyanides	A, K	
Fluoride	E, H, I, J	some adsorption on $CaPo_4$, MgOH
Hydrocarbon - total	B, D, F, I, K	
Iron	A, B, E, G, I, J	I - possible membrane fouling
Lead	A, B, E, I, J	B - requires pH adjustment
Magnesium	E, G, I, J	
Manganese	A, B, E, G, I, J	I - possible membrane fouling
Nickel	A, B, G, I, J	B - requires pH adjustment
Silica - reactive	E, H, I	E - hot
Sulfates	H, I, J	some adsorption with lime
Sulfides	A, E, F, H	
Suspended Solids	B, C	
TOC	A, F, H I	
Zinc	B, C, E, G, I, J	B - requires pH adjustment

* A Chemical oxidation
B Filtration
C Clarification
D Physical separation API, DAF/IAF
E Lime or soda ash softening
F Air/steam stripping
G Cation exchange
H Anion exchange
I Reverse osmosis
J EDR
K Biological/secondary treatment

Table 3.6-9 Wastewater Treatment Processes and Costs* Trans-Texas Water Program						
	Capital Costs		Annual Operation and Maintenance Costs			
			Materials		Labor**	
Unit Process	a	b	a	b	a	b
Coagulation and Filtration	$ 175,000	0.70	$ 28,000	0.80	$ 1,100	0.70
Filtration	210,000	0.90	19,000	0.80	2,750	0.80
Sedimentation	155,000	0.90	1,000	0.75	6,200	0.55
Separate Nitrification	415,000	0.80	7,700	0.75	7,200	0.55
Two Stage Lime Treatment	386,000	0.85	8,700	0.95	21,700	0.65
Lime Recalcination	800,000	0.60	90,000	.90	45,000	0.55
Activated Carbon Adsorption	915,000	0.80	22,000	0.85	20,000	0.55
Chlorination	50,000	0.95	9,000	0.70	5,600	0.60
Dechlorination	43,000	0.95	8,000	0.70	5,600	0.60

* Guidelines for Water Reuse, U. S. EPA (1980); Cost Equation is $C = aQ^b$, where C = Costs, a - coefficient of proportionality, Q = average design flow in MGD, b = exponent indicating economy of scale.
** Labor based on $10./hr. should be adjusted to local conditions, ENR Construction Cost Index = 3,000.

Chemical treatment programs are often required to maintain the desired water quality "within the process" (i.e., cooling tower, boiler). These chemical treatment programs are designed along with any make-up water treatment equipment, in order to achieve and maintain the desired water quality and avoid associated problems. The cost of chemical treatment typically increases when using wastewater as make-up as compared to a freshwater source. This accounts for the fact that many industries are focusing on utilizing only a portion of their"biological effluent" from their wastewater treatment plant. As previously mentioned, many industries are expecting to use biological effluent for 10-25 percent of their cooling tower make-up over the next 5-10 years. The largest treatment chemical increase is realized for microbial control chemicals, antifoulants, scale inhibitors, and antifoams. Different chemical treatment approaches to control different water quality parameters and associated problems, which can affect plant equipment cooling systems, boiler systems, or process control are shown in

Table 3.6-8. A good chemical treatment program to maintain water quality and control problems must involve a balanced approach to controlling several key water quality parameters, using various chemical treatments tailored to the particular industry. In general, considering a balanced program of biocides, inhibitors, pH control and dispersants, the overall chemical treatment cost is about $1.50 per 1000 gallons of blowdown (Table 3.6-10).

The regulatory and institutionally related factors influencing internal wastewater reuse include new toxicity based effluent standards for industry wastewater discharges, new wastewater discharge permit biomonitoring requirements, changes in solid waste classification, handling and disposal costs related to cooling tower basin sludges, increased attention from regulatory agencies promoting internal wastewater reuse, potential regulatory agency and local government involvement in industry water conservation practices, waste minimization and pollution prevention requirements by regulatory agencies, and voluntary initiatives by industry to pursue zero discharge. Depending on the particular regulatory and institutional factors involved, there are considerations which on one hand, promote wastewater reuse (to limit wastewater discharge permit concern), but on the other hand, promote potentially new uses of chemicals or new treatment systems with new waste and wastewater handling issues. For example, the pursuit of biological wastewater effluent reuse in a cooling tower could promote biological growth in the tower, which would then require use of a treatment chemical (biocide). The treatment chemical could then potentially affect the chemical characteristics of the cooling tower blowdown and potentially jeopardize the biomonitoring tests conducted as a part of the wastewater permit. All of these regulatory and institutional issues must be carefully weighed when pursuing any alternative water source, and in particular the reuse of wastewaters.

3.6.6 Industry Outlook Regarding Future Water Demands

Representatives of industry were interviewed regarding water supplies for the future. The majority of major water using industries of the study area indicated that their water demands would continue to increase since it is expected that production will continue to increase. Koch Refinery indicated their current water use of about 2.1 billion gallons per year (6,138 acft) could double to about 4.0 billion gallons per year (12,322 acft) over the next 10-years. The increased water needs would be due to significant production expansion at Koch Refinery.

Table 3.6-10 Cooling System Guidelines* Water as Theoretically Cycled in the System Southern Portion Trans-Texas South Central Study Area			
Contaminant	**Maximum Level (in ppm)****	**Affected Area**	**Cooling Program**
Ammonia	20-40	Microbiological fouling/corrosion (especially copper)	Biocide/surfactant/ inhibitor
BOD	200	Microbiological fouling	Biocide/surfactant
Calcium	1500	Fouling	Dispersant
Chlorides	5000+	Corrosion (especially stainless steel)	Inhibitor
Chlorine - total residual	<5	Corrosion	Inhibitor
Conductivity (μmhos)	15,000+	Corrosion	Inhibitor
Copper	0.5	Corrosion	Inhibitor (azole)
Iron	5-10+	Fouling	Dispersant
Oil and Grease	See hydrocarbon	Microbiological fouling/fouling	Biocide/surfactant
pH	7-9	Corrosion/fouling	pH control
Silica - reactive	300	Fouling	Dispersant
Sulfate	5000+	Corrosion/fouling	Inhibitor/dispersant
Suspended Solids	200	Fouling	Dispersant

* Betz, Water Reuse within a Refinery, 1992.
** In order to compute the required quality of make-up water, this parameter is divided by the number of cooling cycles.

This increased water need takes into account one of the most advanced water conservation programs in Texas. Without conservation, Koch Refinery's future water needs would likely increase to over 5.1 billion gallons per year (15,682 acft/yr), an avoided 12.7 percent increase in water use.

Corpus Christi area refineries are increasingly processing the heavier sour crudes with higher sulphur content that requires more process water. Water demand in particular for these industries will increase. A principal industry effort to assure future water supply options, has been the development of water conservation plans and the development of water conservation measures to improve water use efficiency.

3.6.7 Environmental Analyses

Introduction

This alternative concerns the ways in which industries in the Corpus Christi area use water, current water conservation practices already in place and the potential for additional water conservation. Particular environmental issues of concern can be categorized as follows:

- Disposal of industrial wastewater with elevated mineral concentration; and the
- Disposal of heated water.

Of total industrial water use, 60 percent is for cooling, 30 percent is for boiler feed, and 9 percent is used directly in production processes, by the petroleum, chemical and electrical power generating industries (the remaining 1 percent is used for potable and sanitary purposes). Thus, these uses offer the greatest potential for water conservation. Industries in Corpus Christi lead the state in water conservation measures already implemented, with further opportunities for improvement being limited. In addition, there are constraints on further water conservation including environmental issues arising from the quality of the wastewater that results from common conservation practices.

Impact Assessment

Environmental issues involve concerns related to both the source of the water and the return of treated wastewater to the environment, particularly the Nueces Estuary and the rest of the Corpus Christi Bay system. In terms of supply, water used for boiler feed must be of high quality (i.e., low dissolved solids concentration), although lower quality water can be used for cooling or for boiler feed after treatment. Possible sources of lower quality water include brackish groundwater, wastewater, and seawater. The use of low quality groundwater from the Gulf Coast Aquifer would require the construction of well fields and water transmission lines, and large amounts of higher quality water for blending (see Alternative L-2, section 3.8). Over-pumping water from the Gulf Coast Aquifer also raises concerns regarding subsidence of the land and saltwater intrusion into the aquifer. Pumping higher quality water from the Carrizo Aquifer 100 miles away (Alternative L-3, section 3.9) would require the construction of well fields, pipelines and storage facilities. Treated wastewater can be used for some purposes, such as dust control. Limitations on the use of treated wastewater result from elevated nutrient levels which require that the water be treated, for example with biocides, to minimize fouling and corrosion. Some industrial users can utilize seawater in a once-through process, while other uses would require desalination. In the Corpus Christi area, the use of seawater for once-through cooling of industrial processes would require a major overhaul of equipment in areas for which space is not available, while other uses would require desalination.

The industries in Corpus Christi that recycle and reuse water for cooling purposes typically do so three to five times. Because evaporative cooling increases the concentration of the dissolved constituents in water, the number of times water can be reused is limited by the total dissolved solids in the raw water. High quality water, having low concentrations of solutes, is most desirable for reuse. Effects of the increased recycling of cooling water on constituent concentrations is illustrated for several compounds in Table 3.6-6.

Water standards used for cooling and for boiler feed are presented in Tables 3.6-3 and 3.6-4 respectively. Designated uses of water and associated numerical criteria for water quality for segments of Texas rivers and estuaries are also regulated by the TNRCC.[7] The number of times water can be reused is also affected by the maximum concentration of compounds, as for example heavy metals (e.g. cadmium, copper, mercury, etc.), permitted in the discharged wastewater. The maximum concentrations of constituents in wastewater are permitted under National Pollution Discharge Elimination System (NPDES), and the reuse of cooling water can result in the violation of permitted requirements.

The disposal of heated water also raises concerns in terms of the physiological ecology of organisms. Temperature affects the solubility of oxygen in water, and the metabolic rates of organisms increase with temperature. Thus disposing of heated water in a manner that alters the ambient temperature of the environment can be expected to have ecological consequences. The production of heated water may require either large cooling ponds before it can be released, or transport to larger bodies of water for dispersal. For example, the permit held by the Barney Davis Steam-Electric Power plant requires 1,300 acres of cooling ponds for its 540 million gallons per day of cooling water discharge.

[7] Texas Administrative Code, Texas Surface Water Quality Standards Chapter 307.1-307.10, June 1991.

3.6.8 Implementation Issues

- Through the use of major water conservation efforts, study area industries are among the most efficient water users in Texas.

- Projected industrial water demands for the study area carry forward the significant water conservation effects that study area industries have achieved and are in the process of implementing.

- Any future industrial water conservation programs for the study area should take into account the fact that study area industries have already implemented major water conservation measures.

- The City's water conservation staff should continue to work with industry to promote additional conservation measures and should annually prepare a water audit of each major industrial facility to track water use trends and monitor the effectiveness of conservation measures undertaken.

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3.7 Desalination of Seawater (L-1)

3.7.1 Purpose and Scope

The purpose and scope of this segment of the study was to assess the technical, economic, and institutional viability of current desalination technology. This included the following:

- General desalination background;
- Factors in selecting a seawater desalination process;
- Environmental Issues;
- Costs for a seawater desalination plant.

3.7.2 General Desalination Background

The commercially available processes that are currently used to desalinate seawater to produce potable water are:

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

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

Distillation (Thermal) Processes

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

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

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

The three main distillation processes in use today are: Multistage Flash Evaporation (MSF), Multiple Effect Distillation (MED), and Vapor Compression (VC). All three of these processes utilize an evaporator vessel which vaporizes and condenses the feedstock. The three processes differ in the design of the heat exchangers in the vessels and in the method of heat introduction into the process. The following sections describe each of these processes in more detail.

Multistage Flash Evaporation (MSF): MSF, the thermal process with the most installed capacity worldwide, is not presently utilized in the Continental U.S. for the production of municipal potable water. Due to the expense to build and operate MSF plants, they have been used only when large capacity desalination plants are needed in conjunction with a power plant. MSF plants usually operate at top feed temperatures of 194° - 248° F, so scaling problems can occur. The recovery from a MSF seawater desalination plant is only about 15%, which is the lowest recovery of any of the commonly used thermal processes. The cost of an MSF facility is approximately 30-50% higher than MED (described in the following section), and they are also more costly than non-thermal facilities. Even in Jeddah, Saudi Arabia, where thermal energy is relatively inexpensive, part of an existing MSF plant was replaced by a 15 mgd non-thermal (reverse osmosis) treatment plant.

Multiple-effect Distillation (MED): MED, like MSF, is not currently used in the Continental U.S. to produce municipal potable water. And like MSF, MED requires a low cost source of steam to be competitive with non-thermal processes. However, MED makes the most cost effective use of steam. Most of the newer MED units have been designed to operate at lower temperatures, with a top temperature of approximately 158° F in the first effect, to reduce steam costs and scaling potential. A recovery rate of about 20% may be expected from a MED seawater desalination plant. MED plants typically have capacities ranging from 0.5 to 2.5 mgd. The largest known MED facility to treat seawater is in the former U.S.S.R. and has a capacity of only 11.0 mgd.

Worldwide, the total installed MED treatment capacity is only about 169 mgd, which represents 4.6% of the world's installed capacity. The Virgin Islands Water and Power Authority has operated six MED seawater distillation units ranging from 0.155 to 1.4 mgd on St. Thomas and St. Croix, Virgin Islands. In a report submitted to the National Water Supply Improvement Association (NSWSIA) for the year ended June 30, 1991, they indicated their average water cost was $12.16 per 1000 gallons or approximately $3,960 per acft including distribution. Production costs were $7.81 per 1000 gallons or approximately $2,550 per acft. Larger units, of more recent technology than the nine to 11 year old units in the Virgin Islands, may expect somewhat lower production costs. However, MED plants to date have had very little commercial acceptance worldwide and are primarily used for industrial distillation, not municipal potable water distillation.

Vapor Compression (VC): There are two types of VC plants: thermal (TVC) and mechanical (MVC). The primary differences are the procedures to create a vacuum in the vessel and the compression of the feedwater vapors from the evaporation chamber. TVC plants use steam, while MVC plants utilize mechanical compression. VC plants, which generally have treatment capacities between 0.005 mgd and 0.5 mgd, are typically used for resorts and industries, and, therefore, only account for approximately 3% of the world's total desalination capacity. However, units as large as about 0.8 mgd have been proposed, but to date have not been constructed.

Membrane (Non-thermal) Processes

The two types of membrane processes use either pressure, as in reverse osmosis, or electrical charge, as in electrodialysis reversal, to reduce the mineral content of water. Both processes use semipermeable membranes which allow selected ions to pass through while other ions are blocked. Electrodialysis reversal (EDR) uses direct electrical current applied across a vessel to attract the dissolved salt ions to their opposite electrical charges. EDR can desalinate brackish water with TDS up to several thousand mg/L, but energy requirements make it economically uncompetitive for seawater which contains approximately 34,500 mg/L TDS. As a result, only reverse osmosis (RO) is used for seawater desalination.

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

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

Recovery rates up to 45% are common for a seawater RO facility. RO plants, which comprise about 31% of the world's desalting capacity, range from a few gallons per day to 15 mgd. The largest RO seawater plant in the U.S. is the 6.7 mgd plant in Santa Barbara, California. The current domestic and worldwide trend seems to be for the adoption of RO when a single purpose seawater desalting plant is to be constructed. RO membranes have improved significantly over the past two decades by becoming more efficient, having longer lives and reduced prices.

Geographical and Temporal Trends in Desalination Processes

As shown in Figure 3.7-1, distillation processes were primarily used for desalination until the early 1970's, when reverse osmosis began to see significant use. In the mid-1980's, as membranes improved, the use of RO has increased to the point that most new plants use the RO process.

Desalting plants are installed in over 100 countries, though a large percentage are located in "oil rich" and "water poor" areas (Saudi Arabia 26.8%, Kuwait 10.5%, United Arab Emirate 10.0%). A summary of desalting plant locations is included in Table 3.7-1. Most of the desalting capacity in the Middle East and North Africa was constructed in the 1960's and 1970's when there were large increases in petroleum prices, providing large amounts of capital to build desalting facilities. In addition, an abundance of inexpensive fossil fuel provides them with an affordable energy source to operate these extremely energy intensive facilities.

Worldwide, more than 5,200 desalination plants with capacities of 25,000 gpd or more have been constructed, with 65% using seawater as a feed source and about 27% using brackish water. A summary of land-based desalination plant capacity by type of treatment process is shown in Table 3.7-2 as listed in the *International Desalination Association Worldwide Desalting Plants Inventory*.

Figure 3.7-2 compares desalination processes installed in the U.S. to the worldwide capacity shown in the previous table. It illustrates that while the majority of the installed worldwide capacity uses multistage flash distillation, the most used process in the United States

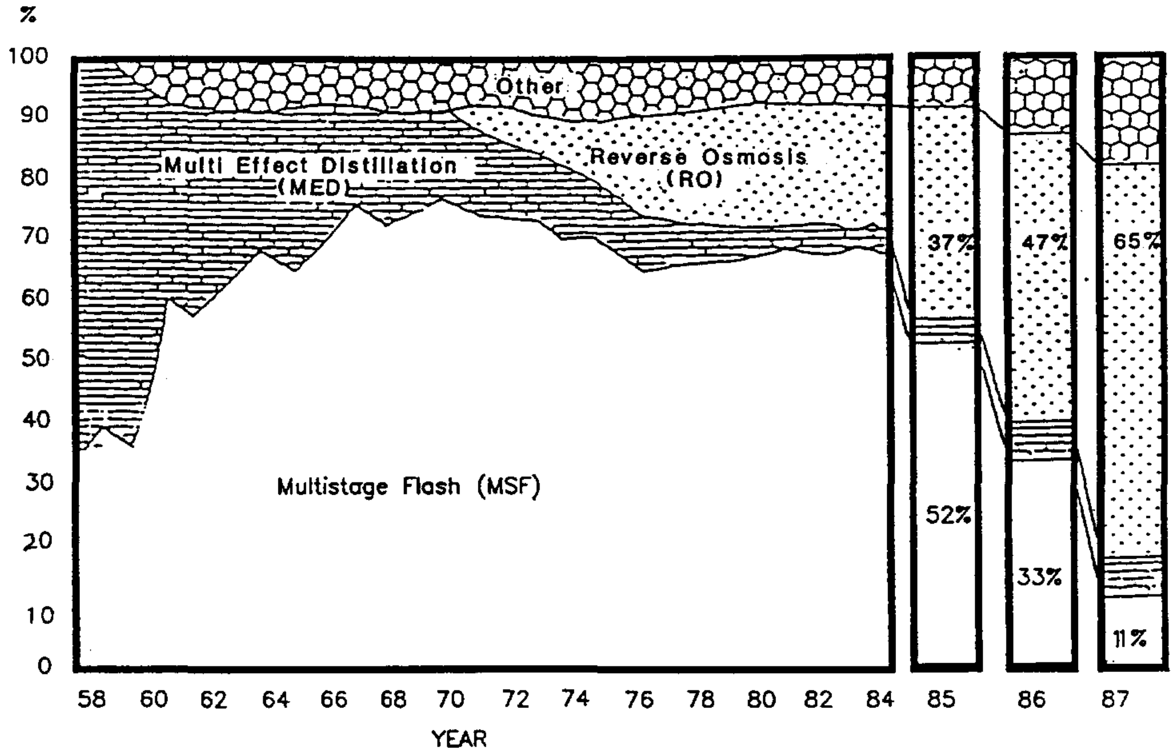

Figure Source: Desalting Plants Inventory, 1988

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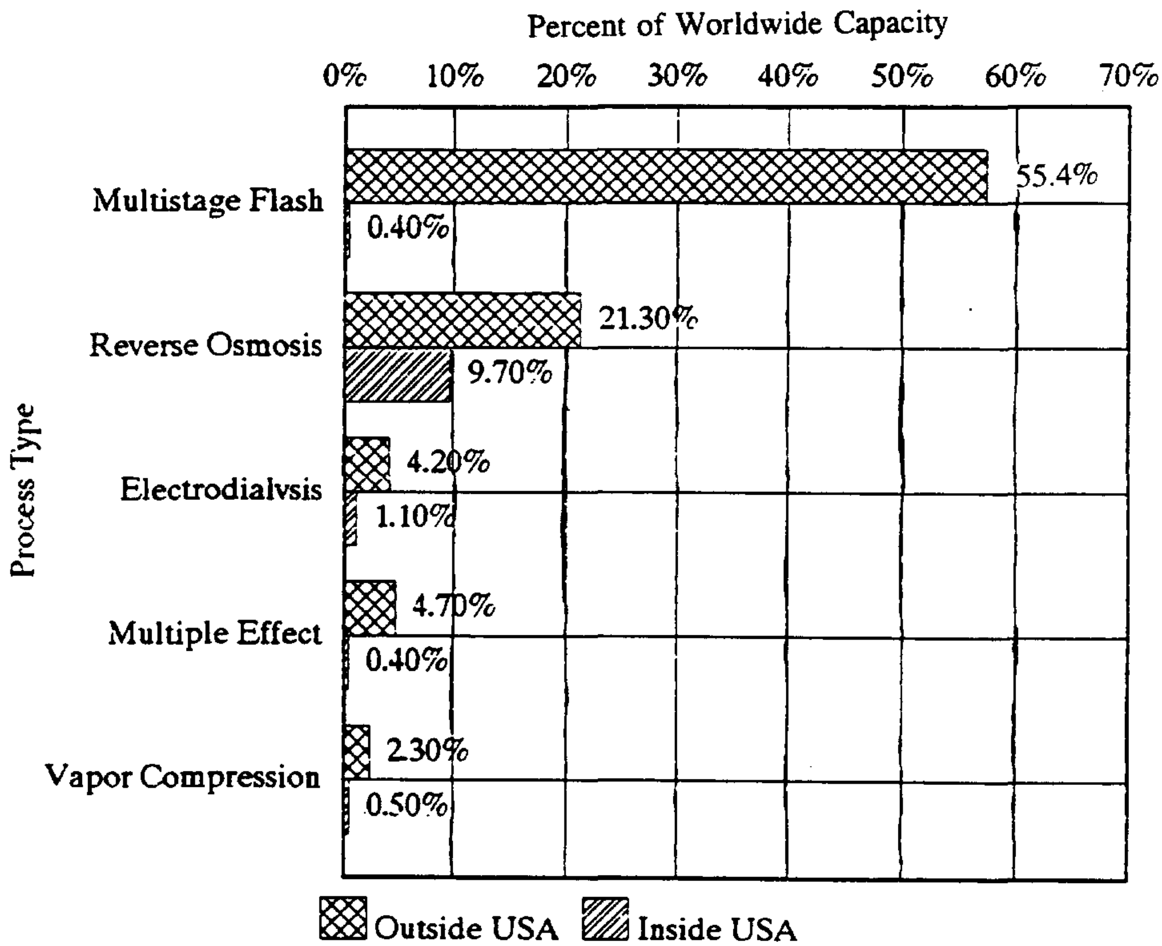
WORLDWIDE MARKET SHARE OF VARIOUS DESALINATION PROCESSES

FIGURE 3.7-1

Table 3.7-1 Summary of Desalting Plants by Location	
Locality	**Percentage of Worldwide Capacity**
Middle East	63%
North America	12%
North Africa	7%
Europe	7%
Pacific	4%
Caribbean	2%
U.S.S.R.	2%
Other	3%

Table 3.7-2 Summary of Desalting Capacity by Type of Treatment Process		
Type of Treatment Process	**Percent Worldwide Capacity**	**MGD Capacity**
Multi-stage Flash Evaporators (MSF)	56%	1,966
Reverse Osmosis (RO)	31%	1,087
Multiple Effect Distillation (MED)	5%	179
Electrodialysis (ED)	5%	169
Vapor Compression (VC)	3%	118
TOTAL	100%	3,513

is reverse osmosis. However, Figure 3.7-3 compares the number of plants using each process in the United States to plants worldwide. This figure shows that the most common process used in both plants in the United States and world wide is reverse osmosis. As indicated previously, multistage flash distillation plants are usually installed with large power plants, hence the large capacity of such facilities. However, the largest percentage of desalination facilities in the United States and in the world use reverse osmosis. RO has been used in 85% of the



Source: International Desalting Association
Worldwide Inventories

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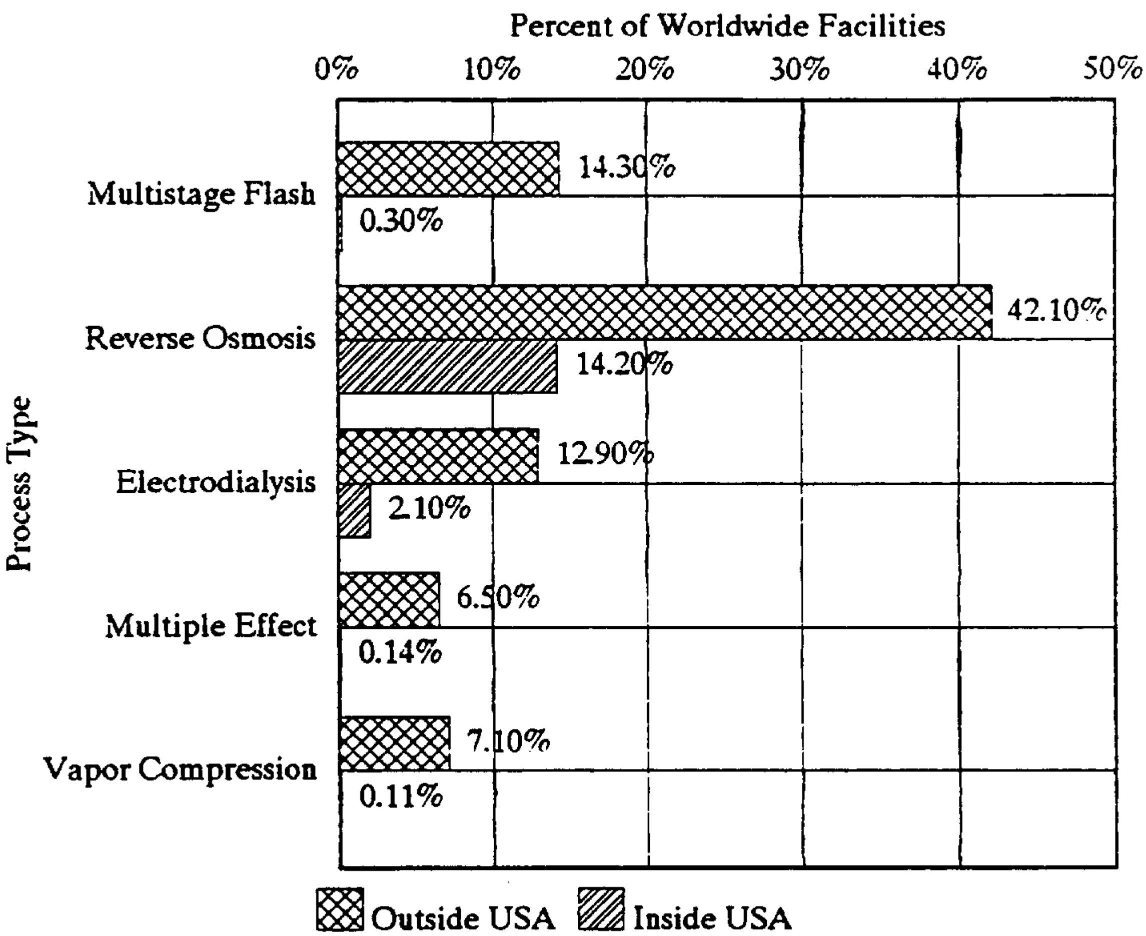
CAPACITY OF DESALINATION
FACILITIES BY PROCESS

FIGURE 3.7-2



Source: International Desalting Association
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NUMBER OF DESALINATION
FACILITIES BY PROCESS

FIGURE 3.7-3

desalination plants constructed in the last five years.

Although 31% of the installed desalination capacity in the world uses the RO process, Table 3.7-3 shows it accounts for only 4.5%, 159 mgd, of the world's capacity to treat seawater. And, as shown in Figure 3.7-4, only 20 mgd of seawater desalination capacity has been installed in the United States as per the 1992 data. Even though the use of RO to produce potable water is increasing, the total capacity for desalination of seawater remains significantly low. For example, water produced by desalination is estimated to be less than one-half of one percent of the total potable water delivered in the U.S., and seawater desalination is only approximately 10% of this figure.

Table 3.7-3
Breakdown of Worldwide RO Capacity

Worldwide RO Processes	Installed Capacity (mgd)	Percent of Total Worldwide Desalt Capacity (%)
Seawater RO	159	4.5
Brackish RO	733	20.9
Other RO	195	5.5

3.7.3 Factors in Selecting a Seawater Desalination Process

Selecting the best seawater desalination process requires consideration of numerous related factors which affect the capital and operation and maintenance (O & M) costs of the facility. Some of these include the source water quality, pre-treatment requirements, recovery efficiency (percentage of feedwater recovered as product water), equipment size, equipment requirements, chemical requirements, product water quality goal, post-treatment requirements, and waste disposal. However, using cost as the primary criteria, process selection is primarily dependent on energy costs. Energy cost constitutes a major portion of desalination O&M costs. Other elements which may require consideration include siting considerations, economies of scale, part time plant operation, and phased construction.

Energy Consumption

Estimated energy consumption for each process is listed Table 3.7-4. As shown in this table, the process which uses the least amount of energy per unit of water produced is the reverse osmosis process. This process is shown to be more cost effective than even a dual purpose MSF facility which produces both electricity and water.

Table 3.7-4
Total Energy Consumption for Various Desalination Processes

Desalination Process	Total Energy Consumption (KWH/1000 gal)
Multi-stage Flash (MSF)	204 to 305
Multiple-effect Distillation (MED)	122 to 305
Vapor Compression (VC)	32 to 43
Reverse Osmosis (RO)	14 to 25
Multi-stage Flash (MSF) Dual Purpose	60 to 116

Most, if not all, of the very large desalination plants in the Middle East were constructed as part of a power plant project. Steam to drive the distillation process is extracted from the turbines driving the electrical generators. However, the efficiency of most modern power plants has largely removed the advantages of dual purpose plants, since, in most cases, there is little "waste heat" in a modern plant. Modern steam turbines exhaust steam at less than atmospheric pressure (vacuum) and the temperature of the spent steam is about 120° F, which is lower than distillation process requirements. If steam is extracted from the turbines at a high enough temperature for distillation, the amount of electrical power produced by the plant will be decreased.

However, dual purpose plants can be economical if power demands are lower than the steam generating capacity of the power plant. At such times, steam could be extracted from the turbine to desalt water. Or, if electrically powered, the desalination plant could be operated during periods when the electrical power demand by consumers is less than the plant's power generating capacity. Steam driven pumps for distillation or membrane desalination plants may also be less expensive to operate than electrically driven pumps.

Dual purpose plants are a potential consideration, but to date there are none producing municipal water in the United States. A dual purpose plant offers many potential co-location benefits, including availability of steam from the power plant as an alternative energy source for desalination, availability of a developed coastal site, use of warm condenser discharge as a feedwater, and the opportunity to share staffing and facilities such as intake structures and, perhaps, discharge channels, etc. A number of feasibility studies recently conducted in California investigated the possibility of dual purpose facilities but none of them have been found to be feasible due to economic or operational constraints. For instance, the Baja California Desalination Project (BCDP) sponsored by the Metropolitan Water District of Southern California, the Los Angeles Department of Water and Power, the San Diego County Water Authority, the Coastal Pan-American Corporation, and Bechtel Power Corporation concluded that the total cost of producing municipal water delivered to San Diego's reservoir would be $1,685 per acft. This feasibility study was based on constructing a $1.2 billion dual purpose plant, consisting of a 100,000 acft/yr seawater desalination plant and a 500-plus mega-watt power plant.

As recognized in Table 3.7-4, all desalination processes are energy intensive. Therefore, the cost of fuel will have a significant effect on the overall cost regardless of the process selected. Over the past two decades, fuel prices have fluctuated from lows in the $13.00 per barrel range to highs in the $40.00 range, with the current price being about $19.00 to $20.00 per barrel. It is generally agreed that as fossil fuels reserves are reduced, energy prices will increase relative to other prices in the economy. Even without inflation, long term energy prices are expected to increase. All other future technological advances aside, desalination processes with lower energy requirements will fare better over time than those processes with higher energy consumption. For example, if the energy costs of a desalination process is 30% of the process' total cost, then a 20% increase in energy costs would result in a 6% increase in the cost of the process. Similarly, if energy costs are 60% of the total costs, the same 20% increase in energy costs would result in a 12% increase in the total cost of the process.

Siting Considerations

Each desalination process requires a different amount of land. Therefore, a "footprint" (i.e., total area required for each process) must be developed for the type and size of plant before selecting the site. Other considerations, in addition to the amount of land required, which affect site selection include: the length and complexity of the raw water intake system needed to serve the site; the distance to acceptable concentrate disposal sites; availability of utility rights-of-way and roadway and, perhaps, rail access to the site; proximity to the distribution system, environmental and other permitting considerations; and as noted earlier, access to a source of power or other energy.

Raw water intake options include a direct ocean intake system, an infiltration gallery with a beach intake system, and beach wells. Concentrate is normally disposed of through an ocean outfall. As with a direct ocean intake, an ocean outfall would involve significant environmental constraints, especially if it is constructed to discharge into a bay area. Other siting issues that will need to be addressed during permitting of the facility include:

- Construction of a desalination plant, intake and outfall structures, and transmission pipelines may impact rare, threatened, and endangered species of plants and animals, and/or their habitat.

- Construction of a desalination plant and auxiliary facilities may affect streams, rivers or wetlands, and may involve offshore construction.

- Construction of a desalination plant and auxiliary facilities may affect archaeological and historic resources.

- Desalination projects must conform to land use regulations.

Economies of Scale

For specific desalination processes, the cost of desalination product water decreases with the size of the plant. In most processes, a large savings is realized as the plant size increases to between 5 and 10 mgd, where a leveling begins to occur. It would also be reasonable for unit costs of a 100 mgd plant to be some percentage lower than a 5 to 10 mgd plant. However, significant factual capital and operational data are not available to determine a specific percentage reduction.

Part Time Plant Operation

"Part time" plant operation has been suggested as a means of reducing the costs of seawater desalination. Part time could mean operation every day, but for only part of each day, or it could mean operation only when drought conditions or some other interruption of normal supplies occur. The major impetus behind proposals for part time operation is that it appears a significant cost savings might be realized if desalination facilities were operated only when other water sources were unable to meet demands. In other words, the desalination plant would be considered a "peaking plant" or a "standby plant". Viewed in this manner, the desalination plant might only be used during certain seasons of the year, or only in those years in which other water sources are unavailable or inadequate.

Since "moth balling" a desalination plant for any extended period is not common practice, the cost of maintaining a standby facility can only be grossly estimated due to limited supporting data. In general, less than one-half of the O&M costs associated with operating a desalination plant full time are truly variable. Membrane replacement, some electric power, maintenance (which can be expected to increase for a non-operating plant), and at least some of the labor cost will be incurred whether or not the plant is operating. Only pre-treatment, power, and post-treatment costs are closely tied to production rates.

There also are numerous technical considerations associated with "moth balling" a desalination plant, in particular an RO operation. Santa Barbara, Santa Catalina Island, and Morro Bay are three California facilities that are presently "moth balling". None of these three operations have been restarted to produce municipal water since they were shutdown, and each of these entities has implemented different shutdown and membrane system preservation procedures. This may result in an expensive "learning experience" should membranes, seals, intake and outfall structures, control systems, chemical feed equipment, or other components deteriorate or fail to adequately produce desired water quality upon future start-up. The membranes in Santa Barbara's 6.7 mgd plant initially cost approximately $1.7 million.

The only plants with some degree of documented maintenance costs are the Santa Barbara, California plant and an RO plant in Key West, Florida. Santa Barbara's 6.7 mgd RO facility was constructed in 1992, operated for approximately three months producing only about 428 AF of desalted water, and then put on indefinite standby. Under the original maintenance agreement with Ionics, Inc., the approximate total annual cost to maintain the plant in operable condition is $2,940,000 for short-term standby (less than six months notice to restart) and $2,484,000 for long-term standby (more than six months notice). This is equivalent to $392 and $331 per acft/yr of plant capacity with no production. The second example is a 3 mgd RO plant owned by Florida Keys Aqueduct Authority. The facility was operated for three years as a privatized operation before it was purchased by the Authority in 1982 as an emergency supply for Key West and local military facilities in case their normal water supply via pipeline is disrupted. The total annual cost to maintain the plant in operable condition is about $500,000 per year with no production. This is equivalent to $165 per acft/yr of plant capacity with no production.

Part time operation can only be cost effective if the cost difference between full time and part time operation of the plant is greater than the total cost of providing water from other sources. The City of Morro Bay, the City of Santa Barbara, and Santa Catalina Island estimate their operation and maintenance costs, after initial capital amortization costs have been paid in full, will be between $900 and $1,600 per acft. In order for part time operation to be cost effective, alternative water costs would have to be equal to or greater than these estimates.

Phased Construction

Phased construction of a desalination facility could offer potential cost savings by deferring capital outlays until the need exists for increased capacity. For instance, Reverse Osmosis membrane trains and pumps are among the system components that can be sized according to immediate water requirements. However, a number of components should be constructed initially to meet the ultimate capacity of the facility in order to minimize cost.

- Land consideration would have to incorporate the ultimate size of the facility at the specific location.

- The raw water transmission pipeline should be sized for ultimate capacity. A large part of the cost of the raw water transmission pipeline would be for installation. The cost savings of using smaller pipe initially is much less compared with the potential cost of replacing the pipe to achieve ultimate capacity.

- The clearwell and buildings required for pretreatment should be sized to house the equipment required for the ultimate capacity.

- The concentrate disposal system should be sized for ultimate capacity. The cost of replacement of a small, initial pipeline with a larger diameter pipe in the future is impractical.

- The connection piping to the primary treated water distribution system should be sized for ultimate capacity. However, the distribution pumps could be installed according to the initial capacity with connection and building allowances made for the addition of pumps as capacity is increased.

- Permitting would have to address the ultimate facility capacity in addition to the initial capacity. Otherwise, phased permitting could result in the possibility of not being able to permit the facility's ultimate capacity at that specific site.

Although capital and annual O&M costs for an initially constructed, ultimate capacity plant would be significantly higher, the total annualized unit cost would be lower than a phased plant. This is because capital costs of the above components would be included in the initial capacity phases being more expensive than subsequent phases. As an example of the economics of phased construction, the University of Santa Barbara completed a desalination feasibility study that involved phased construction of an initial capacity of 600 acft/yr plant expandable to 1,500 acft/yr. Their study concluded that depending on the intake alternative selected, the phased facility resulted in annualized water cost of $2,700 to $3,400 acft/yr versus $1,840 to $2,070 acft/yr for the ultimate 1,500 acft/yr facility.

<u>Summary of Process Selection Findings</u>

There is no "best" method of desalination. The selection of an appropriate treatment process is highly dependent on local site conditions. Local circumstances will play a major role in determining the most appropriate process for the greater Corpus Christi service area. However, in general, distillation (thermal processes) and RO are used for seawater desalination. When an economical source of steam is available, thermal processes such as MED may be cost competitive with RO. If an economical or adequate quantity or quality of steam is not available, RO will be more economical than thermal processes. In California, where seawater desalination has received the most recent analysis, RO has been shown to be less expensive than distillation processes, even in instances where the desalting facility could be sited at a power plant. This is illustrated in various feasibility studies, including studies for the Monterey Peninsula Water Management District and the City of San Diego.

Many factors enter into the capital and operating costs for seawater desalination facilities: capacity, process, location, feedwater, labor, energy, financing, concentrate disposal, and reliability. In general, the cost of desalted seawater is about three to five times the cost of desalting low TDS brackish water from other sources. During the past decade in a number of areas in the United States, the cost of desalting brackish water (i.e., not seawater) has become less than the cost of alternatives supplying large amounts of conventionally treated water.

In 1990 in the United States, the total production costs, including capital recovery, for brackish water systems with a capacity of one to 10 mgd typically ranged from $1.00 to $2.40 per 1000 gallons or $326 to $782 per acft. The probable costs for seawater desalting for plants with capacities of one to five mgd is estimated at $4 to $16 per 1000 gallons or $1,303 to $5,214 per acft. These estimates provide some idea of the range of cost involved, but site and other specific factors will affect the actual costs.

3.7.4 Environmental Issues

The potential environmental effects of constructing and operating a seawater desalination facility include land use changes, including effects on resident fish and wildlife populations, noise and air quality impacts during construction, and impacts to aquatic systems from source water intake and discharge of the concentrate. Due to the expected environmental and regulatory constraints on bay or estuary discharges, the desalination facilities considered to be feasible for Corpus Christi would necessitate the waste concentrate being discharged into the Gulf of Mexico.

Siting Criteria

While the need to minimize cost and construction disturbance to terrestrial and aquatic habitats makes it desirable to site these facilities in close proximity to their water sources and disposal areas, the high economic value and environmental sensitivity of Padre and Mustang Islands would seem to indicate that a mainland location is more likely to be feasible. The amount of land required and the appearance of the facility, both of which may be important siting factors, are dependent on the type and capacity of the desalting process employed. Except for access to source water and disposal locations, siting considerations would be similar to those of any comparably sized industrial facility. They include land cost, environmental sensitivity (presence of endangered species, unique biological communities, wetlands, cultural resources), access, compatibility with adjacent property uses, and other coastal zone issues.

Construction Effects

Environmental effects as a result of construction activities would also be similar to those produced by similar, comparably sized project. Disturbances to soils and vegetation can directly impact resident wildlife, and result in the permanent conversion or alteration of affected habitats, while excess noise and air quality impacts may be a consideration if construction takes place adjacent to developed areas. To access the Gulf of Mexico as a water supply source and concentrate disposal location, construction of pipelines, intakes, and discharge structures are required which would cross terrestrial and aquatic habitats, inshore waters (e.g., Oso Bay, Upper Laguna Madre), barrier island back bay flat-dune-beach complexes, and the near shore Gulf to a depth below the surf zone sufficient to support rapid mixing of the discharged concentrate with ambient water. Environmental effects would be limited to the immediate vicinity of the intake and discharge structures and pipelines, and construction impacts can be minimized by careful siting and pipeline alignment that avoids significant natural and cultural resources.

Operational Impacts

Operational impacts of a desalination facility would include the provision of additional hard, subtidal surface, a resource that is limiting to many marine and estuarine species in the northwestern Gulf of Mexico (Britton and Morton, 1989). A potentially adverse effect would be entrainment of organisms that venture so close to the structure that they cannot escape the intake currents. Entrainment impacts can generally be avoided by using appropriate design and siting criteria; minimizing intake current velocities and avoiding areas where marine organisms are concentrated by hydrographic processes or are attracted by habitat features. Significant entrainment impacts to marine populations may occur if an intake were situated in a Gulf tidal pass where marine organisms are concentrated. However, it would have to divert a substantial fraction of the tidal prism.

While an ocean outfall can provide immediate dispersion into an essentially infinite sink, numerous concerns about the possible effects of discharging concentrate from desalination processes have been raised. For example, marine organisms are known to be generally intolerant of salinity and temperature changes, and they may be sensitive to other components of the discharge. The most important of these are heavy metals, which may be concentrated from the source water or which may originate, along with other materials, in the pre-treatment and cleaning chemicals used during operation and maintenance activities.

Because the Gulf of Mexico is large relative to the amount of concentrate to be discharged, an outfall structure incorporating a jet diffuser to enhance initial dilution of the effluent could reduce any significant change in water quality to a relatively small mixing zone. This type of structure was used to discharge brines into the Gulf of Mexico during construction of the Strategic Petroleum Reserve by solution of salt domes in Texas and Louisiana.

Regulatory Issues

The discharge of water carrying the salts concentrated from raw water during a desalination process is classified as an industrial waste. It is regulated as part of the NPDES permitting program administered by the U.S. Environmental Protection Agency (EPA) and Texas Natural Resource Conservation Commission (TNRCC). The discharge will be subject to the provisions of Section 403c of the Clean Water Act (Ocean Discharge Criteria), and within the three mile limit it must comply with the Texas Water Quality Criteria for Marine Discharges. A permit from the U.S. Army Corps of Engineers (USCE) will be required for pipeline construction in the waters of the United States, and an easement from the Texas General Land Office (GLO) is required to construct on state lands, which include bay bottoms and the Gulf littoral out to the three league limit.

Region VI EPA and National Marine Fisheries Service (NMFS) staff in Galveston have indicated that these discharges have low priorities, and lack the general regulatory constraints, such as mandatory use of best available technology (BAT) or new source performance standards (NSPS), that are in place for industrial processes believed to have more adverse impact potential. However, currently there are no operational seawater desalination plants in Texas. A proposed plant, depending on its size, could result in regulatory agencies reevaluating their position. Both

California and Florida, where the majority of recent desalting activity has occurred, have encountered both stringent review and substantial obstacles in regard to concentrate discharge. An Environmental Assessment (EA) of the potential impacts of this discharge would appear to be a probable requirement for obtaining state and federal permits for a major desalination facility, and in the event that the project becomes controversial, an Environmental Impact Statement (EIS) could be required.

Major issues expected to arise during an EIS process include disturbance to endangered species, wetlands, and benthic environments during construction, the effects of elevated and changing salinities and toxic substances concentrations during project operations, and hazards to navigation and commercial fisheries. Successful completion of an EA or EIS will likely require baseline inventories of wetlands and marine communities to be affected during construction and operation, a siting survey to select a discharge location that considers potential impacts to receiving water communities, and a modeling analysis of initial effluent dilution (i.e., a jet discharge model), and possibly subsequent dispersal of the plume. The key to these analyses will be the selection of a discharge location that avoids critical resources (e.g., reef structures that attract high diversity communities, migration pathways, spawning, nesting or feeding grounds) and insures adequate dilution of the effluent. The latter is of particular interest in that the applicable water quality criteria are quite stringent, and it is possible that undiluted return water (prior to exiting the mixing zone) may exhibit metals concentrations in excess of those criteria, even when considering desalination of marine water.

3.7.5 Costs of Seawater Desalination Facilities

There is very little reliable capital and operating cost information for operating seawater desalting plants since the total installed capacity in the United States for municipal potable water use is only about 20,000 acft/yr. Most of this installed capacity is in California, where the drought of the late 1980's and early 1990's provided the impetus for the construction of three municipal seawater desalting plants. The most notable of these is the 7,500 acft/yr RO plant constructed for the City of Santa Barbara. The other two municipal plants are located on Santa Catalina Island (135 acft/yr) and in the City of Morro Bay (645 acft/yr). Presently, none of these plants are operating.

A number of other California communities looked to the Pacific Ocean as a potential, inexhaustible, drought-proof water supply. Numerous feasibility studies and preliminary design studies were completed, from Marin County, north of San Francisco, to San Diego and even into Baja, California, Mexico. These studies investigated the technical, economic, environmental, and institutional feasibility of seawater desalination plants from as small as 1,000 acft/yr to as large as 100,000 acft/yr. These comprehensive, site specific desalination feasibility studies generally cost the public or private entity $500,000 or more. They considered both commercially accepted thermal and non-thermal desalination processes, single and dual purpose plants, part time operation, and phased construction. **These studies, supplemented with data from operating seawater desalting facilities in California and the Virgin Islands, represent the most current information on seawater desalination.**

The California studies and plant data provide the basis to develop general costs for a conceptualized seawater desalination treatment plant in the Corpus Christi area. Table 3.7-5 presents a summary of the seawater desalting feasibility studies and seawater plants that were reviewed. The table includes location, capacity, purpose, status, unit cost, and some comments regarding each facility. The facilities are grouped into three categories, including: Desalination Feasibility Studies; Operating Seawater Desalting Plants; and Constructed and Previously Operated Plants. The following sections provide additional information regarding each of the plants or studies grouped into these three categories.

3.7.5.1 Desalination Feasibility Studies

Channel Islands Beach Community District (CIBCD)

CIBCD is just south of the City of Ventura, California. It serves approximately 9,000 people and has a current water demand of 950 acft/yr. The district presently relies almost entirely on locally produced groundwater with TDS ranging from 820 to 1,120 mg/L and hardness from 480 to 650 mg/L (as $CaCO_3$). Future demand is expected to increase to approximately 1,050 acft/yr, and they plan to decrease groundwater extractions until total extractions are reduced to the safe yield of their groundwater source. Phase I of their Future Water Supply Feasibility Study evaluated six potential water sources and five treatment processes

TABLE 3.7-5
Summary of Capacity and Unit Cost Data for Selected Desalting Plants

Location	Capacity	Purpose	Status	Cost/A-F	Comments
DESALINATION FEASIBILITY STUDIES					
Channel Islands Beach Community Service District, California	1,000 AFY	Domestic	Feasibility Study	$2,353	Presently still under consideration.
Goleta County Water District, Goleta, California	3,000 AFY	Domestic	Feasibility Study	$1,667-$2,033	Project indefinitely postponed. Contracted with City of Santa Barbara.
City of Buenaventura, California	7,000 AFY	Domestic	Feasibility Study	$2,046	Included existing ocean outfall and expandability to 8,500 acft/yr. Project is on indefinite hold.
Marin Municipal Water District, California	5,000 AFY	Domestic	Feasibility Study, Pilot Plant Preliminary Design	$1,891	Included existing wastewater outfall, lower TDS feedwater (23,700 mg/L), and expandability to 10,000 acft/yr. Project is not being pursued at this time.
San Diego County Water Authority, California	30,000 AFY	Domestic	Feasibility Study	$1,635-$1,729	Dual purpose facility. Project is on indefinite hold.
Baja California Desalting Facility, Mexico	100,000 AFY	Domestic	Feasibility Study	$1,685	Due to estimated costs, the project sponsors decided not to proceed with further development.
University of California Santa Barbara	1,500 AFY	Domestic	Feasibility Study	$1,840-$2,070	Due to the estimated cost, the project is no longer under consideration.
City of Lompoc, California	1,000-4,000 AFY	Domestic	Informational Request for Proposals	$1,413-$4,085	Postponed indefinitely.
City of San Luis Obispo, California	3,000 AFY	Domestic	Feasibility Study	$2,850	5-year temporary facility, existing intake and outfall system, no land costs, emergency permitting. Postponed.
Monterey Peninsula Water Management District, California	3,000 AFY	Domestic	Feasibility Study & Preliminary Design Report	$2,147	500 TDS product water, Ramney Collectors and Reverse Ramney Collectors and existing building.

TABLE 3.7-5 Summary of Capacity and Unit Cost Data for Selected Desalting Plants					
Location	**Capacity**	**Purpose**	**Status**	**Cost/A-F**	**Comments**
Continued...					
OPERATING SEAWATER DESALTING PLANTS					
Chevron Gaviota Oil & Gas Processing Plant, Gaviota, California	460 AFY	Processing Plant & Potable	Operational	$4,000	No energy recovery, new intake system, designed to last 25 years.
St. Nicholas Island, U.S. Navy, California	32 AFY	Domestic	Operational	$6,000	Existing wastewater outfall for concentrate discharge.
Virgin Islands Water & Power Authority, St. Thomas & St. Croix, Virgin Islands	5,154 AFY	Domestic	Operational	$3,962	Includes distribution cost, but does not include total amortized debt service of the projects.
Pacific Gas & Electric - Diablo Canyon Nuclear Power Plant, California	600 AFY	Processing & Potable	Operational	$2,593	Existing intake and outfall structures, unenclosed plant. Doesn't include site cost, site work or distribution cost.
CONSTRUCTED AND PREVIOUSLY OPERATED PLANTS					
Santa Catalina Island, California	135 AFY	Domestic	Indefinite Standby	$2,400	Limited intake and outfall requirements, amortized over 30 years.
City of Morro Bay, California	645 AFY	Domestic	Indefinite Standby	$1,750	Existing power plant outfall, emergency permitting only, no land cost and 18,500 TDS+ seawater feed.
City of Santa Barbara, California	7,500 AFY	Domestic	Indefinite Standby	$1,935	Temporary plant with existing intake and outfall system, temporary permitting, and no distribution or land/site development costs.

to meet their quality goals of 500 mg/L TDS and 170 mg/L hardness. In Phase II of the study, four alternatives were considered, including the State Water Project (transporting water from the San Francisco Bay/Delta Estuary via pipeline), softening existing well water, desalting seawater, and desalting brackish groundwater. The estimated costs for each of these alternatives is summarized in Table 3.7-6.

Table 3.7-6
Comparison of Costs for Water Supply Alternatives for CIBCD

CIBCSD	Desalting		Imported	
	Seawater	Brackish Water	State Water	Ground Water
Capital Cost (Million $)	10.6	8.8	11.1	8.9
Annual Costs (Million $)	2.4	1.9	2.3	2.0
Water Costs ($/AF)	2,353	1,821	2,181	1,936
Water Quality				
TDS	310	235	315	290
Hardness	120	115	135	135

It is interesting to note that even though desalting seawater was estimated to cost $2,353 per acft, it is only 29% more than their least expensive option, desalting of brackish water. The project is still under consideration.

Goleta County Water District

The City of Goleta, located just north of the City of Santa Barbara, California, primarily uses surface water and a limited amount of groundwater. In 1990, during the California drought, the City conducted a seawater desalination feasibility study for a 3,000 acft/yr domestic water supply. The study considered multiple effects distillation, vapor compression, and reverse osmosis. Energy was to be provided by either purchasing power or on-site natural gas power generators. The feasibility study concluded that total water costs would be between $1,667 and $2,033 per acft, depending on the specific site and the selected process. The District did not pursue the project. The District entered into an agreement with the City of Santa Barbara whereby the District has an entitlement of 3,069 acft/yr from the Santa Barbara seawater desalting plant.

City of Buenaventura

The City of Buenaventura, 30 miles south of Santa Barbara, California, recently completed a feasibility study which was similar to the Trans-Texas Water Program. A visit was made to the area in 1994. The City's current ground and surface water supplies can provide 19,000 to 27,000 acft/yr, and they presently deliver 24,000 acft/yr to a population of 103,000 people. By 2040, the population is expected to increase to 147,000 people with a projected demand of 31,000 acft/yr. Their feasibility study identified 15 long term water supply alternatives, including desalination of seawater. Four of the options involved importing 9,000 acft/yr by building 14.5 to 29.6 mile long pipelines to connect to the state water system. One of the import alternatives was a "stand alone" City project, while the other three involved joint projects with other entities.

The desalination segment of the study evaluated 7,000 and 8,500 acft/yr plants using both distillation and reverse osmosis processes. They ultimately determined economical sources of steam were not available in the Ventura County area, in the required quantity and quality, and as a result, only RO was selected for further study. After further study, it was determined a single stage RO plant could be expected to produce water which, when blended with their other supplies, would maintain their TDS between 530 and 820 mg/L, with an average of 560 mg/L. Concentrate disposal was to be via an existing ocean outfall to reduce costs. The cost of desalination is shown in Table 3.7-7, along with the range of costs for their imported water options. Costs are based on a 20 year, 8% capital amortization.

In November 1992, the electorate selected the 7,000 acft/yr desalination option by a 55% to 45% margin. The lack of dependability of water from the state water project and possible environmental constraints in the San Francisco Bay Delta Estuary were cited as reasons for selecting the option with the highest unit cost. After the vote, water conditions improved and the need for a large supplemental water supply was delayed for the foreseeable (15+ years) future. The project is presently on indefinite hold.

Table 3.7-7 Comparison of Alternative Water Supply Sources for City of Buena Ventura				
Develop Source	Desalt		Imported Water	
	8,500 acft/yr	7,000 acft/yr	Most $	Least $
Capital Costs (Million $)	61.9	55.1	85.5	36.8
Annual Capital Costs @ 8% for 20 years (Million$)	6.3	5.6	8.7	3.7
Annual O & M Costs (Million $/Yr)	10.6	8.7	3.5	4.1
Total Annual Costs (Million $)	16.9	14.3	12.2	7.8
Water Cost ($/AF)	1,988	2,046	1,356	867

Marin Municipal Water District (MMWD)

MMWD provides 34,000 acft/yr of local surface water and imported water from the Russian River to 170,000 people in Marin County, San Quentin, Hamilton AFB, and several other federal facilities near San Francisco, California. By 2025, their water demands are expected to be as high as 41,800 acft/yr. To meet both its current and future water needs, the district conducted a feasibility study to evaluate water supply alternatives. Phase I of the study evaluated 15 alternatives, including desalination of seawater, and Phase II further evaluated four alternatives: expanding reclaimed water use, expanding water efficiency programs, obtaining additional water from the Russian River, and desalinating seawater.

In Phase II, the study evaluated a 5,000 acft/yr desalination plant using either the reverse osmosis or mechanical vapor compression (MVC) process. They found that relative to RO, MVC's capital cost would be 25% higher, operation and maintenance cost (excluding energy) would be 15% lower, and energy cost would be 25% higher. RO was selected as the preferred desalination option on the basis of cost and the lack of experience with larger MVC equipment (eight 0.66 mgd units would be required).

A two-stage RO plant with 47.5% recovery was expected as the water was to be withdrawn from San Francisco Bay, which has an average TDS of 23,700 mg/L, while seawater typically has 34,000 TDS. This lower TDS was expected to reduce operating pressures and power costs, extend membrane life, and lower O & M costs. The product water quality goal was 170 mg/L TDS and 70 mg/L hardness (as $CaCO_3$). The 5,000 AF plant was to be expandable to 10,000 acft/yr, requiring a 7.5 acre site. Concentrate disposal would be via an existing wastewater plant outfall.

After the study, a 0.25 mgd RO pilot plant was constructed on San Francisco Bay, and it operated from September 26, 1990 through December 1990 under an environmental permit that required complete removal of the facility at the end of the pilot project. Based on the pilot plant results, a preliminary design report projected a 5,000 acft/yr facility, expandable to 10,000 acft/yr, would have capital costs of $55.0 million and annual O & M costs of $3.85 million/year. Amortizing the capital costs at 8% interest over 20 years, assuming power requirements of 4,500 to 4,900 KWH per acft, and assuming power costs of $0.06 per KWH, resulted in an estimated water cost of $1,891 per acft at 5,000 acft/yr production.

The four alternatives which were investigated in the District's Phase II study are summarized in Table 3.7-8.

Table 3.7-8
Comparison of Cost for
Water Supply Alternatives for Marin MWD

Supply	Yield (Acft)	Capital Cost	Capitalized Annual Cost	Years to Develop
Desalination	5000	$55-60 mil	$1,800-$2,000/AF	3
Reclamation	2,000-3,000	$30-55 mil	$1,600-$1,800/AF	3-10
Water Efficiency	1,200-1,400	$15-30 mil	$1,500-$2,000/AF	15-20
Russian River	10,000	$55 mil	$1,200-$1,400/AF	3-15

The district is presently pursuing improved water reclamation, improved conservation, and the Russian River Project. Desalination is not being pursued at this time.

San Diego County Water Authority

San Diego County Water Authority (SDCWA), California, provides 90% of San Diego County's water. Over 90% of their water is imported via pipeline from the Municipal Water District (MWD) of Southern California at a cost to the consumer of $500 to $600 per acft. The other 10% is provided by local runoff to a reservoir and limited groundwater. A visit with water authority staff was made in 1994. The population of the area is approximately 2.6 million, with an annual demand of more than 500,000 acft/yr. By the year 2010, the population is expected to be over 3.0 million, with demands of 600,000 to 800,000 acft/yr. In addition, imported water is expected to decline due to allocations of Colorado River water to Arizona. As a result, conservation and reclamation are a "daily commitment" and seawater desalting is their only other option.

In 1989, San Diego Gas & Electric (SDG&E) filed a Notice of Intent with the California Energy Commission to construct a 460 MW combined cycle plant at one of five existing power plants. In April 1992, SDG&E and SDCWA completed a feasibility study of a combined power/seawater desalination facility. The dual purpose plant was originally expected to be extremely financially attractive because of: 1) the availability of an already developed site that had existing access to a seawater supply and was previously environmentally permitted; 2) availability of steam as alternate energy source; 3) use of warm condenser water as a feedwater supply; 4) discharge of desalt concentrate through existing power plant discharge channels and structures; 5) use of abandoned tanks for water storage; and, 6) numerous other shared facilities and services. Overall, they felt the desalt plant costs could be as much as 30% lower than a stand alone facility.

The 30,000 acft/yr plant, to be located at the South Bay Power Plant in Chula Vista, California, was to produce 25,000 acft/yr at 75% utilization for the anticipated base loaded power plant. The water source was to be San Diego Bay with TDS of 34,500 mg/L and expected product water quality of less than 400 mg/L TDS to minimize energy and other related operational costs (versus 170 mg/L).

The desalting processes evaluated in the study included multi-effect distillation (MED), reverse osmosis with steam driven pumps (ROS), reverse osmosis with electric motor pumps

(ROM), and a hybrid (ROS/MED). The estimated costs determined in the study are summarized in Table 3.7-9.

Table 3.7-9
Comparison of Costs for Alternative Desalting Processes for San Diego Co. Water Authority

	MED	ROS	ROM	HYBRID
Capital Costs (Million $)	264.0	173.7	170.0	196.5
O & M Costs (Million$/yr)	23.0	16.8	19.0	15.6
Water Cost	$1996/AF	$1380/AF	$1453/AF	$1425/AF
Delivery Cost	$111-$205/AF	$111-$205/AF	$111-$205/AF	$111-$205/AF
Total Cost*	$2107-$2201/AF	$1491-$1585/AF	$1564-$1658/AF	$1536-$1630/AF

*Based on 8% for 20 years.

SDG&E and SDCWA initially selected ROS and began repowering of the existing generating units at the Chula Vista Plant with three 150 MW gas turbine generating units with three heat recovery steam generators. However, after further evaluation of the potential co-location benefits of the dual purpose plant, "critical obstacles" surfaced that ultimately resulted in the project being abandoned. These included SDG&E's concerns over potential contamination of the main steam loop; SDCWA's concerns that modifications to steam generator cross-over piping would necessitate an earlier commitment by them to the project construction date; and SDG&E's reducing the capacity factor after repowering the power plant from 34% to 60%, thereby limiting steam availability for ROS. All of these resulted in additional costs for heat recovery steam generator modifications; changes to the condensate makeup and storage system; changes to condenser and cooling water systems; changes to steam and condensate return pipes; changes to steam and turbine drives; and the necessity to provide backup electric motors for the desalting ROS process. Another expected advantage that raised concern was the use of the condenser water as a feedwater supply to the ROS plant. Temperatures above 100° were expected during summer months, which would approach the maximum operating range of typical seawater RO membranes and also potentially limit their longevity. (This may be an expected situation for a dual purpose RO plant in the Corpus Christi area.) In addition, the discharge of desalt concentrate through the power plant discharge structures was expected to be a major cost benefit, eliminating the need to construct a $14 million pipeline to an existing wastewater outfall and facilitating environmental permitting. However, SDG&E ultimately decided not to allow concentrate discharge through their outfall system, due to potential future limitations on their NPDES permitting and power plant operational flexibility.

As a result, cost figures were revised, increasing ROS by 19 percent from $173.7 million to $206.3 million and ROM by 12 percent from $170.0 million to $190.4 million. Due to the small difference in cost, SDCWA would have selected ROM as the preferred option due to the limited availability of steam and the complexity of steam-driven systems. SDWCA concluded that the cost to discharge concentrate into the bay without power plant cooling water was prohibitive.

Baja California Desalting Facility (BCDF)

BCDF was to be a "dual purpose" plant that would include a 100,000 acft/yr desalination plant in combination with a 500+ mega-watt capacity power plant. The plant was to be located in Baja, California, Mexico on the coast somewhere between Tijuana and Ensenada. The combined plant would supply water and power to the growing Baja area and the Southern California distribution systems. A new natural gas pipeline would provide fuel for the operations. BCDF was expected to be the most modern and efficient seawater desalting facility in the world. A feasibility study completed in 1991 for over $600,000 was sponsored by the Metropolitan Water District of Southern California (MWD), the Los Angeles Department of Water and Power (LADWP), the San Diego County Water Authority (SDCWA), South California Edison (SCE), Coastal Pan-American Corporation, and Bechtel Power Corporation. The project was to utilize both thermal and non-thermal processes in an effort to maximize efficiencies and take advantage of all the benefits of economics of scale associated with the largest desalting plants operating in the world today. Mexico was selected because of the better availability of sites, in comparison to California, and the lower cost of permitting, land acquisition and construction. The study concluded that a combination MED/RO process was the most cost effective, taking advantage of both MED discharge water for RO feed and also the blending of lower quality, less expensive RO product water with higher quality, more expensive MED product water.

A combined cycle power plant provided the heat energy source for MED and the electric power for RO and seawater pumping. The power block configuration was selected in three steps. First, the basic combined cycle (gas turbine, heat recovery steam generator (HRSG), and steam turbine) configuration was chosen based on the premise that the improved heat rate of the combined cycle greatly improved the overall economics of the project over the option of using low pressure HRSG without steam turbines. An un-fired triple-pressure HRSG with integral deaerator was selected as the base design, and reheat was included for the evaluation cases involving 150 MW class combustion turbines, which have sufficiently high exhaust temperatures to support a reheat steam cycle.

Second, combined cycle configurations were developed around three different size combustion turbines, nominal 150 MW, 100 MW and 80 MW, maximizing electrical output within practical limits. The effects of changes in the cycle configuration and steam conditions were analyzed using standard computer programs.

Finally, several of the combined cycle configurations containing different combustion turbines were evaluated in combination with MED and RO plants producing a total of 100,000 acft/yr of product water, and operating under fixed performance parameters. The power block steam cycle was selected to maximize plant efficiency, while producing a constant water output under a fixed set of operating parameters.

The final recommended conceptual design provided a total (gross) power production of 632 MW and a water production rate of 100,000 acft/yr. Approximately 100 MW of power would be utilized within the plant for pumping and other process related needs, leaving 532 MW of capacity available for sale off-site. Power generation was to be from three 150 MW class combustion turbines and three steam turbines in combined cycle.

The water plant would include approximately 58,000 acft/yr production from MED and approximately 42,000 acft/yr production from RO. Twelve - 19 effect MED evaporators would receive the exhaust steam from the steam turbines. Heated seawater from the MED would be used as feedwater to the RO pretreatment system and the ten RO modules. Each 4.2 mgd RO module would operate at 40 percent recovery.

The RO plant product water and the MED product water would be blended prior to post-treatment. After post-treatment to reduce the corrosivity and to disinfect the water, product water would be pumped to three on-site tanks, each with a capacity of 23 million gallons. The product water, which was to meet present drinking water standards, would be delivered through a 25.1 mile, 5-foot diameter conduit to the San Diego County Water Authority (SDCWA) treated water aqueduct near Lower Otay Reservoir with branches on route for supply to Tijuana or other Mexican purchasers.

The combined power plant/desalination intake structure extended approximately 4,000 feet out into the ocean while the combined discharge line extended approximately 5,000 feet into a water depth of about 60 feet with a diffusion section at the end.

The estimated capital cost of the plant was developed from existing projects and estimates. Vendor equipment quotations were also used to confirm and supplement their other pricing. The sources of cost estimates were as follows:

- Combined Cycle Power Plant - based on estimates for active Bechtel combined cycle projects currently under detailed engineering;
- Distillation Plant - pricing from two MED equipment suppliers;
- Reverse Osmosis Plant - RO manufacturers and recent Bechtel projects in the Middle East;
- Seawater Intake and Discharge - conceptual design and quantity estimates from a similar intake structure;
- Product Water Storage and Pumping - recent projects;
- Product Water Pipeline - based on a 60-inch diameter steel line internally lined. The pipeline would cover 20 miles in Mexico and 5 miles in California; and
- Switchyard - based on a recent similar sized switchyard project.

The capital costs for engineering, procurement, and construction are summarized in Table 3.7-10.

Table 3.7-10 Summary of Estimated Costs for Baja California Desalting Facility	
Cost Category	**$ (Millions)**
Combined Cycle Plant	478.0
MED Water Plant	311.0
RO Plant	213.0
Subtotal Plant EPC Costs	1,012.0
Product Water Storage & Delivery	145.0
Total EPC Cost	1,157.00

The pricing is in June 1991 U. S. dollars. Labor rates applicable to Mexican markets were used for the fabrication and construction expected to be performed in Mexico. The estimates do not include capital costs of the natural gas pipeline or owner's start-up costs. The total delivered cost of treated water was estimated to be $1,685 per acft. This included a cost of $485 per acft to transport the water to Lower Otay Reservoir (25 miles).

The sponsors felt this large scale facility provided important economies of scale which would result in reduced costs compared to some of the smaller, less efficient desalination plants. Further, BCDF utilized the most modern desalination technology joined with efficient combined cycle gas turbine power generation facilities and low cost fabrication and construction in Mexico. In December 1990, due to the estimated cost of the water, the project sponsors decided not to proceed with further development.

University of California

The University of California, Santa Barbara, California completed a seawater desalination feasibility study in November, 1989. As in Santa Barbara, reduced rainfall during the drought of the late 1980's and early 1990's reduced water availability and raised uncertainties regarding the school's existing and future water supplies. At that time, the University decided to hire a consulting engineering firm to determine the feasibility of seawater desalination to supplement its 963 acft/yr allotment from the Goleta Water District.

The study involved a phased desalting plant with an initial capacity of 600 acft/yr, expandable to 1,500 acft/yr. Beach front collection using shallow wells and an ocean seawater intake structure were considered as a water supply source. The shallow wells were preferred, as they provided a substantial cost savings by eliminating a lengthy intake pipeline, and unlike the open seawater system, did not have to be initially constructed for ultimate capacity. Additional wells could be added to meet the maximum capacity of the plant when they were needed. However, the ocean seawater intake was their second choice if the hydraulic conductivity of the beach sand made the shallow wells unacceptable or if the option was not environmentally feasible due to construction impacts to the beach. The ocean seawater intake system consisted of two 18" diameter pipes extending 2,000 feet offshore to a water depth of 50 feet.

Both thermal and non-thermal desalination processes were evaluated, but thermal processes were eliminated due to cost and technical considerations associated with their relatively small sized installation. The study recommended using single stage RO, which was expected to have 35% recovery. Concentrate discharge was to be through the Goleta Wastewater Treatment Plant outfall.

Originally, phasing the construction of the desalting plant was perceived to offer substantial cost savings, as capital outlays could be deferred until additional production was needed. However, the large number of components that would still have to be constructed to meet their ultimate capacity resulted in substantially higher unit water cost in the initial phase of the proposed project. These included the ocean intake system, raw water transmission pipeline, clearwell storage facility, treatment building, concentrate disposal system, and connection piping to the University distribution system. In addition, permitting would have to address both the ultimate facility capacity and the initial capacity. Otherwise, permitting only the initial phase could result in significantly higher costs and/or in the possibility of not being able to permit the facility's ultimate capacity when it was needed.

Tables 3.7-11 and 3.7-12 present the costs to phase the construction of a desalting facility for the University, and to initially construct the plant to its ultimate capacity. These costs are based on using an existing concentrate discharge structure and do not include allowances for a connection fee or service charge by the Goleta Sanitary District. The two tables indicate the

Table 3.7-11 Budgetary Cost Estimates for 600 Acft/Yr Expandable to 1,500 Acft/Yr Desalination Facility for University of California		
	Alternative 1	**Alternative 2**
Initial Capital Cost ($)	6,200,000	9,100,000
Annual O&M Cost ($/yr)	940,000	1,060,000
Annualized Cost ($/yr/ac-ft)	2,700	3,430
Notes: Alternative 1 corresponds to the shallow wells alternative for seawater collection. Alternative 2 corresponds to the seawater intake alternative for seawater collection.		

Table 3.7-12 Budgetary Cost Estimates for 1,500 Acft/Yr Capacity Desalination Facility for University of California		
	Alternative 1	**Alternative 2**
Initial Capital Cost ($)	11,400,000	14,200,000
Annual O&M Cost ($/yr)	1,490,000	1,550,000
Annualized Cost ($/yr/ac-ft)	1,840	2,070
Notes: Alternative 1 corresponds to the shallow wells alternative for seawater collection. Alternative 2 corresponds to the seawater intake alternative for seawater collection.		

initial increase in unit cost of water due to phased construction. Due to the high cost, the project is no longer under consideration by the University.

City of Lompoc

The City of Lompoc is located in Santa Barbara County, California, approximately 10 miles from the Pacific Ocean. A visit with City staff was conducted in 1994. The current population of area is approximately 36,300. The City's annual water requirement for those residences on City water is about 5,600 acft/yr. Presently, all water requirements are provided from groundwater and reservoir releases that recharge groundwater locations. In June 1991, City voters did not support connecting to the state water project, even though they were in the midst of a five-year drought. In September 1992, the City prepared an informational request for proposals (RFP) for a 1,000 to 4,000 acft/yr seawater desalting facility. The City did not conduct, or request that the consultant conduct, any type of feasibility study. Lompoc originally thought a dual purpose facility, combining an electric thermal generation and desalination facility, might be feasible. However, the Northern California Power Authority (NCPA) was not interested.

The informational RFP called for alternative evaluations of single purpose RO and distillation processes as well as co-generation. The RFP was sent to 27 firms. Only five responded. The respondents were expected to finance, design, construct, own, operate, and maintain the facility based on a 20-year water contract with the City for a minimum of 1,000 acft/yr to a maximum of 4,000 acft/yr.

The estimated total water costs from the responses to their RFP are summarized in Table 3.7-13.

Table 3.7-13
Summary of Cost Proposals for Desalting Seawater for City of Lompoc

Quantity of Water	Range of Cost per Acft
1,000 acft/yr	$2,130 - $4,085
2,000 acft/yr	$1,685 - $2,653
3,000 acft/yr	$1,485 - $2,184
4,000 acft/yr	$1,413 - $2,119

The wide range of estimates was expected due to the limited information provided by the City of Lompoc. Assumptions included City provided land, provided existing distribution system, emergency status permitting, and other submittal qualifications to provide the lowest "informational" costs.

In 1993, the City of Lompoc tabled the proposal for a seawater desalination facility and is studying other water supply options.

City of San Luis Obispo

The City of San Luis Obispo is located in Central California approximately 12 miles from the City of Morro Bay. A visit with City staff was made in 1994. The population is about 42,000, with an annual water demand of approximately 8,000 acft/yr. The City's current water supply is primarily from the Salinas and Whale Rock Reservoirs ($\approx$6,900 acft/yr). The remaining water is from local groundwater sources ($\approx$2,000 acft/yr). With any serious drought the City will not have enough water, even without growth.

During the recent five-year drought, the City conducted a feasibility study, to obtain approximately 3,000 acft/yr of new water supply. It evaluated eight alternatives, including seawater desalting. Other alternatives included the state water project (since the City was only one-half mile from the main truckline), wastewater reclamation, enlargement and increased yields from their reservoirs, and importing water via pipeline from the Lake Nicimiento Reservoir. The area had entitlements to 16,200 acft/yr from the reservoir, but a pipeline needed to be constructed for conveyance.

The study evaluated several desalting technologies, including MSF, MED, VC, and RO. The study concluded MSF was more applicable for larger size plants than the 3,000 acft/yr plant under consideration; MED required a low cost source of steam to be competitive and the local power company, PG&E, did not have low cost steam available and on-site generation would have both air quality and environmental impacts; and VC had higher capital costs and O&M costs than RO. As a result, seawater RO was selected for further evaluation for the 3,000 acft/yr facility. The plant was to be built on PG&E property where they could utilize PG&E's intake and PG&E's outfall or Morro Bay's wastewater plant outfall for concentrate disposal. Equipment and facility costs were assumed to be for "short term" use of five years, to reduce capital costs. Estimated capital costs for the facility was $19.5 million. Total water cost amortized over five years at 8% was $2,850 per acft. The City Council voted in April 1991 to put the proposed desalination project on hold, after significant rainfall occurred in March 1991.

Monterey Peninsula Water Management District (MPWMD)

MPWMD provides water to a 170 square mile area in the Monterey Peninsula and Carmel Valley on the Central California coast. Their existing water supply sources includes water diversions from the Carmel River and local groundwater. Additional water source options available to MPWMD included seawater desalting or development of additional surface water and groundwater.

In 1991, MPWMD and Pacific Gas & Electric (PG&E) entered into a joint effort to conduct a seawater desalination feasibility study for either a 3,000 or 8,000 acft/yr plant. A number of sites were evaluated including Sand City, Monterey Regional Water Pollution Agency's Wastewater Treatment Plant, and PG&E's Moss Landing Power Plant site. Both thermal and non-thermal desalt processes were investigated, especially at the PG&E site where a steam source might be available. Vapor compression was eliminated due to the size of standard units. MSF was approximately 30 to 50% higher in total water cost than commercially proven MED units. As a result, MED and RO were selected for further evaluation. The initial estimated costs from the study, with capital amortized at 8% over 20 years, for a 3,000 acft/yr facility, are shown in Table 3.7-14.

Table 3.7-14
Comparison of Estimated Costs for Desalt Plants for MPWMD

	2-Stage RO	MED
Capital Costs (M$)	38.0	43.6
First Year O&M Cost (M$)	3.5	5.9
Total Water Costs	$2,443 per acft	$3,433 per acft

RO was the selected process. In the second phase of the feasibility study, a 3,000 and 8,000 acft/yr, 2-stage RO facility, were compared. Feedwater from the Pacific Ocean via Ranney Collectors (a system similar to a shallow well-field) was expected to be 34,500 mg/L TDS, with a product water goal of 300 mg/L TDS. Recovery was expected to be 47.6%, due to the less stringent water quality goal. They did not plan to have pre-treatment, except for chemical addition, due to the Ranney Collectors. Concentrate disposal was to be through the existing wastewater outfall at the regional wastewater treatment plant site. The second phase study estimated total water costs, with capital amortized at 8% over 20 years, to be $1,938 per acft for a 3,000 acft/yr plant and $1,509 per acft for an 8,000 acft/yr plant.

Following preparation of the feasibility study, a preliminary design report better defined costs and other project specifics for a 3,000 acft/yr plant. The plant would be constructed inside an existing building at a site in Sand City that was not considered in the original feasibility study. The preliminary design modified the product water quality goal from a TDS of 300 mg/L to a TDS of 500 mg/L. The operation, thereby, became a single-stage versus the two-stage process in the feasibility study. Recovery was reduced from 47.6% to 40%. Concentrate disposal was to be through Reverse Ranney Collectors, rather than the regional wastewater plant outfall. The estimated capital costs from the preliminary design report was $29.6 million, with an annual O&M cost of $3.4 million and a total product water cost, including water delivery, of $2,147 per acft.

Even though the total water cost was higher in the preliminary design report, the $2,147 per acft is very attractive compared to the other alternatives MPWMD investigated in their water studies, including construction of dams and reservoirs. Four of the dam projects ranged from $3,628 to $6,897 per acft. Two other projects were expected to cost $2,151 and $2,760 per acft. The selected project included the 3,000 acft/yr desalting plant and a dam at a combined cost of $2,959 per acre/foot.

3.7.5.2 Operating Seawater Desalting Plants

Chevron Gaviota Oil and Gas Processing Plant

Since 1987, the Chevron Oil Company has operated an RO plant at its refinery in Gaviota, California to produce plant water and potable water from seawater. A brief inspection of the facilities was made in 1994. The facility includes three RO trains to reduce seawater TDS from 34,000 mg/L to 400 mg/L for potable water and irrigation. Two additional trains reduce a portion of the 400 mg/L TDS water to 40 mg/L TDS for process water. In addition, a portion of this water is further treated by ion exchange to 0.1 mg/L for boiler feedwater. The capacity of the RO system is approximately 460 acft/yr, depending on the product water mix. The RO units use power from an on-site cogeneration plant. Energy use is extremely high at 15,000 kwh/AF, as the system does not use energy recovery. The average cost to produce the water is $4,000 per acft. According to Chevron personnel, this cost is relatively high due to lack of energy recovery, a new and expensive seawater intake system, and the unit was designed to last 25 years.

The Environmental Impact Report/Statement (EIR/S) prepared for the project concluded that the impact of desalination discharges would not be significant as long as the conditions in Chevron's NPDES permit issued by the state were followed. Chevron originally discharged waste concentrate directly to the ocean through an outfall terminating in the surf zone in water 10-15 feet deep. Permitting requirements later required design of a new outfall system. In May 1993, Chevron began discharging combined effluent from the processing plant and the RO unit (concentrate) through a 5,200-foot-long outfall to 100 foot deep water. The combined discharge is authorized under a modified NPDES permit.

San Nicholas Island, U. S. Navy

San Nicholas is an island with no natural water sources. It is located about 60 miles southwest of Los Angeles and 50 miles east of Santa Catalina Island. In October 1990, the State Water Resources Control Board granted the Navy an exemption to the California Ocean Plan and allowed it to discharge desalt concentrate into an "area of special biological significance", conditional on compliance with NPDES permitting requirements. In November 1990, the Navy began operation of a temporary RO seawater desalination unit that produced 24,000 gallons/day of domestic potable water for Navy personnel on the island. In 1992, the Navy replaced the temporary unit with two permanent RO units that each produce 16 acft/yr using seawater from ocean wells. The plant discharges approximately 67,000 gallons/day of concentrate with 40,000 mg/L TDS into a gravel pit 300 feet from the beach. The Navy monitors offshore water quality to ensure that salinity levels do not increase. Membrane backwash is discharged into an existing sewage plant outfall. The cost to produce the water is about $6,000 per acft.

Virgin Islands Water and Power Authority (VIWPA)

Since 1981, VIWPA has operated six multiple effects distillation units and one vapor compression unit on St. Thomas and St. Croix, Virgin Islands. The plants use 36,000 mg/L TDS seawater to produce water with 25 to 60 mg/L TDS for domestic use. The rated capacity of the units ranges from 155,000 gallons/day to 1,400,000 gallons/day. VIWPA provided the National Water Supply Improvement Association with an audited statement of revenues, expenses, and accumulated equity for the year ended June 30, 1991, and reported the seven distillation units produced 1,679,517,000 gallons (5,154 AF), resulting in an average water cost of $12.16 per 1000 gallons ($3,962 per acft). This cost included production costs of $7.81 per 1000 gallons and distribution costs of $4.35 per 1000 gallons. The audited statement includes the note "Depreciation, net of amortization of contributions in aid of construction", indicating the debt service does not include the total capital cost of the project.

Pacific Gas and Electric (PG&E) Diablo Canyon Nuclear Power Plant

A comprehensive site visit was made to the Diablo Canyon Nuclear Plant in 1994. PG&E was the first electric utility in the continental U.S. to produce power plant makeup feedwater using desalinated seawater. Since 1987, they have operated a 600 acft/yr reverse osmosis plant under a lease contract at the nuclear power plant, 12 miles southwest of San Luis Obispo, California. In 1992, a new plant, with the same capacity, became operational under a new lease contract with Ionics, Inc. Prior to selecting desalination of seawater, PG&E had evaluated their only other two alternatives, shipping in water via oceangoing barges and treating wastewater effluent. They had no other feasible economic access to off-site water. They concluded seawater desalination had the lowest capital and O&M costs. The facility uses two-stage RO to produce 200 mg/L TDS water, of which a portion is further treated in a separate facility to obtain ultra pure water for steam. Construction costs were minimized by building the plant outside, utilizing existing intake and discharge structures, and designing for only a five to 10 year life. The facility uses about 9,100 KW of electricity per acft of water produced, and recovers 45% of the seawater treated.

PG&E reported that from October 1985 to March 1987, with the plant operational 99% of the time, the plant produced 6.5 million to 17.5 million gallons per month (on the average 66% of capacity), producing 207 million gallons at an average cost of $7.96 per 1000 gallons ($2,593 per acft). The costs included amortization of the 42 month rental of the facility, but they did not include PG&E's in-house costs for the concrete pad, land costs, power supply, and approximately one to one and one-half miles of distribution piping. Data is not available on the current system, though costs are estimated to be $2,000 or more per acft.

3.7.5.3 Constructed and Previously Operated Plants

Santa Catalina Island

Southern California Edison (SCE) provides gas, electricity, and water to the 2,900 year-round residents and the more than one million visitors to Santa Catalina Island, California. Prior to constructing a desalination plant, the island, which is 26 miles from the mainland, obtained its water from wells that were recharged by a reservoir immediately above the wells. The water supply system was very susceptible to drought. In 1989, a stringent water conservation program was implemented and in June, 1991 SCE and Whitehawk Catalina, Inc. completed construction of a 135 acft/yr RO plant which can provide approximately one-third of the island's annual water requirements. An extensive site visit was made to the island's desalting facility in 1994. The plant, located at the Pebbly Beach SCE Power Plant, operated from July 1, 1991 to early 1992, but, since then, has not been operated to produce potable, domestic water. When it operated, the plant produced water for $2,400 per acft, based on a 30 year amortization of capital costs.

Plant capital costs were minimal compared to similar plants, as two ocean wells on the Pebbly Beach property near the plant pump directly into the feedwater tanks for the two-stage RO plant. After 30% recovery, concentrate is discharged through a swaled structure directly into the ocean surf. It is unlikely California would permit a similar concentrate discharge system to be constructed today. The plant is presently on indefinite standby.

City of Morro Bay

The City of Morro Bay, located on the central California coast, constructed a 645 acft/yr, RO seawater/brackish groundwater desalting plant in 1992. An extensive site visit was made to the facilities in 1994. The City has approximately 9,600 residents, plus 200,000 visitors annually. Its water usage is currently about 1,320 acft/yr, but growth is expected to increase usage to 1,780 acft/yr by the year 2000, and 2,150 acft/yr in 2010. Prior to construction of the desalting plant, water was supplied from twelve local groundwater wells, which during a normal year, produced about 1,600 acft/yr. However, during a drought year, their production is only about 950 acft/yr. During the drought of the late 1980's and early 1990's, nine of their wells went dry, and the remaining three developed nitrate quality problems. They were out of acceptable water, and they did not have time for a feasibility study. The City immediately brought in portable RO units to improve the quality of the water from their remaining water wells. Concentrate was discharged to an existing co-owned wastewater outfall. However, due to a legal suit brought by the other owner, the City of Caycucos, over concerns regarding existing and future discharge permitting, Morro Bay had to abandon this wastewater outfall for the constructed RO plant. In addition to the suit by Caycucos, the EPA had formerly objected to this concentrate discharge system.

The plant was constructed under a state Declaration of Local Emergency. Under the declaration, environmental and City contractual requirements were waived. However, the existing state permit is only applicable for a period of Level 5 Emergency conditions.

The 645 acft/yr facility cost the City about $3.7 million. By adding equipment, the plant capacity can be increased to about 1,500 acft/yr. The plant is in an enclosed structure on existing City property. Seawater, with a TDS of 18,500+ mg/L, is supplied by five wells. According to City staff, the lower than normal TDS is due to an "ancient freshwater seam" in the area. The lower TDS allows them to operate at lower pump pressures and power usage. Water from brackish groundwater wells can also be routed to the plant for processing. Recovery through the single stage RO unit is 40-65%, depending on TDS feed levels. Waste concentrate is discharged, dispersed, and diluted into the 725 mgd power plant cooling water outfall.

The seawater plant operated for only 84 days in 1992. The plant has been shutdown since that date, as a "Level 5 Energy Water Condition" has not existed. The City estimated total product water cost was $1,750 per acft. This was based on the use of PG&E's outfall system, reduced permitting costs due to the Level 5 Emergency, no land cost, 18,500+ mg/L TDS, and 10-year capital amortization. After 10 years, the City estimates total product water cost will be between $800 and $1,100 per acft, assuming there are no additional capital requirements.

The City of Morro Bay is currently re-evaluating their long term water supply program, however, they have few other alternatives. The proposed state water project could supply Morro Bay 1,313 acft/yr at a cost of $1,230 per acft. Of this figure, $710 per acft per year would be paid by the City for a 30 year period. In addition, although the state may not be able to deliver this 1,313 acft/yr due to environmental constraints in the San Francisco delta area, capital costs of the state water project would have to be repaid. It appears desalination of seawater may be the City's least expensive alternative.

City of Santa Barbara

Santa Barbara is an affluent coastal city located approximately 100 miles north of Los Angeles, California. Prior to construction of a seawater desalination plant, their primary sources of water were two local reservoirs and limited local groundwater.

In 1979, 73% of voters defeated a referendum to obtain water at a cost of $100 to $200 per acft from the previous state water project. As a result, in February 1990, due to the drought of the late 1980's and early 1990's, the City Council had to declare a drought condition based on a projected water deficit of 47%. Then, in July 1990, the State of California declared a "State of Emergency" in Santa Barbara, which ultimately allowed the temporary permitting (for five years) of a desalination facility.

Prior to constructing the desalt plant, the City solicited proposals for the delivery of up to 10,000 acft/yr of new water. Proposals were received from private firms to desalt seawater using either RO or distillation and to deliver Canadian water by tanker. The proposed project was to be operated and financed by the proposers; the City would agree to purchase the water; the supply would be used only in an emergency; and proposers were to include both standby and operating costs. Table 3.7-15 presents a summary of the City's lowest cost alternatives for 7,500 acft/yr. As is shown in the table, seawater RO provides the least expensive water at $1,918 per acft. It is also important to note that after complete amortization of the initial capital cost, total product water cost was still $919 per acft, without allowance for capital improvements for the temporary facility. A thorough inspection of the Santa Barbara desalination plant was made in 1994.

The 7,500 acft/yr facility, the largest seawater desalter in the United States, is located on approximately 3 acres of land, previously owned by the City and adjacent to the wastewater treatment plant. Seawater is supplied by a pumping system that is 2,500 feet offshore in approximately 30 feet of water. Water is pumped through a previously unused concrete pipe

Table 3.7-15
Cost Comparison for 7,500 Acft/Yr*
Water Supply for City of Santa Barbara

		Desalting	
Costs	**RO**	**MVC**	**Tanker**
Capital ($)	37,500,000	38,800,000	29,300,000
O&M ($/Year)	6,900,000	7,100,000	13,900,000
First Five Years			
Operations Costs ($/AF)	1,918	2,295	2,634
Standby Costs			
< 6 months			
$/AF	1,215	1,625	1,582
$/Year	14,580,000	19,500,000	18,984,000
> 6 Months			
$/AF	1,154	1,625	2,074
$/Year	13,848,000	19,500,000	24,888,000
Second 5 Years			
Operations Cost ($/AF)	919	1952	1,852
Standby Costs			
< 6 Months			
$/AF	392	282	806
$/Year	2,940,000	2,112,000	6,048,000
> 6 Months			
$/AF	331	282	1,298
$/Year	2,484,000	2,112,000	9,732,000

*5 Year Amortization

that was "slip-lined" with a 3 foot diameter polyethylene pipe. After treatment the concentrate is discharged through an existing wastewater treatment plant outfall. As a result of using existing facilities for both the intake and discharge facilities, Santa Barbara did not have to disturb any beaches or surf zone, thereby reducing costs and environmental impacts. The TDS of the feedwater is 34,120 mg/L, and the single stage RO system, with 45% recovery, produces water with less than 500 mg/L TDS. In the initial contractual arrangement with the provider, Ionics, Inc., Santa Barbara paid $1,935 per acft for product water, or if the plant was not used, $1,312 per acft of capacity for short term standby (less than six month's notice), or $1,231 per acft for long term standby (more than six months notice). These costs are based on amortizing the temporary plant over five years with the option to purchase the facility for approximately one million dollars after the five year period. It should be noted the costs did not include an outfall or intake structures, land costs, site development costs, and there was no distribution piping to convey the product water to consumers. In addition, permitting costs were minimized due to the temporary permit. After operating the $35+ million plant for approximately three months, the operation was placed on indefinite standby due to the 1992/1993 rains which filled their reservoirs and reduced water demand. The plant has not produced potable water since. While it operated, the desalter produced approximately 428 acft of product water with TDS between 284 and 400 mg/L. This equates to less than 25% of constructed capacity during its operational period. Electricity use for the plant was 6,600 KWH per acft. The City's Long Term Water Supply Program projects the desalting plant (if it remains) will be used only seven times in a 62 year period, for a production of less than 20,000 acft.

To reduce costs and because the facility was to be temporary for five years, the RO trains and 600 HP high pressure pumps were constructed in Massachusetts and then transported to Santa Barbara in truck trailers. Long term, the structural integrity of the trailers, from a combination of vibration and weather effects should be of concern. Had Santa Barbara originally amortized the plant over 20 years, instead of five years under its temporary status, the plant would probably have been designed as a more permanent installation at substantially higher costs.

Another important point is that desalination was not only a cost competitive option, but the most expedient alternative for Santa Barbara during the drought. However, in addition to supporting the seawater desalter in an election in June 1991, the voters also approved the expenditure of over $28 million for connection to the state water project for a 3,000 acft/yr allotment at an estimated cost of $1,550 per acft. The cost of the state water could be substantially higher depending on actual deliveries due to environmental constraints in the San Francisco Bay Delta area.

3.7.6 Summary of Costs

While the engineering feasibility of desalination has been clearly demonstrated with a number of technologies, it is essentially the economic feasibility of seawater desalination that has prevented its widespread use. Based on all of the information obtained, visits to facilities, and discussions with desalination plant operators, the cost to desalinate seawater was found to range from $1,635 to $6,000 per acft as shown in Table 3.7-5. Costs were found to vary widely, based on a number of factors, including:

- Siting;
- Plant capacity;
- Water source quality;
- Product water quality goal;
- Raw water intake system;
- Desalination process, including pre-treatment and post-treatment;
- Recovery Rate;
- Concentrate discharge system;
- Transmission, storage, and distribution system; and
- Regulatory issues.

After considering all of the foregoing factors and considering currently accepted desalinating processes, it appears a desalination plant sized to produce 5,000 to 10,000 acft/yr, could produce potable water from seawater in the range of $1,635 to $2,000 per acft. This estimate is based on the assumption that none of the preceding factors would significantly increase the cost of the plant.

Desalination of seawater has been, and is being, considered by many municipal water purveyors in California, but only one major plant has been installed to date (Santa Barbara; 7,500 acft/yr), and two smaller plants have been constructed by the City of Morro Bay and Santa Catalina Island, with capacities of 600 acft/yr and 135 acft/yr, respectively. All of these plants were installed during severe drought conditions and are now (in 1995) shut down.

While relatively inexpensive new water is still available in some areas of the United States, California's days of low cost water are gone. Their current costs to develop conventional water supplies are much higher than they experienced in the past. For example, Marin Municipal Water District's cost for imported surface water ($1,300 per acft) will be 68% of their estimated cost for desalted seawater ($1,900 per acft).

Another example of the high water costs being experienced in California is Monterey Peninsula Water Management District's decision to pursue a project which includes a 3,000 acft/yr seawater desalination plant and a dam, at a combined cost of $2,959 per acft. They found the cost of "dam only" projects ($2,151 to $6,897 per acft) would be more expensive than seawater desalting ($2,147 per acft).

Similarly, the price of imported "new" Northern California water into Southern California has been estimated to be more than $900 per acft, and with the uncertainties of delivery due to environmental problems and the potential for shortages due to drought, this cost could easily escalate. Due to the uncertainties of importing water, Santa Barbara selected to desalt seawater ($1,935 per acft) rather than import state water ($1,550 per acft) at a lower cost.

In almost every case study and for all constructed plants in California, reverse osmosis has been shown to be less expensive than the distillation processes. The issues of new "experimental" plants or new treatment technologies have been repeatedly considered in California. Although some of the proposed new technologies initially appear to have some degree of merit, they are still unproven technologies. If reliable and acceptable desalting options were available at less then $1,200 per acft/yr, a number of desalination projects would have been built along the California coast, not as pilots, but as large operating seawater plants.

The questions arise: "Can improvements in desalination be made to reduce capital and/or operating costs?" and "Are any such improvements likely to occur from 'breakthroughs' that result in substantial cost reductions, or will improvements be made in small increments?" On the basis of historical events and trends, a very probable answer is that there will undoubtedly be improvements, but substantial cost reductions resulting from a technological breakthrough are not likely. Improvements will most likely occur as the result of the efforts of individual desalination equipment designers, in response to a growing demand for such equipment. However, the only breakthrough that is likely to result in major cost reductions would be development of an inexpensive power source for these extremely high energy consuming processes. Otherwise, the projected long term price escalations of energy supplies will provide a counter trend to any lower costs from technological improvements.

3.7.7 Application to the Corpus Christi Situation

If no other suitable water supplies existed and cost was secondary, a desalination plant could be sited in the Corpus Christi area by utilizing currently accepted desalination processes. Due to high economic value and environmental sensitivity of both Padre and Mustang Islands, the most acceptable plant location would be a mainland site, rather than an island site. However, ocean (rather than bay) intake and discharge structures would be required to minimize adverse environmental impacts. In all likelihood, the desalt plant, if designed today, would be a single purpose, two-stage RO process. To date, the RO process has proven to be the least expensive process, even in instances where siting at a powerplant has been possible.

In order to take advantage of the economies of scale, the plant should be at least 5,000 to 10,000 acft/yr. RO desalination systems are relatively compact and are typically installed within a building. Their area requirements vary according to specific plant design. For a 5,000 to 10,000 acft/yr facility, we might expect it to require from three to ten acres of land. Larger facilities would require additional acreage. The height of typical RO equipment will range from 15 to 20 feet.

Product water quality from a two-stage RO system would be about 200 mg/L TDS, primarily consisting of sodium chloride. This water would essentially have no hardness or alkalinity and would not be suitable for introduction directly into the water distribution system without post treatment to add hardness and alkalinity. Addition of these post-treatment material would probably result in the product water exceeding TDS of 300 mg/L with acceptable hardness, alkalinity, sodium, and chloride levels. The expected design recovery for a two-stage RO plant would be approximately 47.5 percent. Therefore, about 52.5 percent would be returned to the ocean as concentrate discharge. The TDS of the concentrate would be about 69,000 mg/L, generally double that of seawater.

To realize minimum unit water cost and to assure the feasibility of permitting the plant to ultimate capacity at the selected site, the plant would need to be constructed initially for its ultimate capacity and operated at its ultimate capacity most of the time. Otherwise, as has been shown for other locations, phased construction would typically result in higher unit water cost. Part-time operation of the plant is generally not desirable due to costs and numerous technical considerations associated with "moth balling", particularly an RO operation. Part-time operation of the plant should only be considered if the cost difference between full-time and part-time operation of the plant is greater than the total cost of providing water from other sources. Part-time plants in California estimate their operation and maintenance costs, after initial capital costs have been fully amortized, to be between $900 and $1,600 per acft. Therefore, for part-time operation to be effective in Corpus Christi, alternative water costs would have to be equal to, or greater than, this type of estimate.

Environmentally, the greatest concerns would be the locations of the intake structure and concentrate discharge structure. Due to the generally dispersed nature of spawning and nursery areas along the near shore Gulf, substantial entrainment impacts to marine populations would probably require the seawater intake structure to be situated in the open Gulf, requiring a substantial feedwater pipeline to the mainland desalination plant. The plant outfall would, in all probability, extend from the mainland plant into the Gulf of Mexico, rather than into the bay due to potential environmental impacts. This would also require a substantial discharge pipe and outfall structure incorporating a jet diffuser to enhance dilution. Although Region VI EPA and the National Marine Fisheries Service (NMFS) have indicated that these discharges have low priorities and lack general constraints, currently there are no operational seawater desalination plants in Texas. A proposed plant, depending on its ultimate capacity, could result in regulatory agencies re-evaluating their position. As we know from our investigations in California and Florida (where the majority of recent desalination activity has occurred), much more stringent review and substantial obstacles, with regard to concentrate discharge permitting, have been, and continue to be, encountered.

In regard to conceptualized costs of 5,000 acft/yr or 10,000 acft/yr RO seawater desalting plant, specific costs are extremely site specific. The cost of developing a seawater supply with a significantly long feedwater and concentrate discharge pipe to and from a mainland plant, as well as delivering the desalted water to consumers, can comprise a considerable portion of the total desalted water cost. This can contribute to a wide range of costs ($1,635 - $6,000 per acft) as shown by the information evaluated in this phase of the study. It may be initially expected that under favorable assumptions, a 5,000 acft/yr or 10,000 acft/yr desalt plant could produce potable water in Corpus Christi in the range of $1,635 to $2,000 per acft. The estimate is based on the assumption that none of the factors in Section 3.7.6 (siting; plant capacity; water source quality; product water quality goal; raw water intake system; desalination process, including pretreatment and post-treatment; recovery rate; concentrate discharge system; transmission, storage and distribution system; and regulatory issues) would significantly increase the cost of a plant in Corpus Christi. However, we anticipate that several of these factors (siting, intake system, concentrate discharge system and potentially regulatory issues) could significantly escalate these costs.

While desalination in the greater Corpus Christi area is an expensive alternative, it should not be ruled out for future consideration. Desalting may merit further consideration when there are no other viable alternatives, when the costs of desalted seawater are comparable or lower than the cost of other new water supplies, or when desalination can make water available in the shortest time frame. In the future, it is recommended that the City of Corpus Christi, at 5-year intervals, update information on the economics of desalination to determine if significant cost reductions have occurred over that period of time.

3.8 Local Groundwater - Gulf Coast Aquifer (L-2)

3.8.1 Local Groundwater Setting

The principal water-bearing formations underlying the City of Corpus Christi and the surrounding area are associated with the Gulf Coast Aquifer. This aquifer extends from south Texas throughout the Texas coastal bend and into Louisiana. It is the same aquifer system which has historically yielded large quantities of water in the Houston, Texas area. This aquifer is comprised of three major geologic trends which outcrop some 60 to 80 miles inland and dip downward toward the Gulf of Mexico. As a result of the southeasterly dip, the water-bearing sands underlying Corpus Christi are fairly deep and contain water which is typically slightly to moderately saline. The available water quality data indicate that the quality of the groundwater in the Corpus Christi area generally does not meet the TNRCC Drinking Water Standards. Most of the groundwater has elevated levels of TDS, chlorides, and sulfates.

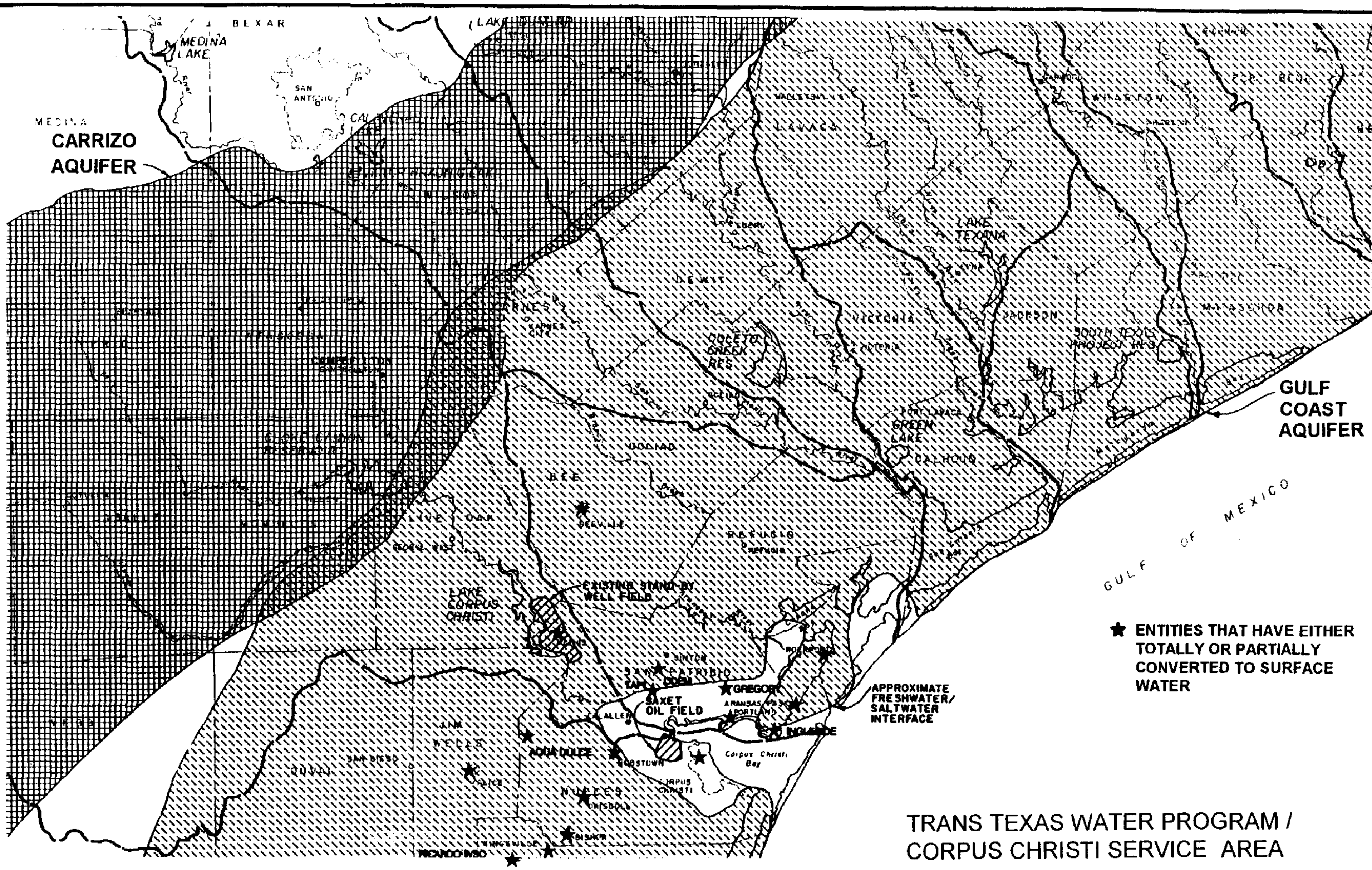
The TWDB Report No. 73, "Groundwater Resources of Nueces and San Patricio Counties, Texas," which was published in 1968, indicates that there is a significant amount of water stored in the Gulf Coast Aquifer, but that only limited quantities of potable groundwater are available for additional development because most of the groundwater in the area is saline. The report states that "quantitative determination of the availability of groundwater is not possible using the existing data." However, in their report the TWDB identified four areas around Corpus Christi where potential development of some additional groundwater might be feasible. These included: the Lake Corpus Christi area, the Kingsville-Bishop area, northwestern San Patricio County, and the Alice-Sandia area. These areas were identified based on the availability of water and the cost of well construction/activation, and on their proximity to the Nueces River system to allow water to be delivered to the existing supply system. The report does not provide data substantiating potential well yields in the four locations, but data suggest that some water is available. The report recommends that flow tests be performed on existing wells in the four areas to determine actual well yields. The report also mentions other groundwater supplies such as the Carrizo Aquifer located to the north of Corpus Christi, but does not recommend pursuing emergency groundwater development of the Carrizo Aquifer due to cost and excessive water loss that would be experienced in transporting the water to Corpus

Christi via stream drainages. However, potential use of the Carrizo Aquifer in other ways is addressed in other sections of this Trans-Texas report.

During the 1980's drought, in conjunction with the development/activation of the City's existing wells, Reed and Associates was commissioned to prepare an aquifer simulation model to determine the quantity and location of wells necessary to produce a total stand-by capacity of 60 MGD. The aquifer model developed assumed that the 60 MGD pumpage would be sustained only during a two-year drought period, that Beeville and Kingsville would use their own groundwater reserves, and that no dewatering would be permitted in the uppermost major producing horizon. The existing City wells were modelled and future wells were assumed to be located in northwestern San Patricio County in an area north of Sinton.

The aquifer model indicated that the drawdown of the water table after two years of continuous pumping would be approximately 100 feet in the area between the two production areas and would approach 190 feet in the area north of Sinton. No land subsidence was expected to occur at drawdowns of this magnitude, but pumping for longer than two years could produce land subsidence which could endanger the structural integrity of Wesley Seale Dam at Lake Corpus Christi and potentially impact highway and railroad structures. These results verify the concern that subsidence could occur in the Corpus Christi area under long-term groundwater pumpage.

Since subsidence has been severe in some parts of the Gulf Coast Aquifer, in particular in and around the City of Houston, there is reason to believe that long-term groundwater pumpage could produce similar problems in the Corpus Christi area. Some areas around the Houston Ship Channel, where groundwater usage is the highest, have subsided more than 10 feet and significant damage has resulted from increased flooding, inundation, and tidal effects. Subsidence and subsequent ground faulting have occurred in isolated areas near Corpus Christi. The Saxet Oil Field located to the west of Corpus Christi (Figure 3.8-1) has undergone approximately six feet of subsidence as a result of the withdrawal of petroleum and brackish groundwater. While this subsidence was caused mainly by the withdrawal of hydrocarbons, it does indicate that the geology near Corpus Christi could be susceptible to subsidence from groundwater removal. In addition, the TWDB Report No. 73 study recommends that future water planning for the area consider demineralization of the brackish groundwater underlying



★ ENTITIES THAT HAVE EITHER TOTALLY OR PARTIALLY CONVERTED TO SURFACE WATER

Legend

Carrizo/Wilcox Aquifer

Gulf Coast Aquifer

0 10 20 Miles
Scale

HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

LOCAL GROUNDWATER OPTIONS GULF COAST AQUIFER ALTERNATIVE L-2

FIGURE 3.8-1

the area since development of additional potable groundwater supplies does not appear to be promising. Demineralization of brackish groundwater as an alternative water source for Corpus Christi is addressed in Section 3.8.4.

Groundwater quality reported to the TNRCC by the Cities of Beeville, Kingsville, Bishop, and Sinton is summarized in Table 3.8-1. As shown on the table, TDS, chloride, and sulfate concentrations reported since the late 1970's indicate that all three of these communities have consistently failed to meet the TNRCC standards. The Cities of Beeville and Bishop have experienced high TDS and chloride concentrations. The City of Bishop has also consistently exceeded the sulfate standards. The City of Kingsville reported water quality which was typically either slightly under or slightly over the TNRCC standards.

Table 3.8-1
Typical Groundwater Quality Around Corpus Christi*

Source	TDS (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
Beeville	1,500	500-700	9
Bishop	1,000-2,000	300-500	200-850
Kingsville	1,000	250-300	150-250
Sinton	800-1,200	150-370	65
TNRCC Standard	1,000	300	300

*Source: Texas Natural Resource Conservation Commission.

The City of Sinton has continued to utilize groundwater as its primary supply. Water quality around the Sinton area is somewhat better, but reported chloride concentrations typically exceed the TNRCC standards.

Due to difficulty in meeting the TNRCC Drinking Water Standards, communities in the region, including Kingsville, Bishop, and Beeville, have partially converted to surface water which is supplied from the CC/LCC System. Table 3.8-2 presents a list of 24 water suppliers who have converted at least a part of their groundwater supply to surface water supplied by Corpus Christi and the corresponding date of conversion. Figure 3.8-1 shows the location of the larger entities that have made conversions to surface water. Additionally, in the Fall of 1994, three additional communities located in Duval County (i.e., San Diego, Benavides and

Table 3.8-2
Public Water Suppliers Who Have Converted Totally or Partially to Surface Water from the Choke Canyon/Lake Corpus Christi System

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

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

Freer) began the process of initiating a TWDB planning study to investigate the feasibility of supplementing their groundwater supplies with surface water.

In the past, Corpus Christi has used groundwater as a back-up water supply source during times of critical drought. The City currently owns or leases several wells around Lake Corpus Christi, along with four wells in the Carrizo Aquifer, which are located near the City of Campbellton in Atascosa County. These wells are maintained on a stand-by basis and function as an element in the City's Drought Contingency Plan. (Note: Condition I (Drought Possibility) of the Plan is initiated when the CC/LCC System reaches a capacity of one year of supply without conservation or rationing. At this level, the Plan directs that all City groundwater wells be inspected and serviced so that they are ready for operation. Condition I also indicates that the wells should be put into service as needed to maintain the water supply.)

The stand-by groundwater system was developed during the drought of the mid-1980's. The study by Reed and Associates identified several areas around the City with the potential for groundwater development or with existing wells which could be utilized to supply the CC/LCC System on an emergency basis. Several wells were subsequently activated around Lake Corpus Christi and pumped directly into the lake or Nueces River downstream of the lake. By the end of the drought in 1984, the City had groundwater supplies on-line consisting of numerous wells located near Lake Corpus Christi and four wells at Campbellton (Figure 3.8-1).

Unlike the wells near Corpus Christi, the four Campbellton wells tap the Carrizo Aquifer and are capable of producing about 11.8 MGD on a short-term basis. Water from these wells was pumped into the Atascosa River during the 1950's drought to augment the inflows to Lake Corpus Christi. No data were found to document the amount of water which ultimately reached the lake, but local officials report that as much as 90 percent of the groundwater from the Campbellton wells was lost due to channel and evaporative losses. More recent channel loss data developed by HDR for the city of Corpus Christi suggests it would not be unreasonable for more than 40 percent of this water to be lost, on the average, between Campbellton and the City's intake at Calallen.

The Carrizo Aquifer near Campbellton contains relatively good quality water, although the Campbellton wells appear to have elevated levels of sodium bicarbonate. The Campbellton wells were once capable of producing water by mostly artesian flow, but their yield has declined as water levels have dropped and the wells have aged. Since the Campbellton wells are located approximately 40 miles from Lake Corpus Christi and approximately 90 miles from the City, transporting groundwater from these wells was not considered a "local" groundwater water source and is not included in this alternative. However, transfer of 6 MGD of water to Choke Canyon Reservoir from these wells is considered as a separate water supply alternative and is presented in a separate section of this report (Section 3.9).

In addition to reactivating and developing wells during the 1980's drought, the City also identified potential lease areas to provide additional groundwater from the Gulf-Coast Aquifer. Additional leases were to be primarily in the area north of the City of Sinton and were to provide an additional 30 MGD of water supply during a two year drought period. However, after the 1980's drought ended, the lease program was not continued.

As previously mentioned, the most significant limitation to development of local, long-term groundwater supplies to augment the existing surface water system is the marginal quality of water typically found in the area. Groundwater around the Corpus Christi area is slightly to moderately saline with typical TDS concentrations ranging from 1,000 to 3,000 milligrams per liter (mg/l). The TNRCC Drinking Water Standards allow a maximum TDS concentration of 1,000 mg/l. In comparison, the total solids concentrations recorded in the Nueces River system during periods of normal flow range from 250 to 750 mg/l. However, the total solids concentrations in the river system are elevated during periods of low flow, thereby limiting the amount of blending capacity available to reduce the TDS concentrations of the groundwater.

Although it may be possible to blend a small portion of saline groundwater with surface water to produce potable water of acceptable quality, there are several other factors which could influence the feasibility of a blending operation. For instance, since Corpus Christi is located in a coastal region, the groundwater supplies are hydraulically linked to the ocean and are very close to the fresh water-salt water interface which separates the highly saline waters (TDS concentrations of 35,000 mg/l or greater) of the ocean from the groundwater recharged by rainfall and runoff (TDS concentrations of 1,000 to 3,000 mg/l). Long-term pumping of groundwater in the area could cause saline ocean waters to be drawn toward the wells. This phenomenon, known as salt water intrusion, could cause the quality of the well supply to degrade significantly over time, to the point at which the water could become unusable in a blending operation. The TWDB Report No. 73 indicates that, as shown in Figure 3.8-1, the fresh water-salt water interface extends inland a significant distance near Corpus Christi and Nueces Bay. As a result, the existing City wells located around Lake Corpus Christi are relatively close to the interface and eventually could be susceptible to salt-water intrusion.

Several factors limit the viability of large scale groundwater development in the Corpus Christi area compared with the Houston area. Houston has pumped large quantities of groundwater from the Gulf Coast aquifer for several decades. The Gulf Coast aquifer in the Houston area is much thicker and the water-bearing sands are coarser-grained and higher permeability than in the Corpus Christi area. Consequently, individual wells generally have much higher average flow rates than wells in the Corpus Christi area. The climatic conditions also impact the long term use of groundwater. The recharge area for the Gulf Coast aquifer is located northwest of the Corpus Christi area in a semi-arid climate with average annual precipitation of about 25 inches. The Houston area generally receives over 40 inches of precipitation per year, resulting in much higher natural recharge rates in the outcrop areas of the aquifer sands.

The Gulf Coast aquifer in the Houston area is much better suited for large scale development than in the Corpus Christi area for the following reasons:

- The aquifer sand thickness is greater;
- The average grain size of the sands is larger;
- The aquifer has much higher transmissivity and storage capacity;
- The aquifer has higher natural recharge rates due to more precipitation and less evaporation; and
- Because of the above factors the natural groundwater quality is generally lower in dissolved solids.

In Houston, long-term groundwater pumpage has caused the lowering of the land surface, a phenomenon called subsidence. Land subsidence results from the compaction of clay layers within the aquifer. As water is removed from the water-bearing sands, the hydrostatic pressure in the aquifer is decreased and water tends to move out of clay layers and into the sands, resulting in a decrease in volume as compaction of the clays occur which causes a lowering of the ground surface. Although Houston has utilized groundwater for several decades, the long-term depressurization of the water-bearing sands has resulted in areas with significant problems with land subsidence, decreased well yields, increased groundwater pumping costs, increased flooding, and increased exposure to tidal and hurricane flooding. In response to these problems, in recent years the city has stabilized groundwater pumpage volumes and increased the use of surface water for the public supply system. In the Houston Ship Channel area, industries have switched from groundwater to surface water that is imported from the Trinity River.

Although the long-term reliability of a significant groundwater system is highly uncertain in the Corpus Christi area, several potential alternatives which consider the use of the Gulf Coast Aquifer have been analyzed at a reconnaissance level. These alternatives are discussed in more detail in the following report sections. These alternatives include:

- Existing Wells near Lake Corpus Christi and the Nueces River;
- Potential Well Field North of Sinton;
- Potential Use of Highly Brackish Groundwater; and
- Feasibility of using the Gulf Coast Aquifer for Storage and Recovery of Surface Water.

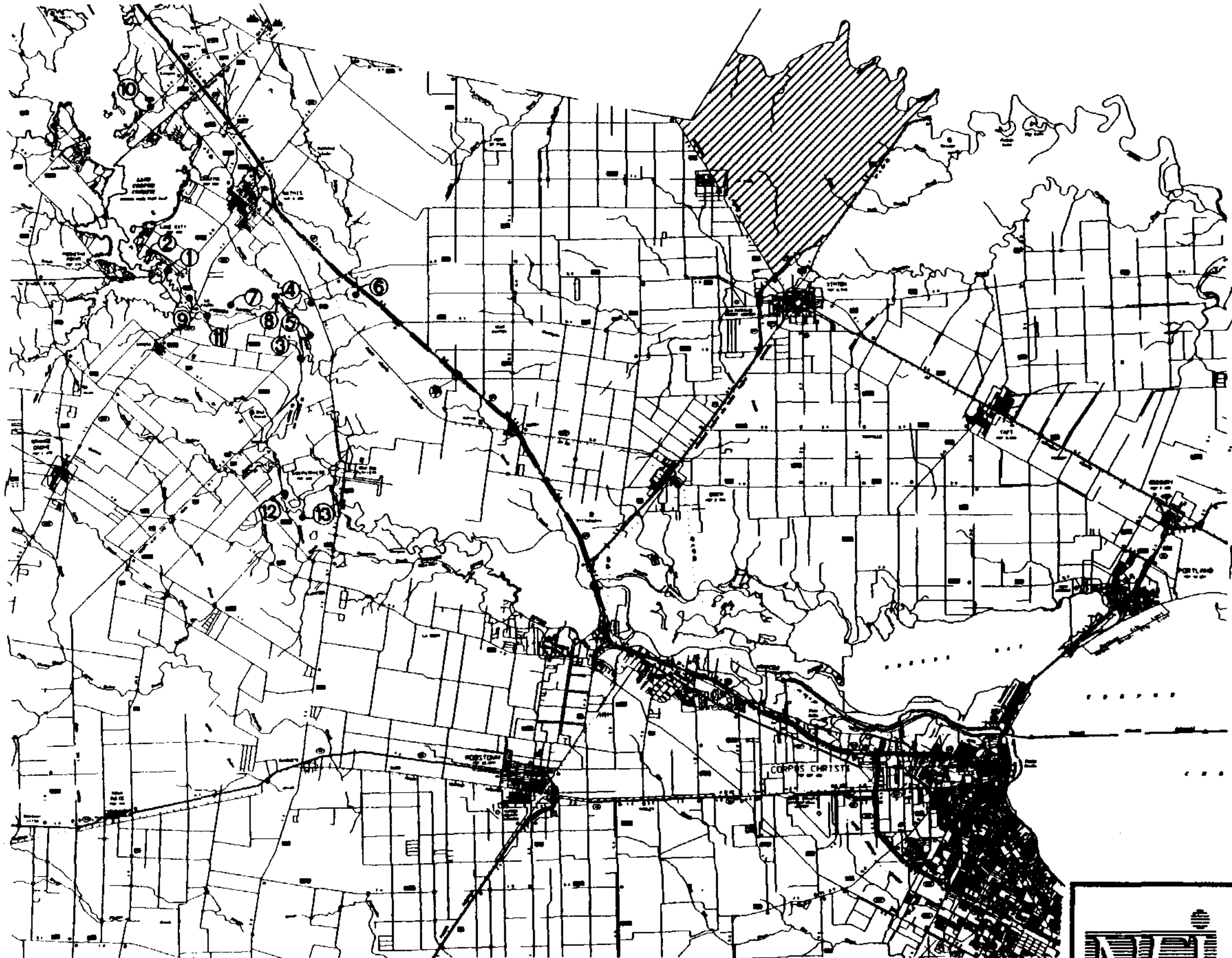
3.8.2 Existing Wells near Lake Corpus Christi and the Nueces River (L-2A and L-2B)

<u>Description of Alternatives and Available Yield</u>

During the 1980's drought, the City of Corpus Christi developed several wells near Lake Corpus Christi and the Nueces River just downstream of Lake Corpus Christi. In addition to new wells, several existing wells were redeveloped, rehabilitated, and fitted with pumps. Well pumps range from 40 to 125 horsepower with most pumps operating with 75 or 100 hp motors.

All operable wells are located adjacent to the lakeshore, main river channel, or on tributaries to the Nueces and have discharge piping directly to the river. The location of the 13 existing wells are shown on Figure 3.8-2 along with the location of a potential new well field site located north of the Sinton area.

To obtain an estimate of the water supply potential of these 13 wells, an analytical groundwater flow model (AQUASIM) was utilized to simulate at a reconnaissance level the regional response of fluid levels in the Gulf Coast aquifer to varying pumping rates. Natural recharge in the northeast-southwest trending Goliad formation was simulated using injection wells in the outcrop area and groundwater pumping was simulated from production wells in the Lake Corpus Christi and Nueces River area as well as the Sinton area. Various projected pumping rates from these wells were used in several model runs to evaluate the approximate



EXISTING CITY OF CORPUS CHRISTI WATER WELL INVENTORY			
MAP NO.	WELL DESIGNATION	YIELD MGD	STATUS
1	WSW 84-1	1.0	
2	WSW 84-2	0.5	
3	WSW 84-3	1.2	
4	WSW 85-1	1.5	
5	WSW 85-2	1.5	
6	WSW 86-1	1.4	
7	WSW 86-2	1.3	
8	WSW 86-3	1.3	
9	CC-1 DAM	1.0	
10	CC-2-NORTH	1.0	
11	CC/DUNN	1.0	
12	CC/PETERS	1.2	
13	CC/NASON	1.0	

20000 10000 0 20000 40000

GRAPHIC SCALE IN FEET

NOTE:

POTENTIAL WELL FIELD—SINTON—ST. PAUL AREA

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ENGINEERING • ENVIRONMENTAL • SURVEYING

CORPUS CHRISTI, TEXAS

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

LOCAL GROUND WATER DEVELOPMENT

HDR Engineering, Inc.

FIGURE 3.8-2

long-term yield of these potential wells.

The results of this preliminary analysis indicate that the approximate long-term yield from this well field would be about 8 MGD (8,960 acft/yr). If this alternative is ever considered as a permanent supply source, a more definitive projection of the long-term yield should be determined by developing a more comprehensive regional groundwater model of the Gulf Coast Aquifer in this area. On an emergency stand-by basis it is estimated that the 13 wells could supply an average of 15 MGD for a period of up to two years.

Water Quality

Groundwater quality data from wells in the Lake Corpus Christi/Nueces River (LCC/NR) area indicates variable concentrations of dissolved solids and chloride. Samples from nine wells collected in the period from 1984-86 indicate the chloride and total dissolved solids averaged approximately 500 and 1350 mg/L, respectively. Because of the lack of long term water analyses from the existing wells in the LCC/NR area, it is not possible to develop a trend in water quality in the Gulf Coast aquifer in this area. Groundwater quality in this area is not believed to have changed significantly in the past several years, but additional data should be developed if this alternative is to be pursued.

A gradual increase in dissolved salts could result as the lowering of the piezometric surface in this area allows increased updip migration of more saline groundwater from the southeast. Additional leakage of more saline water from the interbedded clays may also occur as the piezometric pressure in the sands is lowered.

Although the quality of water obtained directly from the wells will not meet TNRCC Drinking Water Standards for chlorides and dissolved solids, if the water were blended with Nueces River water it would, on the average, meet the standard for chlorides with a median increase in chloride concentrations of 12 percent as shown in Table 3.8-3. Maximum chloride concentrations which exceed the 300 mg/L standard would occur more frequently unless discharges from the wells were stopped during those periods of exceedences. As shown on Table 3.8-3, if the 8 MGD of groundwater from this source were blended with both the Nueces River water and water from Lake Texana the median chloride concentration from the blended water would decrease 9 percent from existing levels and the maximum concentration would be

Table 3.8-3 Chloride Concentrations for Blended Water		
Water Sources		**Chloride (mg/L)**
Nueces River without Blending at Stevens	Max.	338
	Median	162
	Min.	67
Nueces River Blended w/8 MGD groundwater from Lake Corpus Christi/Nueces River Area	Max.	346
	Median	181(+12%)*
	Min.	91
Nueces River Blended w/8 MGD groundwater from Lake Corpus Christi/Nueces River Area and 37 MGD of Lake Texana water.	Max.	293
	Median	147(-9%)*
	Min.	75
*Percentage increase (+) or decrease (-) in concentration.		

lowered to within the 300 mg/L standard.

Engineering and Costing

Cost estimates for this alternative were prepared for two options. The first option (L-2A) does not include a collection pipeline system as water pumped from each well would be discharged directly into either Lake Corpus Christi, the Nueces River or a tributary to the river. A cost estimate for this option is shown on Table 3.8-4. Annual cost which includes estimated costs for groundwater leases and power cost total $1,184,000. With an annual yield available at Calallen of 8,330 acft/year (i.e., 8 MGD adjusted for 7 percent channel losses) the unit cost of water for this option is about $142/acft/yr.

The second option (L-2B) includes a collector pipeline system consisting of 219,000 feet of various size pipelines (see Table 3.8-5) to collect the water pumped from the wells and deliver it to the O.N. Stevens water treatment plant. Under this option channel losses between the wells and the Calallen diversion dam would be eliminated. Annual cost for this option is

Table 3.8-4
Cost Estimate for Local Groundwater
Existing Wells Near Lake Corpus Christi and Nueces River (L-2A)
Well Field Capacity: 8960 acft/yr (8 mgd)
(Discharge to River)
(Mid-1995 Prices)

Item	Estimated Cost (Alt L-2A)
Capital Cost	
Well Improvements (Electric Service, Telemetry & Security)	$468,000
Engineering, Legal and Contingencies	
(Pipelines 30%; Other Facilities 35%)	164,000
Subtotal	$632,000
Environmental Studies and Mitigation	50,000
Land Easements	0
Subtotal	$682,000
Interest During Construction	15,000
Total Project Cost	$697,000
Annual Cost	
Annual Debt Service	$ 65,000
Annual Operation and Maintenance (Excluding Power)	39,000
Annual Power	510,000
Lease Payments	570,000
Total Annual Cost	$1,184,000
Annual Yield at Calallen (0.93 x 8,960)	8,330 acft/yr
Annual Cost of Water[1]	$142 per acft

[1] Cost listed assumes water would be blended with Nueces River water.

shown in Table 3.8-4 and total, $2,810,000 which includes estimated annual lease payments and power costs. With an annual yield available at O.N. Stevens of 8,960 acft/year the unit cost of water for this option is $314/acft/yr if the water is blended with Nueces River water. If special treatment of this water is required to reduce the dissolved chloride concentrations to within drinking water standards, the cost would increase by about $650 per acft/yr to $964 per acft/yr.

3.8.3 Potential Well Field North of Sinton

Description of Alternative and Available Yield

Based on an evaluation of available groundwater resources in the Corpus Christi region it appears that one area that might be suitable for a large scale groundwater supply development is an area in San Patricio County north of Sinton (see Figure 3.8-2). The Gulf Coast Aquifer in this area consists of transmissive sands with relatively fresh groundwater available to depths over 800 feet. The average groundwater quality in this area tends to be lower in dissolved solids and chlorides than in the Lake Corpus Christi/Nueces River (LCC/NR) area.

A preliminary estimate of the long-term groundwater supply potential for the north Sinton area should be based on the yield of this portion of the Gulf Coast Aquifer. Ideally, the combined maximum long-term pumping rate for the LCC/NR and the north Sinton areas should not exceed the long-term recharge to the aquifer, should not cause widespread dewatering below the top of the primary water-bearing interval, should not cause significant subsidence, and should not cause significant deterioration of water quality. As discussed above, a two dimensional analytical groundwater flow model was utilized to make preliminary estimates of the long-term yield of groundwater from the north Sinton and LCC/NR areas. With both well fields operating, hydrologic interference will develop over the years. Based on the results of several runs of the model, it is projected that the long-term design pumping rate from the north Sinton area would be approximately 10 million gallons per day. The preliminary estimate of 10 mgd represents a planning number which should be verified by developing a detailed regional groundwater flow model.

It is estimated that 15 wells would need to be developed for this alternative. The typical well would be equipped with a 100 or 125 horsepower pump. A groundwater model for the north Sinton area developed during the 1980's indicated a potential short-term yield of up to 30

Table 3.8-5
Cost Estimate for Local Groundwater
Existing Wells Near Lake Corpus Christi and Nueces River (L-2B)
Well Field Capacity: 8960 acft/yr (8 mgd)
(Pumping To O.N. Stevens WTP)
(Mid-1995 Prices)

Item	Estimated Cost (Alt L-2B)
Capital Cost	
Wells Improvements (Electric Service, Telemetry & Security)	$470,000
Supply Pipelines	8,650,000
Ground Storage Tank	400,000
Booster Station	1,500,000
Subtotal	$11,020,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	3,420,000
Subtotal	$14,440,000
Environmental Studies and Mitigation	220,000
Land Easements	190,000
Subtotal	$14,850,000
Interest During Construction	590,000
Total Project Cost	$15,440,000
Annual Cost	
Annual Debt Service	$1,450,000
Annual Operation and Maintenance (Excluding Power)	110,000
Annual Power	680,000
Lease Payments	570,000
Total Annual Cost	$2,810,000
Annual Project Yield	8,960 acft/yr
Annual Cost of Water (with blending only)	$314 per acft
Annual Cost of Water[1] (with demineralization)	$964 per acft

[1] Estimated cost with demineralization includes cost of $650 per acft to treat the brackish water to drinking water standards.

Engineering and Costing

Cost estimates for this alternative were prepared for three delivery options. These include:

- Delivery to O.N. Stevens water treatment plant (L-2C);
- Delivery to San Patricio Municipal Water District Reservoir (L-2D); and
- Delivery to Lake Texana Pipeline (L-2E).

All three options include the cost for drilling and developing 15 new wells and the cost of a pipeline collection system consisting of 124,900 feet of various size pipelines. Additionally, the first two options include the construction of an additional 100,000 feet of 30 inch diameter pipeline to deliver the entire volume to either the City's O.N. Stevens water plant or to the District's ground storage facility.

Capital and O&M costs are shown on Table 3.8-6 for the first two options (L-2C and L-2D) and on Table 3.8-7 for the third option (L-2E). Annual cost for the first two options includes estimated costs for groundwater leases and power cost and total $3,900,000. With an annual yield of 11,200 acft/year the unit cost of water for either of these options is $348/acft/yr.

For the third option (L-2E) under which the water would be pumped into the Lake Texana pipeline, annual cost would be reduced by about 20 percent to $3,190,000. The unit cost of water under this option would be about $285/acft/year as shown in Table 3.8-7.

3.8.4 Potential Use of Highly Brackish Groundwater (L-2F)

Based on an evaluation of available groundwater resources in the immediate Corpus Christi area, brackish/saline groundwater (>3,000 mg/L) is available in the Gulf Coast aquifer. Groundwater with total dissolved solids (TDS) concentrations ranging from 3,000 to about 10,000 mg/L would require treatment by a desalination process. In general, this water would be less difficult to treat than saline ocean water containing 35,000 mg/L TDS. The primary sands that could provide moderate to large volume supply wells are in the Goliad Formation and some sands in the overlying younger geologic units.

In the vicinity of Corpus Christi and Nueces Bay, water-bearing sands in geologic units below the Goliad generally contain water with dissolved solids concentrations much higher than 20,000 mg/L at depths below 1,500 feet. Based on the high salinity and potential well depths million gallons per day could be developed for a supplemental stand-by groundwater supply. This model indicated this pumping rate could be sustained for about two years without significant impact except for pumping level lowering for the Sinton and St. Paul water supply wells. Without information from additional regional groundwater modeling, a yield of 30 mgd should be considered as a maximum 2-year drought water supply for stand-by use for this area.

Water Quality

Groundwater from the north Sinton area is generally lower in dissolved solids (including chlorides) than groundwater in the LCC/NR area. Historic sample results from individual wells in the Sinton water system showed a range in chloride concentrations of about 150 to 370 mg/L and total dissolved solids from 870 to 1200 mg/L. The average chloride and total dissolved solids concentrations for these samples were approximately 250 and 1000 mg/L, respectively. Water in this area is relatively low in calcium and high in sodium as the primary cation. Treatment of this water (other than chlorination) is not performed by local municipal users due to the high costs of reducing the concentration of chloride and sodium ions.

A gradual increase in dissolved salts could result as the lowering of the piezometric surface in this area allows increased updip migration of more saline groundwater from the southeast although, presently, dramatic increases in salinity occur about 10 miles to the southeast near Taft. Additional leakage of more saline water from the interbedded clays may also occur as the piezometric pressure in the sands is lowered.

Blending the water from this source with water obtained from the Nueces River will result in relatively minor degradation in median concentrations of dissolved minerals. The median chloride concentration would be expected to increase from 162 mg/L to about 168 mg/L, or about a 4 percent increase. If the 10 MGD of groundwater from this source were blended with both the Nueces River water and water from Lake Texana, the median chloride concentration for the blended water would be about 15 percent less than existing concentrations of Nueces River water.

Table 3.8-7
Cost Estimate for Local Groundwater
Potential Well Field North of Sinton Pumping Into the Lake Texana Pipeline (L-2E)
Well Field Capacity: 11,200 acft/yr (10 mgd)
(Mid-1995 Prices)

Item	Estimated Cost (Alt L-2E)
Capital Cost	
Supply Wells	$6,790,000
Supply Pipelines	2,980,000
Ground Storage Tank	500,000
Booster Station	1,500,000
Subtotal	$11,770,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	3,970,000
Subtotal	$15,740,000
Environmental Studies and Mitigation	130,000
Land Easements	110,000
Subtotal	$15,980,000
Interest During Construction	640,000
Total Project Cost	$16,620,000
Annual Cost	
Annual Debt Service	$1,560,000
Annual Operation and Maintenance (Excluding Power)	120,000
Annual Power	800,000
Lease Payments	710,000
Total Annual Cost	$3,190,000
Annual Project Yield	11,200 acft/yr
Annual Cost of Water	$285 per acft

Table 3.8-6
Cost Estimate for Local Groundwater
Potential Well Field North of Sinton Pumping To Either O.N. Stevens WTP or SPMWD Reservoir (L-2C and L-2D)
Well Field Capacity: 11,200 acft/yr (10 mgd)
(Mid-1995 Prices)

Item	Estimated Cost (Alt L-2C & L-2D)
Capital Cost	
Supply Wells	$6,790,000
Supply Pipelines	8,080,000
Ground Storage Tank	500,000
Booster Station	1,500,000
Subtotal	$16,870,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	5,500,000
Subtotal	$22,370,000
Environmental Studies and Mitigation	220,000
Land Easements	200,000
Subtotal	$22,790,000
Interest During Construction	900,000
Total Project Cost	$23,690,000
Annual Cost	
Annual Debt Service	$2,220,000
Annual Operation and Maintenance (Excluding Power)	170,000
Annual Power	800,000
Lease Payments	710,000
Total Annual Cost	$3,900,000
Annual Project Yield	11,200 acft/yr
Annual Cost of Water	$348 per acft

Since desalination processes use enormous amounts of energy, the cost of the process is controlled mainly by the amount of energy required to purify the water and is directly related to the TDS concentration of the feedstock. Desalination of brackish groundwater has occurred at many locations in Texas, Florida, and California. These application have reported costs which range from $650 to $1,300 per acft. The Brazos River Authority's Lake Granbury Surface Water Treatment System (SWATS), which was designed by HDR Engineering, is a desalination plant typical of those in Texas which treat brackish water for municipal use. The SWATS plant treats brackish surface water with an average TDS of 2,500 mg/l. The operation and maintenance cost to treat to potable conditions is typically around $295 per acft. Coupled with the annual capital cost for the facility, the cost to produce potable water from this plant is approximately $650 per acft.

Because of the large number of wells required, the extensive piping, the land/lease acquisition costs as well as the extensive treatment costs, the development of brackish groundwater in the immediate vicinity of the city would not be a viable, economical source of supplementary water to meet the projected future demand.

3.8.5 Feasibility of Storage and Recovery of Treated Water in the Gulf Coast Aquifer (L-2G)

The use of the Gulf Coast aquifer for storage and recovery of treated water or untreated freshwater runoff was evaluated for potential supplemental water. The two primary means of implementation of this technique appear to be to capture and treat stormwater runoff and inject this water into permeable sands for later recovery and artificially recharging the Goliad sands in the outcrop area through spreading basins or canals.

For recovery and injection of stormwater runoff, an extensive collection network and large volumes of temporary surface water storage would be required. In addition, several injection wells would be needed to put the water in storage within suitable sands. The only available sand units for storage in the city would require injection wells up to 1000 feet deep and injection would be into zones of unsuitable, high salinity water. Because the stormwater collection system in Corpus Christi is spread throughout the city and discharges to several surface water bodies, and the location and distribution of suitable geologic sand units for storage is limited in the immediate vicinity of the city, this method does not appear to be feasible.

and drilling costs, groundwater from geologic units below the Goliad Formation is not considered to be a feasible alternative future source of water.

A review of water well information and an evaluation of selected oil well geophysical logs in the vicinity of the western Nueces River estuary area indicates sands containing brackish to saline groundwater occurred at depths from 75 to 1,360 feet below ground level (BGL). The average total dissolved solids (TDS) concentration reported in water well records or calculated from oil logs was approximately 5,300 mg/L. Generally, TDS concentrations increase with depth, although frequently shallow (0 to 200 feet below ground) water-bearing sands contain higher TDS water than the underlying sands. Additionally, as the sand unit get closer to the coast, the average sand thickness and average grain size generally tend to decrease.

In order to evaluate the operational characteristics of a brackish/saline groundwater supply in the Corpus Christi area, a hypothetical wellfield was designed in an area of the city using a limited amount of available data. Several assumptions were used for the hypothetical wellfield. The water-bearing sand units occur in the depth range of 250 to 450 feet below ground surface. The average transmissivity and storativity of the sands are 8,000 gpd/ft and 0.0001, respectively. A wellfield with 20 operating wells yielding an average of 200 gpm each could be developed on approximately one square mile spacing. This hypothetical well field was evaluated with a groundwater flow model to verify if the maximum potential well yields and corresponding estimated drawdowns were valid.

It was assumed that the well field would be located in the general area bounded by Robstown, Calallen, and the Corpus Christi Airport. Although the quality of groundwater in this area is quite variable, limited data indicates the average TDS in this area could range from 4,000 to 7,000 mg/L. Based on these assumptions, the potential well field described above could produce approximately 5.7 million gallons per day of groundwater containing about 6,000 mg/L TDS. This water would have to be treated by a desalination process to be used in the city's municipal and/or industrial water supply. A desalination process would likely yield about 3.5 to 4.0 million gallons per day of fresh water. The remaining volume of approximately 1.7 to 2.2 mgd would need to be discharged as brine through a permitted disposal process. The brine would have an estimated 15,000-20,000 mg/L of total dissolved solids and would need to be discharged through an ocean outfall which would require a very long pipeline to open water.

the actual impact of connecting existing wells via pipeline to the O.N. Stevens Water Treatment Plant would depend on the final pipeline route, which is yet to be determined, this alternative is roughly comparable to Alternative N-6 (Pipeline from Lake Corpus Christi to Calallen) in terms of the types and relative abundance of habitats involved. Approximately 723 acres total would be affected by installation of the pipeline whereas 207 acres would be maintained as a mowed ROW.

The proposed well field north of Sinton would be roughly triangular and bounded by the Aransas River on the north, State Highway 71 to the southeast and State Highway 181 to the Southwest. This area is rangeland characterized by varying degrees of brush invasion. Rob and Bessie Welder Park is located in the project area along SH 181. Plains gumweed (*Grindelia oolepis*), which was considered for but did not received federal protection, and Welder machaeranthera (*Psilactis heterocapa*), which is a federal C2 candidate species, are reported to occur in the project area.[1] Both of these species are considered by TPWD to be very rare and vulnerable to extirpation.

In addition to 15 wells, construction impacts would include 124,900 feet of collection and transmission lines. This pipeline collection system is expected to affect 401 acres during construction and would require a mowed ROW totaling 115 acres. The wells and collection system would be located in such a way as to avoid or minimize impacts to sensitive resources. The water could be delivered to Corpus Christi via the proposed water transmission line from Lake Texana to the O.N. Stevens Water Treatment Plant (Alternative LN-1, Section 3.13). Alternatively, construction of the proposed transmission lines from the well field to either the San Patricio Municipal Water District's facilities or the O.N. Stevens Water Treatment Plant would affect 322 acres including 92 acres which would be required for a ROW kept clear of woody vegetation. Although the final pipeline routes have not been determined, these would be expected to have impacts similar to Alternative LN-1 between Sinton and the O.N. Stevens Water Treatment Plant in terms of the types and relative abundance of habitats.

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[1] TPWD. 1993. Texas Parks and Wildlife Department National Heritage Program.

Previous studies have shown that Lake Corpus Christi serves as a recharge area for the Gulf Coast Aquifer as the Goliad sands outcrop in the upper end of the reservoir. Recharge to the aquifer which occurs from the reservoir would be available to wells located near Lake Corpus Christi such as those previously discussed. It may be possible to enhance this recharge by constructing canals and recharge basins in the upper end of Lake Corpus Christi or by removal of the large quantities of sediment in the upper end of Lake Corpus Christi as discussed in Section 3.19. However, the net gain in water availability would be small since most of the water to be recharged presently contributes to either the yield of the reservoir system or to the wells around Lake Corpus Christi. Because of the runoff patterns and the control exerted by the two reservoirs, the availability of excess runoff is limited. Only during periods of high rainfall when the reservoirs are full would excess runoff be available. Since this occurs infrequently and only for short periods of time, the benefit of constructing and maintaining recharge facilities in the Goliad outcrop area for only periodic use is difficult to justify at this time.

3.8.6 Environmental Issues

Potential environmental effects from development of local groundwater supplies appear to be limited to the consequences of the following:

- Construction and maintenance well fields, pipelines and associated facilities;
- Subsidence; and
- Construction and operation of desalination facilities, if required to produce potable water (see Alternative L-1, Section 3.7).

Impact Assessment

Direct effects of implementing this alternative can be considered by categorizing the options as follows: 1) Water from existing wells would be either pumped directly into Lake Corpus Christi or its tributaries, or delivered to the O.N. Stevens Water Treatment Plant by a transmission line. 2) A new well field would be constructed near Sinton with several options for delivery; a pipeline to the O.N. Stevens Water Treatment Plant, a pipeline to the San Patricio Municipal Water District's facilities, or delivery via the proposed pipeline from Lake Texana to the O.N. Stevens Water Treatment Plant (Alternative LN-1, Section 3.13). Although

- A gradual increase in dissolved salts may result as the lowering of the piezometric surface in both areas allows increased updip migration of more saline groundwater from the southeast. Additional leakage of more saline water from the interbedded clays may also occur as the piezometric pressure in the sands is lowered.

- Potential environmental issues in both areas include the impacts of pipeline construction and the short-term impacts associated with any well drilling activities. The potential for significant land subsidence in either area is anticipated to be slight, however if the use of long-term pumping were to be implemented, minor subsidence could occur. The potential problems caused by minor subsidence include foundation movements and pipeline, railroad, and highway movements and consequent repairs.

- If long-term use of groundwater were to be implemented, permanent surveying control points should be established and monitored on a regular basis to verify any subsidence effects in the pumping areas.

- Given the lack of significant data with regard to water availability and long-term water quality trends, significant additional groundwater modeling studies are needed if local groundwater is to be considered as a long-term, reliable water source.

- Given the lack of data indicating the availability and location of additional groundwater supplies in the area and considering the unknown dependability of groundwater as a long-term water source, it would be wise to continue the use of local groundwater as an emergency stand-by source to augment the existing surface water supply system during periods of critical drought rather than pursuing groundwater as a primary water source. Upon consideration of the drought history of the CC/LCC System as discussed below, this approach seems to be highly advisable.

  Historically, the CC/LCC System has undergone several severe droughts in which the available water supply has been severely depleted. The Nueces River watershed upstream of the reservoirs is a fairly arid region and studies have indicated the possibility of decreasing trends in the amount of runoff, particularly in the Atascosa watershed. The firm yield and storage characteristics of Choke Canyon and Lake Corpus Christi indicate that, as a system, the reservoirs contain a relatively small amount of conservation storage compared to their contributing drainage area. As a result, the reservoirs can quickly become depleted during drought situations when inflows are reduced.

  By maintaining and/or expanding the existing groundwater supplies as stand-by source, the reliability of the CC/LCC System, on which more than 770,000 people will rely for their water supply in 2050, would be enhanced. While the quality of the groundwater in most cases does not meet the TWC Drinking Water Standards, use in emergency situations would be preferable to water shortages. Long-term effects such as aquifer quality degradation, aquifer overdrafting (i.e., mining), and land subsidence would also be minimized since the groundwater would not be used on a continual basis.

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. For example, in the Kingsville-Bishop area, the species that would be of primary concern include the ocelot, black lace cactus, and slender rush pea, while habitat for the two former species could be present in the areas around Lake Corpus Christi and Alice (Appendix C - Tables 11, 16 and 18).

3.8.7 Implementation Issues

- The ability to implement development of a large well field in the Sinton area will be dependent on obtaining water leases from the landowners. Resolution of issues and negotiation of suitable leases may require a large amount of time. Additionally new leases with landowners in the Lake Corpus Christi/Nueces River area will likely require renegotiation.

- A primary issue in the Sinton area is the impact on existing groundwater supplies in the City of Sinton and St. Paul to the north. The development of a projected new well field in this area will cause significant drawdown in the Sinton and St. Paul areas. The primary impact will be lowering of groundwater levels at the existing wells, resulting in higher pumping costs and potentially reduced yields at the existing supply wells.

- If additional studies are undertaken to evaluate the potential for using the Gulf Coast Aquifer on a more continuous basis and if those studies show favorable results for further development of this resource, then alternative surface water sources with which to blend the poorer quality groundwater should be considered to maintain as high a quality of water as possible for the Corpus Christi service area. This is a particularly important consideration for industrial water users who re-circulate and re-use water as the number of re-use cycles is a function of dissolved mineral concentrations in the water provided to the industries.

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 and diversion structures.
   b. GLO Sand and Gravel Removal Permits.
   c. Coastal Coordinating Council review.
   d. TPWD Sand, Gravel, and Marl permit for river crossings

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

3.9 Use of Groundwater from Campbellton Wells - Carrizo Aquifer (L-3)

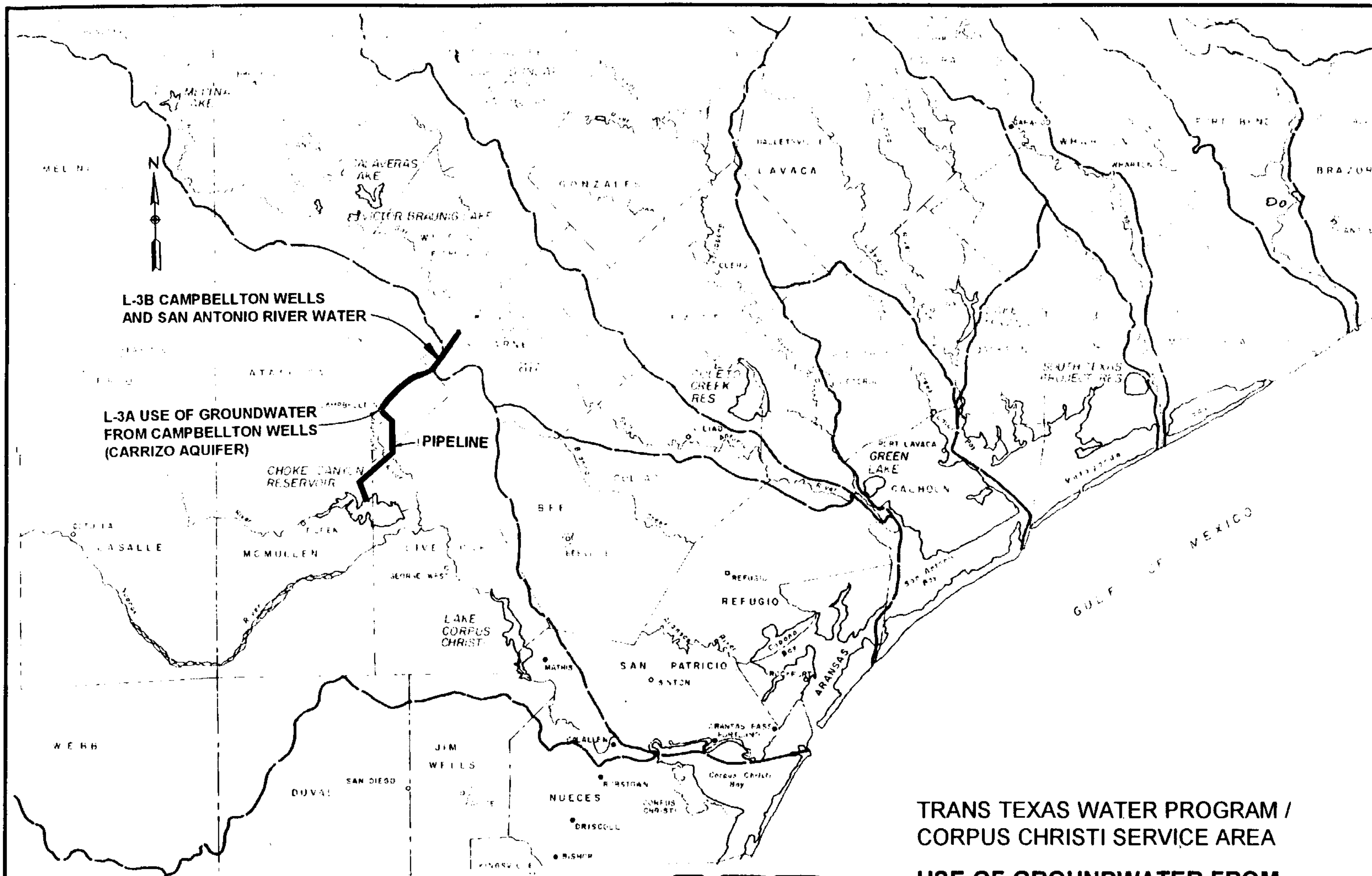
3.9.1 Description of Alternative

The City of Corpus Christi maintains a stand-by groundwater supply system of wells located near the City of Campbellton in Atascosa County. This groundwater system is an integral part of the Corpus Christi Drought Contingency Plan and is used to supplement the CC/LCC System during times of critical drought. In the 1950's drought, water from these wells was pumped into the Atascosa River which flows into Lake Corpus Christi. In Phase I, the general feasibility and additional yield developed from a stand-alone option which considered continuous pumping of the Campbellton wells into Choke Canyon Reservoir was reported. This alternative is included herein as Alternative L-3A. In Phase I studies for the West Central Study Area[1], uses of return flows from City of San Antonio wastewater treatment plants were studied, including diverting return flows from the San Antonio River near Falls City and transferring it to Choke Canyon Reservoir (Alternative L-14, West Central Study Area). Under that alternative, the transfer of water from the San Antonio River would be made to mitigate for yield reductions at Choke Canyon Reservoir resulting from installation of Edwards Aquifer recharge structures in the upper Nueces River Basin. Alternative L-3B in this study considers a combined option whereby the CC/LCC system would receive blended water from both the Campbellton wells and from the San Antonio River to restore and enhance the firm yield of the CC/LCC System.

Supply from the Carrizo Aquifer

At Campbellton, the City of Corpus Christi owns four wells drawing water from the Carrizo Aquifer which underlies a wide belt across south-central Texas as shown in Figure 3.9-1. The aquifer consists of hydrologically connected sand and clay beds of the Wilcox Group and the Carrizo Formation. The aquifer yields fresh to slightly saline water which is acceptable for most uses. The Campbellton well field is within the Evergreen Underground Water Conservation District, which is a special legislative district having jurisdiction in Atascosa,

[1] HDR Engineering, Inc., "Trans Texas Water Program, West Central Study Area, Phase I Interim Report", May, 1994.



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USE OF GROUNDWATER FROM CAMPBELLTON WELLS (CARRIZO AQUIFER) - ALTERNATIVE L-3

HDR Engineering, Inc.

FIGURE 3.9-1

Wilson, and Frio counties, to regulate new wells, well spacing, and transfer of Carrizo water out of the District.

The Campbellton wells were first used during the 1950's drought to supplement the City of Corpus Christi's surface water supply system by pumping groundwater into the Atascosa River. No data were found to document the amount of water which ultimately reached Lake Corpus Christi during the 1950's drought, but local officials report that as much as 90 percent of the water was lost due to channel and evaporative losses. Given the proximity of the Campbellton wells to Choke Canyon Reservoir, Alternative L-3A considers utilizing the Campbellton wells on a continuous stand-alone basis to increase the yield of the CC/LCC System. Alternative L-3B considers combining the Campbellton well water with water from the San Antonio River diverted near Falls City to develop additional firm yield and potentially improve the economies of scale as compared to utilizing only the Campbellton well water.

The TWDB reports 1990 groundwater pumpage from the Carrizo Aquifer in Atascosa County to have been 57,324 acft/yr. TWDB also reports that estimated long-term average annual recharge to the Carrizo for Atascosa County to be 28,730 acre-feet per year. The projections indicate that, if the estimated average annual recharge for Atascosa County is a reasonable estimate, the existing demand on the aquifer is now resulting in the aquifer being overdrafted in Atascosa County. Since the TWDB groundwater data are totals for Atascosa County, it is difficult to quantify the amount of average annual recharge to the aquifer system which is available to one particular area of Atascosa County. Therefore, in addition to considering the TWDB water demand and supply projections referenced above, LBG-Guyton Associates was retained to conduct a preliminary investigation of the aquifer properties around Campbellton and determine if pumpage of the Campbellton wells would result in unreasonable lowering of aquifer water levels.

The result of LBG-Guyton's preliminary investigations (included in Appendix F) indicate that a maximum pumpage of 6 mgd (6,720 acft/yr) can likely be achieved from the City's Campbellton wells on a continual basis without unreasonably lowering water levels in the aquifer. Presently, the artesian head in the aquifer at Campbellton is 50 to 60 feet above ground level. Water levels in the wells after one year of pumpage are expected to be more than 150 feet below the land surface and approximately 200 to 300 feet below land surface after 50 years.

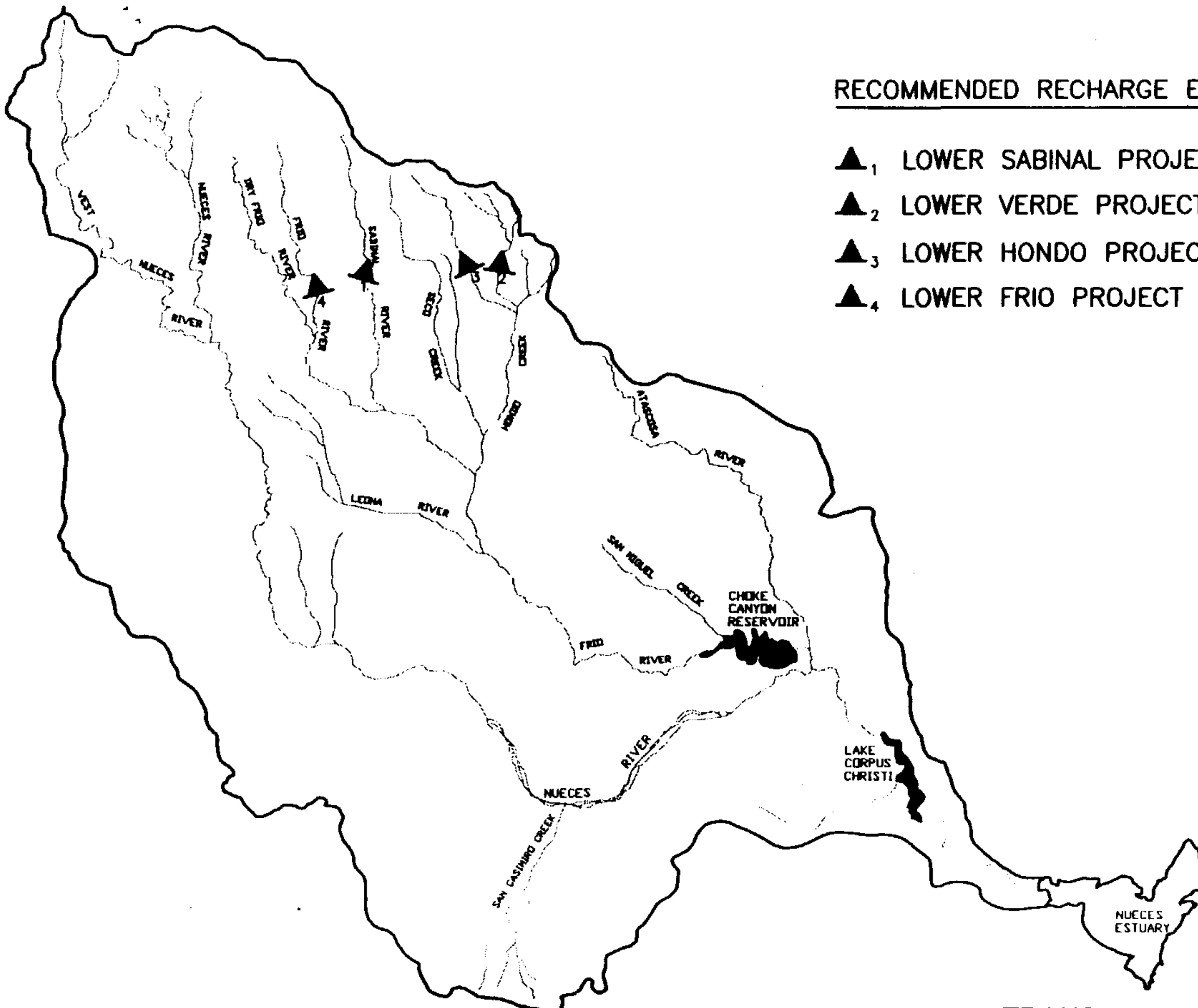
The computer simulation also indicated that water levels north of Campbellton near Jourdanton/Pleasanton and Poteet would be lowered by eight to 15 feet after 50 years. The simulation assumes that water levels will continue to decline in the aquifer at an average rate of two feet per year due to existing overdrafting of the aquifer by others. Therefore, the simulation shows that pumpage of 6 mgd from the Campbellton wells would have a small effect on water levels near Pleasanton/Jourdanton and Poteet during the next 50 years. Based on the results of their investigations, LBG-Guyton estimates that continual pumping of 6 mgd at Campbellton would be a practical 50-year water availability limit.

Supply From San Antonio River for Potential Mitigation of Proposed Recharge Projects

Over the past several years, the Edwards Underground Water District (EUWD) has performed a series of studies to determine the feasibility of constructing Edwards Aquifer recharge enhancement projects within the Nueces River Basin. Phase IV-A of these studies was completed in June 1994, and it identified a recommended program of four recharge projects to be located directly over the recharge zone on the Sabinal and Frio Rivers and on Verde and Hondo Creeks. All four of their projects are located upstream of Choke Canyon Reservoir. Relative locations of the recharge enhancement projects, CC/LCC System and Nueces Estuary within the Nueces River Basin are shown in Figure 3.9-2.

Although the four projects are small to moderately sized and are geographically distant from the CC/LCC System, enhanced recharge from these projects will reduce the firm yield of the CC/LCC System. Estimated recharge enhancement from the four projects averages 44,353 acft/yr over the long-term (1934-89) and 8,632 acft/yr during the drought (1947-56). Estimated maximum reductions in CC/LCC System firm yield under Phase II and Phase IV of the City of Corpus Christi reservoir system operation plan are 7,582 acft/yr (4.2 percent) and 1,355 acft/yr (0.7 percent), respectively for year 1990 reservoir conditions. These are considered to be maximums in that they do not consider potential increases in spring flows at Leona Springs, which will result from the enhanced recharge.

To mitigate for the reduced CC/LCC System yield, this alternative considers diverting a portion of the San Antonio Water System reclaimed water from the San Antonio River near Falls City and transferring it to Choke Canyon Reservoir.



TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

HDR Engineering, Inc.

EDWARDS AQUIFER RECHARGE ENHANCEMENT PROJECTS IN NUECES RIVER BASIN

FIGURE 3.9-2

Currently, San Antonio discharges return flows[2] of about 135,000 acft/yr into streams which flow into the San Antonio River. A portion of the return flows from the San Antonio area are used to supply makeup water for steam-electric cooling at Braunig and Calaveras lakes, and to the Central East Infrastructure Project (i.e. "Tunnel Project"). The combined permitted consumptive use at Braunig and Calaveras lakes is 49,000 acft/yr and the Tunnel Project is estimated to consume about 18,000 acft/yr for a total annual demand of 67,000 acft/yr. Other potential alternatives to reuse return flows are under consideration by entities in the San Antonio area. However, the probability that a sufficient quantity of water could be made available for mitigation purposes is good.

Description of System

Analyses of two alternatives were performed beginning with a smaller system consisting of transferring water available from the Campbellton wells only (Alternative L-3A). A larger system resulting from combining the water available from San Antonio return flows diverted at Falls City with the Campbellton well water was also studied (Alternative L-3B).

Alternative L-3A: Groundwater from Campbellton Well Field

The water supply augmentation available to Choke Canyon for Alternative L-3A is a constant 6 mgd (6,720 acft/yr) pumped from the Carrizo-Wilcox Aquifer at Campbellton. Existing wells owned by the City of Corpus Christi would be utilized and the major new facilities needed for this alternative include a well field collection system, storage facility, pump station, transmission pipeline to Choke Canyon Reservoir, and discharge structure at the reservoir.

Alternative L-3B: Campbellton Well Field Combined with San Antonio River Water

The water supply augmentation available to Choke Canyon for Alternative L-3B is the 6 mgd (6,720 acft/yr) constant pumpage from the Campbellton wells combined with pumping

2 Return flows for Dos Rios, Salado Creek, and Leon Creek WWTPs only.

8,400 acft/yr of San Antonio area return flows diverted from the San Antonio River near Falls City for a total of 15,120 acft/yr.

Diversion amounts needed to fully restore the firm yield of the CC/LCC System due to the construction of the four recharge dams range from a low of 1,940 acft/yr to a high of 10,830 acft/yr, depending upon the reservoir operating policy of the CC/LCC System. These amounts include consideration of channel and evaporation losses in the CC/LCC System. The 15,120 acft/yr of combined water would more than restore the impacts due to the recharge projects under either the Phase IV or Phase II operating policy.

The major facilities needed for Alternative L3-B include a small diversion structure in the San Antonio River near Falls City, surface water intake and pump station, transmission pipeline to Campbellton, where the river water would be blended with the well water and tranported by pipeline to Choke Canyon Reservoir, well field collection system, storage facility, and pump station at the Campbellton well field, and discharge structure in the reservoir.

3.9.2 Available Yield

Alternative L-3B: Groundwater from Campbellton Well Field

The increases in firm yield of the CC/LCC System resulting from the additional 6 mgd of groundwater are presented in Table 3.9-1. The increases range from 3,800 acft/yr for 1990 conditions and 4,800 acft/yr for 2050 conditions. This represents approximately 57 percent (1990 conditions) and 71 percent (2050 conditions) of the 6,720 acft/yr of water pumped annually into Choke Canyon Reservoir from the well fields in Campbellton.

Alternative L-3B: Campbellton Well Fields Combined with San Antonio River Water

For the combined supply, the increases in firm yield are presented in Table 3.9-2. An initial set of model analyses were performed to determine the CC/LCC System firm yield under the City's Phase IV operating policy and 1995 TNRCC Order. Under these conditions, a combined division amount of 15,120 acft/yr would provide an increase in firm yield of 10,500 acft/yr under 1990 and 2050 conditions. When the impact of the four proposed recharge projects are considered in conjunction with the augmentation water, the firm yield of the system under the 1995 TNRCC Release Order is increased by only 9,000 acft under 1990 sediment

Table 3.9-1
Summary of CC/LCC System Firm Yield with 6,720 acft/yr from Campbellton Wells (L-3A)

Reservoir Sedimentation Year	CC/LCC Firm Yield Without Augmented Supply (acft/yr)	CC/LCC Firm Yield with 6 mgd from Campbellton Wells (acft/yr)	Increase in CC/LCC Firm Yield Due to Campbellton Wells[1] (acft/yr)
1990	191,800	195,600	3,800
2050	176,000	180,800	4,800

(1) Supply resulting from 6,720 acft/yr pumped from Campbellton wells under Phase IV Operating Policy and 1992 TNRCC Interim Order.

Table 3.9-2
Summary of CC/LCC System Firm Yield Increases with 6,720 acft/yr from Campbellton Wells, 8,400 acft/yr from the San Antonio River (L-3B), and Considering Impacts of Recharge Reservoirs

Reservoir Sedimentation Year	Total Increase in CC/LCC Firm Yield Due To Augmented Supply of 15,120 acft/yr Without Recharge Reservoirs (acft/yr)	Total Increase in CC/LCC Firm Yield Due to Combined Augmentation With Rechagre Reservoirs in Place (acft/yr)	Change in Firm Yield Due to Recharge Reservoirs (acft/yr) (Decrease)
1990[1]	10,500	9,000	(1,500)
2050[1]	10,500	9,500	(1,000)
1990[2]	10,000	5,500	(4,500)
2050[2]	10,000	5,000	(5,000)

(1) Results based on Phase IV Operating Policy and 1995 TNRCC Release Orders.
(2) Results based on Phase II Operating Policy and 1995 TNRCC Release Orders.

conditions and by a net amount of 9,500 acft/yr under 2050 sediment conditions, as shown in Table 3.9-2. This represents a change in yield, due to the recharge projects of 1,500 acft/yr and 1,000 acft/yr under the 1990 and 2050 sediment conditions, respectively, for the Phase IV Operating Policy.

An additional set of model analyses were performed to determine firm yield increases under the City's Phase II operating policy and 1995 TNRCC Release Order. Under these conditions, a combined diversion amount of 15,120 acft/yr would provide an increase in firm yield of 10,000 acft/yr under 1990 and 2050 sediment conditions (Table 3.9-2). When the impact of the four proposed recharge projects is considered, the firm yield of the system is increased by a net amount of 5,500 acft/yr under 1990 sediment conditions and by a net amount of 5,000 acft/yr under 2050 sediment conditions, as shown in Table 3.9-2. The impact of the recharge dams under the City's Phase II operating policy with the augumentation water is 4,500 acft/yr and 5,000 acft/yr under 1990 and 2050 sediment conditions, respectively.

3.9.3 Environmental Issues

Introduction

Environmental issues related to transferring groundwater from Campbellton Wells to Choke Canyon Reservoir are as follows:

- Effects related to pipeline construction and maintenance;
- Effects related to increased flows to Choke Canyon Reservoir;
- Effects related to wastewater return flows to Nueces Bay and Estuary; and
- Effects related to construction of a small diversion dam on the San Antonio River (Alternative L3-B only).

Methods used to develop this section, including mapping, searches of available literature and databases, and field reconnaissance are described in the Environmental Overview (Section 3.0.2).

Impact Assessment

The Campbellton wells in Atascosa County would be connected by pipeline to Choke Canyon Reservoir through Live Oak and McMullen Counties. The estimated 17 mile pipeline would, to the extent possible, follow existing ROW along State Highway 99 from Campbellton to Choke Canyon (Figure 3.9-1). A description of the region is presented in the Environmental Overview (Section 3.0.2). Acreage impacted during construction and for maintanance following completion of the pipeline would be 292 acres and 84 acres respectively.

Increased flows to Choke Canyon would raise the average operational level of the lake only slightly, about three-tenths of a foot, while downstream flow effects probably would be undetectable. Blending Carrizo Aquifer water with water from Choke Canyon and Lake Corpus Christi will mitigate the somewhat elevated sodium levels characteristic of the aquifer. Water quality changes in the reservoirs would be slight to undetectable and not expected to affect aquatic or marine life.

The predominant habitat type of concern with respect to this alternative is mesquite invaded pasture. The pipeline route traverses upland mesquite-blackbrush and mesquite-granjeno parks east of the Atascosa River and mesquite-blackbrush west of the Atascosa River until it terminates at Choke Canyon Reservoir (TPWD, 1984). Pipeline construction would affect an estimated 249 acres of brushland and 43 acres of cropland and grasslands if it is constructed entirely outside of the existing ROW's. 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 a conventional open-cut trench construction in a 100-foot construction corridor that would affect about 5,000 sq. ft. of riverine wetland and the outflow structure construction at Choke Canyon would disturb approximately 2,500 square feet of littoral wetland. A pair of crested caracaras (*Polyborus plancus*), a rare to common resident in South and South-central Texas, were observed perched in a tree during the spring reconnaissance. Protected species that may occur in the project vicinity are listed in Appendix C - Tables 2 , 14 and 15. There are no recorded occurrences of protected species within the proposed pipeline corridor, some dense brushland habitat suitable for the endangered ocelot (*Felis pardalis*) 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) may be found in the Atascosa River crossing corridor and the cove at Choke Canyon. 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 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 reticulatus*).

The slight increase in inflows to the Nueces estuary from the return flows enhanced by ground water 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.

In addition to the structures needed to supply Choke Canyon Reservoir with water from Cambellton wells (L-3A), combining Cambellton well water with return flows from the San Antonio River (L-3B) would require construction of a diversion facility in the San Antonio River near Falls City and a 29 mile transmission line to Cambellton wells. This alternative is entirely within the South Texas Plains Ecoregion and the corresponding South Texas Plain vegetational area (Section 3.0.2).

The transmission line corridor is within a wide band of mesquite-blackbrush brushland and mesquite-granjeno woods surrounded by cropland. Pipeline installation would affect 492 acres during construction and 141 acres would be maintained free of woody vegetation for the life of the project. Mesquite-blackbrush brushlands are the main vegetational community (70%) in the proposed project corridor. The brushlands are dominated by honey mesquite, blackbrush and other thornbrush species including lotebush, ceniza, whitebrush, agarito, granjeno, yucca, Texas pricklypear, bluewood, and desert yaupon. The herbaceous layer is a mixture of purple three-awn, pink pappusgrass, hairy tridens, hairy grama, coldenia, and dogweed.[3] The

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

mesquite-granjeno woods occupy a central band between the brushland corridor which is more typical of the South Texas Plains of Kleberg and Jim Wells Counties. This dense woods is characterized by honey mesquite, granjeno, retam, bluewood, woollybucket bumelia, catclaw, tasajillo, lotebush, whitebush, and desert yaupon. The woods are about 30 percent of the total area within the corridor. The brushland and the relatively dense woods provide the best wildlife habitat for endemic species such as the regionally important and protected jaguarundi, ocelot and Texas tortoise. An estimated 240 vertebrate species utilize this habitat type, including 5 amphibians, 45 reptiles, 150 birds and 41 mammals.[4] Depending on the transmission line alignment, construction impact may be minimized or avoided by locating in less sensitive cropland and cattle-grazed upland brushland whenever possible. Construction impacts across rivers and streams should be minimized. Although water quality and biota of the Nueces and San Antonio Rivers are similar, an analysis of potential effects arising from water quality differences or from the introduction of organisms not native to the Nueces Basin should be conducted.

Although the Natural Heritage Program does not report any endangered or threatened species directly along the proposed pipeline corridor, some have been reported in the vicinity (Appendix C, Tables 2 and 12). Many of these, such as the jaguarundi, ocelot, Texas tortoise, indigo snake, reticulated collared lizard, Texas scarlet snake, and Texas horned lizard appear to be dependent on thorn bush and woods habitat. The Texas garter snake, black-spotted newt, sheep frog, and lesser Rio Grande siren may be present in wetland habitats. Surveys for protected species or other biological resources of restricted distribution, or other importance, would be conducted within the proposed construction corridor where potential habitat is present.

3.9.4 Water Quality and Treatability

Carrizo Aquifer Water Quality

Groundwater quality data obtained from the TNRCC and TWDB indicate total dissolved solids of groundwater pumped near Campbellton generally range from 500 to 900 mg/L. Chlorides and sulfates are generally on the order of 50 to 60 mg/L. The water has a relatively

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[4] Blair, W. Frank. 1950. "The Biotic Provinces of Texas," Texas Journal of Science, Bol 2, No. 1, pp 93-112.

high temperature, reportedly from 100 to 140 degrees Fahrenheit, and is primarily a sodium bicarbonate type. The sodium content of the water is typically around 200 to 300 mg/l and may present a problem to persons with high blood pressure. Blending of the Carrizo Aquifer water with water from the CC/LCC System will likely mitigate the high sodium levels. As with most groundwater sources, there is the possibility of quality degradation over time with prolonged pumpage. If this alternative is pursued, then a more detailed analysis of water quality should be performed in subsequent Trans-Texas studies.

San Antonio River Quality

Located downstream from the San Antonio area, diversions at Falls City will likely have somewhat greater increased levels of organic matter due to the effects of wastewater return flows and urban runoff. The effects of these contaminants will largely be eliminated by blending the relatively small volume of river water (i.e., 8,400 acft/yr) with Carrizo Aquifer (i.e., 6,720 acft/yr) and Choke Canyon Reservoir with a storage volume of about 700,000 acft.

Although the four secondary water quality constituents reviewed for this study in the San Antonio River[5] meet Secondary Drinking Water Standards, the San Antonio River has the highest and most variable concentrations compared to the other surface water alternatives (Appendix D). However, blending of the San Antonio River water with Carrizo Aquifer water and with Choke Canyon Reservoir water will significantly dampen the variability. Specific water quality assessments and compatibility studies should be completed in later phases of the Trans-Texas program if this alternative should continue to be considered. Appendix E contains further information on water treatment issues.

3.9.5 Engineering and Costing

Alternative L-3A: Augmentation from Campbellton Well Field

For this alternative, water would be pumped from the Carrizo-Wilcox Aquifer at the Campbellton well field, and conveyed by pipeline to Choke Canyon Reservoir. The pumping

[5] Using data from the USGS gage at Goliad, about 84 miles downstream of the possible diversion location at Falls City. The four constituents analyzed are chlorides, hardness, TDS, and sulfates.

rate from the aquifer would generally be uniform throughout the year. No treatment of the Carrizo aquifer water is anticipated to be needed prior to discharging in the reservoir. The major facilities required to implement this alternative are:

Well Field Collection System
Storage Facility
Pump Station
Transmission Pipeline to Choke Canyon Reservoir
Discharge Structure at Reservoir

The well field collection system and transmission pipeline are sized to deliver 6 mgd (9 cfs), requiring an 18 inch diameter pipeline. The operating cost was determined for the total raw water static lift of 150 feet and an annual water delivery of 6,720 acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $700,000 (Table 3.9-3). The cost estimate includes payment to the City of Campbellton as compensation for the lowering of the water table in the vicinity of the wells. The payment was calculated by estimating the costs of power required to pump municipal water to the ground surface and accounting for increased water table depths. Operation and maintenance costs, including power total $490,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $1,200,000. For an annual firm yield of 4,800 acft, the resulting annual cost of water is $250 per acft.

<u>Alternative L-3B: Augmentation from Campbellton Well Field Combined with Return Flows</u>

For this alternative, return flows from the San Antonio area would be combined with Carrizo Aquifer water from wells owned by the City of Corpus Christi near Campbellton. The return flows would be diverted from the San Antonio River near Falls City and pumped to Campbellton and be blended with well water. The blended water would then be conveyed by pipeline to Choke Canyon Reservoir. Return flows would be pumped from the San Antonio River at an intake located in the pool formed by a small new channel dam. The diversion rate would be about 17 cfs (1,000 acft/month) requiring a transmission pipeline size of 30 inches. No treatment of the water is anticipated to be needed prior to discharging in the reservoir. The major facilities required to implement this alternative are:

Table 3.9-3
Cost Estimate for Water Supply Augmentation of Choke Canyon/Lake Corpus Christi System (L-3)
(Mid-1995 Prices)

Item	Alt. L-3A Augmentation from Campbellton Well Field	Alt. L-3B Augmentation from Campbellton Well Field Combined with Return Flows	
Capital Costs			
Channel Dam and Intake			$2,070,000
Pump Stations	$660,000		2,430,000
Well Field Collection System and Storage Facility	1,130,000		1,130,000
Pipelines	3,560,000		14,160,000
Subtotal	$5,350,000		$19,790,000
Engineering, Contingencies, and Legal Costs	$1,600,000		$5,350,000
Land Acquisition	150,000		330,000
Environmental Studies and Mitigation	150,000		300,000
Interest During Construction	270,000		520,000
Total Project Cost	$7,520,000		$26,290,000
Annual Costs			
Annual Debt Service	$700,000		$2,460,000
Compensation to Area Well Owners for Water Table Reductions	10,000		10,000
Annual Operation and Maintenance (Excluding Power)	70,000		270,000
Annual Power Cost	420,000		940,000
Total Annual Cost	$1,200,000		$3,680,000
		Phase IV	Phase II
Total 2050 Yield Increase (acft/yr)	4,800 acft/yr	10,500[2]	10,000[2]
Annual Cost of Water	$250/acft	$350/acft	$368/acft
Percentage of Total Yield Available To Corpus Christi Service Area After Considering Impact of Recharge Projects	n/a	90%	50%

[1] Yield increase based on Phase IV reservoir operating policy and 1992 TNRCC Interim Order.
[2] Yield increase based on 1995 TNRCC Release Order.

Small Diversion Dam
Surface Water Intake and Pump Station
Transmission Pipeline to Campbellton Well Field
Well Field Collection System
Storage Facility at Well Field
Well Field Pump Station
Transmission Pipeline to Choke Canyon Reservoir
Discharge Structure at Reservoir

The well field collection system and transmission pipeline are sized to deliver 6 mgd (9 cfs), requiring an 18 inch diameter pipeline. A combined pumping rate of up to 26 cfs requires a 30 inch diameter transmission pipeline from Campbellton to Choke Canyon Reservoir. The operating cost was determined for the total raw water static lift of 145 feet and an annual water delivery of 15,120 acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $2,460,000 (Table 3.9-3). The cost estimate includes payment to the City of Campbellton as compensation for the lowering of the water table in the vicinity of the wells. The payment was calculated by estimating the costs of power required to pump municipal water to the ground surface and accounting for increased water table depths. Operation and maintenance costs, including power total $1,210,000. No annual payments to the San Antonio Water System (SAWS) for purchase of the diverted return flows are included as it is anticipated that this water would be made available at no charge as mitigation for the recharge projects. The annual costs, including debt repayment, interest, and operation and maintenance, total $3,680,000.

Unit costs of water for this alternative have been figured on the basis of year 2050 reservoir sediment conditions for both the Phase IV operating policy and the Phase II operating policy. As shown in Table 3.9-3, the unit cost of water under the Phase IV policy is $350 per acft/yr.

Provided contractual arrangements could be put in place to jointly finance this alternative, the proportion of the project benefitting the Corpus Christi Service Area would be 90 percent under the Phase IV policy (based on a total yield increase of 10,500 acft/yr and a net increase of 9,500 acft/yr in yield available to the Corpus Christi Service Area). Under the Phase II operating policy, the proportion of the project benefiting the Corpus Christi Service Area would be 50 percent (based on a total yield increase of 10,000 acft/yr and a net increase of 5,000 acft/yr in yield available to the Corpus Christi Service Area).

3.9.6 Implementation Issues

Requirements Specific to Use of the Campbellton Well Field (L-3A and L-3B)

1. Authorization from Evergreen Underground Water Conservation District for transfer of water out of the district may be necessary.

2. Potential compensation to City of Campbellton for water table reduction may be desirable.

3. Necessary Permits:
   a. Water rights permits amendments for the CC/LCC System may be required for use of the increased yield available from the augmented water supply.
   b. TNRCC Bed and Banks Permit for use of the affected reaches of the Frio and Nueces Rivers will be required.

4. Water compatibility testing, including biological and chemical characteristics will need to be performed.

Requirements Specific to Diversion of San Antonio Return Flows (L-3B)

1. Water demand reduction programs by the San Antonio Water System may reduce the quantity of return flows available for transfer to the CC/LCC system.

2. Use of return flows must be negotiated with the San Antonio Water System. Use arrangements should consider drought contingency planning that may result in a reduction of return flows by the San Antonio Water System.

3. Water compatibility testing, including biological and chemical characteristics will need to be performed.

4. Necessary Permits:
   a. Water rights permits amendments for the CC/LCC system may be required for use of the increased yield available from the augmented water supply.
   b. TNRCC Bed and Banks Permit for use of the affected reaches of the San Antonio, Frio and Nueces Rivers.

Requirements Specific to Pipelines (L-3A and L-3B)

1. Necessary Permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings and diversion structures.
   b. GLO Sand and Gravel Removal permit.
   c. Coastal Coordinating Council review.
   d. TPWD Sand, Gravel, and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads.
   b. Creeks and rivers.
   c. Other utilities.

3.10 Municipal Wastewater Reuse (L-4)

A part of the quantity of water that is used for municipal purposes is consumed and a part is used for waste removal from homes and commercial establishments. The latter part (wastewater) is collected, treated to acceptable standards as specified by regulatory agencies (TNRCC and U.S. Environmental Protection Agency), and is either reused for nonpotable 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 which flow into the bays and meet a part of the freshwater needs of the Nueces Estuary. The purpose of this section is to describe wastewater reuse options and present estimates of the quantities of water supply that may be made available through: (1) Wastewater reuse for nonpotable purposes; (2) Wastewater diversions to the Nueces Delta to enhance biological productivity of estuarine marshes (in comparison to present practice of direct discharge of wastewater into the bays and into streams that flow into the bays); (3) Reuse of Northshore municipal wastewater by industry; (4) Wastewater flows from imported water; and (5) Discussions of wastewater reuse and water conservation effects upon estuarine inflows. Both reuse and diversion to the Delta present opportunities to increase the Corpus Christi area water supply. In the Interim Order[1] of March 9, 1992, the TNRCC established temporary operational procedures for the City's reservoirs which 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 locations where increased biological productivity could justify an inflow credit computed by multiplying the amount of discharge by a number greater than one.

On April 28, 1995, the TNRCC replaced the 1992 Interim Order with an Agreed Order (1995 Agreed Order) amending the CC/LCC operational procedures. The 1995 Agreed Order directed the Nueces Estuary Advisory Council to continue studying the development of a methodology using a multiplier system for granting credits for specific return flows that increase biological productivity. These conditions are very important and must be considered in water

[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 Texas Natural Resource Conservation Commission), Austin, Texas, March 9, 1992.

supply planning, water reuse options, and water management programs of 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.

3.10.1 Inventory and Location of Existing Wastewater Sources

According to a 1991 survey, municipal wastewater discharges of freshwater effluent in the Corpus Christi area totaled 27.59 mgd or 30,955 acft/yr (Table 3.10-1). Industrial wastewater discharges of freshwater were 15.76 mgd or 17,683 acft/yr (Table 3.10-1), with the total of municipal and industrial discharges to the Nueces Estuary in 1991 being reported at 43.35 mgd or 48,638 acft/yr. The location of major permitted discharges into the Nueces Estuary are indicated in Figure 3.10-1. The projected quantities of potential municipal and industrial wastewater in 2050, as calculated from projected M&I water use in 2050, are 75,687 and 43,223 acft, respectively, for a total of 118,910 acft annually (Table 3.10-2). These future quantities are gross estimates based on the historical ratio of total return flows to total water use and this ratio has averaged about 47 percent in the 1980's. The potential reuses of this resource for industrial and estuarine needs are discussed below.

3.10.2 Wastewater Reuse for Municipal and Industrial Purposes

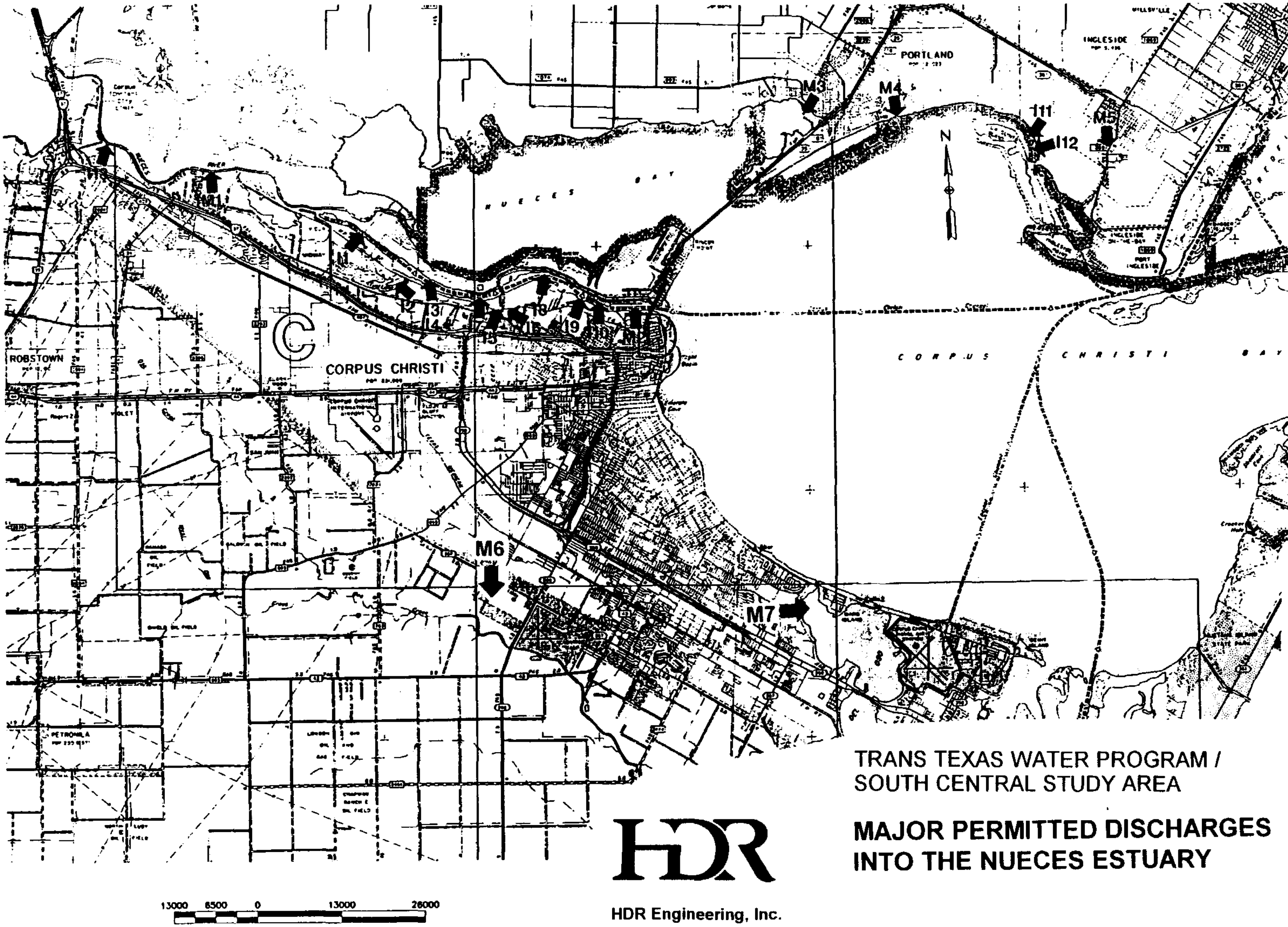
Operators of many of the municipal and industrial facilities in the Corpus Christi area were contacted to determine past, present and planned water reuse plans. The 1984 drought forced Corpus Christi and its water customers to adopt strict water conservation and reuse measures. The operational plans of interest were those in use during the 1984 drought period, current plans of action, and future plans.

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 City water use by diverting a portion of their treated wastewater from its

Table 3.10-1
Summary of Major Permitted Wastewater Discharges into the Corpus Christi and Nueces Bay System

Designation	Facility	Actual Flow (mgd)
M1	City of Corpus Christi Allison WWTP	2.80
M2	City of Corpus Christi Broadway WWTP	6.00
M3	City of Portland WWTP	1.11
M4	City of Portland Northshore WWTP	0.05
M5	City of Ingleside WWTP	0.33
M6	City of Corpus Christi Westside WWTP	3.30
M7	City of Corpus Christi Oso WWTP	14.00
	Total Municipal Discharges	**27.59**[a]
I1	Koch Refining Company	2.20
I2	Champlin Refining and Chemicals, Inc. (West)	0.29
I3	OxyChem Petrochemicals-Corpus Christi	1.10
I4	Valero Refining Company	2.22
I5	Javelina Company	0.05
I6	Coastal Refining and Marketing, Inc.	1.82
I7	Encycle/Texas, Inc.	0.50
I8	American Chrome and Chemicals, Inc.	0.19
I9	Champlin Refining and Chemicals, Inc. (East)	2.40
I10	Southwestern Refining Co., Inc.	1.44
I11	E.I. DuPont de Nemours and Company	1.40
I12	Occidental Chemical Corporation-Ingleside	1.80
I13	Central Power and Light Lon C. Hill Plan	0.35
	Total Industrial Discharges	**15.76**[b]
TOTAL DISCHARGES		**43.35**[c]

M = Designates Municipal Wastewater Discharge
I = Designates Industrial Discharge
Average daily wastewater discharges, in million gallons per day, as of June, 1991.
Naval Air Station discharges (0.75 mgd) and Gregory discharges (0.15 mgd) are not included.
[a] 27.59 mgd equals 30,955 acft/yr.
[b] 15.76 mgd equals 17,683 acft/yr.
[c] 43.35 mgd equals 48,638 acft/yr.
Source: "Regional Wastewater Planning Study -- Phase I, Nueces Estuary," City of Corpus Christi, Port of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, and TWDB, Austin, Texas, 1991.



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TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

MAJOR PERMITTED DISCHARGES INTO THE NUECES ESTUARY

FIGURE 3.10-1

Table 3.10-2
Projections of Municipal and Industrial Wastewater Return Flows from Use of Water Supplied by the Corpus Christi System
Trans-Texas Water Program

Year	Projected Water Use (acft)[1]			Projected Potential Wastewater Return Flows (acft)[2]		
	Municipal	Industrial	Total	Municipal	Industrial	Total
1990	88,475	43,611	132,086	--	--	--
1991[3]	--	--	--	30,955[3]	17,682[3]	48,638[3]
2000	103,111	57,776	160,887	51,127	27,489	75,616
2010	112,763	64,948	177,711	53,164	30,360	83,524
2020	120,696	74,254	194,950	58,320	33,306	91,626
2030	131,457	83,145	214,602	64,199	36,663	100,862
2040	142,255	91,688	233,943	69,985	39,968	109,953
2050	153,053	100,231	253,284	75,687	43,223	118,910

[1] From Table 2.4-3.
[2] Calculated at the rate of 47% return flows.
[3] From survey of wastewater permit holders, with discharges to Corpus Christi and Nueces Bay system.

wastewater treatment plants (WWTPs) to some public facilities for irrigation purposes; i.e., for golf course and park irrigation. For example, during 1991 and 1992, wastewater reuse for golf course and baseball park irrigation was about 252 million gallons or 770 acft/yr. Interviews with City of Corpus Christi wastewater personnel clarified that this practice has some limitations in that the need for wastewater for irrigation is not continuous. Thus, wastewater is not re-used in 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.

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 CC/LCC water needed for these purposes. However, this plan was severely limited due to the facts that: (1) The wastewater treatment plants are not conveniently located and the discharge is not readily available to industrial plants, requiring the construction of extensive force mains to deliver the wastewater to these facilities; and (2) 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.[2]

Since the industrial facilities are large consumers of both raw and treated water from the CC/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 reuse options studied by industry for reuse of their own wastewater have been implemented. Section 3.6 contains additional information about industrial water use and industrial water conservation.

The quantity of wastewater reuse potential for golf course and public park irrigation cannot be accurately calculated based on the limited data available; however, it is estimated to be a small percentage (less than 4 to 5 percent) of the total municipal wastewater flows. Reuse for consumptive purposes such as irrigation conflicts directly with estuarine inflow objectives under the TNRCC order. The possibility of diverting municipal wastewater flows to the Nueces Delta to increase estuarine productivity, and thereby reduce the need for CC/LCC System releases for those purposes appears to offer an environmentally attractive way to increase the supply of water from the CC/LCC System. This option is presented and described below.

3.10.3 Choke Canyon/Lake Corpus Christi Yield Recovery through Diversion of Corpus Christi Wastewater Effluent to Nueces Delta

On March 9, 1992, the TNRCC issued an Interim Order which established operational procedures and a monthly schedule of desired inflows to Nueces Bay to be comprised of releases, spills, and return flows from the CC/LCC System (see Section 2.5.2 of this report for description of the March 9, 1992, TNRCC Interim Order). 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

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

than one[3]. Studies are being made of the 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. The river bypasses the Nueces Delta and flows directly into Nueces Bay. Studies to date show that diversions of both river water and treated wastewater through the Nueces Delta to Nueces Bay 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[4].

Surveys have been made of the locations and quantities of municipal and industrial wastewater being discharged into Nueces and Corpus Christi Bays and into streams that empty into the Bays, namely the Nueces River downstream of Calallen Dam, and Oso Creek. In previous studies, costs were estimated for three river diversions, 11 wastewater effluent diversions, and nine combined river and wastewater effluent diversion projects, each of which would relocate return flows from their present discharge points to points in the Nueces Delta. Additionally, in a study[5] performed in 1993, estimates were made of the increase in yield of the CC/LCC System for each river and wastewater diversion alternative under the 1992 Interim Order, considering the productivity increases from river and wastewater effluent diversions to the Nueces Delta (i.e., for river diversions the productivity increase factor used was three and for wastewater effluent diversions the factor was five). Using the cost and yield data under the 1992 Interim Order, the diversion alternative which provided the highest yield recovery and lowest cost per acft of yield recovered was the alternative which uses 8.8 mgd of wastewater from the Allison and Broadway wastewater treatment plants and a 70 mgd capacity river diversion from Calallen Reservoir to the Nueces Delta.

For this study, this alternative was re-evaluated under the 1995 Agreed Order (see Appendix O) with a productivity factor of 3.0 for freshwater diversions to the Nueces Delta and

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[3] 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.

[4] HDR Engineering, Inc., "Regional Wastewater Planning Study -- Phase II, Nueces Estuary," prepared for the City of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, and Texas Water Development Board, Austin, Texas, June, 1993.

[5] Ibid.

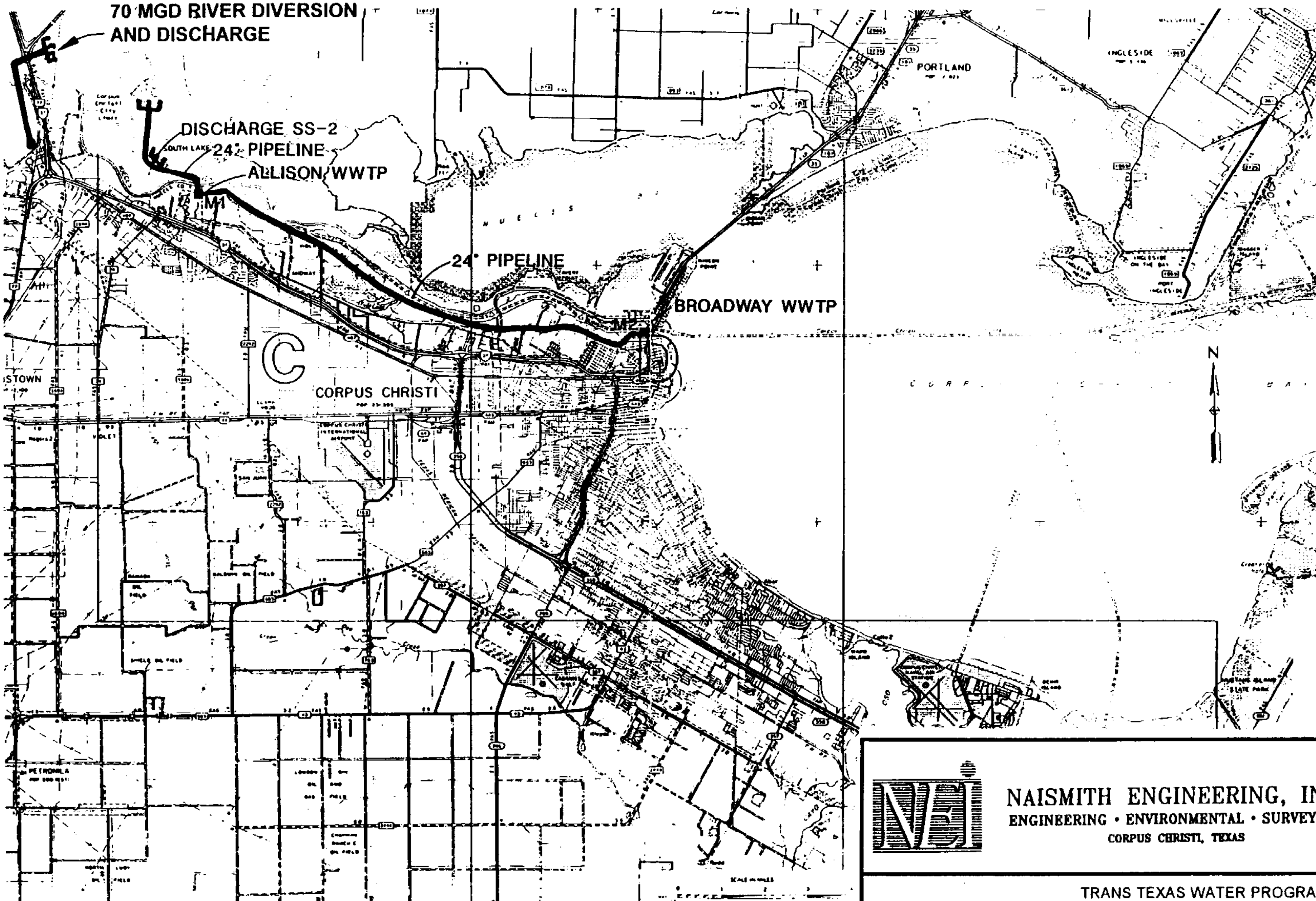
5.0 for wastewater diversions to the delta. This alternative (Alternative L-4A) produces an average annual yield increase over the 2000 to 2050 time period of 5,500 acft/yr as indicated in Table 3.10-3. Two additional alternatives were analyzed to determine the potential increases in system yield for the same 2000 to 2050 timeframe. For Alternative L-4B, the 70 mgd river diversion from Calallen Reservoir pool was eliminated and only the 8.8 mgd of wastewater from the Allison and Broadway plants were included with a productivity factor of five. The yield increase provided by this alternative averaged 3,000 acft/yr as shown in Table 3.10-3. Finally, for Alternative L-4C, only the 8.8 mgd of wastewater from Allison and Broadway was considered and the productivity factor reduced to 1.0 to determine the sensitivity of the alternative to the productivity factor. The yield increase provided by this option averaged only 1,100 acft/yr as shown in Table 3.10-3.

Table 3.10-3
Summary of Average Annual Yield Recovered for Various Wastewater Transfer and River Diversion Alternatives

Alternative	Diversion or Transfer Capability		Biological Productivity Factors		Average Annual Yield Recovered (acft)
	River Diversion (mgd)	Allison & Broadway WWTP (mgd)	River Water	Wastewater	
L-4A	70	8.8	3	5	5,500
L-4B	0	8.8	---	5	3,000
L-4C	0	8.8	---	1	1,100

Engineering and Costing for Diversion of Wastewater Effluent to Nueces Delta

Under alternatives L-4A, L-4B and L-4C, the Broadway WWTP discharge of approximately 6.0 mgd would be pumped to the Allison WWTP and blended with the Allison discharge in new ground storage tanks. The combined discharge (about 8.8 mgd) would then be pumped to South Lake and to the upper Rincon Bayou area as shown on Figure 3.10-2. The major facilities required common to all of these alternatives are:



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WASTEWATER DISCHARGE DIVERSION PIPELINE ALTERNATIVE L-4

FIGURE 3.10-2

- Improvements at Broadway WWTP, including ground storage tank and transfer pumps;
- Improvements at Allison WWTP, including ground storage tank and transfer pumps;
- Wastewater Force Mains;
- Discharge Spreader System.

Additionally for Alternative L-4A, a 70 mgd pump station is required at the Calallen Reservoir pool and a pipeline would be needed to transfer the raw river water to the Nueces Delta as shown in Figure 3.10-2.

Estimated project costs for components of the three alternatives are provided in Table 3.10-4 and the estimated total project costs vary from $7,700,000 to $10,236,000. Total annual costs, including debt service, O&M, and power, totals $1,084,000 for Alternative L-4A, and $781,000 for Alternative L-4B and Alternative L-4C. For an average annual firm yield benefit from the CC/LCC System of about 5,500 acft/yr for Alternative L-4A, the annual unit cost is $197 per acft. For Alternative L-4B, the average annual firm yield decreases to 3,000 acft/yr due to the elimination of the 70 mgd river diversion. The annual unit cost of this alternative is $260 per acft. For Alternative L-4C, the average annual firm yield decreases to 1,100 acft/yr due to the reduction of the productivity multiplier from 5.0 to 1.0 on the wastewater. As a result of this reduction, the average annual unit cost of water increases to $710 per acft/yr.

It is important to note that the costs associated with diversion of wastewater to the delta presented here do not take into account the potential lower wastewater treatment plant costs that could be realized by the City of Corpus Christi as part of this project; i.e., 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 standard 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 CC/LCC System. Once reduced treatment costs are considered, it may be beneficial to consider diverting effluent from the City's Westside WWTP or possibly selected industrial discharges along the route of the pipeline from the Broadway to the Allison plant.

Table 3.10-4
Cost Estimate for Diversion of Wastewater and River Water to the Nueces Delta (L-4)
(Mid 1995 Prices)

Item	Estimated Cost: Alternative L-4A	Estimated Cost: Alternatives L-4B & L-4C	
Capital Cost			
(Items to Be Completed at the Broadway WWTP)			
Connection to Existing Chlorine Contact Basin	$ 11,000	$ 11,000	
Concrete Sump	21,000	21,000	
Low-Lift Pumps (4)	44,000	44,000	
Galvanized, Bolted Holding Tank (1,000,000 Gal)	265,000	265,000	
Transfer Pumps (4)	105,000	105,000	
Meter	5,000	5,000	
Piping (Low Lift and Transfer Pumps)	41,000	41,000	
Electrical and Automated Controls	150,000	150,000	
24" PVC Pipe (57,600 LF)	2,975,000	2,975,000	
(Items to Be Completed at the Allison WWWTP)			
Connection to Existing Chlorine Contact Basin	$ 5,000	$ 5,000	
Concrete Sump	11,000	11,000	
Low-Lift Pumps (2)	22,000	22,000	
Galvanized, Bolted Holding Tank (1,000,000 Gal)(2)	529,000	529,000	
Transfer Pumps (4)	126,000	126,000	
Meter	11,000	11,000	
Piping (Low Lift and Transfer Pumps)	62,000	62,000	
Electrical and Automated Controls	149,000	149,000	
Bore Under Nueces River (250 LF)	79,000	79,000	
24" PVC Pipe (8,000 LF)	413,000	413,000	
16" PVC Pipe (15,200 LF)	597,600	597,600	
Discharge Spreader System Structure	11,000	11,000	
(Items for River Diversion)			
Channel Construction (70 mgd)	1,806,000	-0-	
Subtotal	$7,438,000	$5,632,000	
Engineering Legal and Contingencies (Pipelines 30%; Other facilities 35%)	$2,405,000	$1,772,000	
Subtotal	$9,843,000	$7,404,000	
Interest During Construction	393,000	296,000	
Total Cost	**$10,236,000**	**$7,700,000**	
Annual Cost			
Debt Service	959,000	721,000	
Operations and Maintenance	66,000	50,000	
Power Costs	59,000	10,000	
Total Annual Cost	**$1,084,000**	**$781,000**	
Average Annual Yield Recovered		L-4B	L-4C
Under 1995 Agreed Order	5,500 acft	3,000 acft	1,100 acft
Cost per acft	**$197**	**$260**	**$710**

Source: "Regional Wastewater Planning Study--Phase II; Nueces Estuary," City of Corpus Christi, Port of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, and Texas Water Development Board, Corpus Christi, Texas, March, 1993.

3.10.4 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. A major industrial complex is located between the cities of Portland and Ingleside. Reynolds Metals, a major area industry, is interested in obtaining and using municipal wastewater for nonpotable purposes that are now met with raw water from the CC/LCC System. The San Patricio Municipal Water District (SPMWD), which obtains both treated water and raw water from the CC/LCC System, supplies municipal and industrial water to the area.

The SPMWD and the Texas Water Development Board in cooperation with area cities and industries funded a regional wastewater reuse planning study that was completed in October, 1994. The study recommended a regional wastewater collection, treatment and reuse system, which includes the Cities of Portland, Gregory, Aransas Pass, and Ingleside, with delivery of treated effluent to Reynolds Metals Company for reuse[6]. The project would increase water supply to the SPMWD service area by about 3,237 acft per year, at an estimated cost of $461 per acft (1993 price). However, since 1,400 acft of the municipal wastewater effluent (about 43 percent) is now being discharged to Nueces Bay and is credited towards freshwater inflow requirements for Nueces Bay specified in both the 1992 Interim Order and 1995 Agreed Order, it is necessary to evaluate the effects upon yields of the CC/LCC System of eliminating this 1,400 acft of wastewater flows to Nueces Bay. Under the 1995 Agreed Order, CC/LCC releases to Nueces Bay would have to be increased to offset the loss of the wastewater effluent and water made available for other purposes would be less than the full 3,237 acft mentioned above. Reuse of 1,400 acft of wastewater by industry would reduce the demand upon the CC/LCC System by 1,400 acft; however, the reduction of wastewater discharges to Nueces Bay would cause additional releases from the CC/LCC System under the 1992 Interim Order and reduce the system yield by 340 acft. This results in a net increase of 1,060 acft/yr in regional

[6] "Northshore Regional Wastewater Reuse, Water Supply, and Flood Control Planning Study," San Patricio Municipal Water District, et. al., Ingleside, Texas, October, 1994.

water supply[7]. Since Reynolds Metals is a no discharge facility, there are no return flows from its water use.

It is anticipated that the Northshore Wastewater Reuse Project will be implemented, with contract negotiations among SPMWD, Portland, and Reynolds Metals having begun in early 1995. If this project continues to move forward, a revised analysis of impacts to the City's water supply should be made considering the 1995 Agreed Order.

3.10.5 Estimated Wastewater Flows Originating from Imported Water

At present, about 47 percent of water diverted for municipal and industrial use is discharged as treated wastewater to the Nueces Estuary. Of the total volume of treated wastewater discharged by municipal and industrial plants, about 10 percent is discharged into the Nueces Bay (i.e., Nueces River, Delta, and Bay). The remaining volume of wastewater (i.e., 90 percent) is discharged into Oso Bay, the Corpus Christi Ship Channel, and other locations on or near Corpus Christi Bay. Table 3.10-5 summarizes the quantity and general location (Nueces Bay/Delta or Corpus Christi Bay/Ship Channel) of return flows estimated to be produced by various water supply alternatives. Return flows resulting from new water supplies are assumed to be distributed between Nueces Bay and Corpus Christi Bay at the same 10 percent/90 percent distribution as currently exists.

3.10.6 Analyses and Discussion of Consumptive Wastewater Reuse and Advanced Conservation as Related to Estuarine Inflow Requirements

Under the 1995 Agreed Order, effluent credits for discharge 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 CC/LCC System to meet monthly desired Nueces Bay inflows can be reduced with a consequent increase in system firm yield. Without implementation of water supply alternatives which restrict water use, wastewater

[7] Ibid. Of the total potential wastewater available for reuse (i.e., 3237 acft), only 1,400 acft is diverted from discharges to Nueces Bay.

Table 3.10-5 Potential Water Supply and Wastewater Flow Quantities for Various Water Supply Alternatives (acft/yr)				
Water Supply Alternative	**Potential Water Supply**	**Estimated Additional Wastewater Flows**	**Estimated Additional Quantity Discharged to Nueces Bay/Delta** (10% of total wastewater flow)	**Estimated Additional Quantity Discharged to Corpus Christi Bay or Ship Channel** (90% of total wastewater flow)
Municipal Wastewater Reuse (L-4)	5,500	2,585	258	2,327
1995 B&E Release Order	13,000	6,110	611	5,499
Modify LCC Operating Policy (N-1)	4,000	1,880	188	1,692
Lake Texana (LN-1)	41,840	19,665	1,965	17,700
Garwood (C-1)	21,000	9,870	987	8,883
Additional Colorado Water (C-2)	14,000	6,580	658	5,922
CC/LCC Pipeline (N-5)	18,000	8,460	846	7,614
LCC-Stevens Pipeline (N-6)	6,500	3,055	305	2,750

flows are projected to increase at a rate of about 900 acft/yr. 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 which accelerate the retrofit of existing plumbing fixtures to low-flow fixtures as implemented, then wastewater flows would be reduced to the degree the program is effective. However, if conservation measures are 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.

3.10.7 Environmental Issues

Introduction

Forty-seven percent of the water diverted and used by the city is returned to various points in the estuary as treated wastewater (Table 3.10-2). Presently, the largest portion of these discharges is made into the Nueces River, the Ship Channel, Oso Creek, and Oso Bay (Figure 3.10-1). 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 wastewater discharges from their present discharge points to the Nueces Delta (e.g., Rincon Bayou and associated shallow ponds). Because 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, as is explained below.

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 (Appendix C, Tables 16 and 18). 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.[8,9] Therefore, it has been recommended that wastewater be diverted and discharged into the delta to help meet the freshwater inflow requirement, as specified in the new 1995 Agreed Order, under which the CC/LCC system now operates. This proposed wastewater discharge to the Nueces Delta would increase water availability from the CC/LCC System by obtaining credit at a greater than 1:1 ratio, thereby reducing freshwater releases designed to meet Nueces Bay inflow requirements.

Impact Assessment

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.[10,11] 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.

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[8] HDR et al., 1991. Nueces Estuary Regional Wastewater Planning Study, Phase I Report.

[9] HDR et al., 1994. Nueces Estuary Regional Wastewater Planning Study, Phase II Report.

[10] Whitledge, T.E. and D.A. Stockwell. 1995. 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.

[11] Dunton, K.H., B. Hardegree, and T.E. Whitledge. 1995. 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.

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.[12] 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 ROW's which are located in urban areas (Figure 3.10-2). Less than 30 acres of delta wetlands and brushy uplands would be affected.

3.10.8 Implementation Issues

Major implementation issues include wastewater treatment levels required by regulatory agencies (both EPA and TNRCC), wastewater discharge permit modifications to allow discharge in the Nueces Delta, and water diversion permits to allow diversion of Nueces River water from the Nueces channel to the Nueces Delta. Implementation of this alternative should be considered in conjunction with the City's upcoming wastewater master plan update as well as efforts underway by the U.S. Bureau of Reclamation to lower the north bank of the Nueces River in the Delta area to increase periodic inundation of the Delta with river water. The USBR is in the process of acquiring easements and permits for its Nueces River diversion project in an attempt to enhance productivity in the Delta area. A wastewater demonstration project has been recommended and is currently being implemented by the City to confirm the estimates of the enhanced biological productivity by diversion of the Allison WWTP flows to the Delta. The City of Corpus Christi is in the process of securing a demonstration project site, and plans to apply for the necessary permits when the site has been obtained.

One additional item which should be considered is the potential to deliver municipal wastewater to selected industries located along the pipeline corridor from the Broadway WWTP

[12] Ibid.

to the Allison WWTP. It would be possible to design the pipeline so that it could be used to deliver treated wastewater to industries for cooling and/or other in-plant needs. Additionally, the line could also be designed to receive selected non-toxic wastewater streams from industries located along the pipeline route.

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.
    d. TPWD Sand, Gravel and Marl permit for river crossings.
    e. TNRCC Interbasin transfer authorization.

2. Right-of-way and easement acquisition.

3. Approval from various agencies for these crossings:
    a. Highways and railroads
    b. Creeks and rivers
    c. Other utilities

3.11 Goliad Reservoir (S-1)

3.11.1 Description of Alternative

The proposed Goliad Reservoir site is located on the San Antonio River upstream of Goliad, Texas, and was first proposed in 1965 by the USBR[1] as a water supply option for the City of Corpus Christi. Since the original proposal, the project was studied again by the USBR in 1983, and in 1986, Espey, Huston & Associates[2] (EHA) studied a slightly smaller reservoir about 4 miles from the USBR site. The site studied by EHA is used for this analysis and is shown on Figure 3.11-1.

The Goliad site proposed by EHA is approximately eight miles west of the City of Goliad. The dam would be an earthfill embankment with a gate-controlled, concrete spillway to control the 3,892 square mile watershed. The dam embankment would extend about 2.5 miles across the San Antonio River valley and provide a conservation storage capacity of 707,500 acft at elevation 200.0 feet-msl; at conservation pool the surface area would be 27,810 acres; the probable maximum flood elevation would be 210 feet; and, approximately 45 miles of stream channel would be inundated by the reservoir.

Since completion of Phase I Interim Report for the South Central Study Area, HDR Engineering has performed new yield calculations for the proposed reservoir with application of the Trans Texas Environmental Criteria[3]. Changes in reservoir inflows and operations (which are explained below) resulted in the firm yield being revised from an assumed volume of 100,000 acft/yr in the Phase I study to a calculated firm yield of 85,400 acft/yr in this Phase II study.

3.11.2 Available Yield

The firm yield of the proposed Goliad Reservoir has been updated to account for application of the Trans-Texas Environmental Criteria. Firm yield has been computed without

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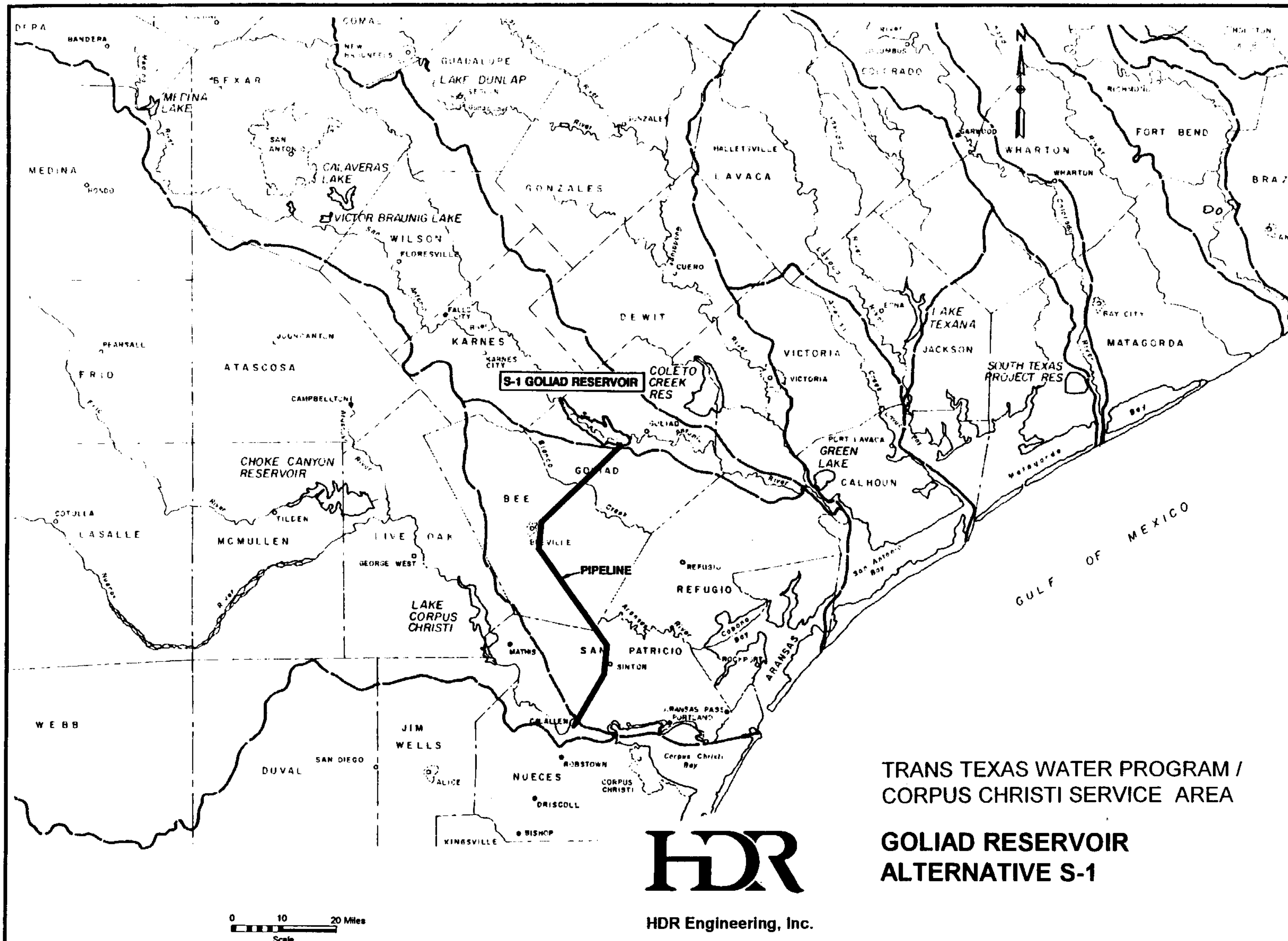
[1] USBR, "Texas Basins Project," February 1965.

[2] Espey Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," February, 1986.

[3] HDR Engineering, Inc., "Trans-Texas Water Program, West Central Study Area, Phase I Interim Report", May, 1994.



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GOLIAD RESERVOIR ALTERNATIVE S-1

FIGURE 3.11-1

consideration of return flows present in the river as the City of San Antonio is considering various reuse options. Additionally, the Applewhite Reservoir project is no longer included as it was defeated in a referendum in August, 1994. Firm yield was computed subject to three capacity thresholds which limit passage of reservoir inflows as specified in the Trans-Texas Environmental Criteria during times of drought. The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations for release of water under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow which occurred during the January, 1954 through December, 1956, historical period.

The Guadalupe - San Antonio River Basin Model[4] (GSA Model) was used to estimate monthly quantities of total streamflow and unappropriated streamflow potentially available at the reservoir site which, in turn, were used to compute the firm yield of Goliad Reservoir. For modelling purposes, streamflows for the San Antonio River at Goliad (ID #1885) were assumed to be representative of inflows to Goliad Reservoir. The firm yield of Goliad Reservoir was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to the Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. All scenarios include the spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights, and hydropower water rights subordinated to 600 cfs[5]. A summary of the firm yield estimates for the 40, 60, and 80 percent capacity thresholds analyzed is provided in Table 3.11-1.

Estimated firm yield of Goliad Reservoir is quite sensitive to the reservoir capacity threshold (Table 3.11-1). Lowering the reservoir capacity threshold for drought contingency operation from 80 percent to 60 percent reduces the firm yield from 97,200 acft/yr to 85,400 acft/yr, or about 12 percent. Further lowering of the threshold to 40 percent reduces the

[4] HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

[5] HDR Engineering, Inc., "Trans-Texas Water Program, West Central Study Area, Phase I Interim Report, Volume 3", November, 1994.

Table 3.11-1 Summary of Goliad Reservoir Firm Yield Estimates	
Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	**Estimate of Firm Yield (acft/yr)[1]**
40 percent	67,700
60 percent	85,400
80 percent	97,200

Notes:
1 All scenarios include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights, and hydropower water rights subordinated to 600 cfs. No return flows from the City of San Antonio were included due to reuse programs under consideration and potential water demand reductions which could significantly affect return flow volumes during drought conditions.
2 The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations for release of water under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

yield to 67,700 acft/yr, an additional 18 percent. Table 3.11-2 summarizes the parameters used in the GSA Model and provides the monthly Trans-Texas Environmental Criteria inflow passage requirements at the reservoir site.

The scenario with a firm yield of 85,400 acft/yr which corresponds to a 60 percent capacity threshold, was selected for consideration of cost and analysis of potential environmental impacts. Figure 3.11-2 illustrates the simulated Goliad Reservoir storage fluctuations for the 1934-89 historical period if operated under the Trans-Texas Environmental Criteria subject to diversion of the firm yield of 85,400 acft/yr. Simulated reservoir storage fell below the 60 percent capacity threshold about 30 percent of the time resulting in the frequent passage of inflows up to the drought median natural streamflow. As a result, median monthly streamflows at the site were noticeably reduced as shown in Figure 3.11-3. Corresponding reductions at the Saltwater Barrier, however, were less noticeable due to the larger volume of flow at this location. Monthly median streamflows and annual streamflows averaged by decile, with and without the project, are presented in Figure 3.11-3 for the site and the Saltwater Barrier. With a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier would be reduced by an average of 122,689 acft/yr or about 8 percent.

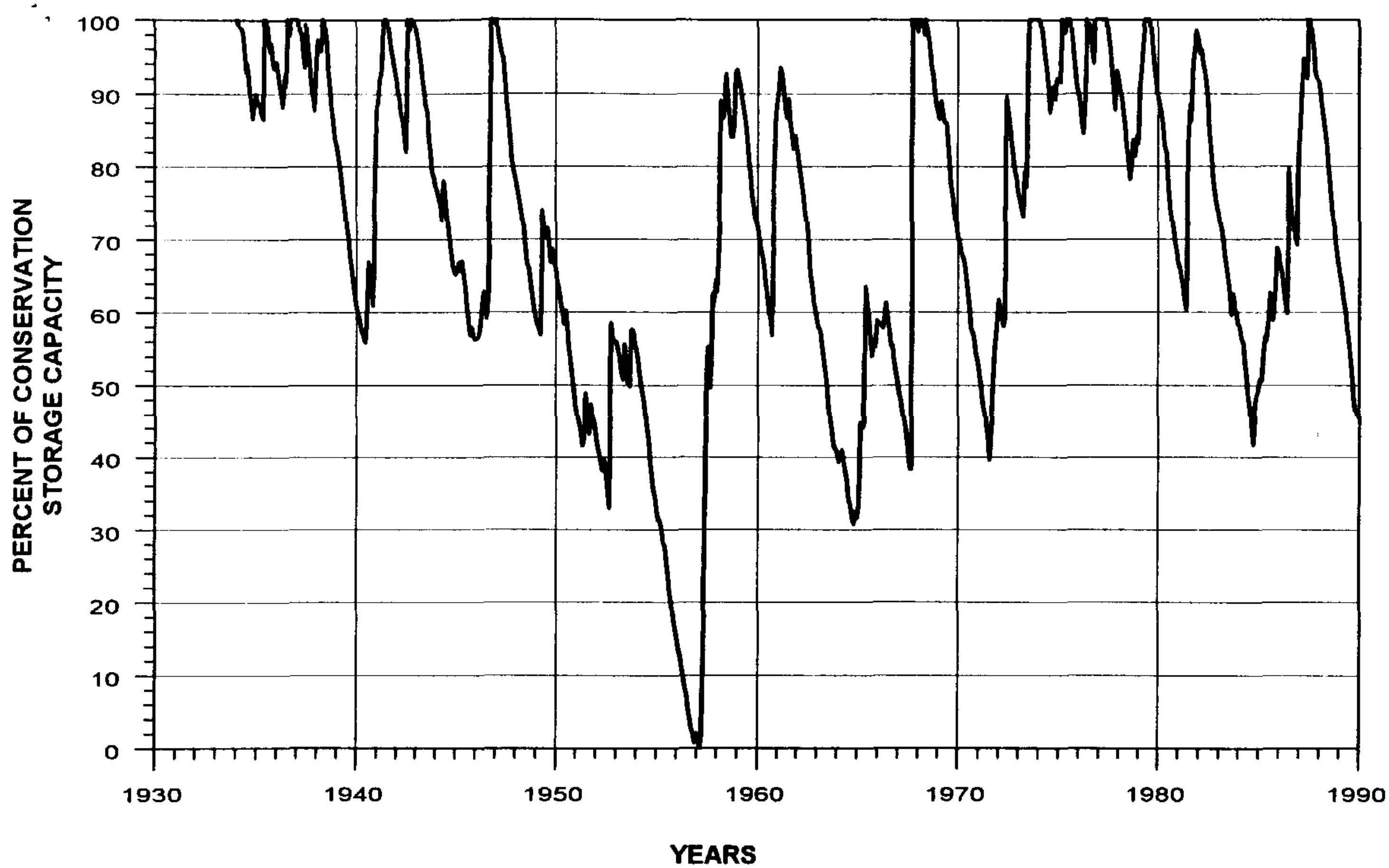
Table 3.11-2
Guadalupe - San Antonio Basin Modeling Parameters
Goliad Reservoir - Alternative S-1

Analysis Point:	San Antonio River at Goliad (USGS Gage 1885)			
Minimum Flow Requirements:	Inflow Passage Requirement at Reservoir		Bay & Estuary Inflow Requirement at Saltwater Barrier	
Month	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	21,068	349	N/A	N/A
Feb	20,989	348	N/A	N/A
Mar	23,775	394	N/A	N/A
Apr	40,890	678	N/A	N/A
May	63,752	1,057	N/A	N/A
Jun	71,977	1,194	N/A	N/A
Jul	17,766	295	N/A	N/A
Aug	24,419	405	N/A	N/A
Sep	59,764	991	N/A	N/A
Oct	47,657	790	N/A	N/A
Nov	20,505	340	N/A	N/A
Dec	20,794	345	N/A	N/A
Drought Median[1]	4,476	74	N/A	N/A
Flow Requirements Based On:	Trans-Texas Environmental Criteria			
Edwards Aquifer Pumpage:	400,000 acft/yr			
Return Flows:				
Surface Water Sources:	None			
Groundwater Sources:	None			
Water Rights:				
Canyon Lake:	50,000 acft/yr			
Hydro Requirement at Lake Dunlap:	600 cfs			
Applewhite Reservoir:	Excluded			
Other Rights:	Full Authorized Amounts			
Steam-electric Diversions:				
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)			
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)			
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)			
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)			
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)			
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)			

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	67,700
60%	85,400
80%	97,200

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.



FIRM YIELD = 85,400 ACFT/YR
CONSERVATION STORAGE CAPACITY = 707,500 ACFT
60% CAPACITY THRESHOLD

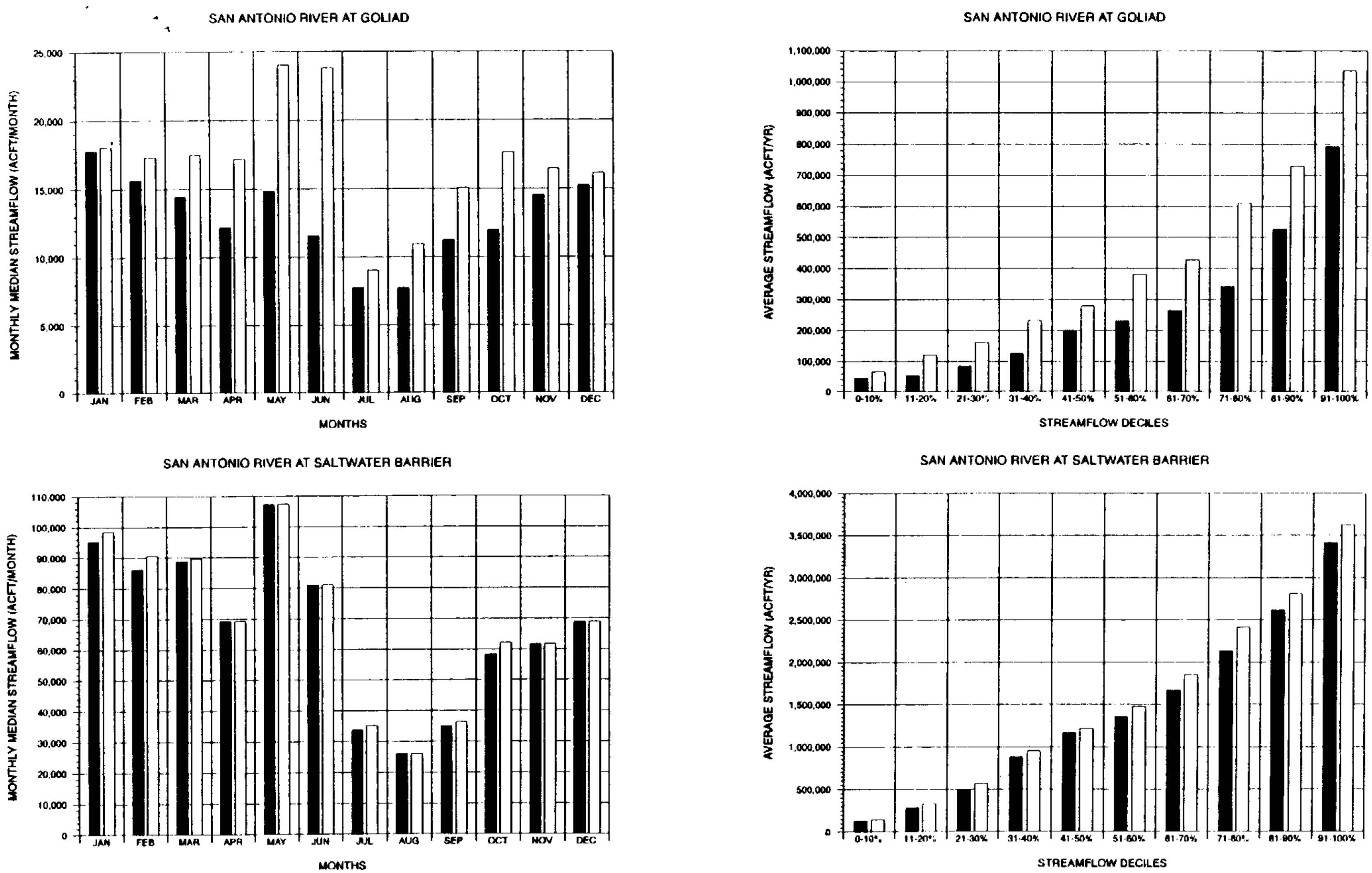
SCENARIO: EDWARDS AQUIFER DEMAND OF 400,00 ACFT/YR
NO SAWS RETURN FLOWS
HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
APPLEWHITE RESERVOIR EXCLUDED

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

STORAGE TRACE
GOLIAD RESERVOIR
ALTERNATIVE S-1

FIGURE 3.11-2



■ **WITH PROJECT**

□ **WITHOUT PROJECT**

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

CHANGES IN STREAMFLOW
GOLIAD RESERVOIR
ALTERNATIVE S-1

FIGURE 3.11-3

3.11.3 Environmental Issues

Introduction

Environmental issues of concern with respect to the Goliad Reservoir alternative can be categorized as follows:

- Effects resulting from the construction and operation of Goliad Reservoir including reductions in river flows downstream of the dam and reduced inflow to San Antonio Bay; and
- Effects resulting from the construction of a water transmission line from the reservoir to the O.N. Stevens Water Treatment Plant.

The Affected Environment

Regional Setting

Goliad Reservoir, Alternative S-1, would impound the San Antonio River approximately eight miles west of the City of Goliad in Goliad County (Figure 3.11-1). Although a specific pipeline route to the City of Corpus Christi water treatment facilities has not been selected, a general corridor which parallels existing ROWs has been identified and is presented in Figure 3.11-1.

Soils of the San Antonio River Basin within the reservoir site are Aransas-Sinton (AS) soils association. These clayey and loamy bottomland soils are nearly level, deep and moderately alkaline. Both soils have firm calcareous stratified clay loam; Sinton soils also have sandy clay loams that are well drained and moderately permeable. Aransas soils are frequently flooded hydric soils.[6] Upland soils include Leming-Papalote (LP) and Runge-Sarnosa association (RS). The LP association is nearly level to gently sloping, deep, slightly acid or neutral, sandy and loamy; the RS association is gently sloping, deep, neutral to moderately alkaline, clayey and loamy. Most LP and RS soils are under cultivation.[7]

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[6] Soil Conservation Service. 1991. Hydric Soils of the United States, In Cooperation with the National Technical Committee for Hydric Soils, Publication 1491. U.S. Department of Agriculture.

[7] Soil Conservation Service. 1975. Soil Survey of Goliad County, Texas. USDA

Goliad County lies within the northeastern extent of the South Texas Plain in what Omernik termed the East Central Plain Ecoregion.[8] The *Acacia* sp. characteristic of the southern and southwestern parts of the South Texas Plain vegetational region are largely replaced by oak and hickory savanna to the northeast. Agricultural activity on the San Antonio River floodplain is not as intense as in the surrounding uplands where little woody plant cover persists. The San Antonio River and its tributaries are generally bordered by bottomland woodlands. These riparian corridors are generally surrounded by cultivated land and consist of a mosaic of wetland and mesic woodland, where substantial stands of mature hardwoods may occur. The majority of the land in Goliad County has been extensively modified for agricultural uses, especially for cattle ranching. The riparian corridors along the San Antonio River, the floodplain and tributaries constitute a significant proportion of the remaining high quality of wildlife habitat in the county.

The bottomland hardwoods and floodplains of the proposed reservoir provide habitat for eastern forest species in the same way that grass and cropland provide habitat for prairie and coastal plain species. Brush and shrublands of the reservoir site and pipeline corridor provide habitat for species found in the Tamaulipan Biotic Province. Vertebrates of this biotic province may include neotropical, grassland, Austroriparian and some Chihuahuan province species.

Bottomland forests provide habitat for a multitude of migrating songbirds, waterfowl, and hawks. The thick nature of the brushland vegetation makes this an excellent nesting habitat for a variety of bird species. Wood ducks, ringed kingfisher, Swainson's warbler, Carolina chickadee, tuffed titmouse, northern cardinal, and great horned owl are among the birds known to nest in this habitat. Bottomland hardwood stands also provide ample food and cover for a number of rodents and other mammalian species, including the white-tailed deer and collared peccary. The protected Texas tortoise utilizes brush habitats for cover, and for food in the form of cacti and herbaceous undergrowth.[9]

Ground cover is occasionally thick in grasslands, thus providing good cover for a variety of rodent species which in turn provide food for carnivores such as the coyote, northern harrier,

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[8] Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1):pp. 118-125.

[9] Davis, W.B. 1978. The Mammals of Texas. *Texas Parks and Wildlife Dept. Bulletin 41*, Austin, Texas.

and common barn-owl. A variety of reptiles, mammals, and birds also use grassland habitats for food and cover. Prairie species like the scissor-tailed flycatcher, white-tailed hawk, Swainson's hawk, long billed curlew, and sandhill crane utilize the pastures and croplands.

Impact Assessment

The general environmental effects of reservoir construction include severe disturbance to vegetation, habitats, and cultural deposits at the dam site and borrow areas, temporary increases in the sediment load in the river below the dam site, and temporary increases in air pollutants, primarily from fugitive dust and vehicle emissions. Sediment loading will need to be minimized by engineering practices during dam construction to prevent large scale movement and deposition in the river channel. Small, temporary increases in sediment load are not expected to have significant impacts to the biological community of the San Antonio River.

Direct operational effects of the Goliad alternative will include permanent inundation of 27,810 acres in the conservation pool, changes in the streamflow regime below the dam, and reductions in inflows to San Antonio Bay. These inflows will be equal to the amount of water diverted and not returned to the river, plus the net increase in evaporation resulting from impoundment. Indirect impacts would include land use changes in the areas surrounding the reservoir, and in mitigation areas that may be required to compensate for losses of terrestrial habitat

Inundated uplands would consist of 3,100 acres of woods, brush and shrublands, 24,807 acres of grass and cropland, and 192 acres of developed property.[10] The bottomland hardwood and riparian communities along the creeks and floodplains represent a particularly important habitat to wildlife in this area of prairie and savanna. Approximately 556 acres of wetlands, primarily stream channels and vegetated floodplain wetlands, would be included in the Goliad Reservoir site. The approximately 500 acres of channel including the San Antonio River (45 river miles), Cabezo, Charo, and Hord Creeks, and portions of Escondido, Ecleto, Hondo, and Cottonwood Creeks, would be converted from lotic (flowing water) habitat to part of a much larger lacustrine environment. Whereas loss of lotic habitat may result in reductions in population size for some aquatic species, other species will experience an increase in habitat and

[10] USGS. 1990. aerial photographs, EROS Center, Sioux Falls, SD.

population size. No species are known to be critically dependent on these stream reaches for species survival.

Application of the Trans-Texas instream flow criteria to the Goliad Reservoir alternative results in a firm annual yield of 85,400 acft, assuming drought operation commences when reservoir content falls below 60 percent capacity. Historical median discharges at Goliad, by month, together with median flows modeled for the same period of record with the project in place are shown in Figure 3.11-3. Changes in monthly median flows reflect reductions in average discharge over the entire range of river flows. Figure 3.11-3 shows reductions in average river flow below Goliad Reservoir amounting to about 47 percent at the lower range of annual flows (driest 30 percent of years), declining to approximately 32 percent reductions in the top half of annual flows. These rather large changes can be expected to result in a reduction in total lotic habitat, increased frequency and duration of low flow events, and changes in the proportions of aquatic habitats in the reach below the dam. These habitat changes can be expected to result in some changes in relative abundance of some species.

With respect to potential effects on the Guadalupe Estuary, Figure 3.11-3 shows only small changes from historical monthly median and annual average discharge statistics at the Saltwater Barrier at Tivoli. The most pronounced reductions, those in the July and August medians, appear to reflect the effects of drought operation on summer low flows during extended dry periods. Annual median and average Guadalupe River flows would decline by about 8 and 10 percent respectively, at the saltwater barrier.

A recent study reported that average freshwater inflow to the Guadalupe Estuary over the 1941 to 1987 period of record was 2.34 million acft/yr.[11] Average monthly inflow was 195,619 acft/month (range: 114,014 acft in August to 296,820 acre-feet in May) while the median monthly inflow was 120,444 acft (range: 88,129 acft in September to 397,102 acft in June). Furthermore, trend analyses indicated that there has been no statistically significant reduction in mean inflow rates to the estuary due to the construction of reservoirs (i.e., Canyon Lake, Lake Calaveras and Coletto Creek Reservoir). However, statistically significant trends

[11] Longley, W. L., ed. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 286 pp.

can be detected during periods of drought. In fact, it appears that inflow was significantly higher during the 1968 through 1987 period compared to the 1941 through 1967 period which contains two significant periods of severe drought. Modeling of the Guadalupe Estuary system indicated that the most important factor affecting freshwater inflow requirements was salinity, while nutrient and sediment levels did not play a significant role in the modeled inflow requirements.

Because of the relatively large wastewater component in the San Antonio River, Goliad Reservoir may experience elevated nutrient loading rates. Assuming that ambient phosphorus levels at Goliad would be similar to those typical in the lower Guadalupe River (0.3 mg/l) if the City of San Antonio's wastewater were not present, annual total phosphorus (TP) loading to Goliad Reservoir would be about 172,000 kg per year. An ultimate wastewater flow of 66,000 acft/yr of treated wastewater, subjected to tertiary treatment to achieve an average TP of 1 mg/l would add about 80,000 kg of phosphorous to the upper river each year. Such high phosphorous levels would be expected to stimulate growth in aquatic plants and algae.

Important species believed to have habitat in the vicinity of the reservoir are listed in Table 3.11-3. Although no protected species occurrences have been reported within the Goliad reservoir site, several of those listed for Goliad and Karnes counties have habitat requirements or preferences indicating that they could be present on the Goliad reservoir site. For example, the Texas horned lizard, *Phrynosoma cornutum*, which was once common and is widely distributed in Texas, lives in semiarid regions with sparse vegetation such as may be found in some upland pastures in the project area. The Texas scarlet snake, *Cemophora coccinea lineri*, requires mixed hardwood scrub on sandy soils, a habitat which is likely to be found on the Sinton soils of the project area.

The proposed 69 mile pipeline corridor would traverse post oak woodlands near the reservoir. However, most of the corridor is within the mesquite shrublands and grasslands of the Western Gulf Coastal Plains.[12] The 140 foot construction corridor would total about 1179 acres of primarily grass and shrubland area. Of this, about 337 acres would become ROW that has to be permanently maintained free of woody vegetation. The proposed corridor crosses

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[12] Omerik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1): pp. 118-125.

Table 3.11-3
Important Species with Habitat in the Project Vicinity (S-1)[1],[2]

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	Listing Agency TPWD
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oaks and old juniper	E	E
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T
Swallow-Tailed Kite, American	*Elanoides forficatus*	Varied; open land, nesting in forested river bottoms	3C	T
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T
Gulf Coast Hog-nosed Skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E
Ocelot	*Felis pardalis*	dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Racer, Specked	*Drymobius margaritiferus*	Dense thickets heavily littered with plant debris; generally near water	NL	E
Texas Scarlet Snake	*Cemophora coccinea lineri*	Sand floored thicket immediately adjacent to the Gulf	NL	T
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	TPWD
Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks when inactive	C2	T
Black -Spotted Newt	*Notophthalmus meridionalis*	Wet or temporarily wet areas such as arroyos, canal, ditches and shallow depressions; aestivates underground during dry periods	C2	E
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporarily wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture to remain	C2	E
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Racer, Specked	*Drymobius margaritiferus*	Dense thickets heavily littered with plant debris; generally near water	NL	E
Texas Scarlet Snake	*Cemophora coccinea lineri*	Sand floored thicket immediately adjacent to the Gulf	NL	T
Guadalupe Bass	*Micropterus treculi*	Rivers of the Edwards Plateau including Brazos, Colorado, Guadalupe, and San Antonio River Basins; lower Colorado River; introduced in Nueces River	C2	NL
Black Lace Cactus	*Echinocereus reichenbachii albertii*	Grows in extremely heavy brush and very localized	E	E
Lila de los Llanos / Chandlers Crag Lily	*Anthericum chandleri*	Lower Rio Grande Valley; South Coastal Texas	C2	NL
Plains Gumweed	*Grindelia oolepis*		C3	NL
Roughseed sea-purslane	*Sesuvium trianthemoides*	Dunes of coastal South Texas	C2	NL

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	TPWD
Runyon's water-willow	*Justicia runyonii*	Calcareous silt loam, silty clay, or clay in openings; subtropical woodlands; active or former floodplains of South Rio Grande Plains; Goliad occurrence questionable	C2	NL
Slender Rush-pea	*Hoffmannseggia tenella*	Gulf Coast prairies and marshes; clayey soils near creeks with buffalo grass, spear grass, mesquite and prickly pear cactus	E	E
South Texas Ragweed	*Ambrosia cheiranthiflora*	Open prairie, various shrublands on deep clay soils	C1	NL
Welder Machaeranthera	*Psilactis heterocarpa*	Coastal Prairie, shrub-invaded grasslands, open mesquite-huisache woodlands on gray colored clayey to silty soils over Beaumont and Lissie Formations	C2	NL
Texas Windmill Grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants; also roadsides and with coastal prairie edemics in slightly saline soils in bare areas around pimple mounds	C2	NL

[1] Source: TPWD, 05/09/88; TPWD. 1993. Natural Heritage Program Files. Resource Protection Division, Austin, Texas. Dixon, J.R. 1987. Amphibians and Reptiles of Texas. Texas A&M Press, College Station, Texas.
[2] Symbols under listing agency are as follows: C1-USFWS Candidate for protection with substantial information to support appropriateness of listing in USFWS files; C2-USFWS Candidate Category for protection; 3C-USFWS no longer under review for protection; E-Endangered; T-Threatened; NL- not listed.

numerous small tributaries to Blanco Creek and the Mission and Aransas Rivers which may result in a cumulative wetlands impact of an acre or less.

Important plants that may be in the proposed reservoir area or the pipeline corridor include the plains gumweed (*Grindelia oolepis*, S2, 3C), Mathis spiderling (*Boerhavia mathisiana*, S1, C2), which has been reported in open thorn shrublands in pedocal soils, Texas windmillgrass (*Chloris texensis*, S2, C2) which is usually found on coastal prairie grasslands and roadsides; and Elemendorf's onion (*Allium elemendorfii*, S2, NL), which can be found in grassland openings in post oak woodlands.[13,14] Although there are no known conflicts with these species, they would be considered in any site specific study of the proposed reservoir site and pipeline corridor.

Protected animal species also may be present; for example, the Bald Eagle is known to nest in tall trees in riparian woodlands of the Western Gulf Coastal Plains. When considering inflow regime alternatives, several endangered marine species that may utilize San Antonio Bay should be considered. The important species, natural communities, and protected resources listed in Appendix C - Tables 3, 9, 12, 17, and 18 should be considered in any site specific studies of the proposed reservoir and pipeline corridor. Studies of instream flows needed to protect aquatic communities within the San Antonio River below the reservoir site, and San Antonio Bay could be conducted to better define potential reservoir yield and needed operational features.

With regard to cultural resources, there is some information that numerous cultural resource sites are located within the proposed reservoir. A systematic pedestrian survey of the entire reservoir site will be required to search for surface indications of cultural deposits, while a geomorphologic study to evaluate the potential for buried deposits is also a likely requirement. Sites that may be located within the project area will have to be tested for cultural and historical significance, and for eligibility for listing on the National Register of Historic Places.

Compensation for unavoidable impacts to wetland and terrestrial wildlife habitats will likely be requested by U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department. However, decisions on the actual extent of required mitigation are made by the permitting agencies, the Texas Natural Resource Conservation Commission in the case of a water rights permit, and the U.S. Army Corps of Engineers for a permit under Section 404 of the Clean Water Act. Compensation is generally accomplished by acquisition of an appropriate tract(s) of land, together with development, funding, and implementation of a vegetation/wildlife management plan that will generate enough new habitat value over the life of the project to compensate for that lost as a result of reservoir construction and operation. Acreage requirements should be based on replacement of habitat value lost during the life of the project

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[13] TPWD. 1993. Natural Heritage Program data files and maps. Resource Protection Division, Austin, Texas

[14] TOES. 1993. Endangered, Threatened and Watch Lists of Texas Plants. Third Revision with supplements from September 1993 and 1994. Austin, Texas.

(50-100 years), and may be determined by one of several formal evaluation procedures (e.g., the U.S. Fish and Wildlife Service Habitat Evaluation Procedure), or by more informal agreements among the parties. we prefer WHAP over the HEP

Mitigation costs will vary depending on the price and availability of land together with the acreage required to generate the necessary habitat value. Required acreages are unlikely to be less than the combined area of the uncultivated lands impacted, including wetlands, woods, brush, shrub, and some fraction of the grasslands (about 15,000 acres), and may be much higher, possibly equal to the entire reservoir area. Ownership and management responsibility for the mitigation site may be retained by the owner of the Goliad alternative or transferred to a resource agency (typically Texas Parks and Wildlife Department) agreeable to the parties involved.

3.11.4 Water Quality and Treatability

Although the four secondary water quality constituents reviewed for this study at the proposed Goliad Reservoir site meet the TNRCC Secondary Drinking Water Standards (SDW Standard), the San Antonio River at Goliad has the highest and most variable concentrations compared to the other surface water options (Appendix D)[15]. Construction of the Goliad Reservoir would dampen the variability in water quality for the four constituents analyzed and tend to be closer to the mean.

The importation of water from Goliad Reservoir to the O.N. Stevens Water Treatment Plant at Calallen where it would be blended with Nueces River water would result in lower concentrations of chlorides for Corpus Christi, as well as comparable, although slightly higher, levels of hardness. However, the TDS concentration after blending does not appear to have as positive a result. Since the TDS concentration in the San Antonio River at Goliad comes closest to exceeding the SDW Standard and the TDS measurements at Mathis are not much lower (Appendix D, Table D-1), it appears that the post-blending TDS concentration of San Antonio and Nueces Basin Water may occasionally approach the SDW Standard of 1,000 mg/l.

Located downstream from San Antonio, a major metropolitan area, Goliad Reservoir will likely have greater than average levels of organic matter due to the effects of wastewater return

[15] The four constituents analyzed include: chlorides, hardness, TDS, and sulfates.

flows, as well as some urban runoff if these flows are not diverted upstream. These contaminants are treatable using conventional methods; however, the high concentration could stress the current treatment system and likely would require modification of the existing disinfection processes at the O.N. Stevens Water Treatment Plant. Specific water quality assessments should be completed in later phases of the Trans-Texas study, if the Goliad Reservoir should continue to be considered as an alternative water supply for Corpus Christi (refer to Appendices D and E).

3.11.5 Engineering and Costing

The cost estimate for the dam and reservoir is an update of a previous cost estimate performed by EHA[16]. That cost estimate was updated by multiplying the individual cost components by the ratio (mid-year 1995 to 1991) of the relevant Bureau of Reclamation Construction Cost Indexes.

For this alternative, the water from the proposed reservoir would be diverted through an intake and pumped in a transmission line to the O.N. Stevens Water Treatment Plant at Calallen. The diversion rate from the reservoir would be uniform throughout the year. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, 3 required
Tie-in to Water Treatment Plant

For purposes of sizing and costing the required pipeline from Goliad Reservoir to the O.N. Stevens water treatment plant, it was assumed that 60,000 acft/yr of the yield of the project (i.e., 70 percent) would be utilized by the Corpus Christi service area and that the remaining 30 percent of the reservoir would be utilized by an alternate entity.

The reservoir intake and pump station is sized to deliver 5,000 acft/month (53.6 mgd) through a 60-inch diameter pipeline. The operating cost was determined for the total raw water pumping head and an annual water delivery of 60,000 acft/yr. Project costs are summarized in

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[16] Espey Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," February, 1986. Austin, Texas.

Table 3.11-4, reservoir costs are summarized in Table 3.11-5, and pipeline costs are summarized in Table 3.11-6. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $29,651,000 (Table 3.11-4). Operation and maintenance costs, including power, total $4,323,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $33,974,000. The resulting unit cost for the 60,000 acft/yr delivered to Corpus Christi is $447 per acft.

Table 3.11-4
Cost Estimate Summary for Goliad Reservoir and Pipeline (S-1)
(Mid-1995 Prices)

Item	Reservoir[1]	Pipeline[2]
Capital Costs	$241,847,000	$74,602,000
Annual Debt Service	$22,661,000	$6,990,000
Annual Operation and Maintenance	$1,434,000	$2,889,000
Total Annual Cost	$24,095,000	$9,879,000
Yield Available from Reservoir or Delivered by Pipeline (acft/yr)	85,400	60,000
Annual Cost of Water	$282 per acft	$165 per acft
Total Annual Project (Reservoir and Pipeline) Cost of Water		$447 per acft

[1] From Table 3.11-5.
[2] From Table 3.11-6.

3.11.6 Implementation Issues

The water supply identified in this alternative is not surplus to the needs of the San Antonio River Basin in year 2050 and can only be considered as an interim (i.e., 25 to 40 years) source for possible supply to the study area. Therefore, this alternative cannot be considered equally with alternatives that provide a permanent source of water for the Corpus Christi service area. The implementation of this alternative would require a determination that the quantity of water to be utilized by the Corpus Christi area would be surplus to the needs of the San Antonio River Basin for the duration of the period of use.

Table 3.11-5 Cost Estimate for Goliad Reservoir (S-1) (Mid-1995 Prices)	
Item	**Estimated Cost**
Capital Cost	
Earthen Embankments	$21,239,000
Spillway and Outlet Works	59,655,000
Administration Facilities	470,000
Relocation of Roads and Bridges	12,903,000
Relocation of Utilities and Pipelines	2,943,000
Subtotal	$97,210,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	34,024,000
Subtotal	$131,234,000
Environmental Studies and Mitigation	34,126,000
Land Acquisition	58,400,000
Subtotal	$223,760,000
Interest During Construction	18,087,000
Total Project Cost	$241,847,000
Annual Cost	
Annual Debt Service	22,661,000
Annual Operation and Maintenance	1,434,000
Total Annual Cost	$24,095,000

Requirements Specific to Reservoirs:

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.
   e. Coastal Coordinating Council review.
   f. TPWD Sand, Gravel, and Marl permit.

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.

Table 3.11-6 Cost Estimate Summaries for Pipeline from Goliad Reservoir to Calallen (S-1) (Mid- 1995 Prices)	
Item	**Estimated Cost**
Capital Costs	
Pump Station	$4,448,000
Booster Station	2,150,000
Pipeline	48,220,000
Subtotal	$54,818,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	16,775,000
Subtotal	$71,593,000
Environmental, Studies and Mitigation	424,000
Land Easements	364,000
Subtotal	$72,381,000
Interest During Construction	2,221,000
Total Project Cost	$74,602,000
Annual Costs	
Annual Debt Service	$6,990,000
Annual Operation and Maintenance (Excluding Power)	759,000
Annual Power	2,130,000
Total Annual Cost	$9,879,000

3. Land and mineral rights[17] will need to be acquired through either negotiations or condemnation.

4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

5. The project will require a sponsoring agency to obtain permits, financing, and construct the project. Additionally, the sponsoring agency will need to find purchasers for the yield of the reservoir not purchased by Corpus Christi, or have other uses for remaining yield. Corpus Christi would need to enter into a water purchase agreement with the sponsoring agency.

[17] Correspondence with a local resident in the reservoir area suggests that costs for mineral rights may warrant additional investigation if this alternative moves forward in the Trans-Texas Program.

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.
   d. TPWD Sand, Gravel and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

3.12 Diversion from the Guadalupe and San Antonio Rivers (with and without McFaddin Reservoir (GS-1)

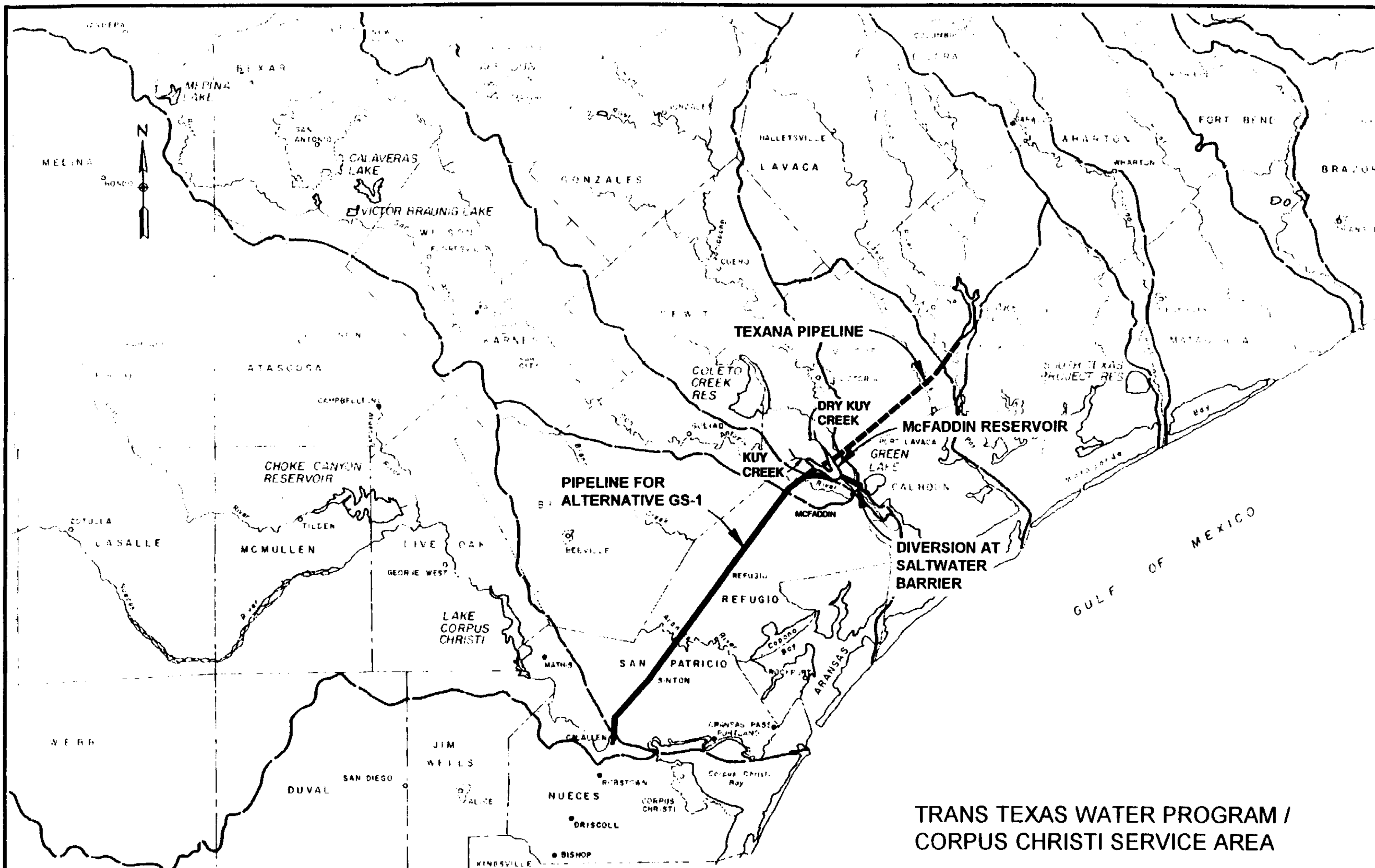
3.12.1 Description of Alternative

The Guadalupe-Blanco River Authority (GBRA) holds parts or all of six water rights permits associated with the Calhoun Canal Division which divert water from the Guadalupe River downstream of the San Antonio River confluence and upstream of the Saltwater Barrier. These permits (Certificate of Adjudication Nos. 18-5173 through 18-5178) are senior to Canyon Lake and total about 172,500 acft/yr. Communications with GBRA indicate that up to 40,000 acft/yr might be made available for interim out-of-basin use. Hence, 40,000 acft/yr (18,400 acft/yr municipal and 21,600 acft/yr industrial) of the GBRA Calhoun Canal Division (GBRA CCD) rights were selected for consideration of potential purchase and transfer to the Corpus Christi Service Area on an interim basis.

However, a companion of projected water demands and supplies from existing sources[1] for the Guadalupe River Basin shows that demands will exceed supply before 2050 and therefore could not be considered for transfer from the Guadalupe River Basin on a permanent basis. This alternative cannot be considered on an equivalent basis to other projects providing a permanent water supply to the Corpus Christi Service Area and the following section of this report is provided in fulfillment of the study scope of work.

In order to firm-up the run-of-the-river water available under these rights, the construction of an off-channel reservoir was considered. McFaddin Reservoir is a proposed off-channel reservoir located on Kuy and Dry Kuy Creeks, both of which are small tributaries to the San Antonio River located immediately upstream of the San Antonio and Guadalupe River confluence. The reservoir would impound water available from the Kuy and Dry Kuy creek watersheds as well as water diverted from the small reservoir pool located at the Saltwater Barrier under rights held by the Guadalupe-Blanco River Authority (GBRA). The reservoir site is about 3.5 miles west of McFaddin, Texas and is shown on Figure 3.12-1. The proposed site was selected due to the favorable topographic relief at the confluence of the two creeks. The natural watershed draining to the site encompasses 52.5 square miles.

[1] HDR Engineering, "Trans-Texas Water Program, West Central Study Area, Phase I Interim Report", May, 1994.



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DIVERSION FROM GUADALUPE AND SAN ANTONIO RIVERS (INCLUDES MCFADDIN RESERVOIR) ALTERNATIVE GS-1

FIGURE 3.12-1

The dam would be a 3,000 foot earthfill embankment with a gated, concrete ogee spillway to control the 52.5 square mile watershed. The top of the embankment would be at elevation 51.5 feet msl; the conservation storage capacity is 9,200 acft at elevation 45 feet-msl; the surface area at conservation pool is 660 acres; and, approximately 6 miles of Kuy Creek stream channel would be inundated. Diversion facilities would be located near the Guadalupe and San Antonio River confluence at the Saltwater Barrier and would include an intake channel, pump station, and pipeline to the reservoir.

Although hydrologic analysis for this alternative considers that an off-channel reservoir (i.e. McFaddin Reservoir) will be included as part of this project, cost estimates have been prepared both with and without the reservoir. This is because the Corpus Christi water supply system has significant water in storage which could potentially be used to firm-up the Guadalupe River water under potential conjunctive use scenarios. Therefore, the construction of McFaddin Reservoir may or may not be required to supply the Corpus Christi Service Area, and this alternative has been costed both with and without the reservoir. This alternative (with some modifications) could potentially be constructed to serve as the first leg of the Lake Texana pipeline as described in Section 3.13 of this report.

3.12.2 Available Yield

The RESOP[2] model was used to estimate the firm yield of McFaddin Reservoir with inflow from Kuy and Dry Kuy Creeks only. For the 1945 to 1965 period, which includes the drought of record, the firm yield was found to be only about 2,500 acft/yr. Since it would not be economical to construct a dam of this size to yield this small volume of water, it was necessary to find an alternate source of water to augment the inflow to the reservoir and provide a larger firm yield. The GBRA CCD water rights located at the Salt Water Barrier were considered. The total authorized diversion of the GBRA CCD rights total 172,500 acft/yr, of which 40,000 acft/yr has been identified as potentially available for purchase on an interim basis for out-of-basin use[3]. However, water demand projections show that the San Antonio-New

[2] Texas Department of Water Resources, "Reservoir Operating and Quality Routing Program".

[3] Guadalupe-Blanco River Authority, Memorandum to HDR, April 18, 1994.

Braunfels-San Marcos metropolitan corridor area needs significant quantities of surface water in the immediate future in order to reduce dependence on the Edwards Aquifer. Since the GBRA CCD rights will probably be needed to supply these areas, an interim purchase of the GBRA CCD rights would be contingent upon determination that the transferred water would not be needed for in-basin demands during the time frame of the purchase (see Section 3.12.1).

For Phase I of the West Central Study Area[4], HDR performed yield calculations for the McFaddin Reservoir with application of the Trans-Texas Environmental Criteria and considering the possible purchase of GBRA CCD water rights.

The Guadalupe - San Antonio River Basin Model[5] (GSA Model) was used to estimate monthly quantities of available streamflow that could be diverted at the Saltwater Barrier by purchase of a portion of the existing GBRA Calhoun Canal Division water rights. The combined firm yield of the reservoir and purchased water was computed to be between 37,100 to 37,500 acft/yr for a range of hydrologic assumptions as shown on Table 3.12-1. Firm yield was computed subject to three reservoir capacity thresholds which limit passage of reservoir inflows as specified in the Trans-Texas Environmental Criteria (see Appendix G) during times of drought. Additionally, water available under the GBRA CCD rights was based on spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights, and return flows set to 1988 levels. Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of 40,200 acft/yr[6].

For the period of 1934-89, monthly flow estimates for the ungaged watershed of Kuy Creek were developed by prorating gaged flow measurements for the nearby Coleto Creek watershed based on drainage area. The GSA Model was utilized to determine the percentage of the monthly allocation for these senior water rights that would be met for each month of the 1934-89 period. As a group, the senior water rights were found to be fully satisfied about 97

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[4] HDR Engineering, Inc., "Trans-Texas Water Program, West Central Study Area, Phase I Interim Report", May 1994.

[5] HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study", Volumes I, II, and III, Edwards Underground Water District, September, 1993.

[6] Ibid

Table 3.12-1 Summary of McFaddin Reservoir Firm Yield			
Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[3]	**40%**	**60%**	**80%**
Reservoir Firm Yield	37,100	37,200	37,500

Notes:
1) Firm yield based on diversion of available water from the purchase of 40,000 acft/yr of water rights (senior to Canyon Lake) from the GBRA Calhoun Canal Division.

2) All yields include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights, and return flows set to 1988 levels. Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of 40,200 acft/yr.

3) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

percent of the time, however, during the worst year (1956) a four month period (June through September) existed during which the water rights were not fully satisfied, and would have resulted in an annual diversion of only 83 percent of the total allocated. Table 3.12-2 summarizes the parameters used in the GSA Model and provides the reservoir inflow passage requirements conforming to the Trans-Texas Environmental Criteria. To determine the monthly quantity of water that could be diverted to McFaddin Reservoir from the Saltwater Barrier during the 1934-89 period, monthly percentages of water available under the grouped senior rights were applied to the 40,000 acft/yr that is potentially available for purchase. These monthly quantities, along with the estimated inflows from the 52.5 square mile watershed, were used to compute the firm yield of McFaddin Reservoir.

The firm yield of McFaddin Reservoir considering diversions under the GBRA rights was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. A sensitivity analysis of reservoir firm yield to conservation storage capacity was performed. Based on this analysis, the optimum conservation storage capacity was found to be about 9,200 acft and this volume was selected for use in computing

Table 3.12-2
Guadalupe - San Antonio Basin Modeling Parameters
McFadden Reservoir - Alternative G-18

Analysis Point:	Kuy Creek at McFaddin Reservoir Site (ungaged)			
Minimum Flow Requirements:	Inflow Passage Requirement at Reservoir		Bay & Estuary Inflow Requirement at Saltwater Barrier	
Month	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	132	2	N/A	N/A
Feb	213	4	N/A	N/A
Mar	195	3	N/A	N/A
Apr	715	12	N/A	N/A
May	1,323	22	N/A	N/A
Jun	1,043	17	N/A	N/A
Jul	117	2	N/A	N/A
Aug	240	4	N/A	N/A
Sep	1,408	23	N/A	N/A
Oct	1,116	19	N/A	N/A
Nov	121	2	N/A	N/A
Dec	150	3	N/A	N/A
Drought Median[1]	9	< 1	N/A	N/A
Flow Requirements Based On:	Trans-Texas Environmental Criteria			
Edwards Aquifer Pumpage:	400,000 acft/yr			
Return Flows:				
Surface Water Sources:	1988 Actual			
Groundwater Sources:	1988 Actual			
Water Rights:				
Canyon Lake:	50,000 acft/yr			
Hydro Requirement at Lake Dunlap:	600 cfs			
Applewhite Reservoir:	Included			
Other Rights:	Full Authorized Amounts			
Steam-electric Diversions:				
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)			
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)			
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)			
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)			
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)			
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)			

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	37,100
60%	37,200
80%	37,500

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.
3) Firm yield based on diversion of available water from the purchase of 40,000 acft/yr of water rights (senior to Canyon Lake) from the GBRA Calhoun Canal Division.

N/A: Not applicable.

the firm yield of the project. A summary of the firm yield estimates for each capacity threshold analyzed is provided in Table 3.12-1. As is apparent in this table, estimated firm yield for McFaddin Reservoir is not particularly sensitive to the capacity threshold for drought contingency operations as required by the Trans-Texas Environmental Criteria. The diversion of the GBRA CCD rights provide about 95 percent of the total firm yield of the reservoir.

Figure 3.12-2 illustrates simulated McFaddin Reservoir storage fluctuations for the 1934-89 historical period. Simulated reservoir storage remained above the 60 percent capacity threshold about 97 percent of the time and remained above 90 percent full for 93 percent of the time, resulting in the frequent passage of inflows from the Kuy Creek watershed up to the monthly mean or median natural streamflow. As a result, monthly median streamflows were essentially unaffected by the reservoir at the site and at the Saltwater Barrier. Monthly median streamflows and annual streamflows averaged by decile, with and without the project, are presented in Figure 3.12-3 for conditions both at the site and at the Saltwater Barrier. With a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by an average of 3,800 acft/yr considering flows originating from the Kuy Creek watershed, or less than 1 percent as shown in Figure 3.12-3, if operated under the Trans-Texas Environmental Criteria and subject to diversion of the firm yield of 37,200 acft/yr.

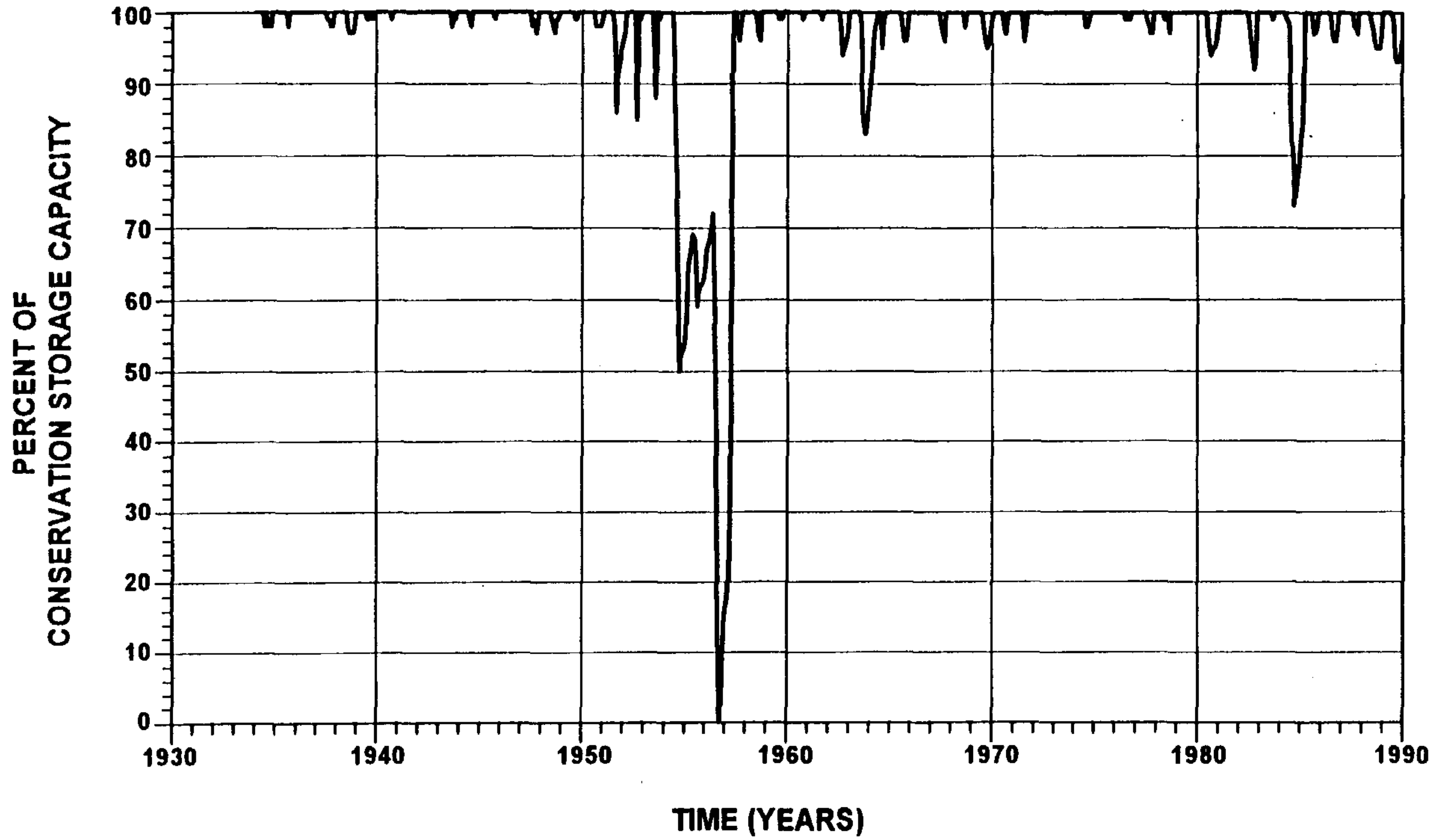
3.12.3 Environmental Issues

Introduction

Environmental issues relevant to the diversion of water from the Guadalupe and San Antonio Rivers can be categorized as follows:

- Effects of the construction and operation of McFaddin Reservoir;
- Effects resulting from the construction and maintenance of a pipeline from McFaddin Reservoir (or the Saltwater Barrier) to Calallen.
- Effects related to diverting water from the Guadalupe and San Antonio Rivers, including effects on the Guadalupe Estuary; and
- Effects related to Nueces Estuary.

Methods used to develop this section, including mapping, searches of available literature and databases, and field reconnaissance are described in the Environmental Overview (Section 3.0.2). Implementation of this alternative is dependent upon construction of the section of the Lake Texana Pipeline (LN-1) between Dry Kuy Creek and Calallen (Figure 3.12-1). A pedestrian survey was conducted along selected sections of this pipeline corridor.



NOTES

FIRM YIELD: 37,200 ACFT/YR (INCLUDES USE OF GBRA CCD RIGHTS)
CONSERVATION STORAGE CAPACITY: 9,200 ACFT
60% CAPACITY THRESHOLD
SCENARIO:

- EDWARDS ACQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

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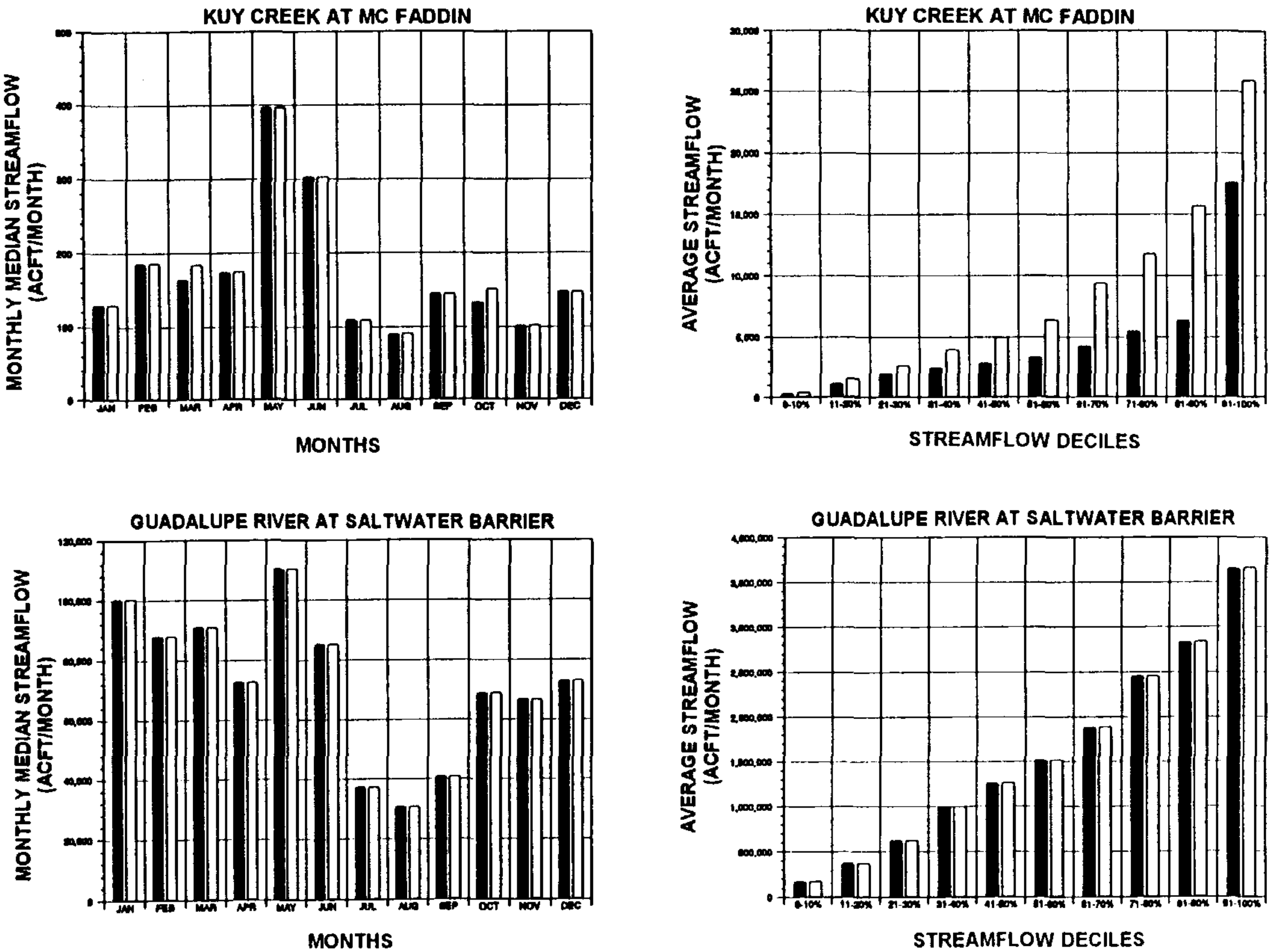
FIRM YIELD STORAGE TRACE MC FADDIN RESERVOIR ALTERNATIVE GS-1

FIGURE 3.12-2



LEGEND

- ■ WITH PROJECT
- □ WITHOUT PROJECT

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CHANGES IN STREAMFLOW
MC FADDIN RESERVOIR
ALTERNATIVE GS-1

FIGURE 3.12-3

Regional Setting

This alternative would involve the diversion of water from the pool behind the Saltwater Barrier below the confluence of the Guadalupe and San Antonio Rivers, possible temporary storage in McFaddin Reservoir, and transport to Corpus Christi by pipeline. This alternative could be developed with or without the construction of McFaddin Reservoir on Kuy and Dry Kuy Creeks in Victoria County.

Soil types of the Texan and Tamaulipan Biotic Provinces are primarily pedalfer and pedocal, respectively. The USDA and Texas Agricultural Experiment Station describe the soils of the reservoir site as being Lake Charles clay on both the nearly level uplands (LaA), and on slopes adjacent to drainages (LaD)[7]. This soil is poorly drained, permeability is slow, and available water capacity is high. McFaddin Reservoir and the proposed pipeline route lie within the Western Gulf Coastal Plain Ecoregion. The reservoir is close to the boundary between the Texan and Tamaulipan Biotic Provinces. These biogeographical regions are described in the Environmental Overview (Section 3.0.2).

Impact Assessment

McFaddin Reservoir

The off-channel reservoir would permanently inundate 660 acres at a conservation elevation of 45 feet-msl, including about 182 acres of wetlands, 390 acres of crop and grassland, and 88 acres of riparian brush and woodland. Although no federal or state protected species are known to occur on the reservoir site, several, including nesting bald eagles and Attwater's Greater Prairie Chicken are known to be present in nearby areas. An on-site investigation will be necessary to further evaluate wetland impacts and the potential for effects on state and federally listed endangered and threatened species. Reservoir development would likely require compensation for the loss of about 270 acres of wetland and woody riparian vegetation.

In addition to habitat mitigation, a reservoir and adjoining lands management plan may be needed. The lands adjacent to the reservoir could be monitored to control the growth of woody vegetation and encourage the development of desirable bottomland species, providing

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[7] United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1982. Soil Survey of Victoria County, Texas. USDA.

suitable shoreline habitat for wildlife. This could possibly be accomplished through seasonal inundation and dewatering.

Proposed Pipeline Route

Implementation of this alternative would require construction of 65 miles of pipeline along the Lake Texana Pipeline route and an 8 mile long diversion pipeline. Together the pipelines include about 1239 acres in the construction corridor, and about 354 acres in the permanently maintained ROW. The pipeline to Corpus Christi would have the same potential impacts (Section 3.13, Figure 3.13-2C-2F, Appendix M (sites 12-39)). Protected species are known to occur in all the counties crossed by the pipeline (Victoria, Refugio, San Patricio and Nueces Counties, Appendix C - Tables 16, 17, 18, 19). Potentially impacted species along the route include the Attwater's greater prairie chicken, the white tailed hawk, the western smooth green snake, black lace cactus, Welder machaeranthera, plains gumween and others. Essential habitat for Attwater's Greater Prairie Chicken occurs along the route of the pipeline in Refugio County. Habitats capable of supporting a number of important species occurs in the project area. These species are listed in Table 3.12-3. Welder machaeranthera was reported along the pipeline route southwest of the San Antonio River (see Section 3.13.3 for a brief description of this plant).

San Antonio River, Guadalupe River, and Guadalupe Estuary

The effects of McFaddin Reservoir operation on flow in Kuy Creek and the Guadalupe River are illustrated in Figure 3.12-3. A McFaddin Reservoir would need to be operated to maintain monthly median flows in Kuy Creek downstream to its confluence with the Guadalupe River. However, substantial proportions of water would be diverted during the periods of highest flow. No substantial effects on the Guadalupe River at the Saltwater Barrier were indicated by the model; total annual discharge changed by an average of only 3,800 acft/yr, or about 1 percent of annual inflow to the estuary. Relative to natural fluctuations characteristic of Texas bays and estuaries, such a decrease is unlikely to have a measurable effect on the

Table 3.12-3
Important Species With Habitat in the Vicinity of the McFadden Project (GS-1)

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	Listing Agency TPWD
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporarily wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E
Indigo Snake	*Drymarchon coralis*	Grassland Prairie to coastal sand hills; prefers woodland and mesquite savannah of Coastal Plain	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks	C2	T
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions	NL	T
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T
Welder Machaeranthe ra	*Machaeranthera heterocarpa*	Shrubland-invaded grasslands, rights-of-way, and open mesquite - huisache woodlands on mostly grey colored clayey to silty soils over Beaumont and Lissie formations on the coastal prairie	C2	NL

Sources: Texas Parks and Wildlife Department. Unpublished data, December 1993. Texas Natural Heritage Program Files; TPWD, Endangered Resources Annual Status Report (E.R.A.S.R.) Appendix G Special Plant List; and TPWD, Unpublished May 1988 species data list by county.

ecology of the Guadalupe estuary.[8] Because the baseline flows were modeled with all existing water rights fully exercised, and Guadalupe River diversions would be made under an existing, purchased right, only the water captured from Kuy and Dry Kuy Creeks affects river flows as modeled.

Nueces Estuary

Supplying the City of Corpus Christi with 37,200 acft/yr of water would increase return flows to Nueces Estuary approximately 17,500 acft/yr. In contrast to diverting water from the Nueces River, this alternative would increase freshwater inflow to the estuary by about 6 percent. Although such an increase in freshwater flow to the estuary might be viewed as positive, a change of this magnitude alone is not likely to produce a measurable effect on the flora and fauna of the bay.

3.12.4 Water Quality and Treatability

Except during periods of very low flows, water quality at the Guadalupe and San Antonio Rivers confluence will generally be more influenced by the Guadalupe than the San Antonio River since the Guadalupe River accounts for about 72% of the flow volume. The secondary water quality constituents analyzed for this study for both rivers meet the TNRCC Secondary Drinking Water Standards. The constituent concentrations in the Guadalupe River are generally lower than in the San Antonio River (Appendix D, Table D-1). The water quality of natural runoff into the proposed McFaddin Reservoir should be relatively. However, specific water quality assessments should be completed in later phases of the Trans-Texas study, if diversions from the Guadalupe and San Antonio Rivers to McFaddin Reservoir should continue to be considered as an alternative water supply for Corpus Christi (refer to Appendix E for more a detailed consideration of treatment issues).

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[8] Longley, W.L. ed. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp.

3.12.5 Engineering and Costing

For this alternative, water from a McFaddin Reservoir could be diverted through an intake and pumped in through the same pipeline that would run from Lake Texana to the O.N. Stevens Water Treatment Plant near Calallen. The diversion rate from the reservoir would be uniform throughout the year. The major facilities required to implement this alternative are:

- Guadalupe River Diversion, Intake, and Pump Station
- Pipeline from River Pump Station to Reservoir
- Dam and Reservoir
- Reservoir Intake and Pump Station
- Texana Pipeline from McFaddin to Calallen
- Raw Water Booster Pump Stations
- Water Treatment Plant Capacity Upgrade
- Finished Water Pump Station

The Saltwater Barrier reservoir intake and pump station are sized to deliver 3,333 acft/month (36 mgd) of interim water for the four pipeline diameters under consideration for the Lake Texana Pipeline. These include 48-inch, 60-inch, 66-inch and 72-inch diameter pipelines. Summary tables showing the annual operating cost, capital cost and total annual cost for each size pipeline is included as Tables 3.12-4 through 3.12-7. Purchase of interim water from GBRA is estimated to cost $53/acft/year for a total annual cost of $1,960,000. Without construction of McFaddin Reservoir, the total annual cost[9], including debt repayment, interest, purchase of water, and operation and maintenance, range from a low of $10,920,000 for the 48-inch pipeline to a high of $14,770,000 for the 72-inch pipeline. These costs include construction of 68 miles of pipeline. For an annual firm yield of 37,000 acft, the resulting annual cost of water ranges from $295 per acft (Table 3.12-4) for the 48-inch pipeline to a high of $399 per acft for the 72-inch pipeline (Table 3.12-7).

With the construction of McFaddin Reservoir, total annual cost[9], including debt repayment, interest, purchases of water, and operation and maintenance, range from a low of $13,520,000 for the 48 inch pipeline to a high of $16,850,000 for the 72 inch pipeline. For an annual firm yield of 39,500 per acft, the resulting annual cost of water ranges from $342 for the 48 inch pipeline to a high of $427 per acft for the 72 inch pipeline.

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[9] Project costs include only the pro rata share of pipeline costs for a McFaddin element of any larger project to move water to Corpus Christi.

Table 3.12-4 Cost Estimate Summary for Diversion from the Guadalupe River With and Without McFaddin Reservoir - 48-inch Pipeline (GS-1A) (Mid-1995 Prices)		
Item	**Alt. GS-1 (48") Divert to WTP and Municipal System with McFaddin Reservoir**	**Alt. GS-1 (48") Divert to WTP and Municipal System without McFaddin Reservoir**
Capital Costs		
Dam and Reservoir, incl. intake and pump station at Saltwater Barrier	$16,590,000	n/a
Transmission Pipeline	40,600,000	$43,700,000
Pump Stations	6,870,000	7,450,000
Total Capital Cost	$64,060,000	$51,150,000
Engineering, Contingencies, and Legal Costs	20,110,000	15,700,000
Land Acquisition	1,330,000	610,000
Environmental Studies and Mitigation	1,190,000	610,000
Subtotal	$86,690,000	$68,070,000
Interest During Construction	3,470,000	2,720,000
Total Project Cost	$90,160,000	$70,790,000
Annual Costs		
Annual Debt Service	$8,450,000	$6,630,000
Purchase of Water	1,960,000	1,960,000
Annual Operation and Maintenance	920,000	710,000
Annual Power Cost	2,190,000	1,620,000
Total Annual Cost	$13,520,000	$10,930,000
Available Project Yield (acft/yr)	39,500	37,000
Annual Cost of Water	$342 per acft	$295 per acft

Table 3.12-5
Cost Estimate Summary for Diversion from the Guadalupe River with and without McFaddin Reservoir - 60-inch Pipeline (GS-1B)
(Mid- 1995 Prices)

Item	Alt. GS-1 (60") Divert to WTP and Municipal System with McFaddin Reservoir	Alt. GS-1 (60") Divert to WTP and Municipal System without McFaddin Reservoir
Capital Costs		
Dam and Reservoir, incl. intake and pump station at Saltwater Barrier	$16,590,000	n/a
Transmission Pipeline	53,490,000	$57,880,000
Pump Stations	3,290,000	3,710,000
Total Capital Cost	$73,370,000	$61,590,000
Engineering, Contingencies, and Legal Costs	22,960,000	18,510,000
Land Acquisition	1,330,000	600,000
Environmental Studies and Mitigation	1,190,000	600,000
Subtotal	$98,850,000	$81,300,000
Interest During Construction	4,100,000	3,230,000
Total Project Cost	$102,950,000	$84,530,000
Annual Costs		
Annual Debt Service	$9,650,000	$7,920,000
Purchase of Water	1,960,000	1,960,000
Annual Operation and Maintenance	960,000	760,000
Annual Power Cost	1,220,000	750,000
Total Annual Cost	$13,790,000	$11,390,000
Available Project Yield (acft/yr)	39,500	37,000
Annual Cost of Water	$349 per acft	$308 per acft

Table 3.12-6 Cost Estimate Summary for Diversion from the Guadalupe River with and without McFaddin Reservoir - 66-inch Pipeline (GS-1C) (Mid-1995 Prices)		
Item	**Alt. GS-1 (66") Divert to WTP and Municipal System with McFaddin Reservoir**	**Alt. GS-1 (66") Divert to WTP and Municipal System without McFaddin Reservoir**
Capital Costs		
Dam and Reservoir, incl. intake and pump station at Saltwater Barrier	$16,590,000	n/a
Transmission Pipeline	65,820,000	71,200,000
Pump Stations	3,290,000	3,710,000
Total Capital Cost	$85,700,000	$74,910,000
Engineering, Contingencies, and Legal Costs	26,100,000	22,330,000
Land Acquisition	1,330,000	600,000
Environmental Studies and Mitigation	1,190,000	600,000
Subtotal	$114,320,000	$ 98,440,000
Interest During Construction	4,570,000	3,900,000
Total Project Cost	$118,890,000	$102,340,000
Annual Costs		
Annual Debt Service	$11,140,000	$9,590,000
Purchase of Water	1,960,000	1,960,000
Annual Operation and Maintenance	1,080,000	900,000
Annual Power Cost	1,060,000	610,000
Total Annual Cost	$15,240,000	$13,060,000
Available Project Yield (acft/yr)	39,500	37,000
Annual Cost of Water	$386 per acft	$353 per acft

Table 3.12-7
Cost Estimate Summary for Diversion from the Guadalupe River with and without McFaddin Reservoir - 72-inch Pipeline (GS-1B)
(Mid-1995 Prices)

Item	Alt. GS-1 (72") Divert to WTP and Municipal System with McFaddin Reservoir	Alt. GS-1 (72") Divert to WTP and Municipal System without McFaddin Reservoir
Capital Costs		
Dam and Reservoir, incl. intake and pump station at Saltwater Barrier	$16,590,000	n/a
Transmission Pipeline	78,090,000	$84,450,000
Pump Stations	3,290,000	3,710,000
Total Capital Cost	$97,970,000	$88,160,000
Engineering, Contingencies, and Legal Costs	29,990,000	26,190,000
Land Acquisition	1,330,000	600,000
Environmental Studies and Mitigation	1,190,000	600,000
Subtotal	$130,480,000	$115,550,000
Interest During Construction	5,220,000	4,570,000
Total Project Cost	$135,700,000	$120,120,000
Annual Costs		
Annual Debt Service	$12,710,000	$11,250,000
Purchase of Water	1,960,000	1,960,000
Annual Operation and Maintenance	1,210,000	1,040,000
Annual Power Cost	970,000	520,000
Total Annual Cost	$16,850,000	$14,770,000
Available Project Yield (acft/yr)	39,500	37,000
Annual Cost of Water	$427 per acft	$399 per acft

3.12.6 Implementation Issues

The water supply identified in this alternative is not surplus to the Guadalupe and San Antonio River Basins in year 2050 and is only considered as an interim (i.e. 25 to 40 years) source for possible supply to the study area. Therefore, this alternative cannot be considered equally with other alternatives providing a permanent source of water for the Corpus Christi service area.

Implementation of this alternative would require purchase of a portion of the GBRA CCD water rights on an interim basis (i.e. 25 to 40 years). Such an interbasin transfer would require determination that the purchased quantity is surplus to the needs of the basin during the duration of the purchase.

Requirements Specific to Reservoirs:

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.

3. Land will need to be acquired by negotiation or condemnation.

4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

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.
   d. TPWD Sand, Gravel and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

Requirements Specific to Treatment and Distribution:

1. Detailed study needed to determine improvements necessary to effectively integrate the new supply into the City's water supply system.

3.13 Lake Texana Pipeline to Corpus Christi (LN-1)

3.13.1 Description of Alternative

Lake Texana (Palmetto Bend Stage I) was constructed in the 1970's by the U.S. Bureau of Reclamation (USBR), with sponsorship of the Lavaca Navidad River Authority and substantial funding assistance from the Texas Water Development Board's storage acquisition program. As shown on Figure 3.13-1, the Navidad River drains 1,346 square miles into Lake Texana, and then, down river from Palmetto Bend Dam and below the confluence with the Lavaca River, empties into the Lavaca-Colorado Estuary. Based on TNRCC's Lavaca-Navidad River Basin Model, the estimated average annual runoff (using 1940 to 1979 data) is 517,000 acft/yr.[1]

The TWDB and LNRA jointly hold a water rights permit with an adjudicated priority date of May 15, 1972, which allows diversion of the water stored in Lake Texana for municipal and industrial purposes. The TWDB owns 57.33 percent of the diversion right and LNRA owns the remaining 42.67 percent, with LNRA having the option of purchasing the TWDB share. Presently, in accordance with amendment number two (1979) of the 1972 contract between TWDB and LNRA, the Authority may sell the Board's water. The permit has been amended several times, most recently in November, 1994 to add a schedule for releases to the Lavaca-Matagorda Bay and Estuary System. The basis of this latest amendment was an agreement between Texas Parks and Wildlife, TWDB, and LNRA, with the terms of the agreement being incorporated into the permit amendment. A copy of the amended permit is included as Appendix L.

Under the provisions of the amended permit, the firm yield of Lake Texana is 79,000 acft/yr and the authorized annual diversion from the reservoir is 74,500 acft/yr, after allowance for the agreed upon releases to the bay and estuary. Of this amount, 32,410 acft/yr is contracted to Formosa Plastics, Inteplast, Calhoun County Navigation District, and the City of Point Comfort and 250 acft/yr is presently uncommitted.

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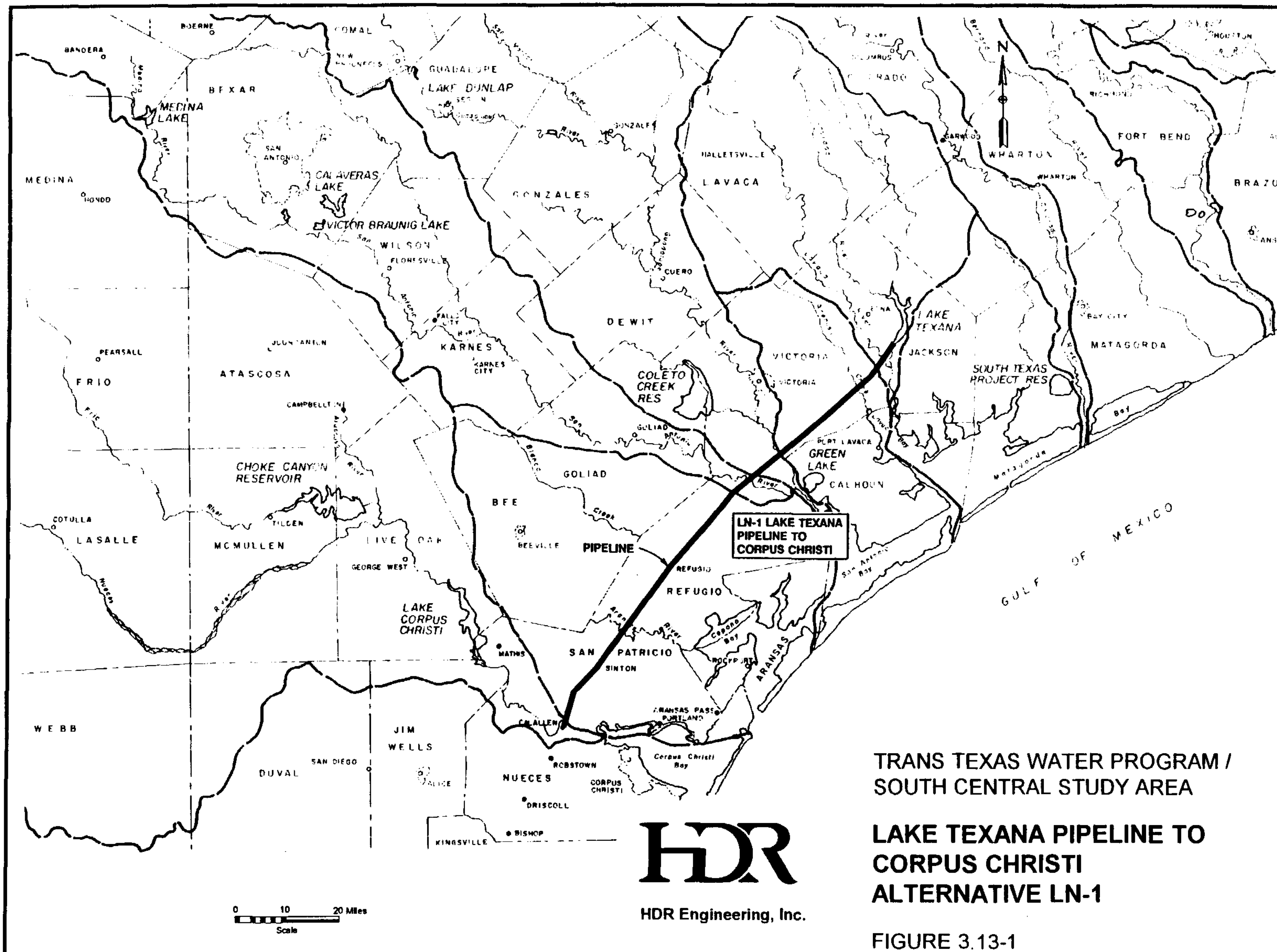
[1] HDR Engineering, Inc. 1993. Trans-Texas Water Program. Corpus Christi Service Area. Phase I Interim Report Summary. Note: This amount of runoff per square mile is more than 8 times the annual average runoff per square mile which flows into Lake Corpus Christi.



TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

LAKE TEXANA PIPELINE TO CORPUS CHRISTI ALTERNATIVE LN-1

FIGURE 3.13-1

In December of 1993, the City of Corpus Christi entered into a water delivery and conveyance contract with LNRA in which Corpus Christi agrees to purchase 31,440 acft/yr of Lake Texana water on a permanent basis and 10,400 acft/yr on a temporary basis until such water is needed, if ever, to supply local demands in Jackson County[2]. Under this contract, the City will be responsible for the following costs:

- It's pro-rata share of Lake Texana operating and maintenance expenses;
- It's pro-rata share of LNRA's project related operating and maintenance expenses;
- It's pro-rata share of principal and interest payments, and premium (if any), and reserve fund payments (if any) due on the Texana Bonds and the Federal Contract payments (these payments end in 2035); and
- Principal, interest, and reserve fund payments (if any) due on the Project Bonds.

Monthly payments to LNRA by Corpus Christi were begun in July, 1995 and will cover Federal debt service. LNRA's most recent estimate of the cost per acre-foot to reserve Lake Texana water is shown in Table 3.13-1.

Table 3.13-1
Estimated Costs to Acquire Water in Lake Texana
(Source: Lavaca Navidad River Authority memo dated January 4, 1995)

Fiscal Year[1]	Costs Per Acft[2]
1995	28.03
1996	38.76
1997	44.53
1998	50.50
1999	56.67
2000	63.07
2001	65.97
2002	68.89
2003	71.82
2004	72.27

[1] From August 1 to July 31.
[2] For either 31,440 ac-ft or 41,840 ac-ft.

Water from Lake Texana would be delivered to Corpus Christi via a proposed pipeline extending approximately 104 miles from the western outlet of Palmetto Bend Dam to the O.N. Stevens Water Treatment Plant at Calallen, near Corpus Christi. For most of its length, the

[2] Water Delivery and Conveyance Contract Between Lavaca-Navidad River Authority and Corpus Christi, December 14, 1993.

pipeline would be adjacent to existing rights of way of highways, pipelines, or electric transmission lines, or the pipeline will be within the ROW for those facilities. The waterline would traverse Jackson, Victoria, Refugio, San Patricio and Nueces counties, passing near the communities of Vanderbilt, LaSalle, Bloomington, Placedo, Refugio, Woodsboro, Sinton, Odem, and would end at the water treatment plant in Calallen.

3.13.2 Available Yield

The total amount of Lake Texana water committed in the water supply contract between the City of Corpus Christi and LNRA has been used to size the facilities to deliver water to the city. The total is 41,840 acft/yr as follows:

	Acft/yr
Permanent Water	31,440
Temporary Water Available	10,400
Total Water Available from Lake Texana	**41,840**

3.13.3 Environmental Issues

Introduction

Potential environmental issues related to constructing a pipeline and transferring water from Lake Texana to Corpus Christi can be categorized as follows:

- Effects on Lake Texana;
- Effects on the Navidad River downstream of Lake Texana;
- Effects on the Lavaca-Colorado Estuary;
- Effects on the Nueces Estuary; and
- Effects along the pipeline ROW.

The impacts, if any, in each of these categories will be identified and described in the following sections. Additional descriptions of the methods, vegetation and wildlife habitat in the area, along with a listing of the areas' water resources, will precede the identification of the impacts. At the conclusion of this section, recommendations regarding possible mitigation for this alternative will be presented.

Methodology

Methods used to develop this section, including mapping, searches of available literature and databases, and a pedestrian survey are more fully described in the Environmental Overview (Section 3.0.2). Field surveys focusing on selected sections of the pipeline study corridor considered to be most sensitive in terms of potential environmental effects were conducted in the summer and fall of 1994. For mapping purposes, habitat types and land use resources were divided into the general physiognomic categories derived from definitions for woodland and brush and vegetational communities developed by TPWD.[3] Areas identified as woodlands were areas with trees over 9 feet tall, growing in clusters or scattered, with 71 to 100 percent canopy coverage. Areas identified as mixed woods and open fields were those areas with trees growing in clusters or scattered, with 11 to 70 percent canopy coverage. Brush described areas with woody-stemmed vegetation, usually less than 9 feet tall, growing in clusters and accounting for 10 percent or more of the canopy coverage. Open grasslands and pastures, shrub-invaded pastures and cropland were included in a single category. Wetlands were separated into swamp and marsh. Areas categorized as urban land use included areas within towns and cities.

The Affected Environment

Regional Setting

The project area traverses Jackson, Victoria, Refugio, San Patricio and Nueces counties in the subtropical Western Gulf Coastal Plain Ecoregion[4] where relative humidity is high and distance from the coast is a determinant of temperature extremes. A description of this region is presented in the Environmental Overview (Section 3.0.2).

Jackson County at the northeastern end has an annual average temperature of 70^0 F, a mean precipitation of approximately 41 inches and a mean relative humidity at noon of about

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[3] McMahan, C.A. R.G. Frye and K. L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD.

[4] Omerik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1): pp. 118-125.

60 percent.[5] Summers are hot with mean maxima in the 90s and winters are moderate with freezing temperatures only about 24 days per year.

Nueces County, at the southwestern end of the project area has an annual average temperature of 72^0 F, with hot summers in the 90's and only about 7 days per year when temperatures are at or below freezing. Annual precipitation averages about 30 inches and mean relative humidity at noon is about 63 percent. However, the portion of the Nueces River watershed upstream of Lake Corpus Christi receives annual average precipitation of about 25 inches.

Water Quality and Aquatic Habitat

Major water resources within the study area include Lake Texana, Navidad River, Lavaca River, Lavaca Bay, Matagorda Bay, Garcitas Creek, Guadalupe River, San Antonio River, Mission River, Melon Creek, Devils Run, Sous Creek, Aransas Creek, and Nueces River.[6]

Lake Texana

Lake Texana was created by impoundment of the Navidad River approximately four miles above its confluence with the Lavaca River. Based on the latest USBR sediment survey, Lake Texana, at conservation pool (44 feet msl) contains approximately 160,000 acre-feet of water and covers 10,000 acres. At maximum flood pool (47 feet MSL), an additional 1,500 acres is inundated. Lake Texana has an average depth of approximately 16 feet and a maximum depth of 58 feet. The lake is located in a rural area remote from urban centers and no significant, adjacent residential or industrial development has occurred. Such development is not permitted on project lands administered by LNRA. However, considerable recreational facilities, including 8 public boat ramps, a primitive recreation area, a state park and campground have been constructed.

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[5] The Natural Fibers Information Center. 1987. The climates of Texas counties. Bureau of Business Research, The University of Texas at Austin, Austin, Texas.

[6] Kuehne, R.A. 1955. Stream Surveys of the Guadalupe and San Antonio Rivers. Texas Game and Fish Commission Report. I F Report Series No. 1, 56 pp.

Prior to construction of the dam, combined average annual discharge of the Lavaca and Navidad Rivers was estimated by the USBR to be 593,000 acft based on records for the period from 1941 to 1968,[7] 614,000 acft/yr based on records for the 1941-1976 period,[8] 656,000 acft/yr based on records for 1941-1986,[9] and 796,000 acft/yr based on records for the period 1960-1982.[10] Of this, the reservoir was estimated to be capable of storing 160,000 acft, resulting in a firm yield of 79,000 acft/yr and authorized diversions of 74,500 acft/yr after consideration of required releases to the bay and estuary.

Required releases to the bay and estuary are stated in the "Bay and Estuary Release Schedule" in the amended permit for Lake Texana (see Appendix L). The release schedule generally states that when the level of Lake Texana exceeds 78.18 percent of capacity (initially above an approximate elevation of 40 feet msl), water is released to pass all inflows to the reservoir up to: 1) the historical monthly median flow for the months of November, December, January, February, March and July; and 2) the historical monthly mean flow for the remaining months. When less than 78.18 percent of the reservoir's capacity contains stored inflows (stages initially below elevation 40 feet msl), all inflows up to the annual median daily flow (approximately 5.0 cfs) for the historical critical drought period from January 1954, through December 1956 are released. This release plan was critically examined[11] and was agreed upon by LNRA, TWDB, TPWD, TNRCC, and the Sierra Club.[12] Thus, impacts, if any, to the bay have been analyzed, found to be acceptable, and are authorized in the permit issued by TNRCC.

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[7] BOR. 1974. Palmetto Bend Project - Texas Final Environmental Impact Statement. Bureau of Reclamation, U.S. Department of the Interior.

[8] TDWR. 1980. Cited in PPA, EA

[9] Jones, R.S. 1986. Studies of Freshwater Inflow Effect on the Lavaca Deleta and Lavaca Bay, Texas. The University of Texas Marine Science Institute, Technical Report No. TR/86-006.

[10] Mueller, A.J. and G.A. Matthews. 1987. Freshwater inflow needs of the Matagorda system with focus on penaid shrimp. NOAA Technical Memorandum NMFS-SEFC-189, National Marine Fisheries Service, Galveston, Texas.

[11] R.J. Brandes Company and M. Sullivan and Assoc. 1991. Evaluation of the Effects of Proposed Release Operation Plans for Lake Texana on Lavaca Bay Salinities. Prepared for Texas Parks and Wildlife Department, Austin, Texas.

[12] Certificate of Adjudication 16-2095B to LNRA and TWDB Concerning Releases from Lake Texana for Bays and Estuaries.

Proposed Pipeline Route

Several alternatives considered in this study are dependent upon the construction of a pipeline from Lake Texana to the O.N. Stevens Water Treatment Plant at Calallen (LN-2, LN-3, C-1, C-2, B-3). Additionally, alternative GS-1 would require a pipeline which would use the same alignment as alternative LN-1 between the San Antonio River and the O.N. Stevens plant.

The route of the proposed pipeline is shown on Figures 3.13-2A through 3.13-2F on which field survey sites are marked, environmental features are identified and general physiognomic categories are labeled as follows: Woodlands (W), Mixed Brush and Grassland (X), Urban (U), Open Grasslands, Pastures, Cropland (O), Brush (B), Marsh and Wetland Pasture (M). The line is shown on both USGS topographic maps and on aerial photographs of the route. Both the maps and the photographs are presented at the same scale for ease in comparing the data presented in Appendix M.

The initial survey of the route and a review of available mapping and aerial photography, including infrared photographs, indicates that a large portion of the 1,764 acres within the 140 foot wide construction easement is currently pastures and croplands. Open grasslands and pastures, shrub-invaded pastures and croplands account for 1,478 acres, or 84 percent of the land within the construction ROW. Brushlands account for less than 300 acres (17 percent), with the majority of this being mesquite-live oak shrub, brush and parkland in Refugio and San Patricio Counties between the San Antonio River and the City of Sinton.[13]

Woodlands represented by large live oak trees (*Quercus virginiana*) and cedar elm trees (*Ulmus crassifolia*) tend to be confined to river banks and floodplains. Thus, the primary impact on woodlands will occur in those locations where the pipeline will cross rivers and floodplains. For example, although the pipeline would follow a petroleum pipeline ROW north of the Lavaca River, the proposed ROW passes through 10 acres of woodland (Fig. 3.13-2A, survey site 5). In other cases, e.g., in low lying areas bordering Garcitas Creek and north of the San Antonio River, large trees are concentrated in mottes that should be avoided where practicable. Similarly, the Guadalupe River is bordered along its south bank by a bald cypress (*Taxodium distichum*) swamp. However, infrared photographs and USGS maps indicate that the proposed

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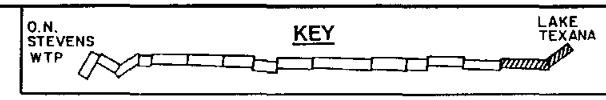
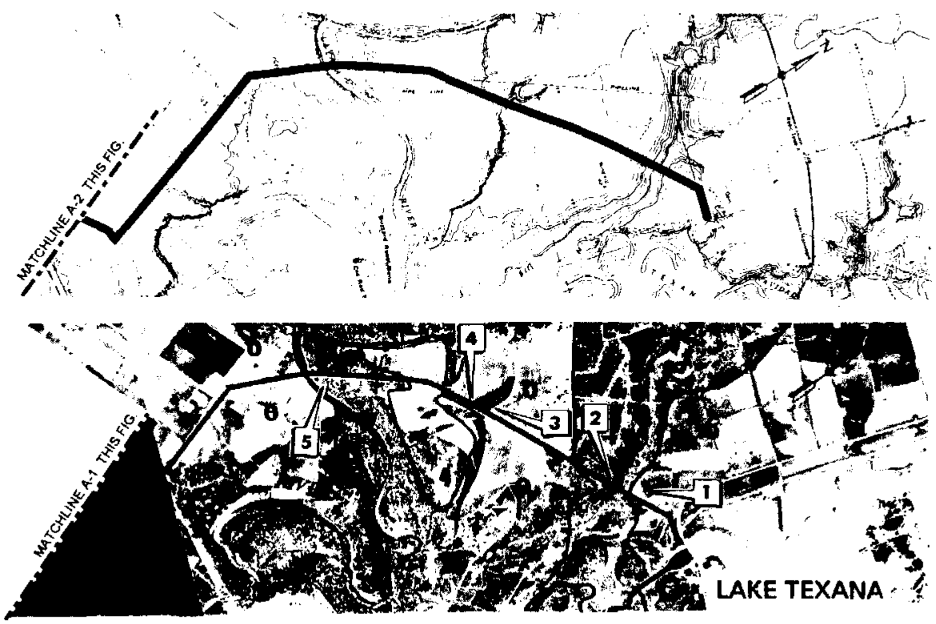
[13] McMahan, C.A. R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. Texas Parks and Wildlife Department.





LEGEND

B = BRUSH
M = MARSH AND WETLAND PASTURE
O = OPEN GRASSLAND, PASTURE, CROPLAND
U = URBAN
W = WOODLAND
X = MIXED BRUSH AND GRASSLAND

30 = FIELD SURVEY SITE LOCATION

SCALE: 0 2000 4000 FEET 0 500 1000 METERS

MAP SOURCE: USGS 7.5 Minute Texas Quadrangle Sheets, 1973 - 1987.
PHOTO SOURCE: USGS EROS Data Center. Negatives and Infrared Photographs, 1989.

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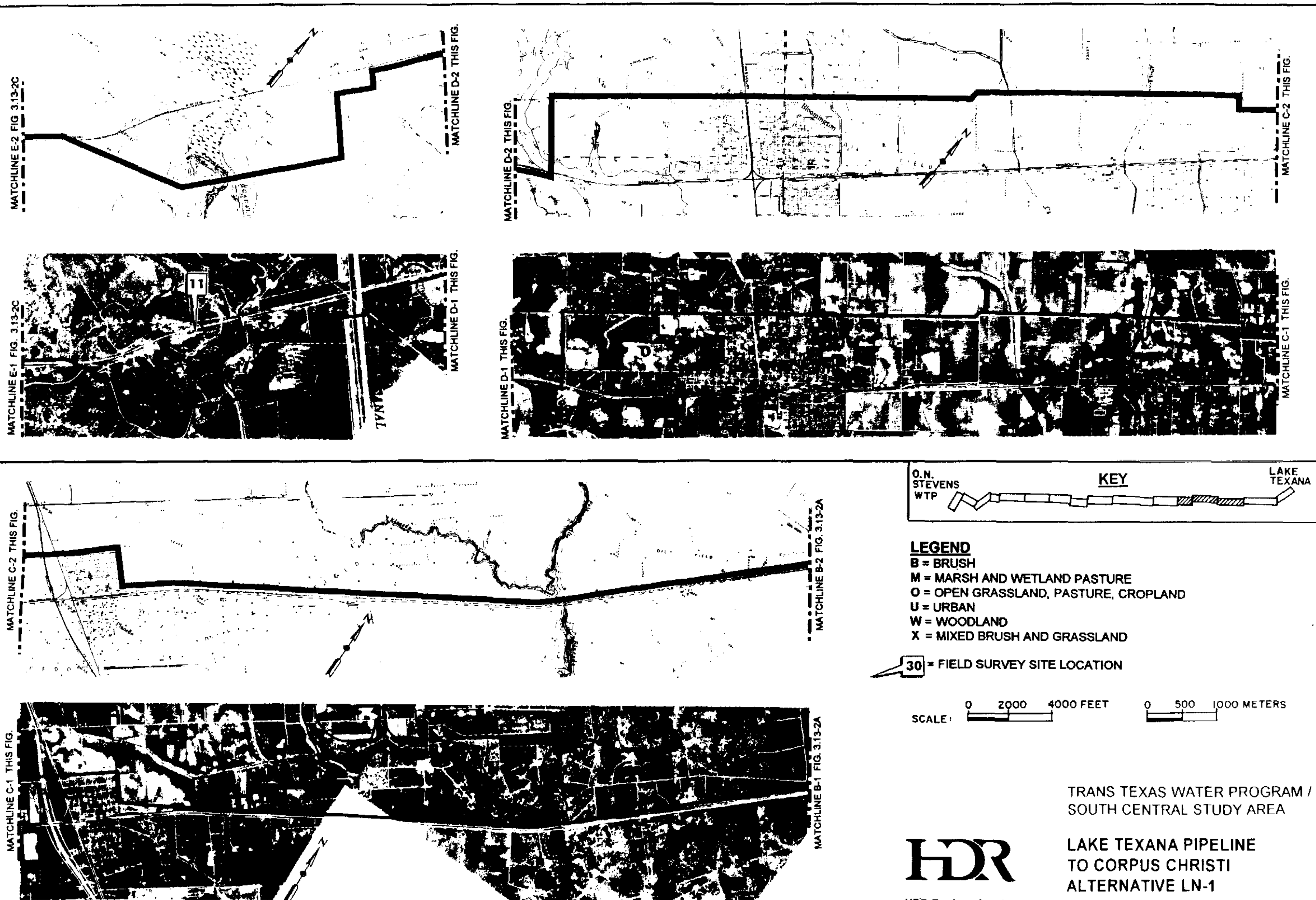
LAKE TEXANA PIPELINE TO CORPUS CHRISTI ALTERNATIVE LN-1

FIGURE 3.13-2A



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X = MIXED BRUSH AND GRASSLAND

30 = FIELD SURVEY SITE LOCATION

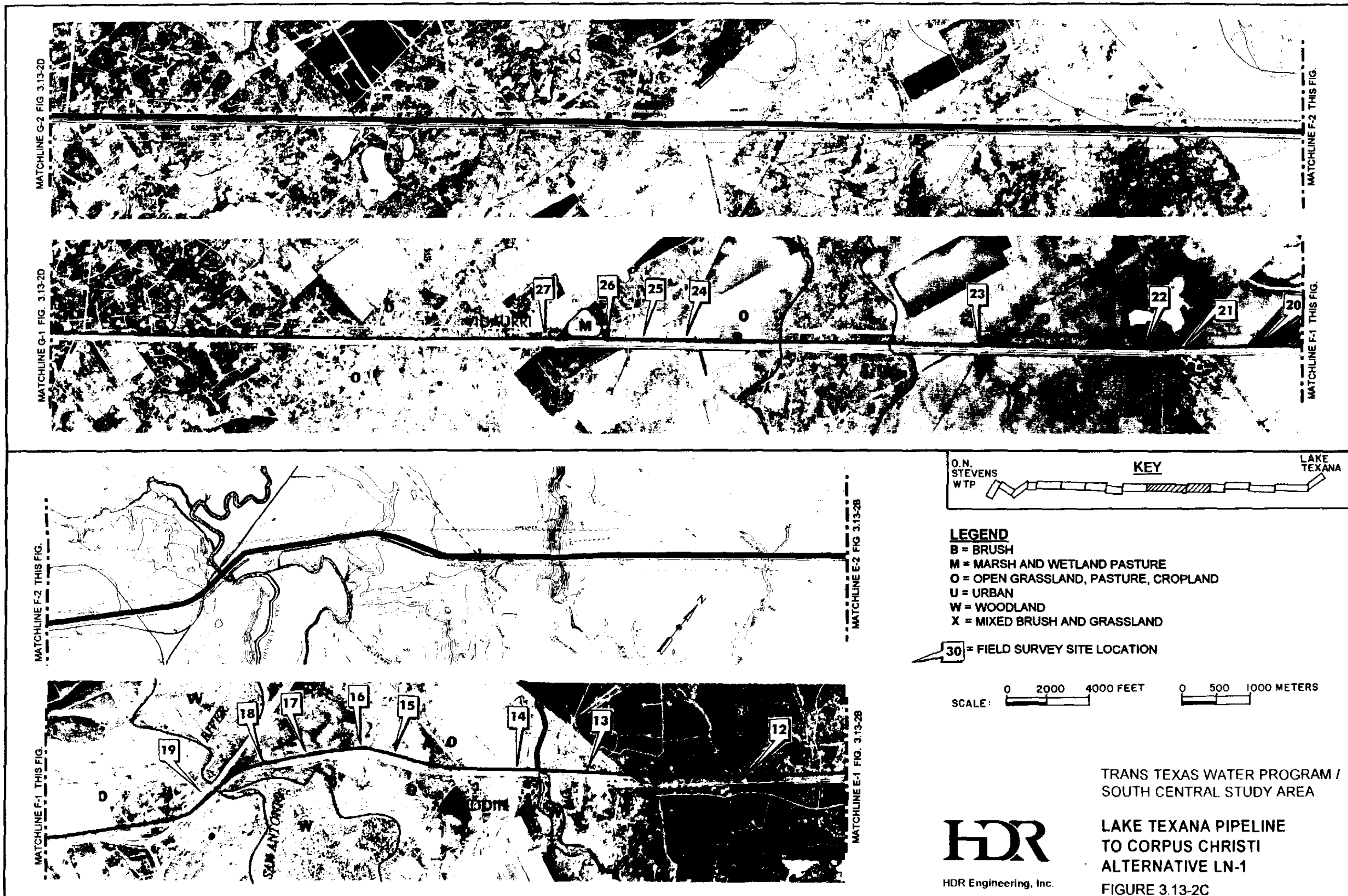
SCALE: 0 2000 4000 FEET 0 500 1000 METERS

TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

HDR Engineering, Inc.

LAKE TEXANA PIPELINE TO CORPUS CHRISTI ALTERNATIVE LN-1

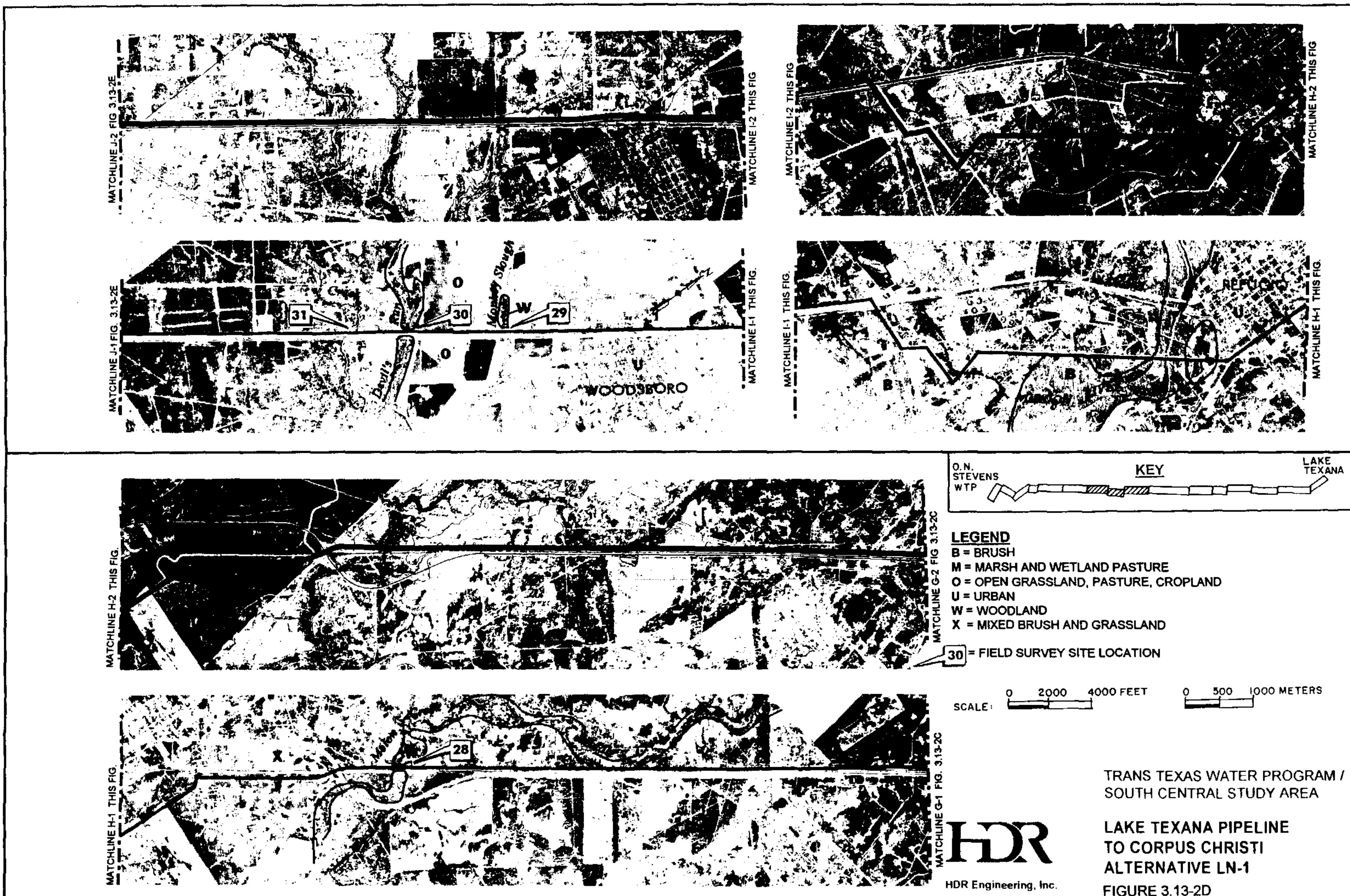
FIGURE 3.13-2B



TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

LAKE TEXANA PIPELINE TO CORPUS CHRISTI ALTERNATIVE LN-1

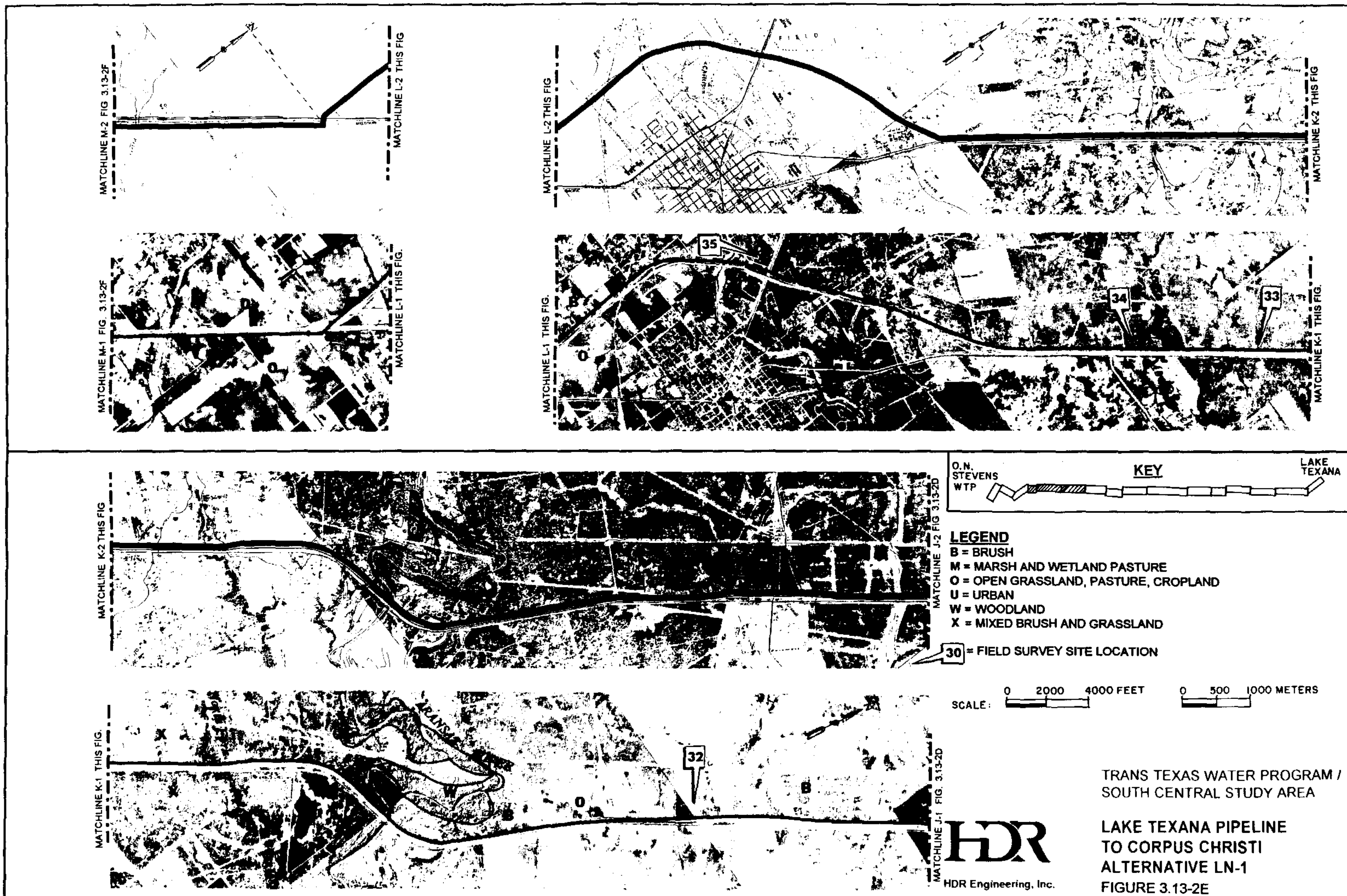
FIGURE 3.13-2C

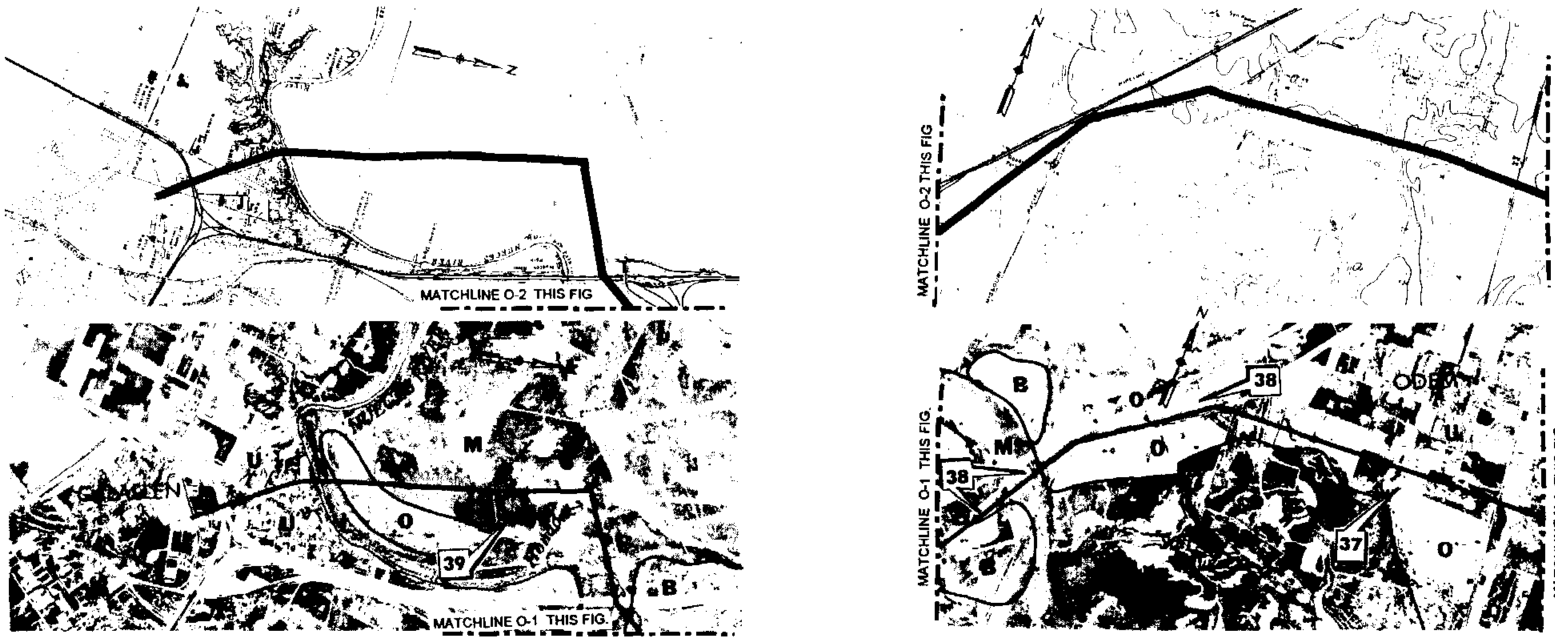


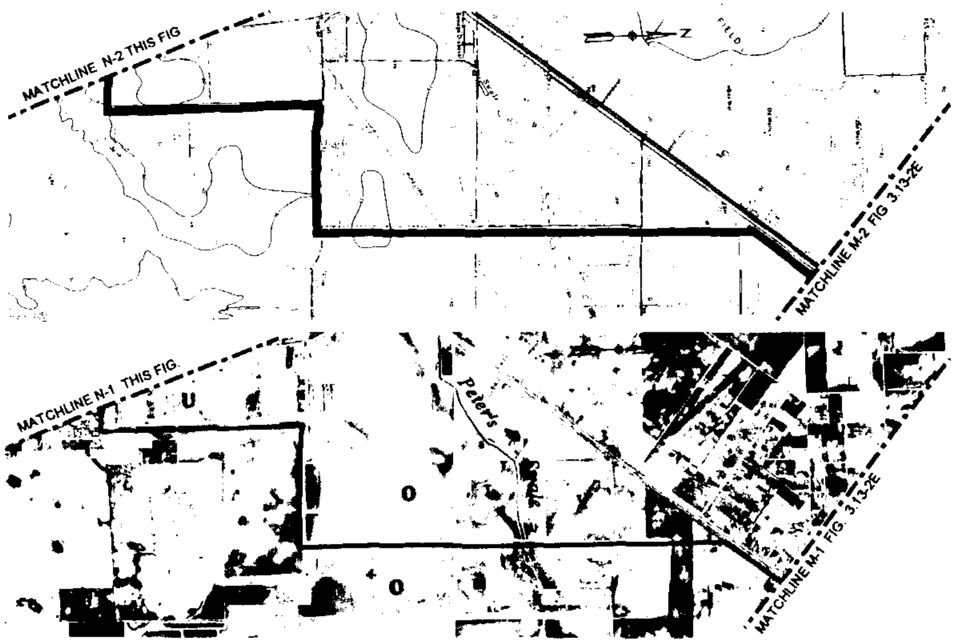
TRANS TEXAS WATER PROGRAM /
SOUTH CENTRAL STUDY AREA

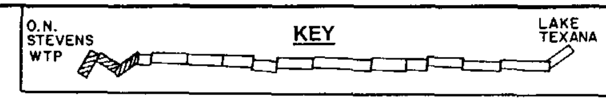
**LAKE TEXANA PIPELINE
TO CORPUS CHRISTI
ALTERNATIVE LN-1**

FIGURE 3.13-2D


MATCHLINE M-2 FIG 3.13-2F
MATCHLINE L-2 THIS FIG
MATCHLINE K-2 THIS FIG
MATCHLINE M-1 FIG. 3.13-2F
MATCHLINE L-1 THIS FIG.
MATCHLINE K-1 THIS FIG.
MATCHLINE J-2 FIG 3.13-2D
MATCHLINE J-1 FIG. 3.13-2D
35
34
33
32
O.N. STEVENS WTP
KEY
LAKE TEXANA
LEGEND
B = BRUSH
M = MARSH AND WETLAND PASTURE
O = OPEN GRASSLAND, PASTURE, CROPLAND
U = URBAN
W = WOODLAND
X = MIXED BRUSH AND GRASSLAND
30 = FIELD SURVEY SITE LOCATION
SCALE: 0 2000 4000 FEET 0 500 1000 METERS
TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA
HDR
HDR Engineering, Inc.
LAKE TEXANA PIPELINE TO CORPUS CHRISTI ALTERNATIVE LN-1
FIGURE 3.13-2E







LEGEND
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M = MARSH AND WETLAND PASTURE
O = OPEN GRASSLAND, PASTURE, CROPLAND
U = URBAN
W = WOODLAND
X = MIXED BRUSH AND GRASSLAND

30 = FIELD SURVEY SITE LOCATION

SCALE: 0 2000 4000 FEET 0 500 1000 METERS

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LAKE TEXANA PIPELINE TO CORPUS CHRISTI ALTERNATIVE LN-1

FIGURE 3.13-2F

pipeline would cross the Guadalupe at a point that would minimize impact to the cypress trees and the swamp (Figure. 3.13-2B, survey site 11). Wetlands must be delineated in accordance with U.S. Army Corps of Engineers requirements, which is expected to be completed for selected alternatives in the next phase (Phase III) of the Trans-Texas studies. For this preliminary analysis, existing mapping was reviewed, aerial photographs were analyzed, and selected areas were visited to identify vegetation and hydrological indicators. Based on this analysis, wetlands are estimated to total 140 acres, which is 7.9 percent of the total acreage. Almost 100 acres (77 percent) of this is riverine and associated with palustrine systems of the Lavaca River, Guadalupe River, San Antonio River, Mission River, and Nueces River, including upper Nueces Estuary where it borders State Highway 77 near its interchange with Interstate Highway 37 (Figure 3.13-2, survey sites 38 and 39). Remaining wetlands (29 percent) were associated primarily with small, often temporary creeks. Flows from Chocolate Swale south of Woodsboro have been impounded to form ponds of less than 2 acres. Additionally, small marshes (< 2 acres) were noted in pastures south of the San Antonio Rivers (Figure 3.13-2, survey sites 26, 27)

Protected species have been observed in each of the counties crossed by the pipeline (Jackson, Victoria, Refugio, San Patricio and Nueces Counties; Appendix C-Tables 10, 19, 17, 18, and 16, respectively).[14] Potentially impacted species located within these counties include the Attwater's greater prairie chicken, the white tailed hawk, the western smooth green snake, black lace cactus, welder machaeranthera, plains gumweed and others. Essential habitat for Attwater's greater prairie chicken (*Tympanicus cupido Attwateri*) occurs along the south of the pipeline in Refugio County.[15,16]

Although the white-tailed hawk (*Buteo albicauda*) is not listed as endangered or threatened under the U.S. Endangered Species Act, it is listed by the TPWD as S2, "imperiled

[14] HDR Engineering, Inc. 1993. Trans-Texas Water Program. Corpus Christi Service Area. Phase I Interim Report Summary.

[15] Silvy, N.J., D.L. Brown, S.E. Labuda, Jr., J.G. Teer and D. Williams. 1993. Attwater's Prairie Chicken Recovery Plan. USFWS, Region 2, Albuquerque, New Mexico.

[16] TPWD. 1993. Natural Heritage Program. Special Animal List. 06 October 1993.

in state, very rare, vulnerable to extirpation, 6 to 20 occurrences," and threatened.[17] During the survey[18] of the pipeline corridor a White-tailed hawk was observed perched on a power transmission line and flying low over pastures on the side of State Highway 77 opposite the proposed ROW in Refugio County. The coastal prairies region of Texas represents the northern most extension of the White-tailed hawk's range. It is a common to uncommon resident inhabiting savanna, prairie, thorn forest, and pastures.[19] The hawk was observed again several days later in the same location.

The western smooth green snake (*Ophedrys vernalis blancharidi*) is not listed under the U.S. Endangered Species Act, however, it is listed by TPWD as S1, "Critically imperiled in state, extremely rare, very vulnerable to extirpation, 5 or fewer occurrences," and endangered.[20] In Texas the Western smooth green snake is known from fewer than 10 specimens, all collected on the coastal plain in Austin, Chambers, Harris, and Matagorda counties.[21] In the recent field survey[22] a green snake identified as a Western smooth green snake was observed in brush along the edge of a pasture, the predominant habitat type in the immediate area. However, the snake could not be captured for closer observation and scale counts could not be used to confirm the identification. The Western smooth green snake inhabits meadows, grassy marshes and moist grassy fields along forest edges.[23]

The black lace cactus (*Echinocerus reichenbachii* var. *alberti*), listed as endangered by USFWS is found in brushy, grassy areas with huisache, mesquite, blackbrush, retama, shrubs in the South Texas Plains area including Refugio, San Patricio and Nueces counties. There is no recorded occurrence within the study corridor and no specimens of black lace cactus were

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[17] Ibid.

[18] Paul Price Associates, Inc., unpublished data.

[19] Rappole, J.H. and G.W. Blacklock. 1994. A Field Guide. Birds of Texas. Texas A&M University Press.

[20] TPWD. 1993. Texas Natural Heritage Program. Special Animal List. 06 October 1993.

[21] Tennant, A. 1985. A Field Guide to Texas Snakes. Texas Monthly Press.

[22] Paul Price Associates, Inc., unpublished data.

[23] Behler, J.L. 1979. The Audubon Society Field Guide to North American Reptiles and Amphibians. Alfred A. Knopf, New York.

observed during the pedestrian survey of potential habitat in the proposed pipeline corridor, however, habitat for this species may be present in the corridor. Some of the areas which could not be accessed during the initial field surveys included brushlands near Bloomington and areas of Refugio County that may be habitat for black lace cactus. Additional surveys covering approximately 10 miles of potential black lace cactus habitat are planned during Phase III of Trans-Texas program.

Welder machaeranthera (*Psilactis heterocarpa*) was identified in a number of pastures in the proposed pipeline ROW south of the San Antonio River.[24] Specimens observed were limited to disturbed habitats along the roadside, mowed fence lines or in open patches in pastures. Although not currently listed as endangered, Welder machaeranthera has a Federal Status of category 2 candidate (C2). Welder machaeranthera is reported to occur in shrub-invaded grasslands and open mesquite-huisach woodlands on mostly gray colored clayey to silty soils over Beaumont and Lissie Formations on coastal prairie.[25]

The species plains gumweed (*Grindelia oolepis*) has been reported along the proposed pipeline corridor. Plains gumweed, proposed endangered in 1976, is now listed by USFWS as C3. Although recommended for listing by Mahler in 1980[26] as threatened, a follow-up distribution report by USFWS did not recommend this species for protection partly due to its adaptation and success in disturbed areas including road ROWs. Although USFWS decided that information gathered on this plant's distribution did not indicate protection was appropriate at this time, Texas Natural Heritage Program and Texas Organization for Endangered Species (TOES) are still monitoring populations. If drastic changes occur, the plant may be listed in the future.[27]

Other important plants monitored by the Natural Heritage Program and TOES that are known in the study area include the Mathis spiderling (*Boerhavia mathisiana*) which has been

[24] Ibid.

[25] TPWD. 1993. Texas Natural Heritage Program. Special Plant List. October 1993.

[26] TPWD. 1993. Natural Heritage Program data files and maps. Resource Protection Division, Austin, Texas.

[27] USFWS. 1980. Report on the distribution of *Grindelia oolepis*. Russell L. Kologiski, endangered species botanist. Region 2, USFWS, Corpus Christi, Texas.

reported in open thorn shrublands in pedocal soils; yellowshow (*Amoreuxia wrightii*) on clayey calcareous soils of the Tamaulipan thorn shrublands; Texas gourd (*Cucurbita texana*) on alluvial soils of river terraces; Texas windmillgrass (*Chloris texensis*) on coastal prairie grasslands and roadsides; and Elemendorf's onion (*Allium elemondorfii*), which can be found in grassland openings in post oak woodlands.[28, 29] These species have been considered in our site specific study of the pipeline corridor and there are no known conflicts with them.

No sites on or eligible for inclusion on the National Register of Historic Places are located within the proposed corridor, although many culturally important sites may occur in the counties traversed by the proposed pipeline. Cultural resources along the pipeline route will be investigated during future surveys.

Impact Assessment

Construction Impacts to the Pipeline ROW

The 104 mile pipeline from Lake Texana to Corpus Christi (Alternative LN-1) begins at an existing intake at Lake Texana and ends at the O.N. Stevens Water Treatment Plant at Calallen. For most of its length, the proposed pipeline route parallels or will be within existing ROWs. The pipeline is expected to require a construction easement 140 feet wide and a permanent easement 40 feet wide.

As noted earlier, the pipeline would be sized to deliver 41,840 acft of water to the treatment plant, and three pump stations are required. The first pump station would be located at Lake Texana near the outlet works, the second would be located near McFaddin, northeast of Highway 445, and the third would be located about one mile southwest of Woodsboro. The exact locations of the second and third pump stations, which will be in-line booster stations, need not be established, as their final location can be determined during design of the pipeline. Since their locations can be adjusted, they can be located so as to minimize or eliminate impacts to environmental features. The only other visible features along the pipeline will be manholes and vent pipes for air release valves, manholes on isolation valves installed in the line, and location

[28] TPWD. 1993. Natural Heritage Program data files and maps. Resource Protection Division, Austin, Texas

[29] TOES. 1993. Endangered, Threatened and Watch Lists of Texas Plants. Third Revision with supplements from September 1993 and 1994. Austin, Texas.

signs to indicate the route of the pipeline. Construction techniques for pipelines are outlined in the Environmental Overview (Section 3.0.2).

Pipeline construction would potentially disturb a maximum of about 1764 acres of vegetation and soils, including: 1,478 acres of grassland, brushy pasture, and cropland; 300 acres of shrub, brush and parkland and 20 acres of woodland. Of the total, approximately 140 acres is wetlands. However, in the long-term only 504 acres in the 40 foot wide permanent easement would be maintained.

Tunneling under the larger rivers, e.g., the Lavaca, Guadalupe, San Antonio, Aransas, and Nueces Rivers, and Garcitas Creek would be expected to reduce impacts to wetlands. Also, it appears impacts to wetlands can be reduced by minor adjustments to the final route of the pipeline. For example, the proposed pipeline would cross Garcitas Creek at a point which would minimize impact to cattail and spartina marshes (Figure 3.13-2, survey sites 8-10). Also a significant portion of the wetlands is highly disturbed. For example, the Nueces floodplain and the saltmarsh associated with the upper Nueces Estuary accounts for 34 acres (24 percent of the total wetland) and is heavily grazed by cattle.

Discussions with representatives of USFWS, including Attwater's prairie chicken Recovery Team personnel, indicate that potential impacts due to construction can be avoided by limiting construction during their season of reproductive activity. This could be accomplished by performing construction in this area during the months of July through January.[30] With respect to Attwater's prairie chicken habitat, a ROW maintained in native grasses, infrequently mowed (no herbicides), and lacking structures that could be employed as perches by raptorial birds would be consistent with its requirements.[31] These requirements are consistent with the restoration and maintenance that would normally follow pipeline construction.

Because the white-tailed hawk was observed perched or flying low over terrain on the side opposite the pipeline on the divided four-lane State Highway 77, and there were no potential nesting sites in or adjacent to the study corridor, it did not appear likely that pipeline construction would interfere with the hawk. Also, habitat near the home range of this hawk

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[30] Steve LaBuda, Attwater's Prairie Chicken Refuge Manager, pers. comm.

[31] Steve LaBuda, Attwater's Prairie Chicken Refuge Manager, pers. comm.

would be restored to its original condition; i.e., pastureland.

In the event black lace cactus is discovered within the ROW, mitigation would be accomplished by avoidance. Where Welder machaeranthera is encountered, preserving and replacing the topsoil along with its seedbank would be expected to restore this species since it is well adapted to disturbed habitats.[32] Also, seeding with a mixture of native plants and infrequent mowing in the 40 foot maintenance ROW may benefit Welder machaerantera by reducing interspecific competition.

Operational Effects

Lake Texana

Withdrawing 41,840 acre-feet per year of water from Lake Texana will nearly complete implementation of the diversion authorized for this reservoir by the TNRCC. The impact of diverting the entire yield of the reservoir has been assessed, a schedule of bay and estuary flow releases has been designed to mitigate the effects of the diversions, all interested parties in the operating rules imposed on the reservoir have accepted the operating rules, and those rules have been incorporated into the permits for Lake Texana (See Appendix L).[33,34,35,36] In addition, projections of water demands and water supplies of the Lavaca Basin show that the 41,840 acft of Lake Texana water is surplus to the Lavaca Basin projected needs in year 2050 (see Section 2.7.4).

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[32] Hartman, R. L. and M. A. Lane. 1987. A new species of *Machaeranthera* section *Psilactis* (Asteraceae: Astereae) from coastal Texas. Brittonia 39(2):253-257.

[33] BOR. 1974. Palmetto Bend Project - Texas Final Environmental Impact Statement. Bureau of Reclamation, U.S. Department of the Interior.

[34] BOR 1991

[35] R.J. Brandes Company and M. Sullivan and Assoc. 1991. Evaluation of the Effects of Proposed Release Operation Plans for Lake Texana on Lava Bay Salinities. Prepared for Texas Parks and Wildlife Department, Austin, Texas.

[36] Espy, Huston and Associates, Inc. 1982. Matagorda Bay: A Management Plan. In Cooperation with University of Texas, Austin, Texas.

Lavaca-Matagorda Estuary

Diversion of the full permitted amount of Lake Texana of 74,500 acft/yr will result in some flow reductions in the Navidad River. However, the diversion of 41,840 acft/yr to Corpus Christi will only reduce median annual flows in the Navidad River by approximately 14 percent and in the Lavaca River below the confluence with the Navidad River by five percent, resulting in reduced median annual inflows to the Lavaca-Matagorda Estuary of 2.7 percent. Previous detailed studies of the effects of these diversions, noted in Section 3.14, found that projected environmental effects in the Lavaca-Matagorda Estuary will be within acceptable limits, even assuming no return flows. Additional efforts to study or mitigate the effects of Lake Texana operation on the Navidad River, the Lavaca River, or the Lavaca-Matagorda Estuary with respect to implementation of this alternative are not expected.

Nueces Estuary

Following use in the Corpus Christi area, a portion of the Lake Texana water would be returned to the Nueces Estuary system as treated wastewater. Based on the 1934 to 1989 period of record, Phase 2 CC/LCC Operating Policy, an interbasin transfer of 41,840 acft/yr, and an estimated wastewater return to Nueces Bay of 47 percent, projected return flows by 2050 with and without the Lake Texana Interbasin transfer have been developed.[37] These studies found that by the year 2050, Lake Texana water would contribute 19,665 acre-feet of water annually (a 6.6 percent increase) to the Nueces Estuary with median monthly changes in return flow ranging between four percent and 23.8 percent Tables 3.13-2 and 3.13-3, Figures 3.13-3). Salinities in Central Nueces Bay were projected to decrease on average from 16.3 ppt to 14.9 ppt, (1.4 ppt) with median salinity decreases ranging between 0.32 ppt and 2.18 ppt (Table 3.13-4, Figure 3.13-4). A schedule of appropriate salinity boundaries was established by the TNRCC in their order concerning required releases from the CC/LCC Reservoir System. This schedule establishes upper and lower salinity bounds for Nueces Bay. Comparisons of salinity levels with and without the Texana pipeline were made. This comparison shows that upper bound salinity violations for the 672 month study period would be reduced from 27 without the transfer to zero

[37] HDR Engineering, Inc. 1993a. Trans-Texas Water Program. Corpus Christi Service Area. Phase I Interim Report Summary.

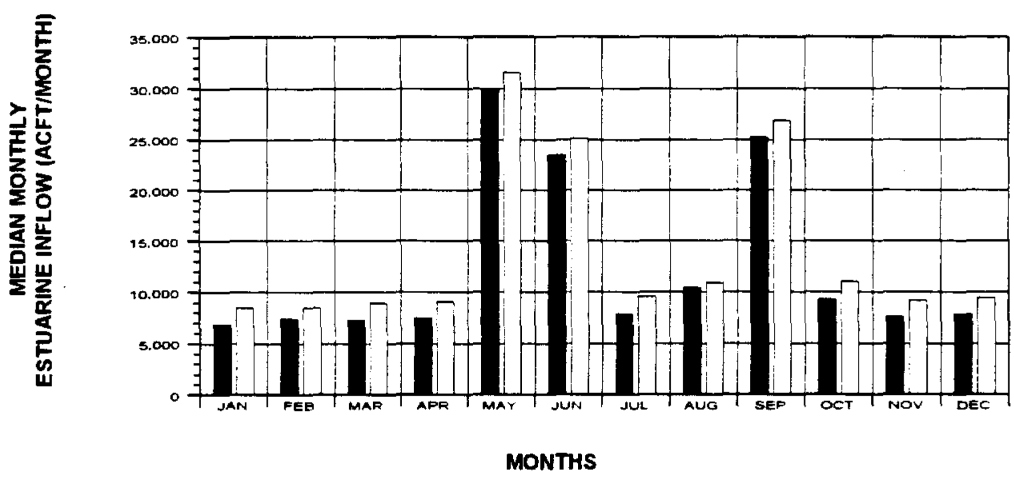
Table 3.13-2 Comparison of Monthly Median Nueces Estuary Inflow with and without Lake Texana Pipeline Diversions (Alternative LN-1)			
Month	**Median Monthly Estuarine Inflow without Texana Pipeline (acft)**	**Median Monthly Estuarine Inflow with Texana Pipeline (acft)**	**Percent Difference (%)**
JAN	6,902	8,547	23.8
FEB	7,452	8,531	14.5
MAR	7,352	8,991	22.3
APR	7,551	9,118	20.8
MAY	29,912	31,580	5.6
JUN	23,488	25,156	7.1
JUL	7,902	9,660	22.2
AUG	10,519	10,941	4.0
SEP	25,258	26,926	6.6
OCT	9,414	11,082	17.7
NOV	7,681	9,272	20.7
DEC	7,898	9,536	20.7

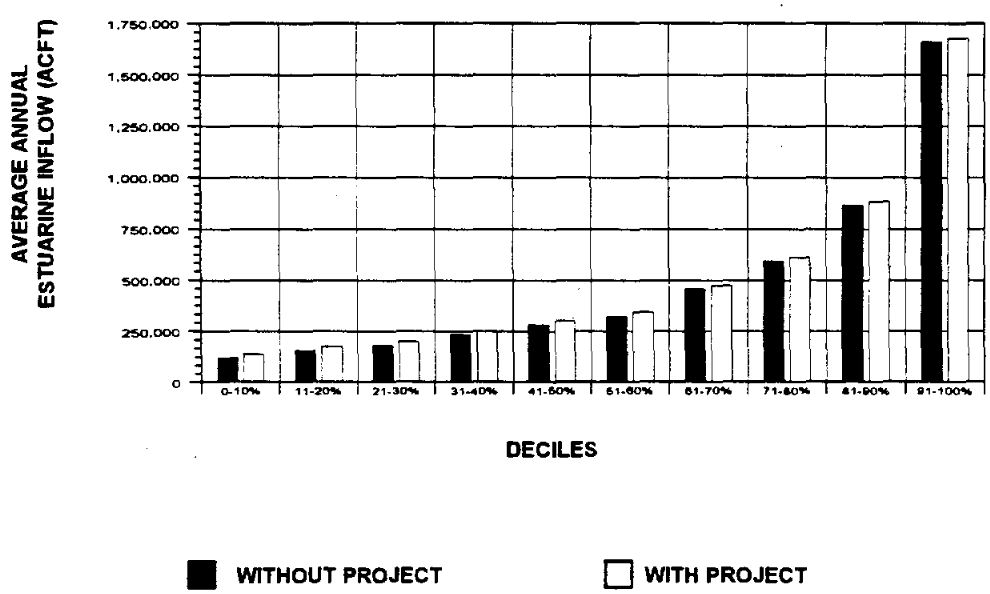
Analysis based on Phase 2 CCR/LCC Operating Policy, 2050 sediment conditions, and an annual diversion of 41,840 acft/yr from Lake Texana to Corpus Christi.

Table 3.13-3
Comparison of Annual Average Nueces Estuary Inflow Deciles with and without Lake Texana Pipeline Diversions (Alternative LN-1)

Decile	Average Annual Estuary Inflow without Texana Pipeline (acft)	Average Annual Estuary Inflow with Texana Pipeline (acft)	Percent Difference (%)
0-10%	121,323	140,626	15.9
11-20%	157,380	176,556	12.2
21-30%	184,824	204,155	10.5
31-40%	236,149	254,092	7.6
41-50%	283,603	303,665	7.1
51-60%	325,466	345,523	6.2
61-70%	458,580	477,164	4.1
71-80%	593,355	612,509	3.2
81-90%	864,299	883,503	2.2
91-100%	1,663,057	1,681,657	1.1

Analysis based on Phase 2 CCR/LCC Operating Policy, 2050 sediment conditions, and an annual diversion of 41,840 acft/yr from Lake Texana to Corpus Christi.





NOTES:
PHASE 2 OPERATING POLICY
2050 SEDIMENT CONDITIONS
41,840 ACFT/YR TEXANA TRANSFER

TRANS TEXAS WATER PROGRAM /
SOUTH CENTRAL STUDY AREA

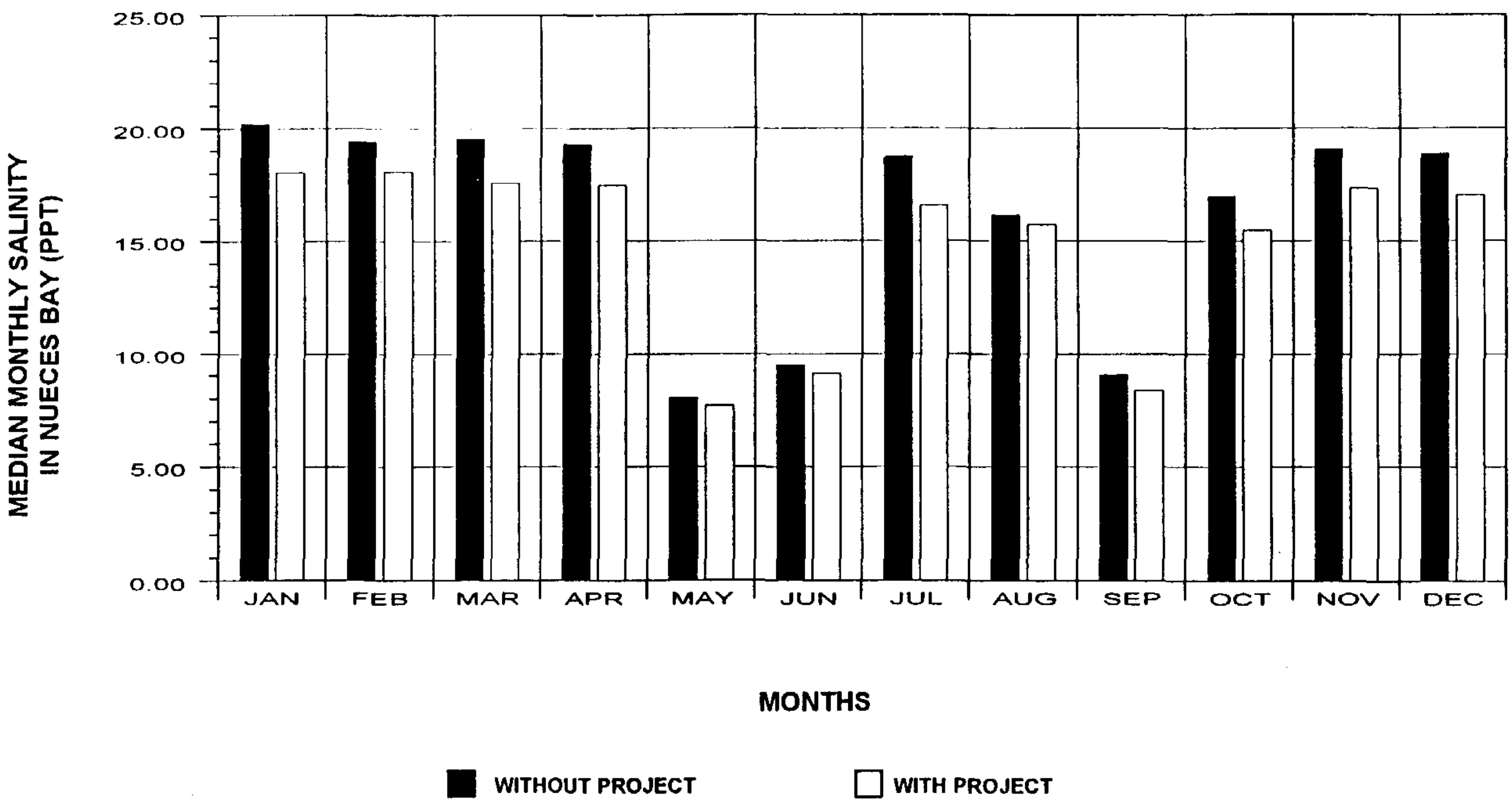
HDR Engineering, Inc.

CHANGES IN NUECES ESTUARY INFLOWS ALTERNATIVE LN-1

FIGURE 3.13-3

Table 3.13-4 Comparison of Monthly Median Salinity in Upper Nueces Bay with and without Lake Texana Pipeline Diversions (Alternative LN-1)			
Month	**Median Monthly Salinity without Texana Pipeline (ppm)**	**Median Monthly Salinity with Texana Pipeline (ppm)**	**Percent Difference (%)**
JAN	20.23	18.10	-10.5
FEB	19.44	18.12	-6.8
MAR	19.58	17.63	-10.0
APR	19.31	17.50	-9.4
MAY	8.03	7.71	-4.0
JUN	9.48	9.13	-3.7
JUL	18.78	16.60	-11.6
AUG	16.16	15.74	-2.6
SEP	9.05	8.38	-7.4
OCT	17.00	15.52	-8.7
NOV	19.11	17.34	-9.3
DEC	18.89	17.06	-9.7

Analysis based on Phase 2 CCR/LCC Operating Policy, 2050 sediment conditions, and an annual diversion of 41,840 acft/yr from Lake Texana to Corpus Christi.



NOTES:
PHASE 2 RESERVOIR OPERATING POLICY
2050 SEDIMENT CONDITIONS
41,840 ACFT/YR TEXANA TRANSFER

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
CORPUS CHRISTI SERVICE AREA

CHANGES IN UPPER NUECES BAY SALINITY ALTERNATIVE LN-1

FIGURE 3.13-4

violations with the transfer (Table 3.13-5). Lower bound salinity violations would increase from 66 without interbasin transfer to 68 with interbasin transfer (Table 3.13-6).

Laboratory studies and positive correlations between increased shrimp harvest and increased freshwater inflows suggest that additional freshwater inflows to Nueces Estuary would benefit shrimp and finfish.[38,39] Also, recent investigation,[40] indicates that treated wastewater may be used effectively to enhance productivity in the Nueces Estuary. In contrast to alternatives involving the diversion of water from the Nueces River Basin, wastewater returns from LN-1 will offset losses to the bay from local alternatives which divert water from the Nueces River. Therefore, impacts to Nueces Bay with alternative LN-1 will be generally positive.

Recommended Mitigation

It is expected that all impacts will be mitigated by 1) avoiding the impact, 2) minimizing the impact, and 3) compensating for unavoidable impacts. The direct effects of project implementation would include construction impacts to vegetation, habitats, and potentially, to cultural deposits in the construction corridor. Mitigative measures will primarily address effects to construction activity which will be limited to the construction corridor. Employing good engineering and construction practices and judicious placement of the pipeline will avoid or minimize environmental impacts. Preserving and replacing topsoil from the construction corridor and restoring the land to its original contours will negate long term effects. Seeding with an appropriate mixture will prevent erosion and restore vegetation. Vegetation in grasslands and shrub-invaded pastures, and cropland, and animal species associated with these habitats, would be expected to return to near its original condition following seeding. According to ranchers in the region, unmowed areas outside the maintenance ROW in the brushlands would

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[38] Mueller, A.J. and G.A. Matthews. 1987. Freshwater inflow needs of the Matagorda system with focus on penaid shrimp. NOAA Technical Memorandum NMFS-SEFC-189, National Marine Fisheries Service, Galveston, Texas.

[39] TWC. 1991. Choke Canyon/Lake Corpus Christi Technical Advisory Commission - Final Report. August 16, 1991.

[40] HDR Engineering, Inc. 1993b. Regional Wastewater Planning Study - Phase II. Nueces Estuary.

Table 3.13-5
Comparison of Monthly Upper Salinity Bound Violations in Upper Nueces Bay with and without Lake Texana Pipeline Diversion (Alternative LN-1)

Monthly	Interim Order Monthly Upper Salinity Bound (ppt)	Number of Upper Bound Violations w/o Texana Pipeline	Number of Upper Bound Violations w/ Texana Pipeline	Change in Number of Violations
JAN	30	0	0	0
FEB	30	0	0	0
MAR	30	0	0	0
APR	30	0	0	0
MAY	20	4	0	-4
JUN	20	6	0	-6
JUL	25	0	0	0
AUG	25	0	0	0
SEP	20	3	0	-3
OCT	30	0	0	0
NOV	30	0	0	0
DEC	30	0	0	0
SUM		13	0	-13

Analysis based on Phase 2 CCR/LCC Operating Policy and existing TNRCC Interim Release Order, 2050 sediment conditions, and an annual diversion of 41,840 acft/yr from Lake Texana to Corpus Christi.

Table 3.13-6
Comparison of Monthly Lower Salinity Bound Violations
in Upper Nueces Bay
with and without Lake Texana Pipeline Diversions (Alternative LN-1)

Month	Interim Order Monthly Lower Salinity Bound (ppt)	Number of Lower Bound Violations without Texana Pipeline	Number of Lower Bound Violations with Texana Pipeline	Change in Number of Violations
JAN	5	4	4	0
FEB	5	1	2	1
MAR	5	1	1	0
APR	5	5	5	0
MAY	1	2	2	0
JUN	1	4	4	0
JUL	2	4	4	0
AUG	2	2	2	0
SEP	5	16	16	0
OCT	5	15	15	0
NOV	5	7	7	0
DEC	5	3	3	0
SUM		64	65	1

Analysis based on Phase 2 CCR/LCC Operating Policy and existing TNRCC Interim Release Order, 2050 sediment conditions, and an annual diversion of 41,840 acft/yr from Lake Texana to Corpus Christi.

be expected to be heavily invaded by woody species within 10-15 years. Clearing areas within dense brush is reported to benefit some species, e.g., white-tailed deer, for which this is considered to be good wildlife management practice.[41]

A discussion of permitting requirements and methods of pipeline construction designed to minimize impact are described in the Environmental Overview (Section 3.0.2). Compensation for unavoidable impacts to wetlands and terrestrial wildlife habitats will likely be requested by USFWS and TPWD. However, decisions on the actual extent of required mitigation are established by the permitting agencies, i.e., TNRCC in the case of a water rights permit and the COE for a permit under Section 10 of the Rivers and Harbors Act or a 404 permit. The pipeline requires a Section 10 permit if it is within navigable water. A 404 permit is required if the line is constructed in "waters of the United States", though pipelines may be permitted under the COE's Nationwide Permit Program provided there is no change in preconstruction contours.

Tunneling under major rivers, where this is feasible, will minimize or eliminate impacts to both wetlands and woodlands. Nearly three-fourths of the 140 acres of total wetland acreage is associated with the Lavaca, Guadalupe, San Antonio, Mission and Nueces Rivers, and Garcitas Creek. The major river crossings also account for almost all of the woodlands within the corridor. Tunneling will reduce the impacts at the river crossings, however, even with tunneling, mitigative measures to wetlands and woodlands will need to be completed to the satisfaction of the COE. Special care should be taken to avoid forested wetlands where practicable. Impacts to other wetland vegetation, which is primarily herbaceous, would be primarily short term.

No impacts to state or federally listed species which would require mitigation are known at this time. If archeological remains are encountered during construction, the TWDB and the Texas Historical Commission will be contacted. No action affecting potential cultural resources should be take without consulting these agencies.

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[41] Inglis, J.M., B.A. Brown, C.A. McMahan, and R.E. Hood. Deer-Brush Relationships on the Rio Grande Plain, Texas. Kleberg Studies in Natural Resources. Texas Agricultural Experiment Station, Texas A&M University.

3.13.4 Water Quality and Treatability

Lake Texana has the best water quality of any option under consideration by Corpus Christi. It has the lowest maximum, median, and minimum values for each of the four constituents analyzed: chloride, TDS, sulfate, and hardness (refer to Appendix D). A sealed pipeline would transport water from Lake Texana to the O.N. Stevens Water Treatment Plant, ensuring that the water quality will not change during the transfer. Blending Lake Texana water with Nueces River water at the O.N. Stevens plant will result in lowering the median constituent concentrations of chlorides by 19 percent from 162 mg/l to 131 mg/l and hardness by 19 percent from 219 mg/l to 175 mg/l.

Although there is no evidence of the existence of other marginal constituents, detailed water quality assessments should be completed in later phases of study. (Refer to Appendix E for a discussion of treatment issues).

3.13.5 Engineering and Costing

The estimated costs for constructing and operating a pipeline from Lake Texana to the O.N. Stevens plant were calculated using estimated 1995 mid-year unit costs and estimated quantities for materials, labor, and land easements. The pipeline size was determined based on a pumping head dictated by pipe friction and the ground profile along the proposed route. Pipeline costs were calculated using unit cost curves which include all costs associated with pipeline construction (except right-of-way and land purchase) and are based on historical cross-country pipeline construction costs adjusted to 1995 prices. Estimated costs for pump stations were also based on historical construction for similar installations. The costs for permanent and construction easements were approximated by assuming the purchase of 140 feet temporary construction easement and 40 feet of permanent right-of-way at $950 per acre along the proposed pipeline route. Unit costs for highway and railroad crossings were estimated using historical data for similar crossings. Power costs were estimated using current Central Power and Light rate schedules for demand and energy changes. Estimated costs for environmental studies of the pipeline corridor are $339,000.

A cost estimate was prepared for a 48 inch pipeline sized to deliver water at a rate of 41,840 acft/yr, which is 40 MGD, 27,800 gpm, and 61 cfs. The cost estimate assumes a uniform diversion rate with five percent downtime during the year and all of the water delivered to the O.N. Stevens Water Treatment Plant. The estimate in Table 3.13-7 includes three pump stations: one station located at Lake Texana which would connect to the existing west intake; one booster station located near McFaddin northeast of Highway 445; and one booster station located about one mile southwest of Woodsboro.

Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $8,138,000. Operation and maintenance costs, including power, total $3,955,000 per year. Tunnelling to avoid environmental features such as creek and river crossings and associated wetlands would cost $1,870,000. Adding the purchase of water from LNRA to the financing cost and the operation and maintenance costs, results in a total annual cost of $14,849,000. As shown in Table 3.13-8, the resulting unit cost for the delivery of 41,840 acft/yr is $355 per acre-foot. These costs are for a stand-alone project and do not consider the reductions in unit cost if the Lake Texana water is combined with other alternatives. For example, studies of other alternatives which would increase the annual volume in an upsized pipeline to about 63,440 acft indicate the above unit cost for the Lake Texana portion would decrease to about $334 per acft.

3.13.6 Implementation Issues

Requirements Specific to Interbasin Transfer of Water

1. It will be necessary to obtain these permits:
   a. Permit amendment from TNRCC for Interbasin Transfer.
   b. Coastal Coordination Council review.

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 Coordination Council review. .
   d. TPWD Sand, Gravel and Marl permit for river crossings.
2. Right-of-way and easement acquisition.

Table 3.13-7 Cost Estimate for 48" Pipeline from Lake Texana to Corpus Christi Flow = 41,840 acft/yr (Mid-1995 Prices)	
Item	**Estimated Cost**
Capital Cost	
Pump Station	$3,300,000
Booster Station	2,330,000
Booster Station	2,700,000
Pipeline	56,220,000
Tunneling at Environmental Features	1,870,000
Subtotal	$66,420,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	17,020,000
Subtotal	$83,440,000
Environmental Studies and Mitigation	339,000
Land Easements	544,000
Subtotal	$84,323,000
Interest During Construction	2,530,000
Total Project Cost	$86,853,000
Annual Cost	
Annual Debt Service	$8,138,000
Annual Operation and Maintenance (Excluding Power)	908,000
Annual Power	3,047,000
Annual Cost of LNRA Water (Average for 1995-2035)	2,756,000
Total Annual Cost	$14,849,000
Yield	41,840 acft/yr
Average Annual Cost of Water	$ 355 per acft

3. Approval from various agencies for these crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

Table 3.13-8
Unit Cost Estimate for
Lake Texana Pipeline to Corpus Christi
(Mid-1995 Prices)

Item	**Flow = 41,840 acft/yr (48" pipeline)**
Capital Costs	$86,853,000
Annual Debt Service	8,138,000
Annual Operation and Maintenance	3,955,000
Annual Cost of LNRA Water	2,756,000
Total Annual Cost	$14,849,000
Yield (acft/yr)	41,840
Annual Cost of Water per acft	$355

3.14 Palmetto Bend (Stage II) Reservoir (LN-2)

3.14.1 Description of Alternative

The proposed Palmetto Bend Stage II reservoir was originally proposed by the U.S. Bureau of Reclamation to be constructed on the Lavaca River and to share a common pool with Stage I (i.e., Lake Texana). In 1991, HDR updated[1] the Bureau of Reclamation's estimated cost and yield for Stage II which had been developed in 1965. In this update, HDR determined that Stage II could be constructed more economically if operated separately from Lake Texana. This change from the earlier Bureau of Reclamation plan reduced the potential yield by only 4.4 percent while reducing the estimated construction cost by 33 percent. Under the HDR plan, Stage II would have a capacity of 93,000 acft and a surface area of 6,900 acres at a normal pool elevation of 44 ft msl. The location of this alternative is shown in Figure 3.14-1.

Since completion of the 1991 update, and prior to the South Central Phase 1 studies, LNRA, TWDB, and TPWD, developed a Bay and Estuary Release Agreement[2] for pass-through of Navidad River flow at Lake Texana to meet the environmental needs of the Lavaca-Tres Palacios Estuary. Subsequent to the Bay and Estuary Release Agreement, and the Phase I study, the TNRCC amended the Certificate of Adjudication[3] for the Stage II reservoir. This recent amendment provides that upon completion of Stage II an additional 18,122 acft/yr is permitted for use for the "maintenance of the Lavaca-Matagorda Bay and Estuary System" in accordance with the following permit authorization:

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

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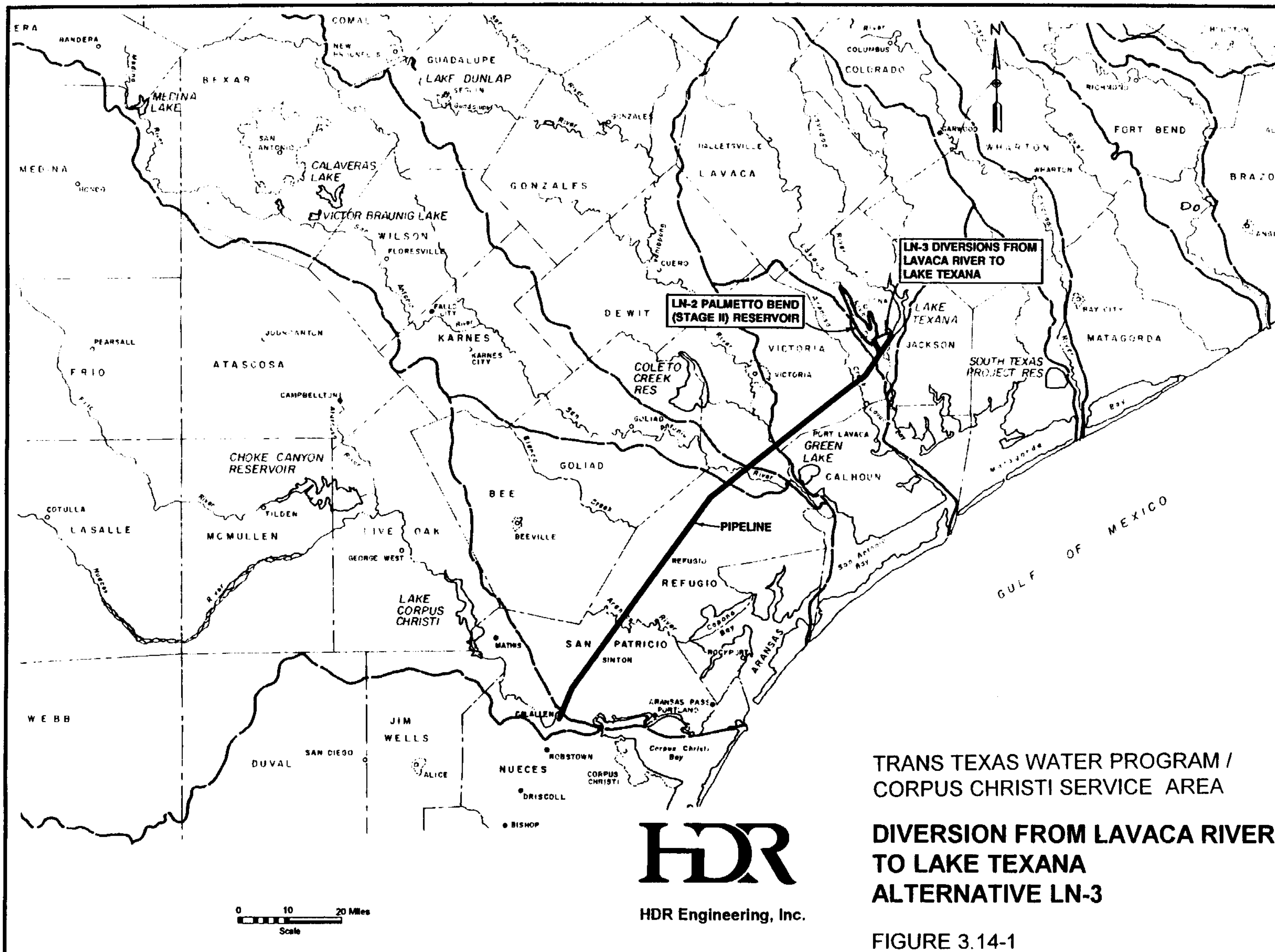
[1] HDR Engineering, Inc., "Regional Water Planning Study, Cost Update for Palmetto Bend Stage 2 and Yield Enhancement Alternative for Lake Texana and Palmetto Bend Stage 2", February, 1991.

[2] "Agreement Concerning Bay and Estuary Releases", Travis County District Court, Cause No. 361,294, signed by TPWD, TWDB, and LNRA, May 22, 1992.

[3] Certificate of Adjudication No. 16-2095B, 1994.



TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

DIVERSION FROM LAVACA RIVER TO LAKE TEXANA ALTERNATIVE LN-3

FIGURE 3.14-1

Release criteria similar to the Lake Texana release agreement would likely be required of Stage II.

3.14.2 Available Yield

The firm yield of Stage II operated separately from Stage I was calculated providing for environmental release requirements as specified under the Trans-Texas Environmental Criteria (see Appendix G). The yield calculations required development of historical flows for the Lavaca River at the dam site, determination of minimum pass-through requirements, and simulation of the Stage II reservoir operation. A historical daily flow set for the Lavaca River was developed using naturalized monthly flows adjusted for senior upstream water rights. This monthly flow set was computed by the TNRCC using the Lavaca-Navidad River Basin Model. The monthly flow set was then distributed to daily flows proportionally to the flows recorded at the nearby USGS gage on the Lavaca River near Edna, Texas. This is similar to the procedure used by the TNRCC in developing inflows to Lake Texana for determination of that lake's yield. Finally, these flows were adjusted using the drainage area ratio method to remove the contribution from the Post Oak tributary which separates Lake Texana from Stage II. The reservoir operation was simulated on a daily basis using RESOP-II (SIMDLY-R). This model was developed by the TWDB specifically for simulating yields of reservoirs with release requirements. An analysis was performed to determine firm yield at alternate capacity thresholds of 40, 60 and 80 percent and the results of these analyses are summarized in Table 3.14-1. The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations for release of water under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954, through December, 1956, historical period.

With no pass-through requirement, the firm yield is estimated to be 48,122 acft/yr. The Lake Texana Bay and Estuary Release Agreement provides a capacity threshold of 78.18 percent for drought contingencies. For Stage II, a similar capacity threshold (i.e., 80 percent) would produce a firm yield of about 38,100 acft/yr. For all capacity thresholds analyzed, the firm yield of the reservoir exceeds the recently permitted volume for water supply purposes of 30,000 acft/yr. Because future studies will be required to develop a detailed release plan for Stage II to more fully address impacts to salinity of the estuary, a yield of 30,000 acft/yr (as called for in the permit for water supply purposes) was utilized for costing and environmental analyses.

Table 3.14-1
Summary of Palmetto Bend Stage II Firm Yield Estimates

Reservoir Capacity Threshold[1] for Implementation of Drought Contingency Operation	Firm Yield (acft/yr)
None	48,122[2]
80 percent	38,100
60 percent	35,900
40 percent	32,600

[1] The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.
[2] Entire remaining firm yield of Stage 2 as specified in the permit.

3.14.3 Environmental Issues

Introduction

Environmental issues associated with the construction of the Palmetto Bend (Phase II) Reservoir can be categorized as follows:

- Effects of the construction and operation of the reservoir;
- Effects with respect to the Lavaca River downstream from the dam; and
- Effects with respect to the Lavaca-Colorado Estuary.

This water supply alternative, if implemented, would be a combined project with the Lake Texana pipeline (Alternative LN-1). Although a stand-alone supply from Palmetto Bend (Stage II) Reservoir delivered to Corpus Christi is possible, in order to reduce environmental impacts, as well as costs, the yield from this project would most likely be delivered in an up-sized Lake Texana pipeline.

Impact Assessment

The proposed reservoir would impound a 6,900-acre conservation pool at 44 feet msl, including 22 miles of the Lavaca River channel. The reservoir would inundate about 4,150 acres of grass and cropland, 1,100 acres of woodland, 300 acres of park or savanna, and 450 acres of wetlands, including river channel and portions of the floodplain.

Although no federal or state protected species are known to be present within the reservoir area, numerous such species are present in surrounding areas, including a nesting pair of bald eagles (Appendix C, Tables 6 and 10). Suitable habitat for protected species may be present on the reservoir site. Several species of migratory birds and marine turtles and mammals considered by USFWS and National Marine Fisheries Service to be endangered or threatened are believed to utilize the Lavaca Estuary.

As noted above, on completion of Palmetto Bend Stage II, TWDB and LNRA are required to release 18,122 acft/yr for the maintenance of the Lavaca-Matagorda Bay and Estuary System.[4] This agreement authorizes the remainder of the total firm yield of Palmetto Bend Stage II (i.e., 30,000 acft/yr) to be used for municipal and industrial purposes. Additionally, "Prior to commencement of construction of Stage 2, or any diversion of water appropriated under the Stage 2 portion of this Certificate of Adjudication, upon the joint recommendation of Lavaca-Navidad River Authority, Texas Water Development Board, and Texas Parks and Wildlife Department, LNRA and/or TWDB shall submit an application to TNRCC to establish a schedule for the release of fresh water inflows from Stage 2 for the maintenance of the Lavaca-Matagorda Bay and Estuary System." Although diversions and releases necessary for maintaining the health of the estuary have been agreed upon, the following discussion is presented to illustrate the potential effects of diverting an additonal 30,000 acft/yr from Lavaca Bay.

Diversion of 30,000 acft/yr from Palmetto Bend Stage II, plus the net evaporation resulting from impoundment, will result in reductions in inflows to the Lavaca Estuary that will be in addition to those caused by Lake Texana operation. Studies of inflow reductions totaling about 131,000 acft/yr (24.7 percent of median annual Lavaca River inflows to Lavaca Bay, 11.7 percent of median annual combined inflows) from the combined Palmetto Bend projects have

[4] Amendment to Certification of Adjudication No. 16-2095.

indicated that no substantial adverse impacts to bay salinities or estuarine populations would result.[5] More recently it has been estimated that inflow reductions to Lavaca bay on full implementation of both phases of the Palmetto Bend Project are estimated to average about 150,000 acft/yr.[6] Inflow reductions of 131,000 acft/yr or 150,000 acft/yr would account for 5.1 percent and 5.9 percent respectively of inflow to the Lavaca-Tres Palacios Estuary based on an annual inflow of 2,540,000 acft for the 1941-1976 period of record. Including more recent data in the period of record (1941-1987) results in an average total inflow of 3,080,301 acft, approximately 21 percent more freshwater inflow than was reflected in the earlier period of record. The differences between periods of record are likely due to drought and other factors. However, these differences provide a good illustration of the variable nature of inflows to Texas bays. Sophisticated and powerful statistical models are commonly used to study the ecology of estuaries, and for making predictions concerning the effects of water diversions. However, the variable nature of bays and estuaries makes it difficult to statistically detect the physical and biological effects of even the larger water diversion projects.[7]

No sites on, or eligible for inclusion on, the National Register of Historic Places are known to be present within the proposed reservoir site. The reservoir area has not been surveyed, but significant historic and prehistoric sites (including National Register Sites) are known to be present within the adjacent Lake Texana and along the lower portion of the Lavaca River.

From an amount of 30,000 acft/yr of water supplied to Corpus Christi, approximately 14,100 acft/yr would be returned to the Nueces Estuary as treated wastewater, representing a 4.8 percent increase in freshwater inflows to the estuary. Because freshwater inflows to the estuary historically were greater than those at present, such an increase can be viewed as

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[5] Ward, G.H., J.M. Wiersma and N.E. Armstrong. 1982. "Matagorda Bay: A Management Plan." Biological Services Program. FWS/OBS-82/73.

[6] HDR. 1991. Regional Planning Water Study. Cost Update for Palmetto Bend Stage 2 and Yield Enhancement Alternative for Lake Texana and Palmetto Bend Stage 2.

[7] Longley, W.L. ed. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp.

generally positive. On the other hand, this increase alone is unlikely to produce a measurable change in the ecology of the bay.

3.14.4 Water Quality and Treatability

A water quality assessment was not performed for this alternative; however, it is anticipated the water quality for the Stage II Reservoir would be similar to the water quality of Lake Texana.

3.14.5 Engineering and Costing

The water supply alternative presented here is a combined project with the Texana Pipeline (Alt. LN-1). A stand-alone supply from Palmetto Bend (Stage II) Reservoir delivered to Corpus Christi is possible, but the costs would be significantly higher.

The cost estimate for the Palmetto Bend Stage II Dam and Reservoir is an update of a previous cost estimate performed by HDR Engineering, Inc. (HDR, 1991). The HDR cost estimate was updated by multiplying the individual cost components of the estimate by the ratio (mid-1995/1991) of the relevant Bureau of Reclamation Construction Cost Indexes (Bureau of Reclamation, 1993).

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the O.N. Stevens Water Treatment Plant at Calallen. The diversion rate from the reservoir would be uniform throughout the year. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations
Water Treatment Plant Expansion

Cost estimate summaries for the reservoir and pipeline (including pipeline sized to also carry Lake Texana water) are shown in Table 3.14-2. The updated construction cost estimate for the Palmetto Bend Stage II Dam and Reservoir is $96,586,000, as summarized in Table 3.14-3. For a construction period of four years, a uniform disbursement of construction funds, and an 8.0 percent annual interest rate compounded monthly, the accumulated interest during construction totals $7,226,000. Financing the project over 25 years at an 8.0 percent interest rate results in an annual expense of $9,050,000. Operation and maintenance costs total $901,000. The annual expense, including construction costs, interest, and operation and maintenance, totals $9,951,000.

The estimated cost of constructing and operating the pipeline from Palmetto Bend Stage II Reservoir and Lake Texana to the O.N. Stevens Water Treatment Plant at Calallen was calculated using projected 1995 unit costs and estimated quantities for materials, labor, and land easements (see Table 3.14-4). For this option, the pipeline configuration would be 6,300 feet of 42-inch line from Palmetto Bend Stage II to a concrete junction box located 1,000 feet from

Table 3.14-2
Palmetto Bend Stage II Reservoir and Pipeline to Corpus Christi (LN-2)
(Includes Lake Texana Pipeline)
(Mid-1995 Costs)

Capital Cost Summary	Total Project[3]	Texana Portion	Palmetto Bend Portion
Palmetto Bend Stage II Reservoir:[1]	$96,586,000		$96,586,000
Pump Stations and Pipeline from Palmetto Bend Stage II Reservoir and Lake Texana:[2]	107,819,000	$54,988,000	52,831,000
Total Capital Costs	$204,405,000	$54,988,000	$149,417,000
Annual Cost Summary	**Total Project[3]**	**Texana Portion**	**Palmetto Bend Portion**
Estimated Annual Debt Service:[2]	$19,153,000	$5,153,000	$14,000,000
Estimated Annual O&M:[2]	5,689,000	2,442,000	3,247,000
Annual Payment on LNRA Water:	2,269,000	2,269,000	---
Total Annual Costs	$27,111,000	$9,864,000	$17,247,000
Average Annual Cost for Each Acre-Foot Delivered at Corpus Christi:	$442	$314	$575

[1] From Table 3.14-3.
[2] From Table 3.14-4.
[3] Consists of 31,440 acft/yr of LNRA water (51%) and 30,000 acft/yr of Palmetto Bend Reservoir water (49%).

Table 3.14-3
Cost Estimate for Palmetto Bend Stage II Reservoir (LN-2)
(Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Mobilization	$2,968,000
Care of Water	1,099,000
Dam	3,834,000
Emergency Spillway	2,538,000
Principal Spillway	15,891,000
U.S. Slope Protection	1,452,000
Underdrain System	981,000
Channel Bed Protection	599,000
Dam Road	1,262,000
Revegetation	790,000
Clearing	1,759,000
Relocations	18,361,000
Subtotal	$15,534,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	$18,037,000
Subtotal	$69,571,000
Environmental Studies and Mitigation	$8,292,000
Land Acquisition	11,497,000
Subtotal	$89,360,000
Interest During Construction	7,226,000
Total Project Cost	$96,586,000
Annual Cost	
Annual Debt Service	$9,050,000
Annual Operation and Maintenance	901,000
Total Annual Cost	$9,951,000

Lake Texana, 1,000 feet of 42-inch line from Lake Texana to the junction box, and 100 miles of 60-inch line from the junction box to Calallen. The preliminary pipeline size was determined based on a flow rate of 178 acft per day (i.e., 89 cfs or 58 MGD) and the pumping head dictated by pipe friction and the ground profile along the proposed route.

The total construction cost for the pipeline from Palmetto Bend (Phase II) Reservoir and Lake Texana to Corpus Christi's O.N. Stevens Water Treatment Plant is $107,819,000 as

Table 3.14-4
Cost Estimate for Pipeline from Palmetto Bend Stage II Reservoir and Lake Texana to Calallen (LN-2)
(Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Pump Station - Lake Texana	$2,740,000
Pump Station - Palmetto Bend Stage II	2,582,000
Booster Station	2,624,000
Booster Station	2,593,000
Pipeline	69,508,000
Subtotal	$80,047,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	$23,637,000
Subtotal	$103,684,000
Environmental Studies and Mitigation	$339,000
Land Easements	560,000
Subtotal	$104,584,000
Interest During Construction	3,235,000
Total Project Cost	$107,819,000
Annual Cost	
Annual Debt Service	$10,103,000
Annual Operation and Maintenance (Excluding Power)	1,125,000
Annual Power	3,663,000
Total Annual Cost	$14,891,000

summarized in Table 3.14-4. For a construction period of one and one-half years, a uniform disbursement of construction money, and an 8.0 percent annual interest rate, the accumulated interest during construction totals $3,235,000. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $10,103,000. Operation and maintenance costs, including power costs, total $4,788,000. The annual payment, including construction costs, interest, interest during construction, and operation and maintenance, totals $14,891,000 (Table 3.14-4).

The annual cost of water for the combined project is $442 per acft (Table 3.14-2) and for just the Stage II portion of the water is $575 per acft. Implementation of this alternative as a stand-alone project would result in significantly higher cost.

3.14.6 Implementation Issues

<u>Requirements Specific to Reservoirs</u>:

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits, including interbasin transfer authorization.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.
   e. Coastal Coordinating Council review.
   f. TPWD Sand, Gravel, and Marl permit

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.

3. Land will need to be acquired through either negotiations or condemnation.

4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

<u>Requirements Specific to Pipelines</u>:

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.
   d. TPWD Sand, Gravel and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

3.15 Diversion from Lavaca River to Lake Texana (LN-3)

3.15.1 Description of Alternative

This alternative was initially considered as a possible alternative to constructing a reservoir on the Lavaca River (Palmetto Bend Stage II). For this alternative, the diversion of existing water rights on the Lavaca River, along with other run-of-the-river flows on the Lavaca River, were evaluated for diversion into Lake Texana. This type of diversion operation would require a river intake and pump station on the Lavaca River, a small channel diversion dam, and approximately four miles of pipeline to Lake Texana. The location of this alternative is shown in Figure 3.14-1 in the previous section of this report.

3.15.2 Available Yield

Investigation of yield enhancement produced by diversion from the Lavaca River to Lake Texana required development of historical flows for the Lavaca River near the pumping location, determination of minimum flow requirements, and simulation of the diversion operation and reservoir operation at Lake Texana.

A historical daily flow set for the Lavaca River was developed using naturalized monthly flows adjusted for senior upstream water rights. This monthly flow set was computed by the TWC using the Lavaca-Navidad River Basin Model. The monthly flow set was then distributed to daily flows proportionally to the flows recorded at the nearby USGS gage on the Lavaca River at Edna, Texas. This is a similar procedure as used by the TWC in developing inflows to Lake Texana for determination of the Lake's yield. Finally, these flows were adjusted to the pumping location using the drainage area ratio method.

For this analysis, the Trans-Texas Environmental Criteria for bay and estuary inflows were used to determine minimum flow requirements. It is likely that actual flow requirements would have to be determined by evaluating the impact to the salinity in the Colorado-Lavaca Estuary. The effect of a salinity analysis may be to increase the minimum flow requirements and therefore reduce the yield enhancement identified in this analysis.

The diversion operation was simulated with facilities to pump 300 cfs (595 acft per day), which would be a large pumping facility. Diverted flows were added to Lake Texana inflows and the enhanced yield of Lake Texana was determined using SIMDLY-R. The increased yield was calculated to be approximately 3,000 acft/year. The relatively low yield increase from this alternative is due to the coinciding drought periods on the Lavaca and Navidad Rivers. During this drought period, flows in the Lavaca River are severely reduced and often are insufficient to satisfy the Trans-Texas minimum flow requirements. Due to the low yield potential of this alternative, additional analyses for environmental, water quality, and costing issues were not pursued.

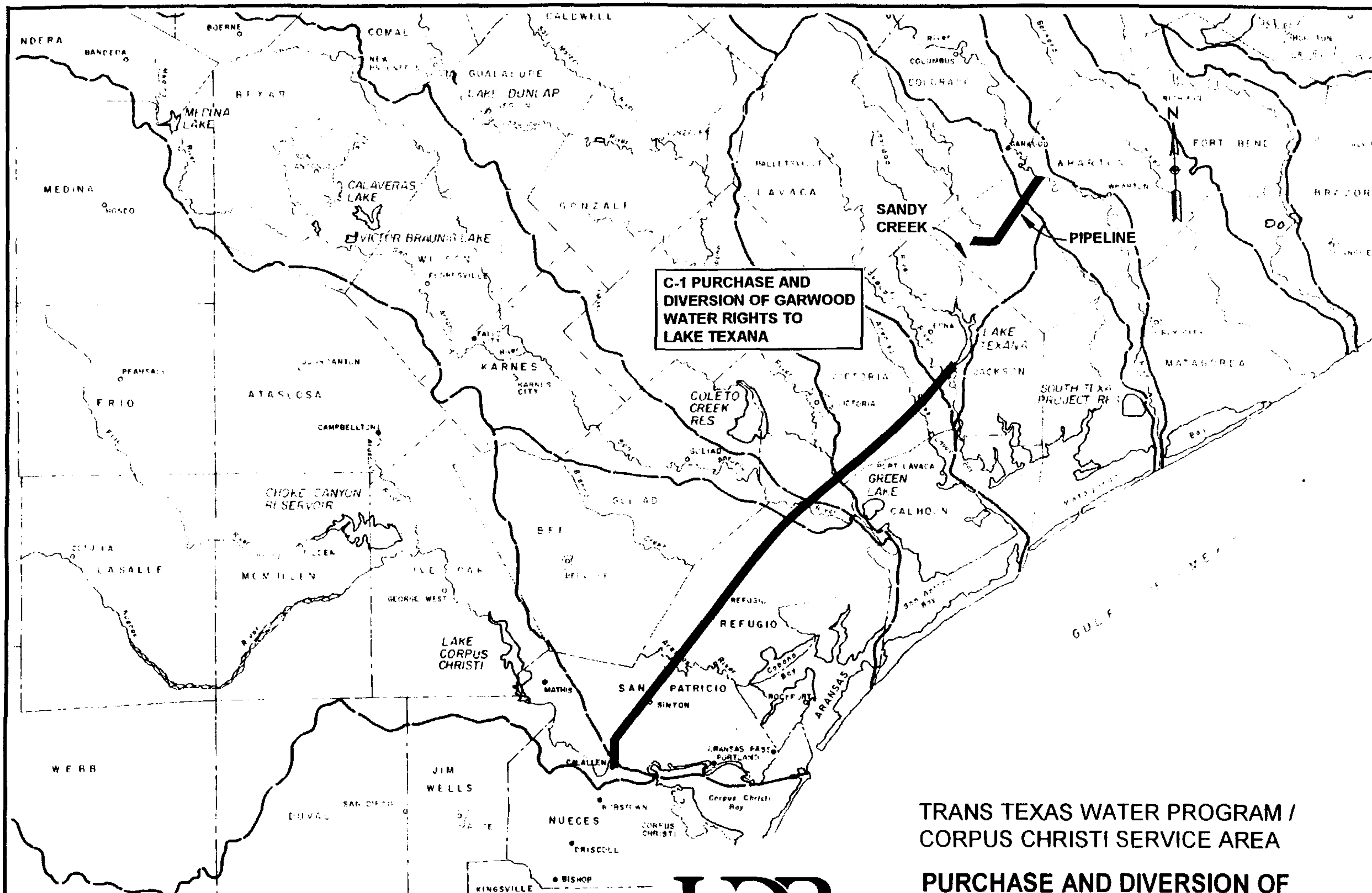
3.16 Purchase and Diversion of Garwood Water Rights to Corpus Christi through Lake Texana (C-1)

3.16.1 Description of Alternative

The Garwood Irrigation Company (Garwood) holds the most significant senior water right in the Lower Colorado River Basin, with a priority date of November 1, 1900. This water right authorizes the diversion of 168,000 acft/yr from the Colorado River at a maximum rate of 750 cfs or 1,488 acft/day. Most of Garwood's service area lies outside the Colorado River Basin, and Garwood currently uses a large part of its right for irrigation of land which is located in the Lavaca-Navidad River Basin. Garwood has expressed a willingness to sell 35,000 acft/yr of its water right for municipal purposes, along with the associated right to divert up to 150 cfs, or 298 acft/day. In September, 1992, the City of Corpus Christi entered into an option agreement for the potential purchase of up to 35,000 acft/yr from the Garwood Irrigation Company. In 1993, the TNRCC authorized an amendment to Garwood's water right which allows for the use of 35,000 acft of its right to be used for municipal and industrial purposes.

Under this alternative, water would be diverted from the Colorado River about 16 river-miles downstream of Garwood's diversion dam as shown in Figure 3.16-1. A new low-head dam intake and pump station would be constructed on the Colorado River at this location which would be similar to Garwood's diversion dam and pumping facilities. A 16-mile pipeline would be required from the point of diversion to a point near the intersection of Highway 1300 and Sandy Creek. At this location, water would be discharged into Sandy Creek, where it would flow a distance of approximately 12 river miles to Lake Texana. After the water enters Lake Texana, it would move through and mix with the waters in the reservoir and then be diverted at the intake structure at the dam and pumped along with Lake Texana water to the O.N. Stevens Treatment Plant near Calallen via an upsized Texana Pipeline (see Section 3.13 for description of Texana Pipeline).

To determine how much water might be lost to channel losses in Sandy Creek, a channel loss study was performed in the fall of 1992. A copy of the memorandum describing the results of this investigation is included in Appendix B. Actual channel losses will vary with streamflow, pumping rate, seasons, and other hydrological conditions. The channel loss study indicated that average losses would range between 5 percent and 10 percent. Essentially, all of these losses



TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

PURCHASE AND DIVERSION OF GARWOOD WATER RIGHTS TO LAKE TEXANA

HDR

HDR Engineering, Inc.

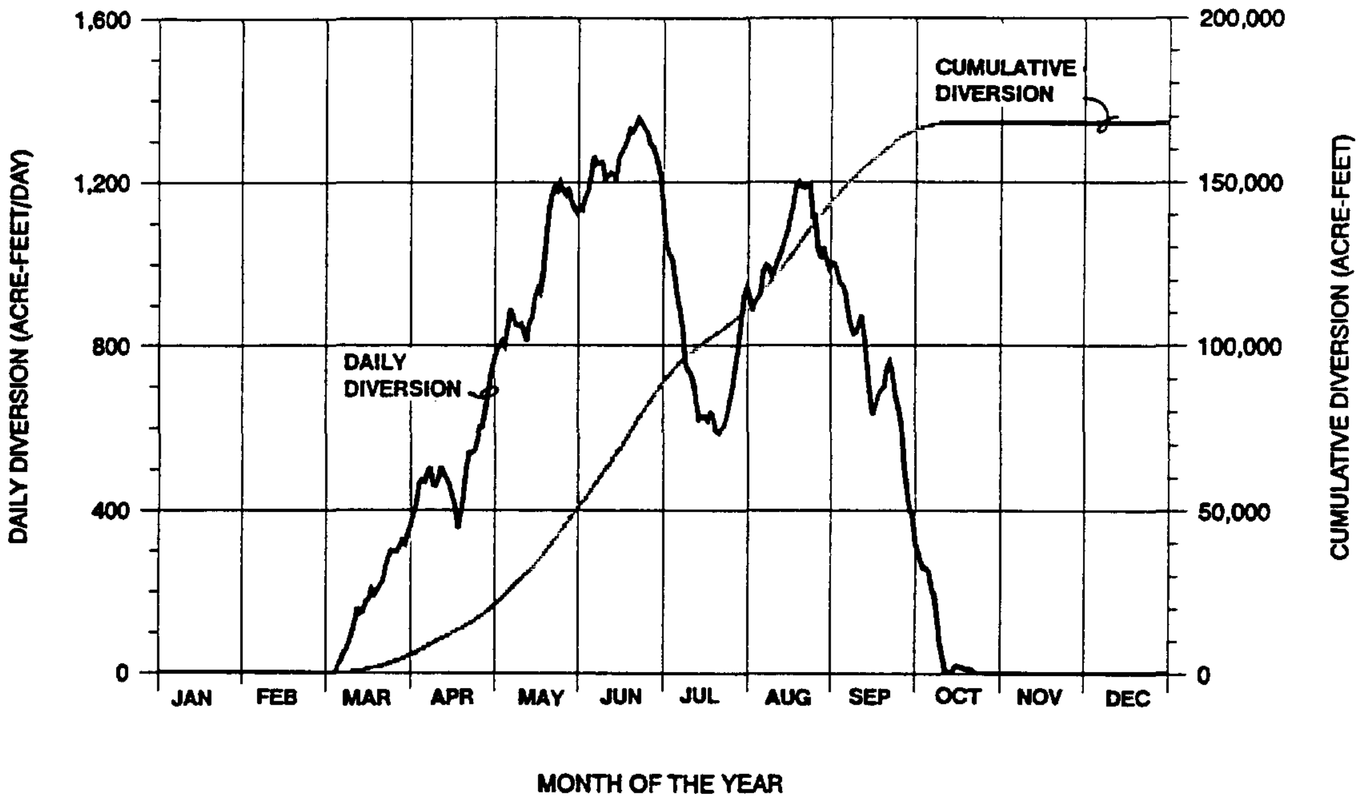
FIGURE 3.16-1

could be eliminated by constructing an additional eight miles of pipeline, but the extra cost to construct the pipeline compared to the volume of water recovered would not be economical.

3.16.2 Available Yield

Water availability to various senior water rights in the Colorado basin were evaluated using the Colorado River Daily Allocation Program (DAP). The DAP model was developed by LCRA and applied to Trans-Texas studies by LCRA staff at HDR's direction for purposes of these evaluations. A major assumption of the DAP model is in the daily simulation of water right diversions. Run-of-river water rights are issued subject to specified maximum annual and instantaneous diversion rates. For the significant water rights on the Lower Colorado River, there are no restrictions (other than the maximum pumping rate) as to when within the year that water may be diverted or how much of it may be used consumptively. This situation is very flexible which makes it difficult to model. In the LCRA model, this situation is simplified by assigning each right a fixed diversion amount for each day of the year. The pattern used in the model for the Garwood right is shown on Figure 3.16-2. The total of these daily diversion amounts exactly equals the total annual right. If any portion of a daily diversion amount cannot be met from run-of-river flows, the model does not allow for that deficit to be recovered at a later date. In actual practice a diverter could make up for the lack of availability by pumping on some later day when water became available. Therefore, the assumptions inherent in this modeling procedure result in underestimation of water potentially available to the more senior rights such as Garwood.

In Phase I studies, two general pumping scenarios for diversion of the 35,000 acft were evaluated. Under the first scenario, a seasonal diversion pattern similar to Garwood's historical irrigation diversion pattern shown in Figure 3.16-2 was evaluated. This scenario required the largest diversion pump station and a 60-inch transmission pipeline to divert the full 35,000 acft/yr. Daily reservoir simulations of Lake Texana were performed to determine the efficiency of the operation under this scenario. Increased yield at Lake Texana was about 83 percent of diversions from the Colorado. The 17 percent loss was due to channel losses, evaporation, and spills. This scenario was least cost-effective due to the large facilities required and the amount of losses.



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TYPICAL PATTERN OF GARWOOD IRRIGATION DIVERSION LCRA WATER ALLOCATION MODEL

FIGURE 3.16-2

The second scenario investigated in Phase I involved a uniform annual pumping operation and required a smaller pump station and a 48-inch transmission pipeline. This scenario resulted in an increase in Lake Texana yield of about 91 percent of the volume diverted from the Colorado with losses primarily attributable to channel losses in Sandy Creek. In addition to the higher yield, the uniform annual diversion scenario resulted in a smaller pump station and pipeline and was the more cost-effective of the two scenarios. The results for the Phase I scenarios are summarized in Table 3.16-1.

Table 3.16-1
Summary of Available Yield for Phase I Operating Scenarios

Phase I Operating Scenario	Required Pipe Diameter	Water Right Purchase (acft/yr)	Increased Yield of Lake Texana (acft/yr)	Operational Efficiency
Irrigation Season Diversions	60-inch	35,000	29,000	83 percent
Uniform Annual Diversions	48-inch	35,000	32,000	91 percent

Because the Phase I study clearly indicated that uniform annual diversions are preferable both in terms of system yield and cost of facilities, only year-round diversions were investigated in Phase II. Also in Phase I, a simplifying assumption was made such that the purchase of 35,000 acft/yr of Garwood's run-of-river diversions had the same priority as Garwood's remaining rights. In Phase II studies, this priority was not assumed and Garwood's remaining rights of 133,000 acft/yr were modeled as being senior to the 35,000 acft purchase volume.

The City of Austin holds several municipal diversion rights in the Colorado River Basin and the earliest has a priority date of 1913. The Garwood Irrigation Company rights are senior to Austin (i.e., Garwood's priority date is 1900) and evaluations were performed to estimate potential impacts, if any, to the City of Austin's rights by the purchase and diversion of a portion of the Garwood right. Initially, a baseline water availability estimate was established based on existing permitted conditions from which four scenarios were evaluated for the 35,000 acft purchase. For each of the four scenarios, impacts to the City of Austin's water rights and to the Highland Lakes were evaluated, along with a determination of the water available from the 35,000 acft purchase.

In the first scenario, the 35,000 acft purchase was subordinated[1] only to Garwood's remaining 133,000 acft right. In the second, the purchase was subordinated to Garwood's remaining rights as well as the City of Austin's 1913 and 1914 rights. In the third, the purchase was given a current priority date (i.e., 1995) effectively subordinating the diversion to all existing water rights. Finally, the fourth scenario investigated a seasonal subordination pattern where the purchase was subordinated only to Garwood's remaining irrigation diversions during the irrigation season months of March through October and then subordinated to all existing water rights during the remainder of the year.

For each of the scenarios, water availability was determined for the 25-year period beginning in 1941 and ending in 1965. This period covers two significant droughts, one which occurred in the 1950's and one which occurred in the 1960's. The critical drought determined for the Lake Texana yield analysis occurred during approximately the 1954-1956 time frame, while the critical drought for the CC/LCC System occurred over approximately the 1961-1963 time frame. Therefore, annual water availability was calculated for each of these 3-year periods, the minimum year, as well as an average for the 1941-1965 period.

Baseline Condition: Water Availability Based on Existing Permits

To produce estimates of water availability for the various rights evaluated under existing priority dates, Garwood's entire diversion right (i.e., 168,000 acft/yr) was evaluated using a fixed daily agricultural demand pattern as shown in Figure 3.16-2. Estimates of water availability as calculated by the model indicate that Garwood is able to divert on the average about 152,500 acft/yr as shown on Table 3.16-2. If Garwood diverts according to the fixed irrigation season pattern illustrated in Figure 3.16-2, it is unable to divert its full 168,000 acft right in any year as estimated by the DAP model. In the model, the fixed diversion pattern

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[1] The principle of "first in time, first in right" (otherwise known as the system of prior appropriation) determines priority among water rights holders. Hence, a "senior" water rights holder has established a first in time claim to a certain amount of water and other rights holders with a later priority date are "subordinated" to the senior right. With regards to the Highland Lakes, water rights existing prior to the lake permits (March 7, 1938 priority date) are said to have "senior" rights and water rights granted after the lake permit are "junior" rights.

Table 3.16-2 Water Availability Under Garwood Permit (Existing Conditions)					
Diversion Pattern	**Permit Right** (acft/yr)	**Water Availability**[1] (acft/yr)			
		Minimum Year	*54-56 Drought*	*61-63 Drought*	*41-65 Average*
DAP Model Fixed Pattern[2]	168,000	124,000	138,000	156,000	152,500
Flexible[3]	168,000	168,000[2]	168,000[2]	168,000[2]	168,000[2]

[1] All senior rights holders attempting to divert full permitted amounts.
[2] Typical irrigation season diversion pattern is shown on Figure 3.16-2.
[3] Availability of Garwood's 750 cfs diversion right was estimated from historical gage flows at Columbus.

limits Garwood's diversion to a maximum of 683 cfs and an average diversion of 368 cfs during the historical irrigation season. However, in actual operation, the full right could be obtained if diversions allowed deficits to be recovered at a later date. Actual diversions are more flexible than the modeled diversion pattern since Garwood's water right allows diversions up to 750 cfs on any day of the year. The availability of Garwood's right under this more flexible operation was estimated from historical gage flows at Columbus. This availability figure is only an estimate because it does not consider other historical diversions and intervening inflow. A summary of water availability for Garwood under this more flexible diversion pattern is presented in Table 3.16-2 and shows that the full 168,000 acft/yr is available in all years.

The City of Austin holds several water rights, two of which are Certificates of Adjudication 14-5471A and 14-5489 and these rights are listed in Table 3.16-3[2]. For purposes of this study, only municipal and steam electric supplies were evaluated (Austin holds other minor rights for hydroelectric, recreational, and irrigation purposes). It is important to note that municipal water supply includes all demands of a municipal utility which may include residential, commercial, non-agricultural irrigation, and industrial uses. Austin currently holds cumulative rights to 292,703 acft/yr of municipal water rights from the Colorado River. Colorado River flows (i.e., run-of-river flows) at Austin can be diverted for municipal use provided that the water is not needed by senior downstream water rights. The first 250,000

[2] "Austin Study Area, Phase 1 Interim Report, Trans-Texas Water Program", HDR Engineering, Inc., prepared for the City of Austin and the Texas Water Development Board, August, 1994.

Table 3.16-3 City of Austin Existing Water Rights				
Permitted Use	**Certificate of Adjudication**	**Priority Date**	**Permit Right (acft/yr)**	**Amount Backed Up By Highland Lakes Storage (acft/yr)**
Municipal	14-5471	June 30, 1913	250,000[1]	
	14-5471	June 27, 1914	22,403	
	14-5489	August 20, 1945	20,300	
Total			292,703	250,000[2]
Steam Electric	14-5471	June 30, 1913	24,000	24,000
	14-5489	February 23, 1965	16,156	16,156
Total			40,156[3]	40,156
Irrigation	14-5471	June 30, 1913	150	
	14-5471	June 30, 1913	1,000[4]	None
Total			1,150	

[1] Includes the 1,000 acft/yr of water currently being used for irrigation. See Note 3.
[2] Amount backed up by Highland Lakes storage is not tied to any single water right held by the City of Austin.
[3] Permit limits consumptive use to quantity shown. There is no limit on diversion rate of pass-through diversions stated in the permit.
[4] This 1,000 acft/yr right is a temporary change of municipal use which expires after December 31, 2011.

acft/yr of Austin's rights are the most senior of Austin's rights and pursuant to the LCRA/Austin settlement agreement, this amount is senior to the Highland Lakes. The only significant water rights within the Lower Colorado River Basin senior to these rights are the Garwood Irrigation Company (168,000 acft/yr) and Pierce Ranch Limited (55,000 acft/yr of 110,000 acft/yr right is senior to Austin). LCRA and Austin have an agreement in which Austin's water rights (up to 250,000 acft/yr) are backed up by storage in LCRA's reservoirs (i.e., Highland Lakes) at times when run-of-river flows are insufficient. The portion of Certificate of Adjudication 14-5471 for 22,403 acft/yr is junior to several downstream rights, but is senior to the Highland Lakes. Although this right is not as dependable as the first 250,000 acft, it is a significant right.

The final 20,300 acft/yr municipal right (i.e. Certificate of Adjudication 14-5489) is junior to the Highland Lakes, therefore, is limited to withdrawal of spills from the Highland Lake and inflows to the Colorado River which occur downstream of the lakes and above the diversion point, that are not required by more senior rights holders. Water availability under this right is substantially less than that under the former two, particularly during periods of drought and during the summer irrigation season.

Austin currently has 40,156 acft/yr of water rights for consumptive use associated with steam electric power generation. Under the steam electric rights, Austin may divert any quantity available as pass-through cooling without limit provided consumptive use for forced evaporation does not exceed the authorized amounts. The first 24,000 acft/yr of Austin's rights is the most senior portion with a priority date of June 30, 1913. This water may be diverted anywhere along the perimeter of Lake Austin or Town Lake and is utilized for the Seaholm and Holly Street power plants. The second right is for 16,156 acft/yr and has a priority date of August 20, 1945.

In 1987, the City of Austin, the LCRA, and the Texas Water Commission entered into a settlement agreement pertaining to the adjudication of water rights on the Colorado River. In the agreement, Austin received the water rights previously described and summarized in Table 3.16-3, and the LCRA agreed to supply stored water, as necessary, to firm a supply up to 150,000 acft/yr of municipal diversion at no cost. Further, LCRA agreed to supply an additional 100,000 acft/yr of stored water for municipal diversions for a payment. This results in 250,000 acft/yr of firm municipal supply water being available to Austin. Finally, LCRA agreed to firm up Austin's steam electric rights of up to 40,156 acft/yr of consumptive use for no payment.

The 150,000 acft/yr of municipal diversion (without payment) is approximately the average amount that Austin could have diverted during extended drought conditions without releases from the Highland Lakes storage and without significant reuse of return flows. Under the terms of the agreement, municipal diversions by Austin in excess of 150,000 acft/yr and diversions other than municipal and steam electric are to be charged LCRA's current rate for firm water regardless of whether stored water has to be released to satisfy the diversion. The current rate for firm water from storage is $105 per acft.

Austin's daily water demand pattern is based upon Austin's historical use from 1976 to 1985 and Austin's return flow pattern is based on a 55 percent return of the annual municipal demand. These return flows are distributed monthly according to the historical pattern from 1978 to 1987. Since the municipal use and steam electric use are not distinguished in the model, both are modeled with the same municipal usage pattern.

The DAP model was run with the assumption that all diverters are attempting to divert their full permitted rights and with Austin return flows included. In the model, only the municipal and steam electric rights were modeled. This includes both the municipal rights (250,000 acft/yr and 22,403 acft/yr) and steam electric rights (24,000 acft/yr and 16,156 acft/yr) for a total demand of 332,859 acft/yr. As summarized in Table 3.16-4, firm yield (i.e., minimum year) of Austin's run-of-river rights (without backup storage) is about 83,000 acft/yr, and long term average availability is about 177,500 acft/yr. The availability of water under existing conditions is summarized in Table 3.16-4 for maximum, average, drought, and minimum availability along with the requirement for stored water from the Highland Lakes.

Table 3.16-4
Water Availability with Current Permits (Existing Conditions)

Water Right Permit Owner (priority date)	**Permit Right** (acft/yr)	**Water Availability**[1] (acft/yr)			
		Minimum Year	*1954-1956 Drought*	*1961-1963 Drought*	*1941-1965 Average*
Garwood Total	168,000	124,000	138,000	156,000	152,500
City of Austin Municipal					
• CA 5471 (1913 & 1914)	272,403	83,000	115,500	186,000	177,500
• CA 5489 (1945)	20,300	0	500	5,500	5,000
Subtotal Run-of-River rights	292,703	83,000	116,000	191,500	182,500
• From Highland Lakes[2]		167,000	134,000	58,500	67,500
Total Austin Municipal	292,703	250,000	250,000	250,000	250,000
City of Austin Steam Electric					
• CA 5471 (1913)	24,000	4,500	8,000	21,500	21,000
• CA 5489 (1965)	16,156	0	0	0	0
Subtotal Run-of-River rights	40,156	4,500	8,000	21,500	21,000
• From Highland Lakes[2]		35,656	32,156	18,656	19,156
Total Austin Steam Electric	40,156	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156	290,156

[1] All senior rights are modelled attempting to divert their full permitted amounts.
[2] Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam electric demands.

Scenario 1: Water Availability with 35,000 acft Purchase Subordinated Only to Garwood's Remaining Right

For Scenario 1, the 35,000 acft/yr purchase from Garwood was subordinated only to the remaining 133,000 acft/yr irrigation demand by Garwood. In this scenario, the 35,000 acft purchase is diverted at a maximum diversion rate of 63 cfs (125 acft/day) each day it is not needed by senior rights until the full 35,000 acft is diverted. The diversion rate requires a 48-inch transmission line. A summary of the water availability under this scenario is provided in Table 3.16-5.

Table 3.16-5
Scenario 1: Water Availability with 35,000 acft Purchase Subordinated only to Garwood's Remaining Right

Water Right Permit Owner (priority date)	Permit Right (acft/yr)	Water Availability[1] (acft/yr)			
		Minimum Year	*1954-1956 Drought*	*1961-1963 Drought*	*1941-1965 Average*
Garwood					
Irrigation[2]	133,000	108,000	116,000	126,500	124,000
Purchase[3] by Corpus Christi	35,000	34,000	34,500	35,000	35,000
Total Garwood/Corpus Christi	168,000	142,000	150,500	161,500	159,000
City of Austin Municipal					
• CA 5471 (1913 & 1914)	272,403	83,000	114,500	186,500	178,000
• CA 5489 (1945)	20,300	0	500	5,500	5,000
Subtotal Run-of-River Rights	292,703	83,000	115,000	192,000	183,000
• From Highland Lakes[4]		167,000	135,000	58,000	67,000
Total Austin Municipal	292,703	250,000	250,000	250,000	250,000
City of Austin Steam Electric					
• CA 5471 (1913)	24,000	4,000	7,500	21,000	21,000
• CA 5489 (1965)	16,156	0	0	0	0
Subtotal Run-of-River Rights	40,156	4,000	7,500	21,000	21,000
• From Highland Lakes[4]		36,156	32,656	19,156	19,156
Total Austin Steam Electric	40,156	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156	290,156

[1] All senior rights are modelled attempting to divert their full permitted amounts.
[2] Using fixed daily irrigation diversion pattern.
[3] Diverting at 63 cfs through a 48 inch pipeline.
[4] Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam electric demands.

A comparison of water availability under this scenario with the baseline run for existing conditions (see Table 3.16-4) shows that the maximum reduction to Austin's combined run-of-river rights occurs during the 1954-1956 drought when 1,500 acft/yr (1.2 percent) less would be available. The maximum impact on the release of stored Highland Lakes water would occur during the 1954-1956 drought and 1941-1965 average when 1,500 acft/yr (0.7 percent) of additional stored water would be needed to firm up Austin's run-of-river water supply.

Scenario 2: Water Availability with 35,000 acft Purchase Subordinated to Garwood's Remaining Right and to Austin's Rights

For Scenario 2, the 35,000 acft purchase was subordinated to Garwood's remaining irrigation right as well as to the City of Austin's senior rights under Adjudication 14-5471. In this scenario, the 35,000 acft/yr is diverted at a maximum diversion rate of 98 cfs (194 acft/day) each day it is not needed by senior rights until the full 35,000 acft is diverted. A 60-inch transmission line is needed. A summary of the water availability under this scenario is provided in Table 3.16-6.

Table 3.16-6
Scenario 2: Water Availability with 35,000 acft Purchase Subordinated to Garwood's Remaining Right and to Austin's Rights

Water Right Permit Owner (priority date)	**Permit Right** (acft/yr)	**Water Availability**[1] (acft/yr)			
		Minimum Year	*1954-1956 Drought*	*1961-1963 Drought*	*1941-1965 Average*
Garwood Total					
Irrigation[2]	133,000	108,000	116,000	126,500	124,000
Purchase[3] by Corpus Christi	35,000	33,000	35,000	35,000	35,000
Total Garwood/Corpus Christi	168,000	141,000	151,000	161,500	159,000
City of Austin Municipal					
• CA 5471 (1913 & 1914)	272,403	88,500	123,500	195,500	184,500
• CA 5489 (1945)	20,300	0	500	5,500	5,000
Subtotal Run-of-River Rights	292,703	88,500	124,000	201,000	189,500
• From Highland Lakes[4]		161,500	126,000	49,000	60,500
Total Austin Municipal	292,703	250,000	250,000	250,000	250,000
City of Austin Steam Electric					
• CA 5471 (1913)	24,000	4,000	7,500	21,000	21,000
• CA 5489 (1965)	16,156	0	0	0	0
Subtotal Run-of-River Rights	40,156	4,000	7,500	21,000	21,000
• From Highland Lakes[4]		36,156	32,656	19,156	19,156
Total Austin Steam Electric	40,156	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156	290,156

[1] All senior rights are modelled attempting to divert their full permitted amounts.
[2] Using fixed daily irrigation diversion pattern.
[3] Diverting at 98 cfs through a 60 inch pipeline.
[4] Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam electric demands.

Comparison of water availability under this scenario with existing conditions shows that water availability to the City of Austin's combined run-of-river rights increases in all years. Under this scenario, about 7,000 acft/yr less water on the average is required from the Highland Lakes.

Scenario 3: Water Availability with 35,000 acft Purchase Subordinated to All Existing Rights

In the third change of priority for the Garwood purchase, the purchase was given a current priority date (i.e., 1995), effectively subordinating the purchase to all existing rights. In this scenario, the 35,000 acft purchase is diverted at a maximum diversion rate of 141 cfs (280 acft/day) each day it is not needed by senior water rights until the full amount is diverted. A 72-inch transmission line is needed. A summary of water availability under this condition is shown in Table 3.16-7.

Table 3.16-7
Scenario 3: Water Availability with 35,000 acft Purchase Subordinated to All Existing Rights

Water Right Permit Owner (priority date)	**Permit Right** (acft/yr)	**Water Availability**[1] (acft/yr)			
		Minimum Year	*1954-1956 Drought*	*1961-1963 Drought*	*1941-1965 Average*
Garwood Total					
Irrigation[2]	133,000	108,000	116,000	126,500	124,000
Purchase[3]	35,000	35,000	35,000	35,000	35,000
Garwood Total	168,000	143,000	151,000	161,500	159,000
City of Austin Municipal					
• CA 5471 (1913 & 1914)	272,403	88,000	123,000	195,500	184,500
• CA 5489 (1945)	20,300	0	500	5,500	5,000
Subtotal Run-of-River Rights	292,703	88,000	123,500	201,000	189,500
• From Highland Lakes[4]		162,000	126,500	49,000	60,500
Total Austin Municipal	292,703	250,000	250,000	250,000	250,000
City of Austin Steam Electric					
• CA 5471 (1913)	24,000	4,500	8,000	22,000	21,500
• CA 5489 (1965)	16,156	0	0	0	0
Subtotal Run-of-River Rights	40,156	4,500	8,000	22,000	21,500
• From Highland Lakes[4]		35,656	32,156	18,156	18,656
Total Austin Steam Electric	40,156	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156	290,156

[1] All senior rights are modelled attempting to divert their full permitted amounts.
[2] Using fixed daily irrigation diversion pattern.
[3] Diverting at 141 cfs through a 72 inch pipeline.
[4] Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam electric demands.

Comparison of water availability under this scenario with existing conditions shows that water availability to the City of Austin's combined run-of-river rights increases in all years. The results also show that compared to existing conditions, the average volume of stored water needed from the Highland Lakes averages about 7,500 acft/yr less.

Scenario 4: Water Availability with 35,000 Acft Purchase Subordinated Seasonally

In the fourth scenario, the purchase was assigned a combination priority. In the irrigation season, March through October, when the agricultural diversions have historically been made, the purchase amount kept its seniority except that it was still subordinated to Garwood's irrigation diversions. In the remaining months, the purchase was subordinated to all water right holders in the basin. This scenario is a combination of the first and third scenarios previously discussed. Under this scenario, the 35,000 acft purchase is diverted at a maximum diversion rate of 80 cfs (157 acft/day) each day it is not needed by senior water rights until the full amount is diverted. A 54-inch transmission line is needed. A summary of water availability under this condition is shown in Table 3.16-8. Comparison of the results obtained under this scenario with existing conditions shows that water availability to the City of Austin combined run-of-river rights increases in all years with the average increase totalling 2,000 acft/yr. The results show that the average annual volume of stored water needed from the Highland Lakes averages about 2,000 acft/yr <u>less</u> than under existing conditions.

Summary of Water Availability Results

In summary, variations in water right priorities for the proposed purchase of 35,000 acft/yr from Garwood has a direct impact on the size of transmission facilities needed to obtain the full 35,000 acft/yr. With subordination to Garwood's remaining irrigation rights only, a 48-inch transmission line is needed and with subordination to both Garwood and the City of Austin's senior rights, a 60-inch transmission line is needed. If the purchase is given a current priority date (i.e., 1995) and becomes junior to all existing rights, the diversions become less frequent and a 72-inch transmission line is needed. Finally, if the 35,000 acft is subordinated only to Garwood during the irrigation months of March through October and subordinated to all

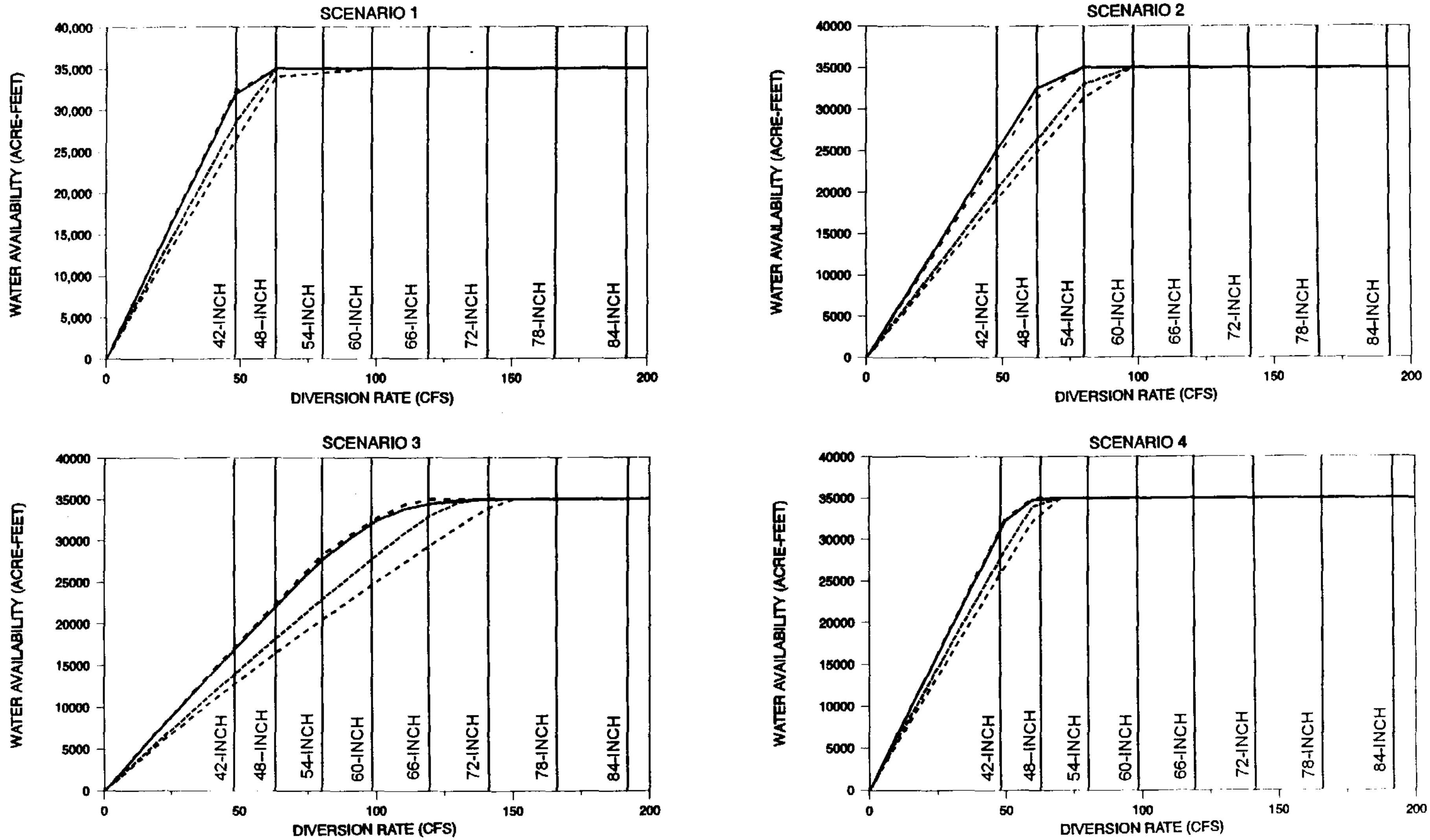
Table 3.16-8 Scenario 4: Water Availability with 35,000 acft Purchase Subordinated Seasonally March to October--Subordinated only to Garwood Irrigation November to April--Subordinated to All Existing Rights					
Water Right Permit Owner (priority date)	**Permit Right** (acft/yr)	**Water Availability**[1] (acft/yr)			
		Minimum Year	*1954-1956 Drought*	*1961-1963 Drought*	*1941-1965 Average*
Garwood					
Irrigation[2]	133,000	108,000	116,000	126,500	124,000
Purchase[3] by Corpus Christi	35,000	35,000	35,000	35,000	35,000
Total Garwood/Corpus Christi	168,000	143,000	151,000	161,500	159,000
City of Austin Municipal					
• CA 5471 (1913 & 1914)	272,403	84,000	116,500	189,000	179,500
• CA 5489 (1945)	20,300	0	500	5,500	5,000
Subtotal Run-of-River Rights	292,703	84,000	117,000	194,500	184,500
• From Highland Lakes[4]		166,000	133,000	55,500	65,500
Total Austin Municipal	292,703	250,000	250,000	250,000	250,000
City of Austin Steam Electric					
• CA 5471 (1913)	24,000	4,500	8,000	21,500	21,000
• CA 5489 (1965)	16,156	0	0	0	0
Subtotal Run-of-River Rights	40,156	4,500	8,000	21,500	21,000
• From Highland Lakes[4]		35,656	32,156	18,656	19,156
Total Austin Steam Electric	40,156	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156	290,156

1 All senior rights are modelled attempting to divert their full permitted amounts.
2 Using fixed daily irrigation diversion pattern.
3 Diverting at 80 cfs through a 54 inch pipeline.
4 Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam electric demands.

existing rights during the other months, a 54-inch transmission line is needed. Figure 3.16-3 illustrates the yield available for various pipeline diameters for each of the four scenarios.

The impact to water availability to the City of Austin's run-of-river rights is relatively small under all scenarios and overall water availability to the City is essentially unchanged. The reason this occurs is because, under the terms of Austin's senior 250,000 acft right and 1987 settlement agreement, the City's run-of-river rights are firmed up from storage in the Highland Lakes.

The combined impact on the Highland Lakes of converting a portion of the Garwood right from a typical agricultural demand pattern to a more uniform demand pattern, along with the various subordination options, generally reduces the annual demand on the Highland Lakes. One reason for this is due to the smoothing of the demand through the year. As demand is reduced during the peak summer usage months when shortages on the Colorado River are most



Legend

- Minimum Year
- 1954-1956 Average
- 1961-1963 Average
- 1941-1965 Average

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

WATER AVAILABILITY UNDER GARWOOD WATER RIGHTS ALTERNATIVE C-1

FIGURE 3.16-3

prevalent and redistributed to other months when demands on the Colorado River are lowest and run-of-river water downstream of the Highland Lakes is generally more plentiful, water available from run-of-river water increases and less stored water is required.

3.16.3 Environmental Issues

Introduction

In addition to potential environmental issues involving supplying water from Lake Texana to Corpus Christi (Alternative LN-1, Section 3.13), those related to diverting water under Garwood Irrigation Company's water rights from the Colorado River through Lake Texana can be enumerated as follows:

- Effects involving the construction and operation of a diversion facility on the Colorado River;
- Effects to the Colorado River downstream from the diversion including the Lavaca-Colorado Estuary;
- Effects to Sandy Creek, Lake Texana, and the rivers below Lake Texana;
- Effects to the Nueces Estuary; and
- Effects along the pipeline ROW from the diversion point on the Colorado River to the outfall at Sandy Creek.

Methods used to develop this section, including mapping, literature review, and searches of existing databases are described in the Environmental Overview (Section 3.0.2). Also presented in the overview (Section 3.0.2) are descriptions of the biogeography of the region, the Lavaca-Colorado Estuary, and Nueces Estuary. A reconnaissance level survey of the proposed pipeline route was performed.

The Affected Environment

Regional Setting

The project area lies within Wharton and Jackson Counties. Both counties have hot and humid summers relieved by occasional thundershowers with average growing seasons of 266 days and 290 days respectively.[3] Mean precipitation averages about 41 inches annually. Both counties are major rice growing areas with oil production also being economically important.

[3] Griffiths, J. and J. Bryan. 1987. The Climates of Texas Counties. Natural Fibers Information Center, The University of Texas in cooperation with Office of the State Climatologist, Texas A&M University.

The terrain of Wharton county consists of prairie bisected by the Colorado River. Soils are alluvial, black and sandy loam types. The terrain of Jackson county consists of prairie draining into rivers creeks and bays. Soils are loam, clay, and black types.

This alternative would include construction of a diversion dam on the Colorado River approximately 16 miles downstream from Garwood's existing diversion dam. The bottomland in the area of the dam consists of a Miller-Norwood soil association which includes moderately well drained soils that have a surface layer and lower layers of clay and silt loam.[4] The predominant soils are classified as Mollisol (Miller Clay) on the southwest riverbank and Entisol (Norwood silt loam with less than 1 percent slope) on the northeast riverbank. These relatively young bottomland soils were laid down by the meandering Colorado River.

Colorado River, Lavaca-Colorado Estuary

The Colorado River flows from west to southeast through Texas from the Llano Estacado in New Mexico, across the Western High Plains Ecoregion through the Central Plains and across the Central Texas Plateau before crossing the Balcones Escarpment and flowing through the Blackland Prairies and East Central Plains to the Western Gulf Coastal Plains. In Wharton County, the Colorado River is a large, low gradient stream generally exhibiting fine-grained sediments in extensive sandy braided reaches and occasional cobble and gravel riffles. As is commonly the case in coastal plain reaches, pool-riffle sequences are poorly developed. Low head dams impound two significant reaches of the river below Wharton. In addition to the numerous impoundments on the upper river and on major and minor tributaries, the Highland Lakes (large mainstream reservoirs constructed on the Edwards Plateau) are operated by the Lower Colorado River Authority to provide hydropower, flood control, and water storage in the lower Colorado River Basin. Operation of these reservoirs, particularly winter storage and summer releases of water for rice irrigation in Colorado, Wharton and Matagorda Counties, has substantially altered the annual hydrography of the lower river (below Austin) from its historical

[4] McEwen, H. F. and J. Crout. 1974. Soil Survey of Wharton County, Texas. United States Department of Agriculture, Soil Conservation Service, in cooperation with the Texas Agricultural Experiment Station.

condition.[5]

In order to establish minimum flow guidelines that would protect existing biological communities in the lower Colorado River while continuing to provide water for its traditional uses, LCRA conducted extensive instream flow studies on Segments 1428 and 1402 (from Austin to Bay City)[6]. Also, based on the distribution and abundance of habitat suitable for the maintenance of populations of a set of representative native riverine species, LCRA divided the lower river into five distinct reaches, of which the lowest, the Egypt reach, encompasses the proposed intake location for this alternative. Instream flow guidelines were established for each reach based on evaluations of habitat use by representative fish species, coupled with an assessment of the effect of river discharge on the amount of suitable habitat at selected locations within each reach. In the Egypt reach, monthly target flows (those to be maintained when supplies are adequate, but to be considered interruptable subject to demand curtailment during drought periods) range from 160 cfs during August to 670 cfs in May and 540 cfs in June. The target flows are substantially lower than the corresponding modern monthly medians at Columbus, and lower than the target flows developed for the upstream reaches. The disparity is due to the general lack of suitable habitat for the primary evaluation species (blue sucker, *Cycleptus elongatus*) and other flow-sensitive forms in the Egypt reach. The proposed diversion of water held under existing water rights will meet the Lower Colorado River Authority's instream flow targets.

Below Bay City the Colorado River is tidally influenced (Segment 1401), and its aquatic community is characterized by more marine species. The river mouth has recently been relocated by the U.S. Army Corps of Engineers (USCE) so that it no longer discharges directly into the Gulf of Mexico, but into the eastern arm of Matagorda Bay, as it did prior to its rapid delta progradation some 60 years ago. This action is expected to increase Colorado River inflows to Matagorda Bay by about 30 percent (from an average of 1.2 million to about 1.7

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[5] Mosier, D.T. and R.T. Ray. 1992. Instream flows for the Lower Colorado River. Lower Colorado River Authority, Austin, Texas.

[6] Ibid.

million acft/yr), but hydrologic and modeling studies are still in progress.[7]

Sandy Creek

American bald eagles formerly nesting on Sandy Creek have relocated to Lake Texana, and no other listed endangered, threatened, or unlisted species of concern, have been reported to presently occur there.[8] A mature eagle was observed March 15, 1995, perched in a tree overlooking the service spillway channel about 300 yards downstream of Palmetto Bend Dam.[9] Also, on Goldenrod Creek, about three quarters of a mile upstream from its confluence with Sandy Creek there are woods of the coastal live oak - post oak series and water oak - coastal live oak series.[10]

The coastal live oak - post oak series is listed as G4S4, apparently secure globally, apparently secure in the state.[11] The Texas Natural Heritage Program description of this plant community is as follows:

> This mainly deciduous to mainly evergreen upland woodland occupies acid, sandy, usually clay pan soils along the northern rim of the Coastal Prairie and the far Southwestern Post Oak Savannah. Blackjack oak (*Quercus marilandica*), *Crataegus* spp., yaupon (*Ilex vomitoria*), and grasses such as little bluestem (*Schizachyrium scoparium*) and brownseed paspalum (*Paspalum plicatulum*) may be important. Composition ranges from mostly live oak to mainly post oak and blackjack oak with scattered live oak. Adjacent communities include water oak (*Quercus nigra*)-live oak on river floodplains, live oak-pecan (*Carya illinoinensis*) over clayey soils, and little bluestem-brownseed paspalum (*Schizachyrium scoparium-Paspalum plicatulum*) on adjacent grasslands[12]

The water oak-coastal live oak series is listed as G3S3, very rare and local throughout

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[7] TWDB. 1990. Unpublished data, Bay and Estuaries Study Program, Texas Water Development Board, Austin, Texas.

[8] TPWD. 1993. Texas Parks and Wildlife Department National Heritage Program special animal files; and Mark Mitchell, pers comm.

[9] Paul Price Associates, Inc. Personal observation.

[10] Ibid.

[11] Ibid.

[12] Ibid.

range or found locally in restricted range, 21 to 100 occurrences, threatened throughout range, rare or uncommon in state.[13] The Texas Natural Heritage Program describes this plant community as follows:

> This mainly deciduous woodland occurs on floodplains and along bayous in the upper Coastal Prairie. Pecan (*Carya illinoinensis*), cedar elm (*Ulmus crassifolia*), sugarberry (*Celtis laevigata*), yuapon (*Ilex vomitoria*), *Crataegus* spp., and deciduous holly (*Ilex decidua*) may be present. This type is similar to water oak and willow oak (*Quercus phellos*) dominated bottomlands to the east. It may occur in the landscape with coastal live oak-pecan or post oak-coastal live oak upland forests and little bluestem grasslands.[14]

The discharge of Colorado River water into Sandy Creek proposed under this alternative is unlikely to have an impact on these communities or the riparian woodlands along Sandy Creek (see the discussion on Sandy Creek in the Impact Assessment section below).

Proposed Pipeline Route

The route of the proposed pipeline is shown on Figure 3.16-4 on which physical and environmental features are identified as well as general physiognomic categories are labeled. The line is shown on both USGS topographic maps and on aerial photographs of the route.

The Texas Natural Heritage Program does not report any endangered or threatened species within the pipeline corridor. Endangered or threatened species reported to occur in Wharton and Jackson Counties are presented in Appendix C, Tables 10 and 20. On highway 71, a quarter of a mile north of where the proposed pipeline route crosses the highway there is a little bluestem-brownseed paspalum series prairie.[15] The little bluestem-brownseed paspalum series is listed as G2S2, imperiled globally, very rare, 6 to 20 occurrences, endangered throughout range, imperiled in state, very rare, vulnerable to extirpation.[16] The Texas Natural Heritage Program description of this grassland community is as follows:

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[13] Ibid.

[14] Ibid.

[15] Plant Communities of Texas (Series Level). Texas Natural Heritage Program, April 1993.

[16] Ibid.

This tallgrass grassland occupies uplands of the Coastal Prairie and loamy soils of the Fayette Prairie. Indiangrass (*Sorghastrum nutans*), tall dropseed (*Sporobolus asper*), bristlegrasses (*Setaria nutans*), big bluestem (*Andropogon gerardii*), hairyawn muhly (*Muhlenbergia capillaris*), fimbry (*Fimbristylis puberula*), and a variety of forbs and sedges may be important. To the north, similar habitats are occupied by Blackland Prairie tallgrass communities, while gulfward the type contacts coastal marshes, especially the gulf cordgrass (*Spartina spartinae*) series.[17]

Construction and pipeline maintenance would not impact this prairie remnant.

Impact Assessment

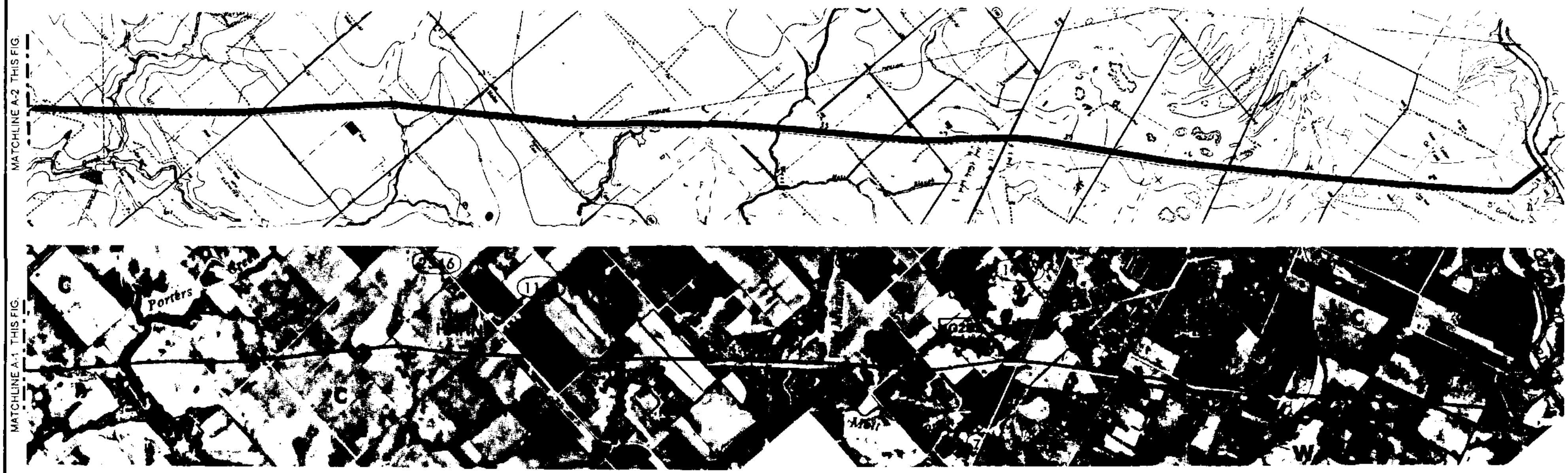
Construction Impacts to the Pipeline ROW

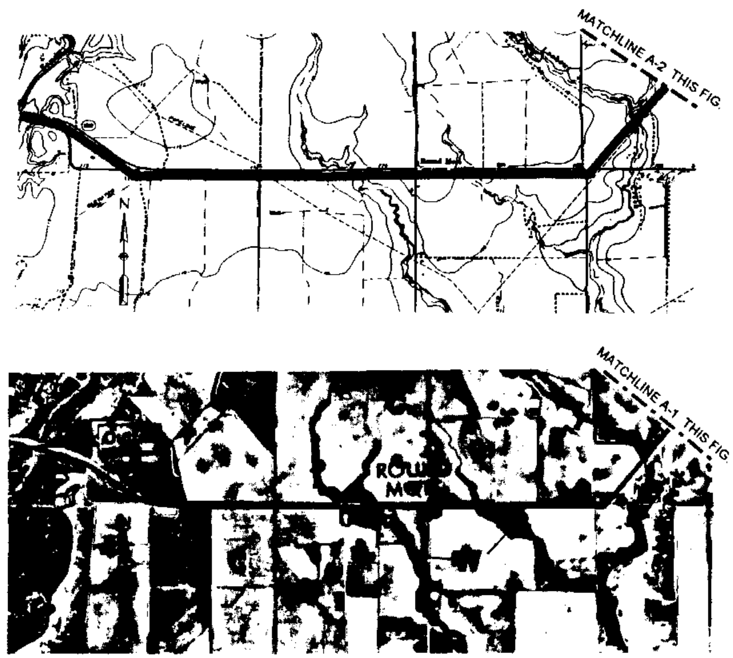
Construction of the 16 mile long pipeline will require a construction ROW 140 feet wide affecting 272 acres total. Approximately 24 acres (8.8 percent) of the impacted area is wooded. The remaining 248 acres (91.2 percent) is agricultural land used for crops or as pasture. A 40 foot wide ROW maintained free of woody vegetation for the life of the project would affect a total of 78 acres. Most of the affected land would be expected to be returned to agricultural uses following construction. Pipeline construction would include some impact to woods, however, such impacts would be reduced from the figures given above by judicious pipeline alignment. Several small creeks would be crossed by the proposed pipeline: West Mustang Creek, Porter's Creek, Lookout Creek.

Vegetation in cropland and pastures, and animal species associated with these habitats, would be expected to return to near original condition following seeding. Important localized impacts would occur at the Colorado River and Sandy Creek, however, the proposed construction sites are adjacent to existing disturbed areas; a pipeline and a highway bridge in the case of the Colorado River and Sandy Creek respectively. Other woodland acreages occur in association with small creeks along the pipeline corridor between the Colorado River and Sandy Creek. No marshes or swamps were observed during the reconnaissance level survey. However, care should be taken to avoid forested wetlands where practicable.

With respect to cultural resources, all areas to be disturbed during construction will be surveyed by qualified professionals. Additional measures to mitigate impacts may be required

[17] Ibid.





LEGEND

- B = BRUSH
- M = MARSH AND WETLAND PASTURE
- O = OPEN GRASSLAND, PASTURE, CROPLAND
- U = URBAN
- W = WOODLAND
- X = MIXED BRUSH AND GRASSLAND

SCALE: 0 2000 4000 FEET; 0 500 1000 METERS

MAP SOURCE: USGS 7.5 Minute Texas Quadrangle Sheets, 1973 - 1987.

PHOTO SOURCE: USGS EROS Data Center. Negatives and Infrared Photographs, 1989.

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TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

GARWOOD PIPELINE FROM COLORADO RIVER TO SANDY CREEK - ALTERNATIVE C-1

FIGURE 3.16-4

by the presence of significant cultural deposits that cannot be avoided.

Operational Effects

Potential effects on the Colorado River from operation of this alternative include entrainment of Colorado River flora and fauna, and reduced streamflows below the diversion. Although the numerous long-term agricultural diversions in place on this reach suggest that the present riverine community is tolerant of the effects of entrainment, it would be minimized by selection of an intake location that does not attract fish, and by use of appropriate screening technology to reduce potential losses to aquatic populations. Because of channel losses in Sandy Creek, a diversion of 35,000 acft/yr of water from the Colorado River would be required to increase the yield of Lake Texana by about 32,000 acft/yr.

Sandy Creek, which already receives rice irrigation return flows originating from the Colorado River, will experience substantial increases in flow if this alternative is implemented. Mean flow statistics for 1978-1993 from a gage on Sandy Creek 0.9 miles downstream from Goldenrod Creek, can be used to illustrate the magnitude of change resulting from diverting 35,000 acft/yr of water to the creek. During this period, average monthly flow ranged between 23.1 cfs (August) and 381 cfs (June) resulting in stages of 5.8 feet and 8.0 feet respectively. Much of the low flow results from rice irrigation return flows originating from the Colorado River. The peak flow for 1993 was 8,310 cfs resulting in a stage of 19.73 feet on June 21. Calculated increases in flow in Sandy Creek resulting from Alternative C-1 during the irrigation season (April-September) ranged between 82 percent (August) and 22 percent (June). Water depth, assuming the cross-sectional area of Sandy Creek at the gage is representative, increased from 5.8 feet to 6.8 feet in August, and from 8.0 feet to 8.5 feet in June. With respect to the day of peak discharge (June 21, 1993), the diversion would have represented an increased flow of 1 percent. Such changes in the flow of Sandy Creek resulting from this alternative are unlikely to produce adverse impacts to Sandy Creek or its tributaries such as Goldenrod Creek. Pumping the 35,000 acft/yr throughout the year, rather than only during the irrigation season, would reduce the changes in discharge compared to pumping only during the irrigation season.

This alternative (C-1) involves transferring Colorado River water through Lake Texana to the Lake Texana pipeline to Corpus Christi (Alt. LN-1). Furthermore, Colorado River irrigation return flows currently flow to Sandy Creek and Lake Texana. Thus, the additional water due to this alternative (C-1) would not be expected to produce changes in the ecology of Lake Texana or the rivers and bays downstream.

Nueces Estuary

Following use in the Corpus Christi area, a portion of the combined Lake Texana and Garwood water would be returned to the Nueces Estuary system as treated wastewater. Based on the 1934 to 1989 period of record, Phase 2 CC/LCC Operating Policy, an interbasin transfer of 63,440 acft/yr, and an estimated wastewater return to Nueces Bay of 47 percent, projected return flows by 2050 with and without the interbasin transfer have been developed.[18] These studies found that by the year 2050, the combined transfer water would contribute 29,817 acft of water annually (a 10.1 percent increase) to the Nueces Estuary with median monthly changes in return flow ranging between 9.9 percent and 36.0 percent (Tables 3.16-9 and 3.16-10 and Figure 3.16-5). Monthly average salinities in Upper Nueces Bay were projected to decrease on average ranging from 0.66 ppt to 2.54 ppt, with median salinity decreases ranging between 0.48 ppt and 3.02 ppt (Table 3.16-11, Figure 3.16-6). A schedule of appropriate salinity boundaries was established by the TNRCC in their order concerning required releases from the CC/LCC Reservoir System. This schedule establishes upper and lower salinity bounds for Nueces Bay. Comparisons of salinity levels with and without the combined Texana and Garwood water were made. This comparison shows that upper bound salinity violations for the 672 month study period would be reduced from 13 without the transfer to zero violations with the transfer (Table 3.16-12). Lower bound salinity violations would increase from 64 without interbasin transfer to 65 with interbasin transfer (Table 3.16-13).

Increased freshwater inflows into Nueces Estuary might be expected to benefit shrimp and some other aquatic species. However, in relation to natural variation in instream flows changes in freshwater inflows before and after the construction of Choke Canyon Reservoir and

[18] HDR Engineering, Inc. 1993a. Trans-Texas Water Program. Corpus Christi Service Area. Phase I Interim Report Summary.

Table 3.16-9
Comparison of Monthly Median Nueces Estuary Inflow (Alternative C-1)
with and without combined Lake Texana & Garwood Diversions of 63,440 acft/yr

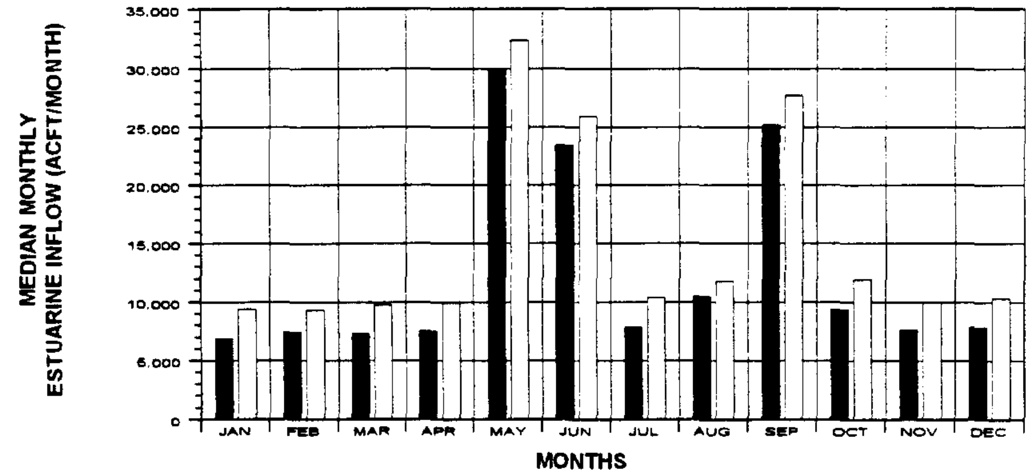
Month	Median Monthly Estuarine Inflow without Texana & Garwood Diversions (acft)	Median Monthly Estuarine Inflow with Texana & Garwood Diversions (acft)	Percent Difference (%)
JAN	6,902	9,388	36.0
FEB	7,452	9,364	25.7
MAR	7,352	9,832	33.7
APR	7,551	9,959	31.9
MAY	29,912	32,421	8.4
JUN	23,488	25,997	10.7
JUL	7,902	10,411	31.8
AUG	10,519	11,782	12.0
SEP	25,258	27,767	9.9
OCT	9,414	11,932	26.7
NOV	7,681	10,031	30.6
DEC	7,898	10,387	31.5

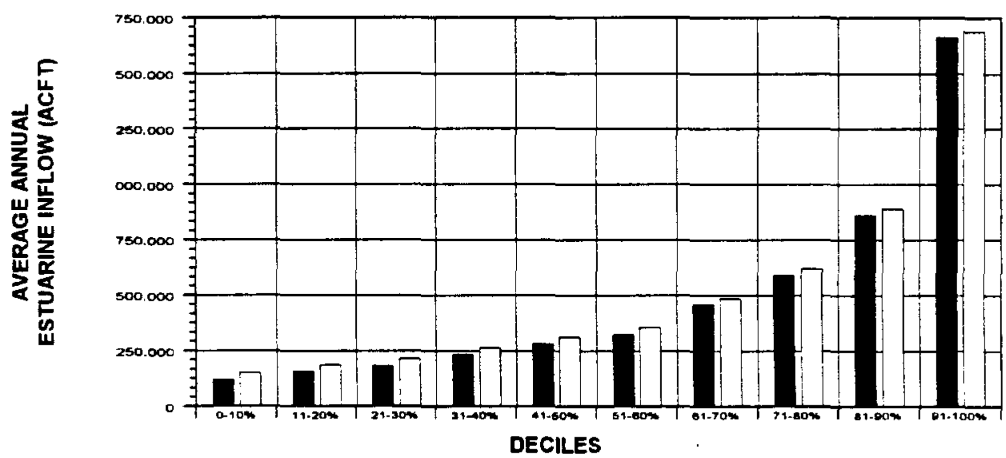
Analysis based on Phase 2 CCR/LCC Operating Policy, 2050 sediment conditions, and an annual diversion of 63,440 acft/yr from Lake Texana and Garwood to Corpus Christi.

Table 3.16-10
Comparison of Annual Average Nueces Estuary Inflow Deciles (Alternative C-1)
with and without combined Lake Texana and Garwood Diversions of 63,440 acft/yr

Decile	Average Annual Estuary Inflow without Texana & Garwood Diversions (acft)	Average Annual Estuary Inflow with Texana & Garwood Diversions (acft)	Percent Difference (%)
0-10%	121,323	151,345	24.8
11-20%	157,380	187,755	19.3
21-30%	184,824	214,574	16.1
31-40%	236,149	263,800	11.7
41-50%	283,603	313,584	10.6
51-60%	325,466	356,106	9.4
61-70%	458,580	487,022	6.2
71-80%	593,355	622,313	4.9
81-90%	864,299	893,514	3.4
91-100%	1,663,057	1,691,836	1.7

Analysis based on Phase 2 CCR/LCC Operating Policy, 2050 sediment conditions, and an annual diversion of 63,440 acft/yr from Lake Texana and Garwood to Corpus Christi.





■ WITHOUT PROJECT　　□ WITH PROJECT

NOTES:

PHASE 2 RESERVOIR OPERATING POLICY
2050 SEDIMENT CONDITIONS
63,440 ACFT/YR TEXANA & GARWOOD TRANSFER

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TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

CHANGES IN NUECES ESTUARY INFLOWS ALTERNATIVE C-1

FIGURE 3.16-5

Table 3.16-11
Comparison of Monthly Median Salinity in Upper Nueces Bay (Alternative C-1)
with and without Texana & Garwood Diversions

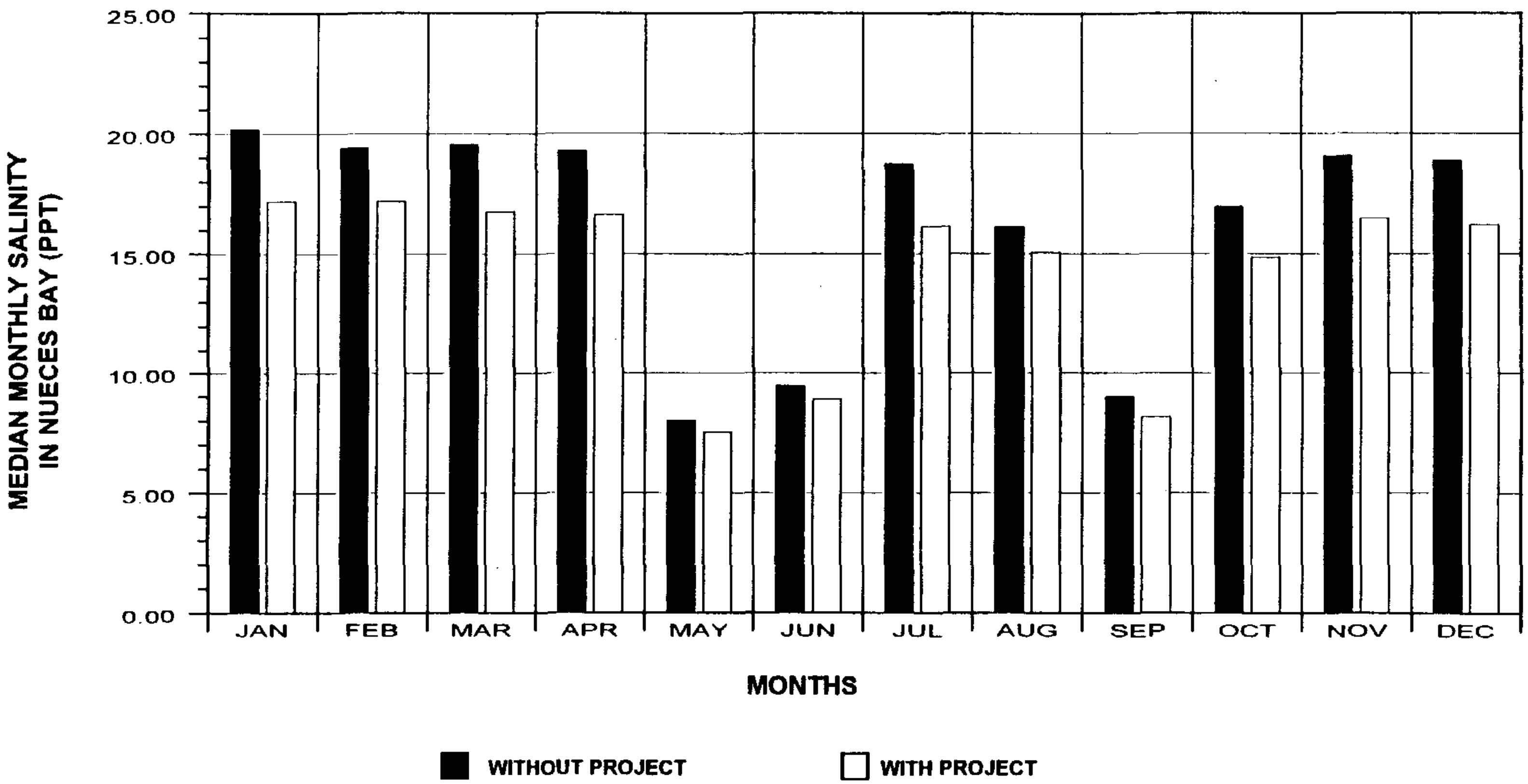
Month	Median Monthly Salinity without Texana & Garwood Diversions (ppt)	Median Monthly Salinity with Texana & Garwood Diversions (ppt)	Percent Difference (%)
JAN	20.23	17.21	-14.9
FEB	19.44	17.24	-11.3
MAR	19.58	16.78	-14.3
APR	19.31	16.66	-13.7
MAY	8.03	7.55	-6.0
JUN	9.48	8.95	-5.6
JUL	18.78	16.17	-13.9
AUG	16.16	15.08	-6.7
SEP	9.05	8.20	-9.4
OCT	17.00	14.87	-12.5
NOV	19.11	16.52	-13.6
DEC	18.89	16.26	-13.9

Analysis based on Phase 2 CCR/LCC Operating Policy, 2050 sediment conditions, and an annual diversion of 63,440 acft/yr from Lake Texana and Garwood to Corpus Christi.

Table 3.16-12
Comparison of Monthly Upper Salinity Bound Violations in Upper Nueces Bay
with and without Texana & Garwood Diversions (Alternative C-1)

Month	Interim Order Monthly Upper Salinity Bound (ppt)	Number of Upper Bound Violations w/o Texana & Garwood Diversions	Number of Upper Bound Violations w/ Texana & Garwood Diversions	Change in Number of Violations
JAN	30	0	0	0
FEB	30	0	0	0
MAR	30	0	0	0
APR	30	0	0	0
MAY	20	4	0	-4
JUN	20	6	0	-6
JUL	25	0	0	0
AUG	25	0	0	0
SEP	20	3	0	-3
OCT	30	0	0	0
NOV	30	0	0	0
DEC	30	0	0	0
SUM		13	0	-13

Analysis based on Phase 2 CCR/LCC Operating Policy and existing TNRCC Interim Release Order, 2050 sediment conditions, and an annual diversion of 63,440 acft/yr from Lake Texana and Garwood to Corpus Christi.



NOTES:
PHASE 2 RESERVOIR OPERATING POLICY
2050 SEDIMENT CONDITIONS
63,440 ACFT/YR TEXANA & GARWOOD TRANSFER

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

CHANGES IN UPPER NUECES BAY SALINITY ALTERNATIVE C-1

FIGURE 3.16-6

Table 3.16-13 Comparison of Monthly Lower Salinity Bound Violations in Upper Nueces Bay with and without Texana & Garwood Diversions (Alternative C-1)				
Month	Interim Order Monthly Lower Salinity Bound (ppt)	Number of Lower Bound Violations without Texana & Garwood Diversions	Number of Lower Bound Violations with Texana & Garwood Diversions	Change in Number of Violations
JAN	5	4	4	0
FEB	5	1	2	1
MAR	5	1	1	0
APR	5	5	5	0
MAY	1	2	2	0
JUN	1	4	4	0
JUL	2	4	4	0
AUG	2	2	2	0
SEP	5	16	16	0
OCT	5	15	15	0
NOV	5	7	7	0
DEC	5	3	3	0
SUM		64	65	1
Analysis based on Phase 2 CCR/LCC Operating Policy and existing TNRCC Interim Release Order, 2050 sediment conditions, and an annual diversion of 63,440 acft/yr from Lake Texana and Garwood to Corpus Christi.				

Lake Corpus Christi can be difficult to detect statistically.[19] The effect of additional freshwater contributed by this alternative alone would be negligible. In contrast to alternatives involving the diversion of water from the Nueces River Basin, wastewater returns from interbasin transfer alternatives (i.e., Alternative C-1 and LN-1) will offset losses to the bay from local alternatives which divert water from the Nueces River.

3.16.4 Water Quality and Treatability

Both Lake Texana and the Colorado River have generally good water quality as indicated by the analysis in Appendix D. The four constituent concentrations (hardness, TDS, chlorides, and sulfates) analyzed for Lake Texana were typically less than one-third of the TWC Secondary Drinking Water (SDW) Standards and the Colorado River at Wharton generally had concentration levels less than one-half the SDW Standards (see Table D-1). Since this option would include the mixing of 32,000 acft/yr of Colorado River water into Lake Texana, which

[19] Longley, W.L. ed.. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp.

has an average inflow of 517,000 acft/yr, the resultant concentrations of the water quality constituents of the water in Lake Texana would slightly increase (7 to 10 percent). The resulting concentration would still be significantly lower than those of Nueces River water and after blending would result in lower median concentration of chlorides and hardness of about an additional 10 percent from the concentrations expected with only the Lake Texana water, due to the increased blending volume. Therefore, the total improvement in water quality at the O.N. Stevens water treatment plant will be an approximate 25 percent reduction in chlorides and 12 percent reduction in hardness considering both the Lake Texana and Garwood combined blending volume.

The data reviewed included water quality data for hardness, TDS, chlorides, and sulfates. Although there is a strong likelihood that there are no other marginal constituents, specific water quality assessments should be completed in later phases of the study, if the importation of Colorado River water to Lake Texana should continue to be considered as an alternative water supply for Corpus Christi (refer to Appendix E for more a detailed consideration of treatment issues).

3.16.5 Engineering and Costing

The water supply alternative presented here is a combined project with the Lake Texana Pipeline (Alt. LN-1).[20] A stand-alone project from the Colorado River to Corpus Christi is possible, but the unit cost of water would be significantly higher. Cost estimates for each of the subordination scenarios have been prepared and the necessary facilities to implement the alternative only vary in size, depending on the scenario. Water purchased from Garwood would be diverted through an intake at a small diversion structure to be located near Garwood on the Colorado River. A pump station at the intake structure would pump the water through a 16-mile

[20] Corpus Christi has acquired 41,840 acft/yr of Lake Texana water, which includes 10,400 acft/yr reserved for potential future demands in Jackson County. The 41,840 acft/yr will meet projected demands of the Corpus christi Service Area until 2029, at which time additional quantities will be needed. The completion of facilities in 2029 to begin the transfer of 35,000 acft/yr of Colorado River water purchased from Garwood Irrigation Company would yield about 32,000 acft/yr at Lake Texana, of which 10,400 acft/yr would be available to replace the 10,400 acft/yr of Lake Texana water reserved for potential future demands of Jackson County. This is a "worst case" assumption, as water demand projections for Jackson County show that this water will not be needed before 2050. Under these assumptions, the combined availability of Lake Texana and Garwood water for delivery to the Corpus Christi Service Area after 2029 would be 63,440 acft/yr (41,840 + 32,000 - 10,400 = 63,440). If the 10,400 acft/yr is not needed in Jackson County, then implementation of subsequent alternatives could be delayed.

transmission pipeline to a discharge structure on Sandy Creek. After flowing down Sandy Creek and mixing with water in Lake Texana, the water would be diverted through the intake structure at the dam and pumped through the Texana Pipeline to the O.N. Stevens Water Treatment Plant near Calallen. The major facilities required to implement this alternative are:

Small Diversion Structure on Colorado River;
Surface Water Intake and Pump Station;
Transmission Pipeline from Colorado River to Sandy Creek;
Discharge Structure at Sandy Creek;
Upsized Pump Station at Lake Texana;
Upsized Transmission Pipeline from Lake Texana to Corpus Christi;
Upsized Booster Pump Stations;
Tie-In to O.N. Stevens Water Treatment Plant.

From Lake Texana to Corpus Christi, facility and operation costs are estimated for a combined water delivery of 63,440 acft/yr. This is the quantity resulting from the delivery of 32,000 acft/yr into Lake Texana from the Garwood purchase (considering channel and evaporation losses) added to the 31,440 acft/yr that the City of Corpus Christi has purchased from LNRA on a permanent basis from the yield of Lake Texana.[21] The 63,440 acft/yr would be delivered to the O.N. Stevens Water Treatment Plant at a uniform rate of 5,287 acft/month throughout the year through an up-sized Texana pipeline. Assuming 5 percent down time for the pumping equipment, the pumping rate would be about 59 mgd and the pipeline size would be 60-inches diameter. Project costs for purchase and delivery of the Garwood water delivered to Lake Texana are summarized in Table 3.16-14. Project costs to upsize the Texana Pipeline to Corpus Christi to a 60-inch diameter line are summarized in Table 3.16-15. Summary cost tables are provided in Tables 3.16-16 through 3.16-19 for each of the flow subordination scenarios showing the cost of both the Garwood and Lake Texana water.

Financing the Garwood portion of the project over 25 years at an 8 percent annual interest rate results in an annual expense ranging from $1,780,000 for Scenario 1 (48-inch pipeline) to $3,020,000 for Scenario 3 (72-inch pipeline) (Table 3.16-14). Operation and maintenance costs, including power, range from $1,060,000 (Scenario 3, 72-inch) to $810,000 (Scenario 1, 48-inch). Total annual costs, including debt repayments, interest, purchase of

[21] Ibid.

Table 3.16-14
Cost Estimate for Garwood Pipeline to Lake Texana (Sandy Creek) Pumping All Year Flow = 35,000 acft/yr (Mid-1995 Prices)

Item	Estimated Cost Scenario 1 (48-inch pipeline)	Scenario 2 (60-inch)	Scenario 3 (72-inch)	Scenario 4 (54-inch pipeline)
Capital Cost				
Diversion Dam	$ 1,750,000	$ 1,750,000	$ 1,750,000	$ 1,750,000
Pump Station	2,800,000	3,430,000	4,000,000	3,150,000
Pipeline	9,240,000	12,240,000	17,930,000	10,690,000
Subtotal	$13,790,000	$17,420,000	$23,680,000	$15,590,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	4,350,000	5,470,000	7,380,000	4,910,000
Environmental Studies and Mitigation	390,000	390,000	390,000	390,000
Land Easements	140,000	140,000	140,000	140,000
Subtotal	$18,670,000	$23,420,000	$31,590,000	$21,030,000
Interest During Construction	370,000	470,000	630,000	420,000
Total Project Cost	$19,040,000	$23,890,000	$32,220,000	$21,450,000
Annual Cost				
Annual Debt Service	$ 1,780,000	$2,240,000	$3,020,000	$ 2,010,000
Annual Operation and Maintenance (Excluding Power)	210,000	270,000	350,000	240,000
Annual Power	600,000	640,000	710,000	620,000
Annual Cost of Garwood Water[1]	1,410,000	1,410,000	1,410,000	1,410,000
Total Annual Cost	$ 4,000,000	$ 4,560,000	$ 5,490,000	$ 4,280,000

[1] Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest, or $40.29 per acft/yr.

Table 3.16-15
Cost Estimate for 60" Pipeline
from Lake Texana to Corpus Christi
Flow = 63,440 acft/yr
(Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Pump Station	$4,010,000
Booster Station	2,770,000
Booster Station	3,490,000
Pipeline (60 inch)	70,060,000
Tunneling at Environmental Features	2,110,000
Subtotal	$82,440,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	21,110,000
Subtotal	$103,550,000
Environmental Studies and Mitigation	340,000
Land Easements	550,000
Subtotal	$104,440,000
Interest During Construction	3,130,000
Total Project Cost	$107,570,000
Annual Cost	
Annual Debt Service	$10,080,000
Annual Operation and Maintenance (Excluding Power)	1,120,000
Annual Power	3,470,000
Annual Cost of LNRA Water[1]	2,071,000
Total Annual Cost	$16,741,000

[1] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA; average cost from year 1995 to 2035.

Table 3.16-16
Cost Estimate for 60" Pipeline from Texana to Corpus Christi and 48"Pipeline From Colorado to Sandy Creek
Scenario 1: 35,000 acft Purchase Subordinated Only to Garwood Remaining Rights

Annual Delivery to Corpus Christi[1]	63,440 acft/yr
Delivery Rate at Corpus Christi	63 mgd (98 cfs)
Pipe Diameter (Texana to Corpus Christi)	60 inches
Pipeline Length	104 miles
Annual Diversion from Colorado	35,000 acft/yr
Annual Yield Increase at Texana	32,000 acft/yr
Delivery Rate from Colorado[2]	39 mgd (63 cfs)
Pipeline Diameter (Colorado to Sandy Creek)	48 inches
Pipeline Length	16.3 miles

Capital Cost Summary	Total Project	Texana Portion	Garwood Portion
Pump Station and Channel Dam On Colorado and Pipeline to Sandy Creek	$19,040,000		$19,040,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi	$107,570,000	$53,785,000	$53,785,000
Total Capital Costs	$126,610,000	$53,785,000	$72,825,000

Annual Cost Summary	Total Project	Texana Portion	Garwood Portion
Estimated Annual Debt Service	$11,860,000	$5,040,000	$6,820,000
Estimated Annual O&M	$5,790,000	$2,490,000	$3,300,000
Annual Payment on LNRA Water[3]	$2,071,000	$2,071,000	
Annual Debt Service on Garwood Water Purchase[4]	$1,410,000		$1,410,000
Total Annual Costs	$21,131,000	$9,601,000	$11,530,000
Average Annual Cost (per acft) Delivered at Corpus Christi	$333	$305	$360

[1] Consists of 31,440 acft/yr of LNRA water (50%) and 32,000 acft/yr of Garwood water (50%). See Section 3.16.5.
[2] Rate is based on diverting 35,000 acft in 280 days.
[3] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.
[4] Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest or $40.29/acft/yr.

Table 3.16-17
Cost Estimate for 60" Pipeline from Texana to Corpus Christi and 60" Pipeline From Colorado to Sandy Creek
Scenario 2: 35,000 acft Purchase Subordinated to both Garwood and City of Austin

Annual Delivery to Corpus Christi[1]	63,440 acft/yr		
Delivery Rate at Corpus Christi	63 mgd (98 cfs)		
Pipe Diameter (Texana to Corpus Christi)	60 inches		
Pipeline Length	104 miles		
Annual Diversion from Colorado	35,000 acft/yr		
Annual Yield Increase at Texana	32,000 acft/yr		
Delivery Rate from Colorado[2]	63 mgd (98 cfs)		
Pipeline Diameter (Colorado to Sandy Creek)	60 inches		
Pipeline Length	16.3 miles		
Capital Cost Summary	**Total Project**	**Texana Portion**	**Garwood Portion**
Pump Station and Channel Dam On Colorado and Pipeline to Sandy Creek	$23,890,000		$23,890,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi	$107,570,000	$53,785,000	$53,785,000
Total Capital Costs	$131,460,000	$53,785,000	$77,675,000
Annual Cost Summary	**Total Project**	**Texana Portion**	**Garwood Portion**
Estimated Annual Debt Service	$12,320,000	$5,040,000	$7,280,000
Estimated Annual O&M	$5,890,000	$2,490,000	$3,400,000
Annual Payment on LNRA Water[3]	$2,071,000	$2,071,000	
Annual Debt Service on Garwood Water Purchase[4]	$1,410,000		$1,410,000
Total Annual Costs	$21,691,000	$9,601,000	$12,090,000
Average Annual Cost (per acft) Delivered at Corpus Christi	$342	$305	$378

[1] Consists of 31,440 acft/yr of LNRA water (50%) and 32,000 acft/yr of Garwood water (50%). See Section 3.16.5.
[2] Rate is based on diverting 35,000 acft in 180 days.
[3] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.
[4] Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest or $40.29/acft/yr.

Table 3.16-18
Cost Estimate for 60" Pipeline from Texana to Corpus Christi and 72" Pipeline From Colorado to Sandy Creek
Scenario 3: 35,000 acft Purchase Subordinated to All Existing Rights

Annual Delivery to Corpus Christi[1]	63,440 acft/yr		
Delivery Rate at Corpus Christi	63 mgd (98 cfs)		
Pipe Diameter (Texana to Corpus Christi)	60 inches		
Pipeline Length	104 miles		
Annual Diversion from Colorado	35,000 acft/yr		
Annual Yield Increase at Texana	32,000 acft/yr		
Delivery Rate from Colorado[2]	91 mgd (141 cfs)		
Pipeline Diameter (Colorado to Sandy Creek)	72 inches		
Pipeline Length	16.3 miles		
Capital Cost Summary	**Total Project**	**Texana Portion**	**Garwood Portion**
Pump Station and Channel Dam On Colorado and Pipeline to Sandy Creek	$32,220,000		$32,220,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi	$107,570,000	$53,785,000	$51,785,000
Total Capital Costs	$139,790,000	$53,785,000	$86,005,000
Annual Cost Summary	**Total Project**	**Texana Portion**	**Garwood Portion**
Estimated Annual Debt Service	$13,100,000	$5,040,000	$8,060,000
Estimated Annual O&M	$6,040,000	$2,490,000	$3,550,000
Annual Payment on LNRA Water[3]	$2,071,000	$2,071,000	
Annual Debt Service on Garwood Water Purchase[4]	$1,410,000		$1,410,000
Total Annual Costs	$22,621,000	$9,601,000	$13,020,000
Average Annual Cost (per acft) Delivered at Corpus Christi	$357	$305	$407

[1] Consists of 31,440 acft/yr of LNRA water (50%) and 32,000 acft/yr of Garwood water (50%).
[2] Rate is based on diverting 35,000 acft in 125 days.
[3] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.
[4] Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest or $40.29/acft/yr.

Table 3.16-19
Cost Estimate for 60" Pipeline from Texana to Corpus Christi and 54" Pipeline From Colorado to Sandy Creek
Scenario 4: 35,000 acft Purchase Seasonally Subordinated

Annual Delivery to Corpus Christi[1]	63,440 acft/yr		
Delivery Rate at Corpus Christi	60 mgd (98 cfs)		
Pipe Diameter (Texana to Corpus Christi)	60 inches		
Pipeline Length	104 miles		
Annual Diversion from Colorado	35,000 acft/yr		
Annual Yield Increase at Texana	32,000 acft/yr		
Delivery Rate from Colorado[2]	51 mgd (80 cfs)		
Pipeline Diameter (Colorado to Sandy Creek)	54 inches		
Pipeline Length	16.3 miles		
Capital Cost Summary	**Total Project**	**Texana Portion**	**Garwood Portion**
Pump Station and Channel Dam On Colorado and Pipeline to Sandy Creek	$21,450,000		$21,450,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi	$107,570,000	$53,785,000	$53,785,000
Total Capital Costs	$129,020,000	$53,785,000	$72,235,000
Annual Cost Summary	**Total Project**	**Texana Portion**	**Garwood Portion**
Estimated Annual Debt Service	$12,090,000	$5,040,000	$7,050,000
Estimated Annual O&M	$5,840,000	$2,490,000	$3,350,000
Annual Payment on LNRA Water[3]	$2,071,000	$2,071,000	
Annual Debt Service on Garwood Water Purchase[4]	$1,410,000		$1,410,000
Total Annual Costs	$21,411,000	$9,601,000	$11,810,000
Average Annual Cost (per acft) Delivered at Corpus Christi	$338	$305	$369

[1] Consists of 31,440 acft/yr of LNRA water (50%) and 32,000 acft/yr of Garwood water (50%). See Section 3.16.5.
[2] Rate is based on diverting 35,000 acft in 220 days.
[3] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.
[4] Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest or $40.29/acft/yr.

water, operation, and maintenance, range from $4,000,000 for Scenario 1 to $5,490,000 for Scenario 3 (Table 3.16-14). The resulting annual cost of additional yield of 32,000 acft/yr delivered to O.N. Stevens WTP ranges from a low of $360 per acft for Scenario 1 (Table 3.16-16) to a high of $407 per acft for Scenario 3 (Table 3.16-18). Implementation of this alternative as a stand alone project would result in significantly higher cost.

Combined Project with Additional Colorado River Water

Alternative C-2 (Purchase of Colorado River Water, Section 3.20) identifies additional water supplies available from the Colorado River. These potential supplies include purchase of stored water from LCRA (approximately 50,000 acft/yr available) and purchase of run-of-river rights currently owned by LCRA or Pierce Ranch (up to 55,000 acft/yr available from either source). Either of these sources could potentially be diverted at the Garwood diversion and pumped to Lake Texana through an up-sized Garwood pipeline, thereby increasing water availability to Corpus Christi through an up-sized Texana Pipeline.

Cost estimates have been made for increasing the Texana Pipeline from a 60-inch diameter to 66-inch. The annual capacity of a 66-inch Texana Pipeline would be 14,000 acft/yr greater than a 60-inch pipeline and this additional capacity would require increasing the Garwood pipeline from a 48-inch to a 60-inch diameter pipeline. Purchase of additional Colorado River water is costed at the same rate as purchase of Garwood water rights; i.e., a one-time $430 per acft cost. For a 9 percent channel and evaporation loss rate the additional quantity purchased would be 15,300 acft/yr, resulting in availability of 14,000 acft/yr at Lake Texana. Table 3.16-20 contains the cost estimate summary for the up-sized Garwood pipeline portion of the project and Table 3.16-21 summarizes the Texana pipeline cost estimate for the upsized project. Project costs for the combined system of both pipelines are summarized in Table 3.16-22. The resulting annual cost of additional yield of 46,000 acft/yr delivered to O.N. Stevens WTP is $333 per acft, or about $27 per acft lower than the cost of delivery of 32,000 acft/yr.

3.16.6 Implementation Issues

As formulated here, this alternative is combined with the Texana Pipeline (Alternative LN-1) and an agreement with the Lavaca-Navidad River Authority would be necessary for use of any of their pipeline or pumping facilities and for temporary storage of Colorado River Water in Lake Texana.

Table 3.16-20
Cost Estimate for Garwood Pipeline (60")
to Lake Texana (Sandy Creek) Pumping All Year
Flow = 50,300 acft/yr
(Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Diversion Dam	$1,750,000
Pump Station	2,540,000
Pipeline (60-inch)	11,630,000
Subtotal	$15,920,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	4,180,000
Subtotal	$20,100,000
Environmental Studies and Mitigation	340,000
Land Easements	140,000
Subtotal	$20,580,000
Interest During Construction	400,000
Total Project Cost	$20,980,000
Annual Cost	
Annual Debt Service	1,970,000
Annual Operation and Maintenance (Excluding Power)	230,000
Annual Power	680,000
Annual Cost of Water*	2,025,000
Total Annual Cost	$ 4,905,000

* Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest or $40.29 per acft/yr.

Table 3.16-21
Cost Estimate for 66" Pipeline
from Lake Texana to Corpus Christi
Flow = 77,440 acft/yr
(Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Pump Station	$ 4,330,000
Booster Station	3,000,000
Booster Station	3,760,000
Pipeline (66 inch)	86,730,000
Tunneling at Environmental Features	2,190,000
Subtotal	$100,010,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	25,540,000
Subtotal	$125,550,000
Environmental Studies and Mitigation	340,000
Land Easements	550,000
Subtotal	$126,440,000
Interest During Construction	5,060,000
Total Project Cost	$131,500,000
Annual Cost	
Annual Debt Service	$12,320,000
Annual Operation and Maintenance (Excluding Power)	1,340,000
Annual Power	3,960,000
Annual Cost of LNRA Water[1]	2,071,000
Total Annual Cost	$19,691,000

[1] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA; average cost for years 1995 to 2035.

Table 3.16-22
Cost Estimate for 66" Pipeline from Texana to Corpus Christi and 60" Pipeline From Colorado to Sandy Creek For 35,000 acft/yr Purchase From Garwood Combined with 14,000 acft/yr of Other Colorado River Water

Annual Delivery to Corpus Christi[1]	77,440 acft/yr
Delivery Rate at Corpus Christi	77 mgd (98 cfs)
Pipe Diameter (Texana to Corpus Christi)	66 inches
Pipeline Length	104 miles
Annual Diversion from Colorado	50,300 acft/yr
Annual Yield Increase at Texana	46,000 acft/yr
Delivery Rate from Colorado[2]	63 mgd (98 cfs)
Pipeline Diameter (Colorado to Sandy Creek)	60 inches
Pipeline Length	16.3 miles

Capital Cost Summary	Total Project	Texana Portion	Garwood/ Colorado Portion
Pump Station and Channel Dam On Colorado and Pipeline to Sandy Creek	$20,990,000		$20,990,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi	$131,500,000	$53,915,000	$77,585,000
Total Capital Costs	$152,490,000	$53,915,000	$98,575,000

Annual Cost Summary	Total Project	Texana Portion	Garwood/ Colorado Portion
Estimated Annual Debt Service	$14,290,000	$5,051,200	$9,238,800
Estimated Annual O&M	$6,210,000	$2,173,000	$4,037,000
Annual Payment on LNRA Water[3]	$2,071,000	$2,071,000	
Annual Debt Service on Garwood Water Purchase[4]	$2,025,000		$2,025,000
Total Annual Costs	$24,596,000	$9,295,200	$15,300,800
Average Annual Cost (per acft) Delivered at Corpus Christi	$318	$296	$333

[1] Consists of 31,440 acft/yr of LNRA water (41%) and 46,000 acft/yr of Garwood water (59%).
[2] Rate is based on diverting 50,300 acft in 260 days.
[3] From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.
[4] Based on one-time purchase price of $430/acft financed for 25 years at 8.0% interest or $40.29/acft/yr.

Requirements Specific to Interbasin Transfer of Water

1. It will be necessary to obtain these permits:
   a. Permit amendment from TNRCC to allow for the use of the water in the Corpus Christi service area.
   b. Coastal Coordinating Council review.
   c. TPWD Sand, Gravel, and Marl permit.
   d. GLO Sand and Gravel Removal permit.

2. Permitting, at a minimum, will require these studies:
   a. Evaluation of instream flow impacts.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.

3. Land and easements will need to be acquired by negotiations or condemnation.

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.
   d. TPWD Sand, Gravel and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Approval from various agencies for these crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

3.17 Accelerated and Additional Municipal Water Conservation (L-6)[1]

A major public policy objective is to increase water use efficiency through water conservation without adversely affecting population and economic growth potentials. The general methods to accomplish this objective in the South Central Trans-Texas Study area are to: (1) Reduce per capita water use in the municipal water use category; and (2) Recycle and reuse municipal and industrial wastewater in appropriate industries of the study area. Specific methods of water conservation for municipal purposes, together with conservation potentials and estimates of costs of water conservation methods are presented below. Industrial water recycling and reuse of wastewater are evaluated in Sections 3.6 and 3.10 of this report.

The quantity of water used within a typical city or water supply service area is usually expressed in terms of number of gallons per person per day (per capita water use). It is important to note that the per capita municipal water use statistic includes per capita water use within the home for drinking, toilet flushing, bathing, food preparation, dishwashing, laundry, and cleaning, and outdoor uses at the home, including landscape irrigation, carwashing, outside cleaning, and in some cases air conditioning. In addition to the water used at homes, the per capita water use statistic includes a person's share of water used in the workplace for toilet flushing, drinking, cleaning, showers, and lawn irrigation of office and commercial complexes, as well as a person's share of water used in commercial establishments such as restaurants, laundries, carwashes, and lawn and garden centers. The per capita water use statistic also includes a person's share of water used in institutions such as schools, churches, and recreation centers, and water used by the city for fire protection, sanitation, and public recreation, including irrigation of city parks and scenic places as well as unaccounted for water from leaks in the distribution system. For example, water sales data for Corpus Christi show that 53.8 percent of municipal water use was at residences, 35.1 percent was at commercial and workplace locations, 6.9 percent was at institutions, and 4.1 percent was through government functions. Thus, in order for water conservation efforts to achieve their maximum effectiveness in reducing per capita water use, such efforts will need to be focused at both private residences

[1] Actions to accomplish the water conservation potentials of low flow plumbing fixtures at an earlier date than has been assumed by the TWDB in the municipal water demand projections of Section 2.0 of this report, plus additional water conservation potentials through modifications to landscaping and lawn irrigation methods, and water rate structures.

and the commercial and workplaces where people also use water.

Municipal water conservation can be accomplished by using plumbing fixtures such as toilets, shower heads, and faucets which are designed for low quantities of flow per unit of use, by the selection and use of more efficient water using appliances such as clothes washers and dishwashers, by modifying lawn and landscaping systems to use grass and plants which require less water, by repair of plumbing and water using appliances to reduce leaks, and by modification of personal behavior which controls the use of plumbing fixtures, appliances, and lawn watering methods.

With respect to plumbing fixtures, in 1991 the Texas Legislature enacted legislation (Senate Bill 587) which established minimum standards for plumbing fixtures sold within Texas[2]. The bill became effective on January 1, 1992 and allowed until January 1, 1993 for wholesalers and retailers to clear existing inventories of pre-standards plumbing fixtures. The standards for new plumbing fixtures, as specified by Senate Bill 587, are as follows:

Fixture	Standard
Wall Mounted Flushometer Toilets	2.00 gallons per flush
All Other Toilets	1.60 gallons per flush
Shower Heads	2.75 gallons per minute at 80 psi*
Urinals	1.00 gallons per flush
Faucet Aerators	2.20 gallons per minute at 80 psi*
Drinking Water Fountains	Shall be self-closing

* pounds per square inch

The Texas Natural Resource Conservation Commission (TNRCC) has promulgated rules requiring the labeling of both plumbing fixtures and water using appliances sold in Texas. The labels must specify the rates of flow for plumbing fixtures and lawn sprinklers, and the amounts of water used per cycle for clothes washers and dishwashers[3].

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2 Senate Bill 587, Texas Legislature, Regular Session, 1991, Austin, Texas.

3 Chapter 290. 30 TAC Sections 290.251, 290,253-290.256, 290.260, 290.265, 290.266. Water Hygiene. Texas Register. December 24, 1993. Page 9935.

The TWDB estimated that the installation of the new plumbing fixtures in dwellings, offices, and public places can reduce per capita water use by about 22 gallons per person per day[4]. The estimated water conservation effect was obtained as follows:

Plumbing Fixture	Water Savings (gallons per person per day)
Toilets -- 1.6 gal/flush	14.0 gallons
Shower Heads -- 2.75 gal/minute	5.5 gallons
Faucets Aerators -- 2.2 gal/minute	2.1 gallons
Urinals -- 1.0 gal/minute	0.3 gallons
Drinking Fountains (self-closing)	0.1 gallons
Total	22.0 gallons

The TWDB estimated that the installation of the low flow plumbing fixtures in new construction and in replacement of fixtures in existing structures will phase in most of this conservation effect by the year 2020, and will result in a reduction of high case (dry year) per capita water use for the 12-county region by about 10.6 percent by year 2020, and 14 percent by 2050. The additional savings after 2020 are due to additional water conservation efforts through more efficient water using appliances.

The projections of municipal water demands for the 12-county area included the potential water conservation effects of low flow plumbing fixtures (Section 2.0, Table 2.3-1). For the 12-county region, the water conservation effects of the use of low flow plumbing fixtures resulted in a projected municipal water demand of 150,931 acft in year 2020 vs 169,182 acft, or a reduction of 10.8 percent from the projection without low flow plumbing fixtures (Table 3.17-1, Columns 3 and 4). In 2050, the projected municipal water demand with low flow plumbing fixtures is 186,054 acft compared to 216,449 without such fixtures (Table 3.17-1, Columns 3 and 4). The projections with and without low flow plumbing fixtures for the Choke Canyon/Lake Corpus Christi service area are 153,498 acft and 181,643 acft, respectively, in year 2050 (Table 3.17-2, Columns 3 and 4).

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[4] Water Conservation Impacts on Per Capita Water Use," Unpublished Water Planning Information, Texas Water Development Board, Austin, Texas, 1994.

Table 3.17-1
Projections of Municipal Water Conservation Effects of Low Flow Plumbing Fixtures
Corpus Christi Area--Trans-Texas Water Program[*]

Year	Projected Population[1]	Projected Municipal Water Use			Projected Water Savings	
		Conservation Case				
		Without[2] (acft)	*With Low Flow Fixtures*[3] (acft)	*With Accelerated Adoption of Low Flow Fixtures* (acft)	*With Low Flow Fixtures* (acft)	*With Accelerated Adoption of Low Flow Fixtures* (acft)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1990	530,878	117,749	115,473	---	---	---
2000	614,529	136,302	132,035	128,035	4,267	4,000
2010	693,814	153,888	142,492	132,102	11,396	10,390
2020	762,768	169,182	150,931	145,231	18,251	5,700
2030	835,006	185,204	162,622	158,985	22,582	3,637
2040	905,440	200,827	174,338	172,395	26,489	1,943
2050	975,874	216,449	186,054	186,054	30,395	0

[*] Low Flow Plumbing fixtures, as specified in Senate Bill 587, 1991 session of the Texas Legislature; the standards of the low flow fixtures are described in the text at the beginning of this section (Section 3.17.0) of this report.

[1] Population projections from Table 2.1-1.

[2] Computed from 1990 water use reports and 1990 Census of Population; high case (dry year) per capita water use, without conservation.

[3] High case projections, with conservation; regional totals from Table 2.3-1.

Table 3.17-2
Projections of Municipal Water Conservation Effects of Low Flow Plumbing Fixtures Upon Choke Canyon/Lake Corpus Christi Reservoir System Service Area Corpus Christi Area--Trans-Texas Water Program*

Year	Projected Population[1]	Projected Municipal Water Use			Projected Water Savings	
		Conservation Case				
		Without[2] (acft)	*With Low Flow Fixtures*[3] (acft)	*With Accelerated Adoption of Low Flow Fixtures* (acft)	*With Low Flow Fixtures* (acft)	*With Accelerated Adoption of Low Flow Fixtures* (acft)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1990	379,293	89,210	88,917	---	---	---
2000	452,815	106,502	103,554	100,437	2,948	3,117
2010	522,557	122,905	113,206	103,623	9,699	9,583
2020	583,585	137,259	121,140	115,725	16,119	5,415
2030	647,801	152,363	131,901	128,459	20,462	3,442
2040	710,046	167,003	142,700	140,802	24,303	1,898
2050	772,291	181,643	153,498	153,498	28,145	0

* Low Flow Plumbing fixtures, as specified in Senate Bill 587, 1991 session of the Texas Legislature; the standards of the low flow fixtures are described in the text at the beginning of this section (Section 3.17.0) of this report.

[1] Population projections from Table 2.2-1.

[2] Computed from 1990 water use reports and 1990 Census of Population; high case (dry year) per capita water use, without conservation.

[3] High case projections, with conservation; regional totals for the Choke Canyon/Lake Corpus Christi surface water service area; regional totals from Table 2.4-2 adjusted for industrial water demands.

Given that the water conservation effects of new, low flow plumbing fixtures and more efficient water using appliances will be phased in through the installation of these fixtures and appliances in new construction and replacement of existing fixtures and appliances, it is the purpose of the analyses in this section to evaluate the potentials and estimate costs of specific efforts and programs to gain municipal sector water conservation at a more rapid rate than was included in the municipal water demand projections of Section 2.0 and, if possible, to gain additional water conservation. The following water conservation methods are evaluated below: (1) Public Information; (2) Plumbing retrofit; (3) Modifying landscaping of existing dwellings to conserve water; (4) Water conserving landscaping standards for new development; (5) A water audit program for large landscaped areas; (6) Leak detection and repair; and (7) Water conservation rate structures. (Note: Water audit and water reuse in industrial uses are considered in Sections 3.6 and 3.10.)

3.17.1 Public Information

An important step to accomplishing municipal water conservation is to inform water users about ways to save water inside homes and other structures, in landscaping and lawn watering, and in recreation uses. Public information can work in two ways to accomplish water conservation. One way 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 or washing one's hands, and watering lawns, gardens, and shrubs during evening as opposed to daytime hours.

A second way public information and education can work to conserve water 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 lawn and shrubbery watering where regulations allow it, and to take advantage of water conservation incentives where available. In addition, public information programs would be a necessary part of any accelerated water conservation effort, such as retrofitting showerheads, faucets and commodes with low flow types, in order to inform the public about the programs and to communicate the availability to large numbers of participants.

Public information programs about water conservation typically include the distribution of water conservation brochures, water conservation tips enclosed in monthly water bills, public service announcements by local radio and TV stations, newspaper articles, presentations to clubs and civic organizations, and water conservation literature for school children. On a per capita basis, such programs cost approximately $0.50 per person per year and are estimated to reduce per capita water use by about 1.5 gallons per person per day.[5] At this rate, the potential reduction in municipal water use in the 12-county study area is approximately 1,032 acft/yr in year 2000 and 1,640 acft/yr in 2050. For the CC/LCC service area, the estimates are 637 acft/yr in year 2000 and 1,298 acft/yr in 2050. Estimated cost of the public information program described above would be $307,000 in the 12-county area in year 2000, and $488,000 in year 2050. For the CC/LCC service area, the costs would be $226,000 in year 2000 and $386,000 in 2050. Cost per acft of municipal water demand reduction would be about $298, since the expenditure would need to be continued annually at the $0.50 per person per year rate.

3.17.2 Plumbing Retrofit

Retrofitting existing plumbing fixtures, such as replacing showerheads with the new low flow types, the addition of faucet aerators, the installation of toilet displacement bags, and the replacement of commodes with new models that use 1.6 gallons per flush can increase the rate of water conservation in comparison to the case in which low flow plumbing fixtures are phased in through new construction and ordinary replacement of fixtures. It is estimated that the maximum potential water conservation from a plumbing retrofit program for the 12-county area that would begin in 1996, with completion by 2010, would be a total of 246,000 acft for the 1996-2050 period (55 years).[6] The average savings per year would be 4,485 acft and are estimated to be 10,390 acft in year 2010, 5,700 acft in 2020, and 1,943 in 2040 (Table 3.17-1; Column 7). Over 90 percent, or 226,750 acft (4,123 acft per year) of these water savings would occur within the Choke Canyon/Lake Corpus Christi Service Area; i.e., 9,583 acft in 2010,

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[5] "Hays County Water and Wastewater Study," Hays County Water Development Board, San Marcos, Texas, May 1989.

[6] The Texas Water Development Board estimates that conservation from the low flow plumbing fixtures would be phased in by 2020. Thus, the retrofit program completed by 2010 would result in an earlier water conservation response, but in effect would have a relatively short life because in time the fixtures would be replaced with the low flow type.

5,415 acft in 2020, and 1,898 acft in 2040 (Table 3.17-2, Column 7). It is emphasized, however, that these are estimates of conservation in addition to that which is expected to occur from the installation of low flow plumbing fixtures in newly constructed dwellings, workplaces, commercial and institutional establishments, and from normal replacement of plumbing fixtures in dwellings, workplaces, commercial and institutional establishments in existence now. Since fixtures of presently existing structures will ultimately be replaced with low flow fixtures, the retrofit program results will decrease in future years, in terms of quantity of water saved per year, because the normal replacement program would have taken place and accomplished the same objective. Thus, in this evaluation, the water savings from a plumbing fixtures retrofit and replacement program are computed as the difference between total municipal water use when low flow plumbing fixtures are phased in by year 2020 and total municipal water use when plumbing fixtures of existing structures are replaced with low flow types during the period 1996 through 2010 (Tables 3.17-1 and 3.17-2, Columns 7).

The installation costs of replacing (retrofit) plumbing fixtures in existing dwellings, commercial establishments, the workplace building and institutions of the 12-county study area with low flow fixtures are estimated at $65.36 million (1995 prices) or about $123.00 per person (Table 3.17-3). At the average rate for the 12-county area, the retrofit cost for the Choke Canyon/Lake Corpus Christi Reservoir System would be about $46.65 million. Average annual water savings for the 12-county area are estimated at 4,485 acft, with average annual water savings for the Choke Canyon/Lake Corpus Christi Reservoir service area of 4,123 acft. Plumbing retrofit costs for the city of Corpus Christi are estimated at $28.39 million, or $110.00 per person (Table 3.17-4). Estimated annual water savings for Corpus Christi are about 75 percent of the savings for the Choke Canyon/Lake Corpus Christi Reservoir service area, or 3,092 acft per year.[7]

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[7] A recent study of conservation potentials in Corpus Christi through the use of retrofit kits consisting of low-flow shower heads, faucet aerators, and toilet tank displacement bags costing approximately $12 per kit, with homeowners performing the installation at no cost, was estimated to reduce per capita water use by about 9 gallons per day in homes where the installations were made. Assuming that 39% of Corpus Christi households would install the fixtures, the city wide savings were estimated at 432 acft per year. The cost of such a program was estimated at $310,757, which results in a cost per acft of water saved of $67. Prouty, Jennifer S., et.al., "Retrofit Study of Summer Water Use in Single-Family Households, Corpus Christi, Texas", Corpus Christi, Texas, March, 1995.

Table 3.17-3
Estimated Costs of Retrofit to Low Flow Plumbing Fixtures in Residential, Commercial Establishments, Workplaces, and Institutions
Corpus Christi Area--Trans-Texas Water Program

Dwellings & Workplace Structures[1]	Number of Units[1]	Cost Per Unit[4]	Total Cost Per Structure	Total Cost 12-County Area ($ million)
(1)	(2)	(3)	(4)	(5)
Housing[1]				
3+ bedrooms/2 bath	103,825			
Commodes/house	2.0	$ 115.00	$ 230.00	
Showers/house	2.0	8.90	17.80	
Faucets/house	4.0	1.40	5.60	
Labor/Adm/Inf/house	1.0	90.00	90.00	
TOTAL	103,825		$ 343.40	$ 35.65 M
2 (and less) Bedrooms & Apartments	104,124			
Commodes/house	1.2	$ 115.00	$ 138.00	
Showers/house	1.0	8.90	8.90	
Faucets/house	3.0	1.40	4.20	
Labor/Adm/Inf/house	1.0	45.00	45.00	
TOTAL	104,124		$ 196.10	$ 20.42 M
Mobile Homes	11,760			
Commodes/house	1.1	$ 115.00	$ 126.00	
Showers/house	1.0	8.90	8.90	
Faucets/house	2.0	1.40	4.20	
Labor/Adm/Inf/house	1.0	45.00	45.00	
TOTAL	11,760		$ 249.60	$ 2.16 M
Motel & Hotel Rooms[2]	8,800			
Commodes/room	1.0	$ 115.00	$ 115.00	
Showers/room	1.0	8.90	8.90	
Faucets/room	1.0	1.40	1.40	
Labor/Adm/Inf/room	1.0	30.00	30.00	
TOTAL	8,800		$ 155.30	$ 1.37 M
Commercial Establishments, Workplaces, & Institutions				
Commodes	30,150	$ 115.00	---	3.47
Urinals	8,300	115.00	---	0.95
Showers	2,000	8.90	---	0.02
Faucets	30,152	1.40	---	0.42
Labor/Adm/Inf.	30,152	30.00	---	0.90
TOTAL	---		---	5.76
TOTAL				$ 65.36 M

Total Population: 530,878 *Installation Cost Per Person: $123.00*

[1] Number of housing units, as reported in the 1990 Census of Housing, Detailed Housing Characteristics, Texas, U.S. Department of Commerce, 1992.
[2] As reported by the Corpus Christi Convention and Visitors Bureau for Corpus Christi (7,000), with estimates for remainder of area made from hotel and motel employment statistics at the rate of one room per 0.86 employees.
[3] Texas Water Development Board estimates of number of plumbing fixtures per employee and student: One toilet per ten employees and students; one urinal per 20 males; one shower per 150 employees and students; and one faucet per toilet. Total employees and students in 1990 were 301,523, Texas Employment Commission, Austin, Texas, 1994.
[4] Costs Per Unit: Showerheads $8.90; Faucet Aerator $1.40; Toilet Displacement Bags $2.75; Low Flush Commodes $105.00; Commode Disposal $10.00. Administration/Labor/Information: Retrofit Program $8.50; Fixture Replacement Program for large homes $90.00 and small homes $45.00.

Table 3.17-4
Estimated Costs to Retrofit to Low Flow Plumbing Fixtures in Residential, Commercial Establishments, Workplaces, and Institutions
The City of Corpus Christi, Texas
Trans-Texas Water Program

Dwellings & Workplace Structures[1]	Number of Units[1]	Cost Per Unit[4]	Total Cost Per Structure	Total Cost 12-County Area ($ million)
(1)	(2)	(3)	(4)	(5)
Housing[1]				
3+ bedrooms/2 bath	45,800			
Commodes/house	2.0	$ 115.00	$ 230.00	
Showers/house	2.0	8.90	17.80	
Faucets/house	4.0	1.40	5.60	
Labor/Adm/Inf/house	1.0	90.00	90.00	
TOTAL	45,800		$ 343.40	$ 15.73 M
2 (and less) Bedrooms (1.2 baths)	16,000			
Commodes/house	1.2	$ 115.00	$ 138.00	
Showers/house	1.0	8.90	8.90	
Faucets/house	3.0	1.40	4.20	
Labor/Adm/Inf/house	1.0	45.00	45.00	
TOTAL	16,000		$ 196.10	$ 3.14 M
Apartments	24,000			
Commodes/apt.	1.1	$ 115.00	$ 126.00	
Showers/apt.	1.0	8.90	8.90	
Faucets/apt.	3.0	1.40	4.20	
Labor/apt.	1.0	45.00	45.00	
TOTAL	24,000		$ 184.10	$ 4.42 M
Mobile Homes (same as Apt's)[1]	3,400	$ 184.10	$ 184.10	$ 0.63 M
Motel & Hotel Rooms[2]	7,000			
Commodes/room	1.0	$ 115.00	$ 115.00	
Showers/room	1.0	8.90	8.90	
Faucets/room	1.0	1.40	1.40	
Labor/Adm/Inf/room	1.0	30.00	30.00	
TOTAL	7,000		$ 155.30	$ 1.08 M
Commercial Establishments, Workplaces, & Institutions[3]				
Commodes	17,440	$ 115.00	---	2.06
Urinals	4,885	115.00	---	0.56
Showers	1,163	8.90	---	0.01
Faucets	17,440	1.40	---	0.24
Labor	17,440	30.00	---	0.52
TOTAL	---		---	3.39
TOTAL				$ 28.39 M

Total Population: 257,453 *Installation Cost Per Person: $110.00*

[1] Number of housing units, as reported in the 1990 Census of Housing, Detailed Housing Characteristics, Texas, U.S. Department of Commerce, 1992.
[2] As reported by the Corpus Christi Convention and Visitors Bureau for Corpus Christi.
[3] Texas Water Development Board estimates of number of plumbing fixtures per employee and student: One toilet per ten employees and students; one urinal per 20 males; one shower per 150 employees and students; and one faucet per toilet. Total employees and students in 1992 were 174,400, Texas Water Development Board, Austin, Texas, June 1994.
[4] Costs Per Unit: Showerheads $8.90; Faucet Aerator $1.40; Toilet Displacement Bags $2.75; Low Flush Commodes $105.00; Commode Disposal $10.00. Administration/Labor/Information: Retrofit Program $8.50; Fixture Replacement Program for large homes $90.00 and small homes $45.00.

3.17.3 Modifying Landscaping of Existing Dwellings to Conserve Water[8]

Landscape irrigation of existing dwellings places increased demands upon municipal water supplies during spring, summer and fall months. For example, in Corpus Christi for the 5-year period of 1986 through 1990, average daily diversions of raw water for municipal use was 204 acft, as shown in Table 3.17-5. During the summer months, average daily use was 234, 243, and 259 acft for the months of June, July, and August, respectively. Average diversions for municipal use in January, February, November, and December were in the 160 to 180 acft per day range (Table 3.17-5 and Figure 3.17-1). Diversions for use in the spring (March, April, and May) and fall (September and October) months were in the 195 to 210 acft per day range (Table 3.17-5 and Figure 3.17-1). On a per capita basis, during the summer peak months, per capita water use is in the 230 gallons per person per day range, while the spring and fall rates are about 190 gallons per person per day, and the rate for winter months is about 160 gallons per person per day. If the summer peak of 230 gallons per person per day could be reduced to the spring and fall level of 190 gallons per person per day--a reduction of 40 gallons per person per day for a period of 90 days--the potential reduction in municipal water demand within the 12-county area would be 5,865 acft per year (population in 1990 of 530,878 x 40 gpd x 90 days divided by 325,851 gallons per acft). The potential reduction in water demand upon the CC/LCC Reservoir System would be 4,190 acft per year (population in 1990 of 379,293 x 40 gpcd x 90 days divided by 325,851 gallons per acft).

In order to accomplish the level of conservation estimated above, it would be necessary to replace much of the existing lawn grasses with more drought tolerant species. It is estimated that it would cost homeowners $0.05 per square foot to replace Saint Augustine grass with Buffalo Grass, and that this change in grass type would reduce summer peak water use by 40 gallons per person per day or about 3,600 gallons per person per year. At this rate, the cost to achieve the summer peak reduction of 40 gallons per person per day, as outlined above, could be as much as $21.6 million (61,800 dwellings at $350 per dwelling = $21.6 million) for the City of Corpus Christi, $72.78 million (207,949 dwellings at $350 per dwelling) for the

[8] Conservation landscaping standards for new development are discussed in Section 3.17.4 which follows.

Table 3.17-5 Monthly Raw Water Diversions for Municipal Use (acft) Corpus Christi, Texas--1986-1990 Corpus Christi Area--Trans-Texas Water Program*							
Month	1986	1987	1988	1989	1990	Average Monthly	Average Daily
January	3956	4160	5307	5457	6834	5143	166
February	3634	3330	4726	5541	5261	4498	161
March	5365	5492	6446	6732	6180	6043	195
April	4790	6323	6797	7226	5383	6103	203
May	4737	5642	6895	8016	6798	6418	207
June	4022	4782	7578	9130	9630	7028	234
July	6584	6150	8140	8308	8515	7539	243
August	6010	6989	8919	9170	9112	8040	259
September	4601	5651	5775	8040	7434	6300	210
October	3821	5289	7103	8253	7229	6339	204
November	3155	4531	6544	6647	6244	5424	180
December	3345	4597	6194	6317	6651	5421	175
TOTAL	54,025	62,941	80,430	88,844	85,277	---	---
Average	4,502	5,245	6,702	7,403	7,106	6,191	204

* Raw water diverted for municipal purposes, as reported to the Texas Natural Resource Conservation Commission (TNRCC).

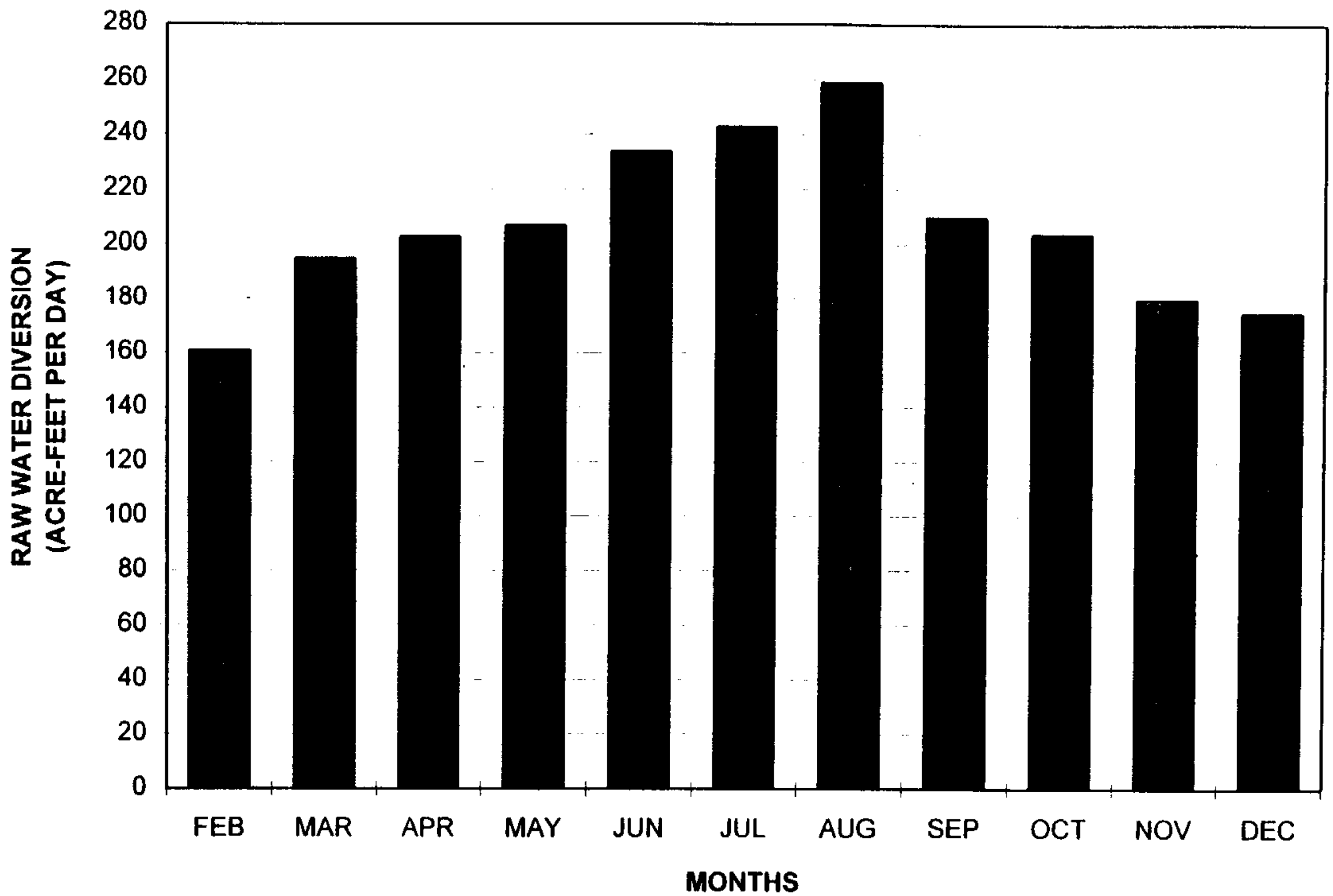
12-county study area and $51.67 million for the CC/LCC Service area.[9] Note: If a landscape modification policy is adopted to reduce peak summer demands, a rate structure such as is described in Section 3.17.7 may not be applicable.

3.17.4 Conservation Landscaping Standards for New Development

The adoption of conservation landscaping standards for new housing and commercial development has a potential to reduce peak summer demands. In Southern California, drought tolerant lawn grasses, such as Buffalo Grass, and Xeriscape techniques have been shown to reduce lawn irrigation water demands by 30 percent in comparison to requirements for well maintained St. Augustine landscapes.[10] However, data on water savings in the study area from landscaping standards for new development have not been reported. Thus, estimates of the

[9] See Tables 3.17-3 and 4 for number of dwellings.

[10] "Xeriscaping Promises, and Pitfalls", Water Conservation division, Austin, Texas, 1994.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM/
CORPUS CHRISTI SERVICE AREA

AVERAGE DAILY MUNICIPAL RAW WATER DIVERSION BY MONTH CORPUS CHRISTI, TEXAS

FIGURE 3.17-1

potential water conservation from such standards will have to be based upon experience from other areas.[11]

Data for Corpus Christi and its municipal customers show that water use in the spring, summer, and fall months is higher than in the winter months, and that the difference (11,860 acft/yr) accounted for about 16 percent of total annual municipal water use during the 1986-1990 period (calculated from data in Table 3.17-5). About 6,850 acft of this difference occurred during the peak lawn irrigation season of June, July, and August. Thus, one might conclude that the potential water conservation from "landscape standards" that reduces landscape irrigation demands might be on the order of 10 to 15 percent of the projected new municipal water demands that are associated with population growth, since net growth would be expected to reside in new houses with new lawns. For the 12-county study area this would be between 1,656 and 2,484 acft in year 2000; between 3,546 and 5,319 acft in 2020; and between 7,058 and 10,587 acft in 2050. For the CC/LCC service area, the estimates are between 1,464 and 2,196 acft in 2000; between 3,222 and 4,833 acft in 2020; and between 6,458 and 9,687 acft in 2050 (calculated from projections shown in Table 3.17-1: Column 4; and Table 3.17-2: Column 4 for water use due to population increase after 1990). However, the costs of such a program cannot be estimated at this time since cities would have to develop standards and conduct public demonstrations and information campaigns in order to achieve adequate public acceptance to obtain the level of conservation estimated above.

3.17.5 Water Audit Program for Large Landscaped Areas

For sites of one acre and larger, an irrigation audit and irrigation efficiency evaluation would need to be conducted in order to determine the water conservation potentials for each site. As in the case of "landscaping standards for new development" as described in Section 3.17.4, data specific to the study are not available, but such water audits and the development and use of efficient irrigation plans have reduced irrigation water use for such types of areas in other locations by 20 to 40 percent.[12] This type of audit results in information useful to improved

[11] It is recommended that experiments be undertaken in the study area to measure the lawn water requirements of various landscape types suitable for new development in the area.

[12] "Report for Water Conservation Plan", City of Austin, Austin, Texas, 1993.

equipment performance, the application of only those quantities of water needed at each site and the development of irrigation schedules to fit weather conditions. Usually, there is little, if any, additional cost for equipment, and reduced water bills provide an incentive to participate.

Most large areas to which this conservation method would apply are city parks and open spaces, school grounds, and college campuses. Water sales data for Corpus Christi show that about 11 percent of total municipal water use during the 1986-1990 period was at institutions and for government functions. However, these data do not indicate the proportion that was used for each purpose, such as toilet flushing, fire fighting, public swimming pools, and irrigation. If 20 percent is for irrigation and the conservation rate is 20 percent, then the maximum potential water conservation from water audits and efficient irrigation systems for large landscape areas could be about 819 acft per year for the study area in 2050 (186,054 x 0.11 x 0.20 x 0.20), of which 675 acft (153,498 x 0.11 x 0.20 x 0.20) would be in the CC/LCC service area (computations from projections data of Tables 3.17-1 and 3.17-2). Based on experience in other areas, the annual costs of water audits and the development of efficient irrigation plans and procedures for such areas are estimated at $1,600 per audit. It is estimated that the 12-county area would need 800 audits and plans for a total cost of $1.28 million. For the CC/LCC service area, 570 audits and plans would be needed, which at $1,600 per audit would result in a total cost of $0.91 million. The life expectancy of audits and plans is about 20 years.

3.17.6 Leak Detection and Repair

One way to reduce the quantity of raw water needed to meet municipal water demands is to find and repair leaks in the treated water distribution system. However, in the South Central Trans-Texas study area, there may not be significant potential opportunity for additional municipal water conservation via this method. For example, through its existing leak detection and repair efforts, the City of Corpus Christi has reduced unaccounted for water between the water treatment plant and the retail meters from 19 percent in 1990 to only 11 percent in 1993. Thus, the potential for additional water conservation within Corpus Christi through leak detection and repair appears limited. (Note: A loss rate of less than about 12 percent is difficult to maintain.) Therefore, estimates of additional reduction in municipal water demand through leak detection and repair cannot be made at this time.

3.17.7 Water Conservation Rate Structures

The demand for water for municipal use is influenced by a number of factors, including the price of water, income levels of consumers, and the weather. In the study area, the City of Corpus Christi, the largest water supplier, has adopted increasing block rates for inside city residential customers and constant but significantly higher rate structures applicable to residential customers located outside the city. However, a declining block rate structure is used for commercial customers. For example, Corpus Christi's rates have a minimum charge for the first 2,000 gallons per month for both residential and commercial customers, with the minimum for residential customers located inside the city presently set at $4.52 per month and the minimum for commercial customers located inside the city set at $6.31 per month (Table 3.17-6). The minimums for 2,000 gallons for customers located outside the city are double those inside the city (Table 3.17-6). For residential customers located outside the city, the rate for quantities above 2,000 gallons per month is a constant $3.168 per 1,000 gallons, while the rates for residential customers located inside the city increases from $1.643 per 1,000 gallons for quantities between 2,000 and 6,000 gallons per month; $1.762 per 1,000 gallons for quantities between 6,000 and 15,000 gallons per month; $2.215 per 1,000 gallons for quantities between 15,000 and 30,000 gallons per month; $2.655 per 1,000 gallons for quantities between 30,000 and 50,000 per month; and $3.168 per 1,000 gallons for quantities above 50,000 gallons per month. A residential customer inside the city uses an average of 9,000 gallons of water per month[13] at her/his residence, with a monthly water bill of $16.37. Average water use per month[14] by commercial customers is 70,000 gallons, with a monthly water bill of $109.47.

Given that consumers ordinarily will purchase less of a good or service if the price is increased, an increase in water rates would be expected to result in a reduction in the quantity of water used. However, a 1991 TWDB study showed that the demand for water in the Corpus

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[13] "Water Utility Cost-of-Service Rate Study", City of Corpus Christi, Corpus Christi, Texas, August 1990.

[14] Ibid.

Table 3.17-6
Municipal and Commercial Water Rate Structure
Corpus Christi, Texas
Corpus Christi Area--Trans-Texas Water Program*

Blocks	Rate Per 1,000 Gallons: Inside City	Rate Per 1,000 Gallons: Outside City
Residential		
First 2,000 gallons	Included in Minimum	Included in Minimum
Next 4,000 gallons	1.643	3.168
Next 9,000 gallons	1.762	3.168
Next 15,000 gallons	2.215	3.168
Next 20,000 gallons	2.655	3.168
Over 50,000 gallons	3.168	3.168
Commercial		
First 2,000 gallons	Included in Minimum	Included in Minimum
Next 13,000 gallons	1.643	3.287
Next 85,000 gallons	1.488	2.977
Next 900,000 gallons	1.190	2.369
Next 9,000,000 gallons	0.987	1.045
Over 10,000,000 gallons	0.737	0.964
	Minimum Monthly Bill	
Size of Meter		
5/8 and 3/4 (residential)	$ 4.525	$ 9.051
5/8 and 3/4 (commercial)	6.312	12.636
1.0 inch	9.778	19.544
1.5 inch	16.090	32.180
2.0 inch	24.760	49.509
3.0 inch	87.562	175.115
4.0 inch	99.829	199.660
6.0 inch	149.746	299.504
8.0 inch and larger	224.672	449.357

Source: Corpus Christi, Texas, 1995.
* Commercial includes business, workplace, and institutional establishments.

Christi Metropolitan Statistical area is quite inelastic; i.e., the price elasticity of demand coefficient was -0.07, which means that at present water rates, a 1 percent increase would result in a 0.07 percent (seven one-hundredths percent) reduction in water use.[15] Thus, across the board water rate increases in the study area would have to be extremely high in order to result in significant reductions in water use. For example, according to the price elasticity of demand estimate, a 20 percent water rate increase would only reduce municipal water demand by 1.4 percent in the Corpus Christi area, and a 100 percent water rate increase would reduce municipal water demand by 7 percent. (Note: Corpus Christi has a 6 percent per year rate cap.) However, a rate structure for the CC/LCC System customers that raises rates in the upper quantity categories (14,000 gallons per month and above) would be expected to reduce the peak summer demands for lawn watering, and thereby reduce overall per capita demands for the area. The quantity of reduction would depend upon the level of the rate increase, and although no estimates of price elasticity of demand for lawn irrigation water are available, the demand for such water is obviously much more elastic than is demand for inside water; i.e., a doubling of water rates for quantities above the average residential use rate of 9,000 gallons per month might reduce monthly water use during the summer months by 10 percent. Such a result would be on the order of 30 gallons per person per day for Corpus Christi during the three summer months, which would lower the summer peak demands to a level that is only 10 percent higher than the spring and fall demands, and would amount to about 5,092 acft per year in 2000, and 8,086 acft per year in 2050 for the 12-county area. For the CC/LCC Service area, the water savings would be 3,750 acft in 2000 and 6,400 acft in 2050. Note: If a rate structure policy is chosen to lower peak summer demand, then landscape modification described in Section 3.17.3 would not be applicable.

3.17.8 Estimated Water Conservation Potentials and Costs of Accelerated Municipal Water Conservation

The results of the calculations presented in Sections 3.17.1 through 3.17.6 are summarized below for the 12-county study area and the CC/LCC service area. The estimated

[15] "Understanding Trends in Texas Per Capita Water Consumption", Holloway, M.L., and Bob S. Ball, Southwest Econometrics, Austin, Texas, 1991.

potential average annual reduction in municipal water demand for the period 1996 through 2050 for the 12-county study area through plumbing retrofit is 4,485 acft at a cost of $1,365 per acft (Table 3.17-7). For the CC/LCC service area, the estimated reduction in demand is 4,123 acft/yr at a cost of $1,060 per acft (Table 3.17-7).

The estimated potentials from landscape modification that replace present varieties of lawn grasses of existing lawns with more drought tolerant species are 5,865 acft/yr for the 12-county area, with 4,190 of this being in the CC/LCC service area at a cost of $1,162/acft and $1,156/acft, respectively (Table 3.17-7).

A conservation rate structure with double the rates now charged residential customers by Corpus Christi for blocks above 14,000 gallons per month is estimated to reduce peak summer demands and thereby reduce annual water use in the CC/LCC service area by about 6,400 acft per year (Table 3.17-7). Landscape standards for new development are estimated to have the potential to reduce annual water use in the CC/LCC service area in 2050 by about 9,700 acft per year, however, it's not possible to estimate the costs of such a program, although with appropriate ordinances, the cost to the city could be zero, with any costs being placed upon new homes.

A program of water audits and irrigation planning for large landscaped areas (one acre in size or more) is estimated to reduce annual water demand in the CC/LCC service area by about 675 acft per year at a cost of approximately $130 per acft (Table 3.17-7).

The analyses and estimates presented above indicate that plumbing retrofit would result in a relatively high cost per acft of municipal water demand reduction--more than $1,000 per acft--with relatively low quantities (less than 5,000 acft/yr). Landscape modification, landscape standards for new development, water audits and irrigation planning for large areas, and conservation rates to lower peak summer demands appear to be the most promising water conservation methods, with potential reductions in municipal water demands in the 675 to 9,700 acft/yr range by 2050 at cost per acft of $130 for the lower quantity and $1,160 for landscape modifications (Table 3.17-7).

Table 3.17-7
Estimated Water Conservation Potentials and Cost of Accelerated Municipal Water Conservation
Corpus Christi Study Area--Trans Texas Water Program

Conservation Method	12-County Study Area			Choke Canyon/Lake Corpus Christi Service Area		
	Total Cost ($ million)	Demand Reduction (acft/yr)[1]	Cost (per acft)	Total Cost ($ million)	Demand Reduction (acft/yr)[1]	Cost (per acft)
Public Information	---	1,640	$ 298	---	1,298	$ 298
Plumbing Retrofit[2]	$ 65.36	4,485	$ 1,365	$ 46.65	4,123	$ 1,060
Partial Plumbing Retrofit	$ 0.64	890	$ 67	$ 0.46	636	$ 67
Modifying Existing Landscaping	$ 72.78	5,865	$ 1,162	$ 51.67	4,190	$ 1,156
Landscaping Standards for New Development	N/A*	10,587	N/A*	N/A*	9,687	≤ 100 N/A*
Water Audit Large Landscape Areas	1.28	819	150	0.91	675	130
Leak Detection & Repair[3]	---	---	---	---	---	---
Conservation Rates[4]	---	8,086	---	---	6,640	---

* Not applicable.
[1] Demand reduction in year 2050.
[2] Average annual demand reduction for the period 1996 through 2050.
[3] No estimates are made, since loss/unaccounted for water for Corpus Christi has been reduced to 11 percent.
[4] Demand reduction not achievable if other conservation methods are adopted.

3.17.9 Environmental Analyses

Some of the water conservation programs outlined reduce the volume of wastewater that must be treated and discharged and could reduce return flows, including nutrients to the bays and estuaries. Other programs could result in changes to urban landscapes. The latter would be in the form of vegetation changes that might result in slight increases to local area temperatures, and could result in aesthetic changes due to less luscious appearing landscapes. Neither of these effects would be expected to have a significant detrimental effect upon the local environment. An indirect environmental effect from accelerated municipal water conservation could be to slightly delay the timing of construction of new water supply projects. Such action could delay the environmental changes emanating from new water supply projects.

3.17.10 Implementation Issues

Major issues involving accelerated municipal water conservation include public acceptance and willingness to:

1.) Replace plumbing fixtures in their homes, workplaces, and institutions;
2.) Change landscaping at homes and public places, including recreational areas;
3.) Accept a conservation oriented water rate structure; and
4.) Become more conscious of and directly involved with management of personal water using functions.

The replacement of plumbing fixtures would be a temporary inconvenience, the most significant of which would be the removal and replacement of commodes within homes. Water conservation landscaping would result in views of different types of grasses and plants, and during the dry times more brown and less green lawns and public places.

A conservation oriented rate structure could mean higher costs for the same or lower quantities of water; i.e., the purpose of such rates is to reduce the quantity of water use through the pricing mechanism.

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3.18 Groundwater Recharge and Recovery (Carrizo/Wilcox Aquifer) (L-7)

3.18.1 Description of Alternative

Groundwater recharge and recovery, hereafter referred to as "GRR", is an emerging technology for utilizing aquifers to store surface water for later use. Typically, surface water would be diverted during average and wet periods, treated to drinking standards, injected into an aquifer using dual-purpose wells, stored until needed during drought, and then recovered by pumping from wells. GRR increases the firm yield available from a surface water source by providing a large facility to store water during periods of average and above average runoff with very little evaporation loss. However, losses occur due to discharge by the formation to overlying streams as well as adjacent formations. Potential loss of artificially recharged water to other wells in the area is also possible. Offsetting these losses is the ability to withdraw more water than artificially recharged by pumping aquifer water which originates from natural recharge during the recovery period. Relatively few GRR projects are in existence and the feasibility of a project must be examined with detailed site-specific studies. Permitting and regulatory requirements in Texas are still very uncertain and can only be determined on a project-specific basis after considerable evaluation.

Only one GRR project is known to exist in the State and was constructed by the Upper Guadalupe River Authority (UGRA) in association with the City of Kerrville. The project diverts water from the Guadalupe River and recharges the Trinity Aquifer through two injection wells at a maximum rate of about 1.6 mgd (1,775 acft/yr). The Trinity Aquifer at Kerrville is confined and consists of fine-grained sand interbedded with shale and limestone. The withdrawal rate through the two wells is 2.7 mgd (3,000 acft/yr). Although the project has a surface water diversion permit from TNRCC and is constructed and functional, it has not been put into operation because of continuing legal challenges by local interest groups.

This section provides an overview of the hydrology, cost, and environmental issues associated with a potential GRR project in the South Central Study Area. The project chosen for study would divert surface water from Choke Canyon Reservoir for storage in the recharge zone of the Carrizo-Wilcox Aquifer. During drought conditions, the stored water would be recovered and discharged back into Choke Canyon Reservoir for downstream use in the Corpus Christi area.

The Carrizo-Wilcox aquifer is one of the most extensive aquifers in Texas, furnishing water to an area from the Rio Grande to the northeast corner of the state. The aquifer provides large quantities of ground water to counties overlying the aquifer, including Atascosa, Wilson, Medina, Frio and others in the south central part of the state. LBG-Guyton Associates state in a report prepared for HDR[1], that the possibilities are good for artificially recharging the Carrizo-Wilcox formation and they identified Atascosa, Wilson, and southern Bexar counties as favorable for GRR. In these areas, the Carrizo-Wilcox Aquifer is unconfined and consists of coarse to fine grained sand and sandstone interbedded with silt, clay, and lignite.

In 1991, CH2M-Hill and Lee Wilson & Associates[2] studied potential sites for conventional recharge projects using large spreading basins. In general, sites were evaluated for several factors, including: (a) amounts of continuous clay layers above the water table; (b) hydraulic conductivity and thickness of the saturated interval; (c) water quality; (d) land availability, access, costs, zoning and environmental issues; and, (e) location of the area relative to sources of water and users. The study identified four areas as candidates for recharge sites with the closest one to Choke Canyon Reservoir being in northern Atascosa County near the town of Rossville as shown on Figure 3.18-1. CH2M Hill determined from reconnaissance-level studies that the Rossville site is favorable for recharge both with spreading basins and injection wells and a pilot project with spreading basins was performed. The Rossville site covers 36 square miles of the Carrizo outcrop and CH2M Hill estimated that about 2,400 acft/month (28,800 acft/yr) could be recharged.

Potential regulatory issues that could be required of GRR projects include obtaining a diversion permit at the surface water source, pipeline permit, treatment requirements for water to be recharged, ownership of recharged water, discharge permit for water returned to the surface water source, and requirements of local jurisdictions. For the potential use of the Carrizo-Wilcox Aquifer in Atascosa County, the Evergreen Underground Water Conservation District of Atascosa, which is a special legislative district, has jurisdiction to regulate new wells,

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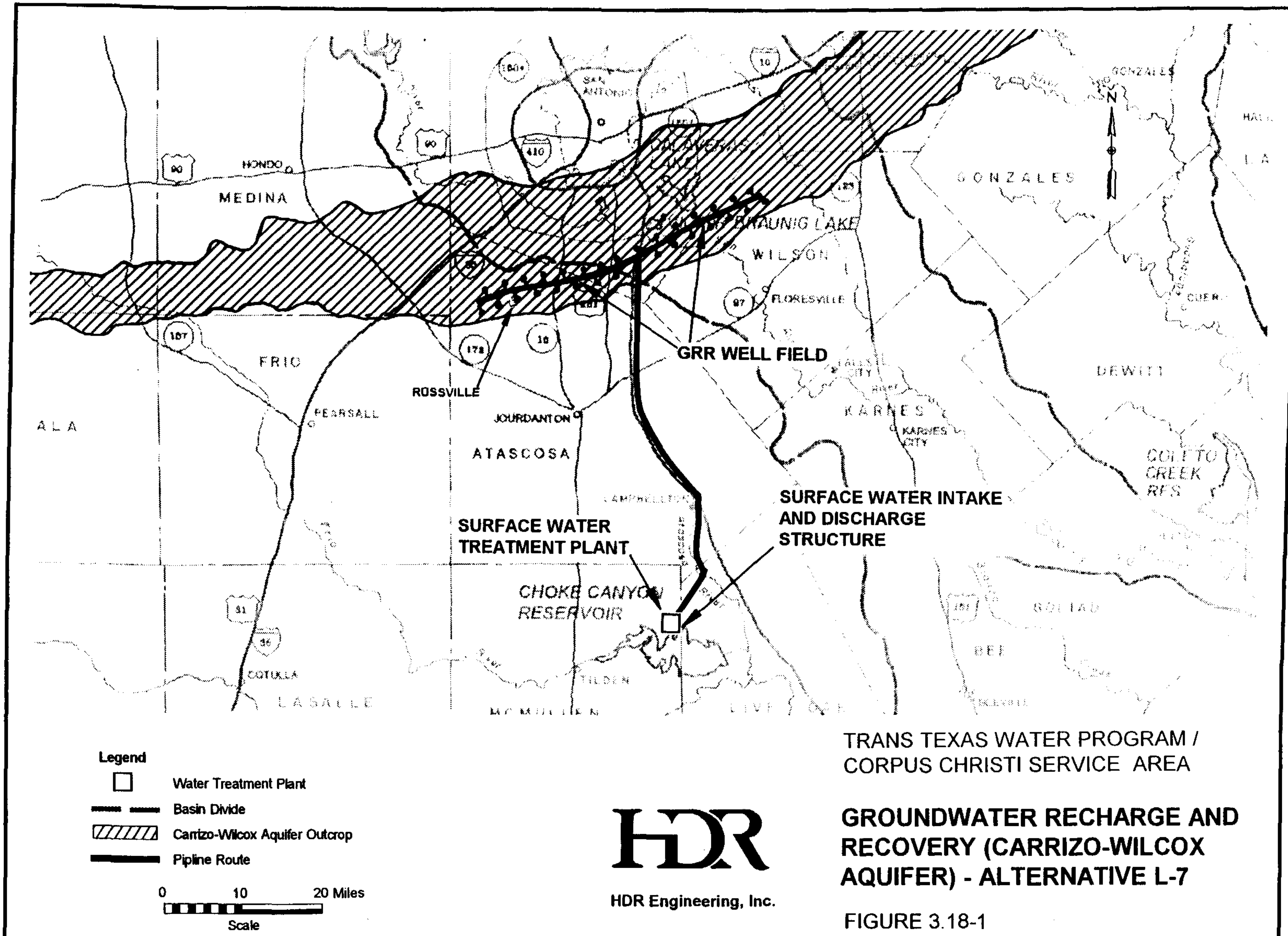
[1] LBG-Guyton Associates, "Phase I Evaluation, Carrizo-Wilcox Aquifer, West-Central Study Area, Trans-Texas Water Program", January 1994.

[2] CH2M Hill and Lee Wilson Associates, "Carrizo Recharge Study", Alamo Water Reuse and Conservation District, 1991.



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TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

GROUNDWATER RECHARGE AND RECOVERY (CARRIZO-WILCOX AQUIFER) - ALTERNATIVE L-7

FIGURE 3.18-1

well spacing, and transfer of Carrizo water out of the District.

The facilities necessary for implementation of this alternative include a surface water intake and pump station at Choke Canyon Reservoir, water treatment plant, water transmission pipeline to the GRR facility, pipeline distribution and collection system at the well field, dual-purpose injection and recovery wells, small storage facility and pump station at the well field, and a discharge structure into Choke Canyon Reservoir.

3.18.2 Available Yield

To compute the firm yield of the CC/LCC System with GRR, the Lower Nueces Basin simulation model developed by HDR was modified to operate a GRR system between Choke Canyon Reservoir (CCR) and the Carrizo/Wilcox Aquifer (CWA). The updated model continued to simulate and operate the existing lake system under present operating policies, namely the City of Corpus Christi's Phase II operation policy and the TNRCC March 9, 1992 Release Order.

The GRR operation in the updated model involved the tracking and accounting of water from CCR to CWA during average to wet conditions in the region and pumpage from CWA back to CCR during times of drought. The decision on whether to pump to the aquifer or from the aquifer was based on two trigger levels in CCR. The first trigger was the elevation in CCR above which water is pumped from CCR to the CWA for recharge. The second trigger was the elevation in CCR below which water stored in the aquifer is pumped back to the lake. When the lake level was between the two trigger elevations no water is pumped and the pipeline and well fields are idle. Additional model input parameters for the GRR option included the maximum annual quantity of water that can be pumped from CCR to CWA and the maximum monthly rate water can be pumped.

During simulation, the model tracked the cumulative storage in the aquifer due to GRR recharge or withdrawal. In a sense, a bank account of water in aquifer storage was set up in which only the quantity deposited in the bank account by CCR during wet times can be withdrawn by CCR during drought. The maximum deposit into this bank account can be no more than the maximum monthly pump rate. Likewise, the annual sum of the monthly deposits into the aquifer bank can be no more than the diversion from CCR in any one year.

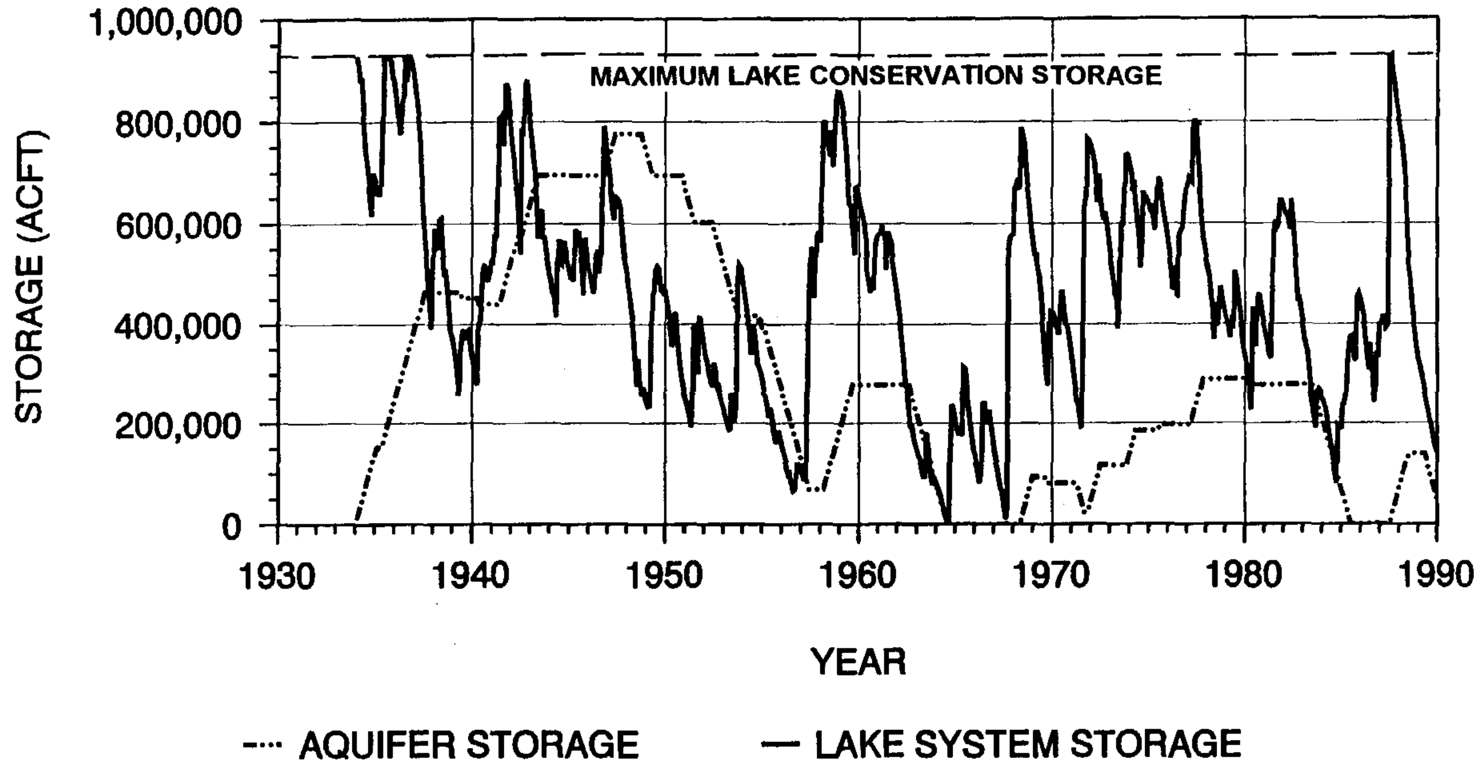
A series of model runs were used to optimize the selection of the two trigger levels. The maximum annual diversion from CCR was assumed to be equal to the diversion volume in Choke Canyon's water rights permit. This permitted volume is 139,000 acft/yr. The maximum monthly pump rate was assumed to be one-twelfth of the annual diversion, or 11,583 acft/month. Various combinations of trigger elevations were evaluated which resulted in a range of yield increases in the CC/LCC System. Preliminary estimates of the optimum trigger levels were found to be 210.0 feet-msl for the upper trigger and 190.0 feet-msl for the lower trigger. This GRR operation plan, in conjunction with the reservoir system Phase II Operation Plan and the 1992 TNRCC Interim Order, resulted in a firm yield increase of approximately 39,000 acft/yr under 1990 sediment conditions in the lakes. This was an increase of approximately 23 percent in the Phase 2, 1990, firm yield of the CC/LCC System alone. The increase in firm yield was 40,300 acft/yr, or 26 percent under 2050 sediment conditions. The firm yield computations are summarized in Table 3.18-1.

Table 3.18-1
Summary of System Firm Yields with and without Groundwater Recharge and Recovery

Reservoir Sedimentation Year	Firm Yield Without GRR (acft/yr)	Firm Yield With GRR (acft/yr)	Increase in Firm Yield Due to GRR (acft/yr)
1990	168,500	207,800	39,300
2050	153,100	193,400	40,300

Using Phase 2 Operating Policy and TNRCC March 9, 1992 Release Order.

The simulation period of record was from 1934 to 1989. Figure 3.18-2 provides a time series trace of lake system storage for the 56 year period, as well as the enhanced aquifer storage due to diversions from CCR. Figure 3.18-2 also indicates that the maximum cumulative amount stored in the aquifer during the 56 year period was 776,000 acft between 1934 and 1948.



NOTES:

1. PHASE 2 RESERVOIR OPERATING POLICY.
2. 1990 SEDIMENT CONDITIONS
3. 139,000 ACFT/YR MAXIMUM WITHDRAWAL FROM CHOKE CANYON RESERVOIR.

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

GROUNDWATER RECHARGE AND RECOVERY STORAGE TRACES ALTERNATIVE L-7

FIGURE 3.18-2

In their study of the Carrizo, CH2M Hill[3] estimated that about 10 percent of the recharged amount could be lost to discharge into surface drainages (about 78,000 acft of water would be lost for this project), and about 2 percent could be lost to adjacent formations. However, for purposes of this reconnaissance level analysis, it was assumed that the above losses could be made up from water stored from natural recharge to the aquifer.

As shown in Figure 3.18-3, the additional firm yield produced under this option slightly increases the monthly median estuary flows in each month due primarily to the increased return flows to the estuary. However, the GRR option reduces spills from Choke Canyon Reservoir and therefore, reduces flows below CCR during major flood events. The existing required minimum release of 2,000 acre-feet per month from CCR would be continued. Figure 3.18-4 shows that the median monthly salinity in upper Nueces Bay slightly decreases in eleven out of twelve months under the GRR operation and is essentially unchanged in June.

3.18.3 Environmental Issues

Introduction

The Carrizo aquifer encompasses several adjacent formations of hydrologically connected cross-bedded sands interspersed with clay, sandstone, silt, lignites (Wilcox Group) and overlying massive sands of the Carrizo formation. The formations outcrop in a southwest-northeast trending crescent near the inland margin of the Gulf Coastal Plain (see section 3.0.2), and dip downward toward the coast. Aquifer recharge occurs over the general surface of the outcrop area.[4] The thickness of the Carrizo in the downdip artesian areas varies from 400 feet in Gonzales and Caldwell counties to more than 1000 feet in Atascosa county. The maximum thickness of the Carrizo aquifer in this area is about 2500 feet.

The proposed well field extends from Atascosa County northeast through Bexar County to Wilson County. The proposed water pipeline crosses Bexar, Atascosa, Live Oak, and McMullen Counties to Choke Canyon Reservoir. The study area lies within the South Texas

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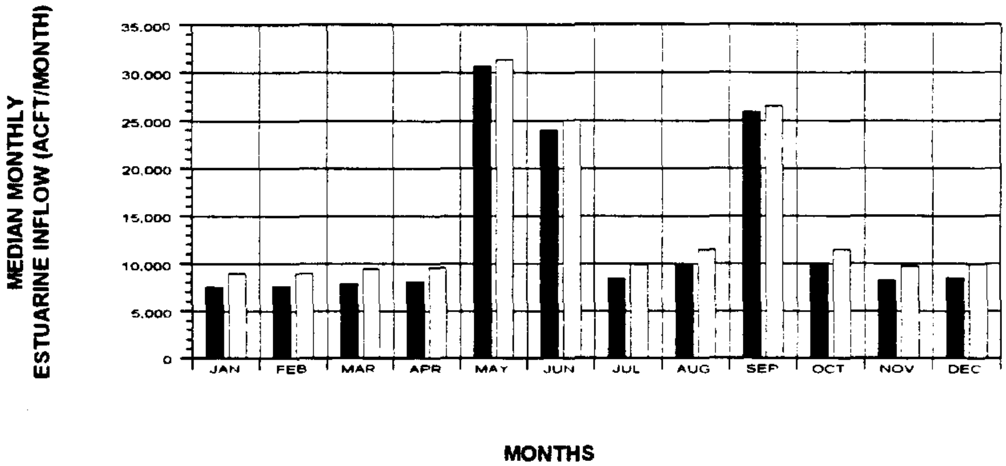
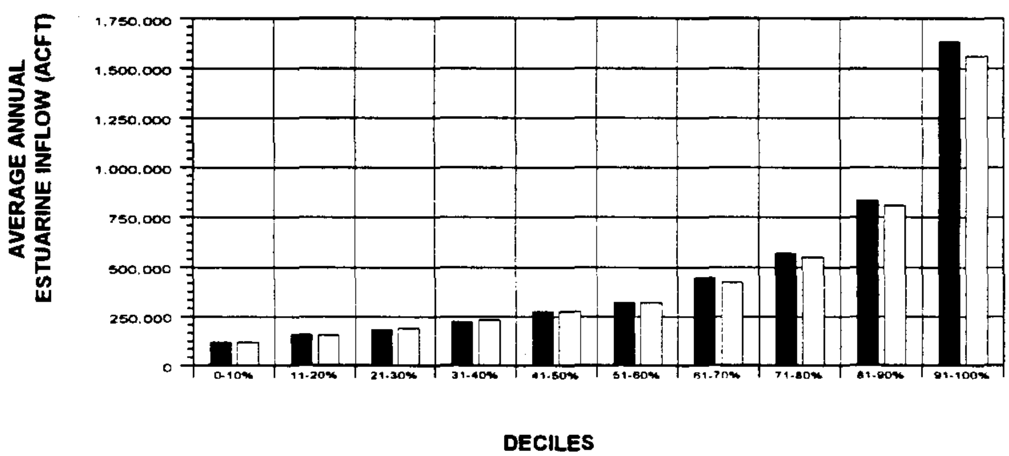
[3] CH2M Hill and Lee Wilson Associates, "Carrizo Recharge Study", Alamo Water Reuse and Conservation District, 1991.

[4] LBJ-Guyton Associates. January 1994. Phase I Evaluation Carrizo-Wilcox Aquifer. Prepared for HDR. Austin, Texas.





WITHOUT PROJECT   WITH PROJECT

NOTES:

1. PHASE 2 RESERVOIR OPERATING POLICY.
2. 1990 SEDIMENT CONDITIONS
3. 139,000 ACFT/YR MAXIMUM WITHDRAWL FROM CHOKE CANYON RESERVOIR.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

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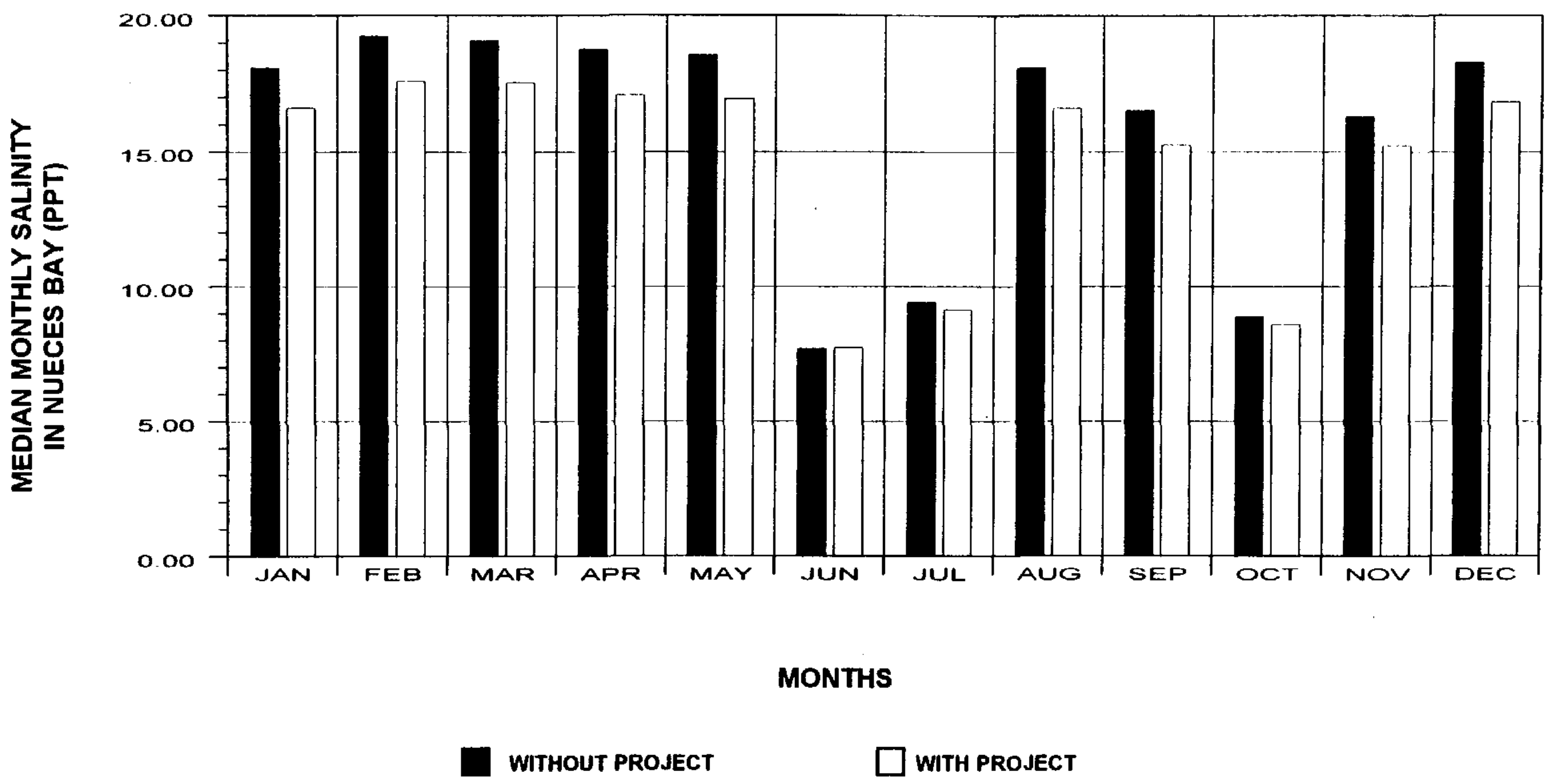
CHANGES IN NUECES ESTUARY INFLOWS ALTERNATIVE L-7

FIGURE 3.18-3



NOTES:

1. PHASE 2 RESERVOIR OPERATING POLICY.
2. 1990 SEDIMENT CONDITIONS
3. 139,000 ACFT/YR MAXIMUM WITHDRAWL FROM CHOKE CANYON RESERVOIR.

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TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

CHANGES IN UPPER NUECES BAY SALINITY ALTERNATIVE LN-7

FIGURE 3.18-4

Plains vegetation region (Section 3.0.2).[5] The South Texas Plains is dissected by streams flowing into the Rio Grande and Gulf of Mexico. Soils range from clays to sandy loams, and vary in reaction from very basic to slightly acid. A wide range of soil types is responsible for great differences in soil drainage and moisture holding capacities in this region.[6],[7] Wetlands in the project area consist of riverine habitats of Cibolo Creek, the San Antonio River and their tributaries, as well as associated palustrine habitats generally composed of narrow bands of wetlands along the watercourses.

Vertebrate fauna typifying these regions include the opossum, raccoon, weasel skunk, white-tailed deer, and bobcat. The coyote and javelina are found mainly in brush/shrub areas and the red and gray fox in woodlands[8] A wide variety of species of amphibians, reptiles and birds are also found throughout the region.[9]

Installing the proposed 220 miles of pipeline would require a construction ROW of 3,736 acres and a mowed ROW of 1,067 acres for the life of the project. Wells, water treatment plants and other facilities would impact an additional 123 acres.

The potential environmental effects resulting from the construction and operation of water transport pipelines (or well pads) depends to a large extent on the exact placement of the construction corridor. In general, sensitive habitats, or habitats critical to the survival of protected species are rare or of restricted distribution so that adverse impacts can often be avoided or minimized. More generally distributed habitats, perhaps important to regional wildlife populations in some areas, may not be so easy to avoid, but the small area affected by these corridors would not have significant impacts.

Plant and animal species listed by the USFWS and TPWD as endangered or threatened

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[5] Correll, D.S. and M. C Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

[6] Blair, W.F. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1): pp.93-117.

[7] McMahan, C.A. et al. 1984. The Vegetation Types of Texas. TPWD Austin, Texas.

[8] Jones, K.J., et al., May 1988. "Annotated Checlist of Recent Land Mammals of Texas," Occasional Papers, The Museum, Texas Tech University No. 119.

[9] Dixon, James R., 1987. Amphibians and Reptiles of Texas, Texas A&M University Press, College Station, Texas.

in the project area, and those with candidate status for listing are presented in Appendix C, Tables 2, 4, 14, 15, and 21. Surveys for protected species or other biological resources of restricted distribution, or other importance, would be conducted within the proposed construction corrridors where preliminary studies have indicated that habitat may be present.

The primary impacts that would result from construction and operation of this alternative include temporary disturbance to soils and habitat during construction of wells, pipelines and other facilities, as well as permanent conversion of existing habitats or land uses to maintained pipeline ROW; disturbance of minor acreages for construction of water treatment plants, storage reservoirs and well injection fields; and mixing of treated surface water with waters of the Carrizo Aquifer. If this alternative is pursued, water quality impacts on the Carrizo Aquifer from treated surface water will be studied in a later phase of Tran-Texas. Indirect effects of construction may include mitigation areas converted to alternate uses to compensate for losses of terrestrial habitat.

Because there are no known metazoan inhabitants present, recharging and withdrawing water from the Carrizo aquifer would not be expected to impact an endemic fauna. Northeast of Atascosa County, the Carrizo aquifer is full and discharges water to streams and rivers that cross the outcrop (Figure 3.18-1). Because this alternative involves both recharging and withdrawing water from the aquifer there would be no effects resulting from a permanent drawing down of the aquifer.

The effects of Groundwater Recharge and Recovery on Choke Canyon Reservoir have been modeled and the results are presented in Figure 3.18-2. Withdrawing water from the reservoir during normal to wet periods and pumping water into the reservoir during drier periods, would attenuate fluctuation in Choke Canyon Reservoir levels. Initial changes in average lake level with implementation of the project could alter the distribution and abundance of rooted aquatic vegetation and consequently alter the distribution of fish using these habitats. Because fluctuating lake levels can adversely affect nesting success in Centrarchid game fish, the tendancy of this alternative (L-7) to reduce fluctuations in lake levels would favor the nesting success of centrarchid game fish.

Construction in brush/shrub habitat and maintenance activities would potentially impact populations of the Texas Tortoise and Texas Horned Lizard. Since over half of the proposed well field corridor consists of cropland, wildlife habitats tend to be small and fragmented, and may be disproportionately valuable to regional wildlife populations. Construction impact can be minimized or avoided, however, by locating project features in less sensitive cropland, pasture or upland woodland whenever possible. Construction across rivers and streams should be avoided, if possible, as riparian zones support wetlands and are valuable to wildlife. However, riparian zones are relatively resilient and impact can be minimized by crossing streams at right angles. Mitigation may be required for impacts associated with the pump stations, injection wells, recharge structures, water treatment plants, and pipelines if sensitive ecological or cultural resources are identified in a future phase of this study.

All areas to be disturbed during construction will be first surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

3.18.4 Water Quality and Treatability

Water from Choke Canyon Reservoir is of good quality, exhibiting high quality aquatic habitat[10] and is designated for contact recreation and public water supply. Elevated chloride levels exist (> 250 mg/l) in the headwater region of the reservoir, and this problem is increased during low flow periods. Source water for recharge of the Carrizo aquifer would be withdrawn from the main body of the reservoir and treated to drinking water standards in a conventional water treatment plant. Treatment of the Choke Canyon water is primarily necessary to remove suspended solids and provide disinfection to prevent the buildup of solids or the formation of algae in the recharge wells that could plug the aquifer.

The Carrizo-Wilcox aquifer generally yields water that meets the National Primary Drinking Water Regulations standards required for public health. However, secondary standards for iron may be exceeded by water produced in certain areas and hydrogen sulfide or methane gas may be found in localized areas. Because of the high quality treated water used for artificial recharge and the high quality of the indigenous water, water recovered from the aquifer is also expected to be of high quality. Compatibility studies will be required to determine if precipitates occur that may plug the recharge system when water from the two sources is combined.

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[10] Texas Water Commission, "The State of Texas Water Quality Inventory, 11th Edition", August, 1992.

3.18.5 Engineering and Cost Analysis

Pumping, transmission, and recharge facilities have been sized and costed for a recharge and withdrawal rate of 11,583 acft/month or 139,000 acft/yr. CH2M Hill estimated that the Rossville site could recharge about 28,800 acft/yr over 36 square miles, or about 800 acft/yr per square mile. Using this recharge rate to develop the required size of a GRR field to recharge 139,000 acft/yr, results in a 174 square mile recharge field. Assuming that each injection well has an effective radius of one to two miles and that three rows of wells would be installed in the outcrop, an estimated width of the well field would be about four miles. A possible well field configuration on the Carrizo Aquifer outcrop covering 174 square miles is shown on Figure 3.18-1. The major facilities required to implement this alternative are:

- Surface Water Intake and Pump Station
- Water Treatment Plant
- Water Transmission Line and Booster Pump Stations
- Well Field Distribution and Collection System
- Dual-Purpose Injection and Recovery Wells
- Storage Facility and Pump Station at Well Field
- Discharge Structure at Choke Canyon Reservoir

The water transmission line is sized to deliver 139,000 acft/yr through an 84-inch diameter pipe. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $27,600,000 (Table 3.18-2). Operation and maintenance costs total $11,760,000 and power costs are estimated to be $3,590,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $42,950,000. For an annual firm yield of 40,300 acft/yr, the resulting annual cost of water is $1,066 per acft (Table 3.18-2).

3.18.6 Implementation Issues

<u>Requirements Specific to Diversion of Surface Water and Discharge to Surface Waters</u>

1. Required permits:
   a. TNRCC Surface Water Diversion Permit.
   b. TNRCC Discharge Permit.

Table 3.18-2
Cost Estimate for Groundwater and Recovery (Carrizo/Wilcox Aquifer) (L-7)
(Mid-1995 Costs)

Item	Estimated Cost
Capital Cost	
Reservoir Intake/Pump Station/WTP	$39,060,000
Water Transmission Pipeline and Booster Pump Stations	75,680,000
Dual Purpose Injection and Recovery Wells	57,020,000
Well Field Distribution/Collection and Pumping System	31,930,000
Subtotal	$203,690,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	66,020,000
Subtotal	$269,710,000
Environmental Studies and Mitigation	1,800,000
Land Acquisition	1,180,000
Subtotal	$272,690,000
Interest During Construction	21,820,000
Total Project Cost	$294,510,000
Annual Cost	
Annual Debt Service	27,600,000
Annual Operation and Maintenance (Excluding Power)	11,760,000
Annual Power	3,590,000
Total Annual Cost	$42,950,000
Annual Project Yield	40,300 acft/yr
Annual Cost of Water	$1,066 per acft

Requirements Specific to Use of Aquifers

1. Determination of ownership of GRR water and affect of ownership rights on other well owners in the area of the GRR field.

2. Permit requirements of Evergreen Underground Water District.

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.
    d. TPWD Sand, Gravel, and Marl permit for river crossings

2. Right-of-way easement acquisition.

3. Crossings:
    a. Highways and railroads
    b. Creeks and rivers
    c. Other utilities

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3.19 Dredging of Lake Corpus Christi (N-7)

3.19.1 Description of Alternative

The reduction in water storage capacity of Lake Corpus Christi as a result of sediment accumulation has been documented in past studies as indicated in Table 3.19-1.

Table 3.19-1
Summary of Lake Corpus Christi Capacity Data

Year	Conservation Pool Capacity (Acft)	Source of Capacity Data
1959	302,160[1]	Initial Capacity of Enlarged Lake Corpus Christi, 1959
1972	272,352[1]	1972 McCaughan & Etheridge Sediment Survey
1987	241,241[1]	1987 USGS Sediment Survey Modified by HDR
1990	237,473[2]	1987 USGS (Modified) Relationship Adjusted for 3 Years of Sedimentation
2010	213,112[2]	1987 USGS (Modified) Relationship Adjusted for 23 Years of Sedimentation
2050	164,192[2]	1987 USGS (Modified) Relationship Adjusted for 63 Years of Sedimentation

[1]Capacity based on sediment survey results.
[2]Estimated capacity based on historical trends from sediment surveys (i.e., 1,223 acft/yr).

A long-term sedimentation rate of 1,223 acft/yr was used to estimate the capacity of Lake Corpus Christi for 1990, 2010, and 2050 conditions. Estimates of future elevation-area-capacity relationships for Lake Corpus Christi are presented in Table 3.19-2 and indicate the capacity of the lake will decrease an additional 73,000 acft or 31 percent between 1990 and 2050. This is a high loss rate for a reservoir. As a comparison, the capacity of Choke Canyon Reservoir is projected to decrease by 13,620 acft or only 2 percent during the same timeframe.

Table 3.19-2 Elevation-Area-Capacity Data for Lake Corpus Christi						
Elevation Ft. (MSL)	1990 Conditions		2010 Conditions		2050 Conditions	
	Area (Acres)	Capacity (Acft)	Area (Acres)	Capacity (Acft)	Area (Acres)	Capacity (Acft)
94	19,251	237,473	19,251	213,112	19,251	164,192
90	16,635	165,601	15,599	142,622	13,110	97,021
86	13,674	104,982	12,559	86,306	9,881	51,036
82	8,467	60,700	7,405	46,379	4,855	21,564
78	5,565	32,636	4,618	22,332	2,343	7,160
74	3,292	14,920	2,490	8,112	565	1,329
70	1,206	5,924	562	2,001	0	0
66	689	2,133	204	462	0	0
62	163	427	0	0	0	0
58	10	80	0	0	0	0
54	7	46	0	0	0	0
46	0	0	0	0	0	0

1. Borland, W.M. and Miller, C.R. "Distribution of Sediment in Large Reservoirs," Journal of the Hydraulics Division, ASCE, April, 1958.
2. USBR, "Revision of the Procedure to Compute Sediment Distribution in Large Reservoirs," Sedimentation Section, Hydrology Branch, U.S. Department of the Interior, May, 1962.

This section of the report includes estimates of increased yield, environmental effects and costs for dredging Lake Corpus Christi. Analysis of the dredging program includes consideration of long-term maintenance dredging to offset the sedimentation rate as well as accelerated dredging to restore the reservoir to it's initial capacity of 302,160 acft by about the year 2020.

A maintenance dredging program to offset the annual sedimentation rate of 1,223 acft will require that approximately 2 million cubic yards of sediment be dredged each year. An accelerated dredging program to restore Lake Corpus Christi storage capacity to 1959 conditions (302,160 acft) will require that approximately 163 million cubic yards of sediment be dredged, by the year 2020. The accelerated program would require the removal of about 6 million cubic yards of sediment each year.

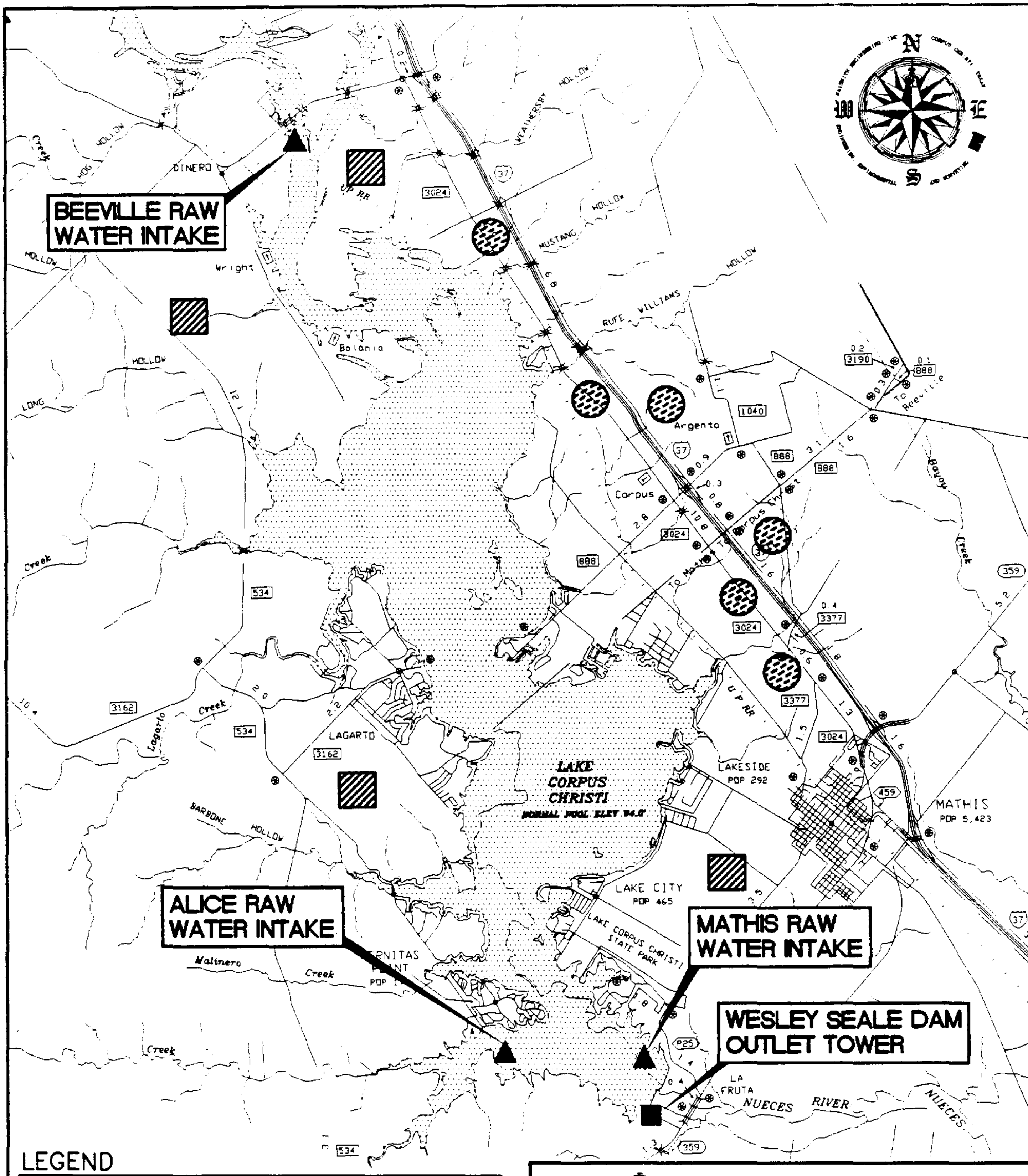
Spoil disposal alternatives have not been completely evaluated at this time. The disposal areas would likely consist of constructed levees that would contain the dredged material. It is estimated that the dredged material will initially contain approximately 85 percent water and 15 percent solids. Provision will need to be made to decant the water over spillways or weirs in order to dry the solids and return as much of the water to the reservoir as possible. A determination of the locations of acceptable disposal areas has not been made at this time. However, Figure 3.19-1 shows possible disposal sites near Lake Corpus Christi. Table 3.19-3 shows the approximate number of acres required to store the dredged material under the accelerated program for a range of storage depths. This alternative would impact fewer acres if a portion of the dredged material were ultimately hauled away and used in a soil replacement program and/or the maintenance dredging program were implemented.

Table 3.19-3
Estimated Size of Sediment Disposal Area for Accelerated Dredging Program

Average Depth of Material in Disposal Area (Feet)	Acres Required for Disposal Area (Acres)
5	20,000
10	10,000
15	6,800

3.19.2 Yield Analysis

Reservoir operation studies of the CC/LCC system indicate that without a dredging program, the firm yield of the system is projected to decrease over the next 25 years at an average annual rate of about 290 acft/yr (see Table 3.19-4). If the maintenance dredging program were in-place for this 25-year period of time, this would result in an avoided yield reduction of about 7,200 acft/yr by the year 2020. Under the accelerated dredging program the firm yield of the system would be increased by about 23,000 acft/yr over the same 25-year period.



LEGEND

- POTENTIAL DREDGE SPOIL DISPOSAL IN CALICHE/GRAVEL PIT AREAS
- POTENTIAL DREDGE SPOIL DISPOSAL IN UPLAND AREAS

NOTE: LOCATIONS OF POTENTIAL DREDGE SPOIL DISPOSAL AREAS ARE APPROXIMATE.

10000 5000 0 10000 20000

GRAPHIC SCALE IN FEET

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TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

LAKE CORPUS CHRISTI DREDGE DISPOSAL SITES ALTERNATIVE N-7

FIGURE 3.19-1

Table 3.19-4 Summary of Firm Yield Reductions in Lake Corpus Christi Due to Sedimentation			
LCC Capacity (acft)	**Reduction in LCC Capacity* (acft)**	**Reduction in System Yield* (acft/yr)**	**Average Annual Reduction in Yield (acft/yr)**
302,160 (1959 conditions)	---	---	---
237,473 (1990 conditions)	64,687	14,700	475
213,112 (2010 conditions)	24,361	5,300	265
164,192 (2050 conditions)	48,920	13,000	325
Totals For 1959-2050 Conditions	137,968	33,000	363 Avg.

*The reductions tabulated in columns 2 and 3 are reductions since the previous year tabulated. System firm yield was computed using the City's Phase 2 Operating Policy and the TNRCC Interim Release Order.

3.19.3 Environmental Analysis

Introduction

Environmental issues related to the dredging of Lake Corpus Christi can be categorized as follows:

- Effects of the dredging operation on Lake Corpus Christi; and
- Effects related to the storage, processing and disposal of dredged sediment.

The biogeography of the region around Lake Corpus Christi is present in the Environmental Overview (Section 3.0.2). A reconnaissance survey of the area around Lake Corpus Christi was performed.

Impact Assessment

The habitats surrounding Lake Corpus Christi have been characterized as cropland to the east of the lake and mesquite blackbrush to the west.[1] Additionally, there is significant lakeside residential development. Protected species known to this area, which includes Live Oak, Jim Wells and San Patricio Counties, are listed in Appendix C, Tables 11, 14 and 18. Habitat for the endangered jaguarundi (*Felis yagouaroundi*) and coati (*Nasua nasua*) may be within the project area west of the lake. The jaguarundi inhabits dense, thorny shrublands especially near streams. The coati is an inhabitant of open plains. The presence of mesquite-blackbrush vegetation, pasture and water also provide habitat for state protected species such as the indigo snake (*Drymarchon corais erebennus*), reticulated collard lizard (*Crotaphytus reticulatus*), and the Texas horned lizard (*Phrynosoma cornutum*). Several species considered by TPWD to be threatened or endangered require wet habitats such as canals, ditches or shallow depressions. These include the black-spotted newt (*Notophthalmus meridionalis*), Rio Grande lesser siren (*Siren intermedia texana*) and sheep frog (*Hypopachus variolosus*). The black-spotted newt inhabits temporarily wet areas and aestivates underground during dry periods.

Direct effects of dredging on Lake Corpus Christi will result from the operation of from one to three dredges, the installation of temporary transport pipes, and pump stations. Although effects would be expected to be localized around the area of dredge operation, these effects would continue for as long as the dredging operations. Dredging will suspend sediment and increase turbidity in the water near the dredging operation. The round-the-clock operation of dredges and other heavy equipment, pipelines, and access roads would represent a considerable nuisance to residents along the lake, commercial interests and recreational users.

Depending on disposal methods and circumstances, analyses of the sediments may need to be performed in order to determine concentrations of possible contaminants in the bottom sediments or wastewater to be returned to the lake from the decanting process. Several potential sources of contamination should be considered. These include existing contamination of the bottom sediments, and contamination arising during the processing and disposal of the sediment. Existing contaminants may include metals such as arsenic (which is used to defoliate cotton),

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

cadmium, chromium, copper, lead, mercury, zinc, pesticides, and other chemicals which can accumulate in bottom sediments. The presence of contaminants in the bottom sediments may indicate that additional studies would need to be conducted in order to determine whether contaminants could become resuspended in the wastewater or remain in the sediments during the dewatering process and disposal. Contamination not associated with dredging may occur as a result of the dewatering process or sediment disposal. Anoxic conditions common in sedimentation ponds can cause contamination. The presence of contaminants or total dissolved solids in excess of standards would require waste disposal permits and a monitoring program to discharge water back into Lake Corpus Christi, and to dispose of the dewatered sediment.

The effects of sediment disposal, assuming the sediment is not contaminated, would depend on the dredging plan to be implemented, which will generate between two million and six million cubic yards of sediment annually (1240 acres one foot deep or 3719 acres one foot deep respectively). Table 3.19-3 presents the volume of dredged material generated during the life of the accelerated dredging program. The temporary impoundment of sediment for dewatering would require the construction of dikes for sedimentation ponds. Alternatively, caliche pits and gravel pits might serve as sedimentation ponds. In lieu of constructing gravity feed systems near the shore or tributaries to return decanted water to the lake, pumping stations would be required to remove decanted water from the sedimentation ponds (e.g. caliche pits and gravel pits). Although decanting would reduce the volume of the sediment, spreading and turning the sediment to promote drying may be required. Conventional confined disposal operations involving the placement of dredged sediment in a diked area frequently result in a release of large amounts of contaminants arising from the anoxic nature of these areas.[2] Anoxic mud could cause odor problems and overflow water may require treatment before being returned to aquatic ecosystems. Following decanting and possibly drying, the sediment would require a significant upland acreage for disposal. The discharge of dredge and fill into waters of the United States, including wetlands, is regulated by the COE under Section 404 of the Clean Water Act (33 USC 1344).

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[2] Lee, F. and R.A. Jones. 1977. An assessment of the environmental significance of chemical contaminants present in dredged sediments dumped in the New York Bight. Occasional Paper No. 28. Environmental Engineering, Colorado State Univ., Fort Collins, Colorado.

3.19.4 Cost Analysis

Previous reports on the feasibility of dredging large reservoirs were reviewed to confirm budget cost estimates. Several dredging contractors were also contacted and provided input into the size of equipment that would be required and cost estimates. Discussions were also held with agency representatives, such as the Corps of Engineers, regarding construction, permitting, and spoil disposal issues.

A maintenance dredging program to dredge Lake Corpus Christi would include:

- Mobilization/demobilization of a portable cutter-suction dredge;
- Installation of temporary discharge piping (18-inch to 20-inch PVC or steel pipe);
- Intermediate booster pump stations; and
- Purchase of spoil disposal areas and construction of containment levees.

It is estimated that mobilization and demobilization costs will be approximately $200,000 for an 18-inch dredge. The length and size of discharge piping, and number of intermediate booster pump stations that are required will depend on a number of factors. It is anticipated that disposal areas will be about three to five miles away from the areas being dredged. Elevations of disposal areas will be higher than the reservoir pool and it would not be unreasonable for three or more booster pumping stations to be required.

A dredging program for Lake Corpus Christi would differ from typical channel maintenance dredging programs administered by the Corps of Engineers (COE). Major COE dredging projects utilize large capacity dredges, ranging in size from 27" to 30". These large capacity dredges can be mobilized by water to coastal marine sites more economically than the smaller portable dredges required for an inland reservoir. The largest portable dredge is 18" in size and is transported by truck and assembled/disassembled at the site. the unit price for dredging with a smaller capacity dredge will be more than dredging with a larger dredge.

In addition, local project sponsors frequently obtain and provide land for dredged material disposal at no cost to the COE projects. Disposal sites are typically adjacent to or nearby the channel areas being dredged. Therefore, pumping costs would be less than the cost to pump to disposal sites around Lake Corpus Christi, which could be three to five miles away from the areas being dredged.

Unit costs for the dredging program were based on discussions with private dredging contractors and COE staff, and a review of previous reports on similar inland reservoirs. Cost ranges were estimated as follows:

UNIT COSTS FOR ANNUAL DREDGING PROGRAM	
Mobilization/Demobilization	$0.10/CY
Booster Station & Discharge Piping	$1.60/CY - $3.20/CY
Dredging	$1.40/CY - $2.85/CY
Disposal Areas	$0.90/CY - $1.85/CY
Contingency (25%)	$1.00/CY - $2.00/CY
TOTAL UNIT COST	$5.00/CY - $10.00/CY

Note: Engineering and permitting costs not included. Environmental mitigation costs (if any) not included.

Using a conceptual budget estimate of $6.00/CY for the annual maintenance dredging program for the removal of approximately 2 million cubic yards per year, results in an annual cost of $12,000,000. If this program were in place over a 25-year period of time, the yield of the reservoir system could be increased by about 7,200 acft/yr. This results in a unit cost of restored yield of $1,667/acft for the annual maintenance program.

Under an accelerated dredging program (which would essentially restore the capacity of Lake Corpus Christi to it's original capacity), several dredges would be required for about a 25 year period of time. The cost of the accelerated program based on a unit cost of $5.50/CY (some economies of scale would be anticipated with the higher sediment removal rates) the annual cost of this would be $33,000,000 and it would increase the yield of the system by about 23,000 acft/yr. This would result in the unit cost of accelerated program being about $1,430/acft.

Alternative Silt Disposal Concepts

Conceptually, a program to release accumulated sediment from a reservoir could be accomplished by (1) construction of an outlet structure which includes gates at the reservoir bottom that can be used to periodically sluice out silt, or (2) dredging portions of the reservoir immediately upstream from the dam and pumping the dredged material downstream, directly into the river.

The feasibility of designing outlet structures that include gates at the reservoir bottom, to allow periodic sluicing of accumulated sediment has been considered for other reservoirs during the initial construction of the outlet works. Retrofitting the existing outlet structure at Wesley Seale Dam would be cost prohibitive based on the fact that construction would need to occur in the deepest part of the reservoir.

The feasibility of a dredging program to incorporate the release of accumulated sediment from the reservoir downstream to the Nueces River, instead of disposal of sediment into leveed disposal sites, would require that several major issues be addressed, including:

1. Economic Feasibility - The cost of a dredging program that includes disposal of sediment in dredge disposal sites was estimated to range between $5-$10 per cubic yard. A program that eliminates the disposal site cost will still include costs for: Mobilization of dredging equipment; dredging; installation of discharge piping and intermediate booster stations. It is estimated that only approximately 15% to 25% of the total unit cost would be saved by eliminating the disposal site costs.

2. Water Quality Concerns - A Corps of Engineers Section 404 permit would be required for such a sediment release program. Water quality concerns in the Nueces River downstream from the dam would require evaluation of the possible detrimental effect of additional sediment on parameters such as dissolved oxygen, toxicity to aquatic species, etc.

3. Water Treatment Concerns - Increased turbidity resulting from the release of sediment would significantly impact the City's water treatment process and result in higher chemical usage and treatment costs.

4. Sediment Control - Release of sediment downstream from the dam will very likely result in the need to periodically dredge areas of the Nueces River to prevent excessive silt deposition.

In summary, alternative silt disposal concepts which involve discharging extremely high turbidity water into the lower Nueces River will have high cost, significant impact on the City's water treatment costs and be potentially environmentally damaging to the aquatic communities in the lower Nueces River.

3.19.5 Implementation Issues

The accumulation of sediments in Lake Corpus Christi is a serious long-term problem. The first step recommended to better define the problem is the performance of a new sediment survey to determine if recent sedimentation trends are in-line with historical trends. The City presently has a contract with the Texas Water Development Board to perform a capacity survey as soon as the level of Lake Corpus Christi returns to near full conditions. Once the results of this survey are performed, the City should re-assess the sedimentation problem and, if appropriate, begin to develop a long-range plan to address this problem. Future evaluations of this problem should consider the effectiveness of watershed sedimentation control measures as well as the economies of adding capacity to Lake Corpus Christi by raising or enlarging the reservoir as opposed to the removal of sediments which may contain toxic deposits and potentially affect sizeable areas for disposal.

1. A dredging program may make it necessary to obtain these permits:
   a. U.S. Army Corps of Engineers Section 10 and 404 dredge and fill permits.
   b. GLO Sand and Gravel Removal permit.
   c. Coastal Coordinating Council review.
   d. TPWD Sand, Gravel, and Marl permit.

2. Permitting, at a minimum, will require these studies:
   a. Habitat mitigation plan.
   b. Water quality and suspended sediment studies.
   c. Characteristics of decant water at disposal sites.
   d. Toxicity studies of accumulated sediment.
   e. Sound impact studies.

3. Land rights for the disposal areas will need to be obtained.

4. Disposal pipeline will have to obtain permission for crossings:
   a. Highway and railroads.
   b. Creeks.
   c. Other utilities and petrochemical pipelines.

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3.20 Purchase of Colorado River Water (C-2)

3.20.1 Description of Alternative

This alternative evaluates the potential purchase of water from either the Lower Colorado River Authority (LCRA) and/or Pierce Ranch for diversion to Lake Texana and delivery to Corpus Christi in conjunction with the use of Lake Texana water as described in Section 3.13, and potentially in conjunction with the use of Colorado River from the Garwood Irrigation Company is addressed in Section 3.16. Water is potentially available from several sources listed below.

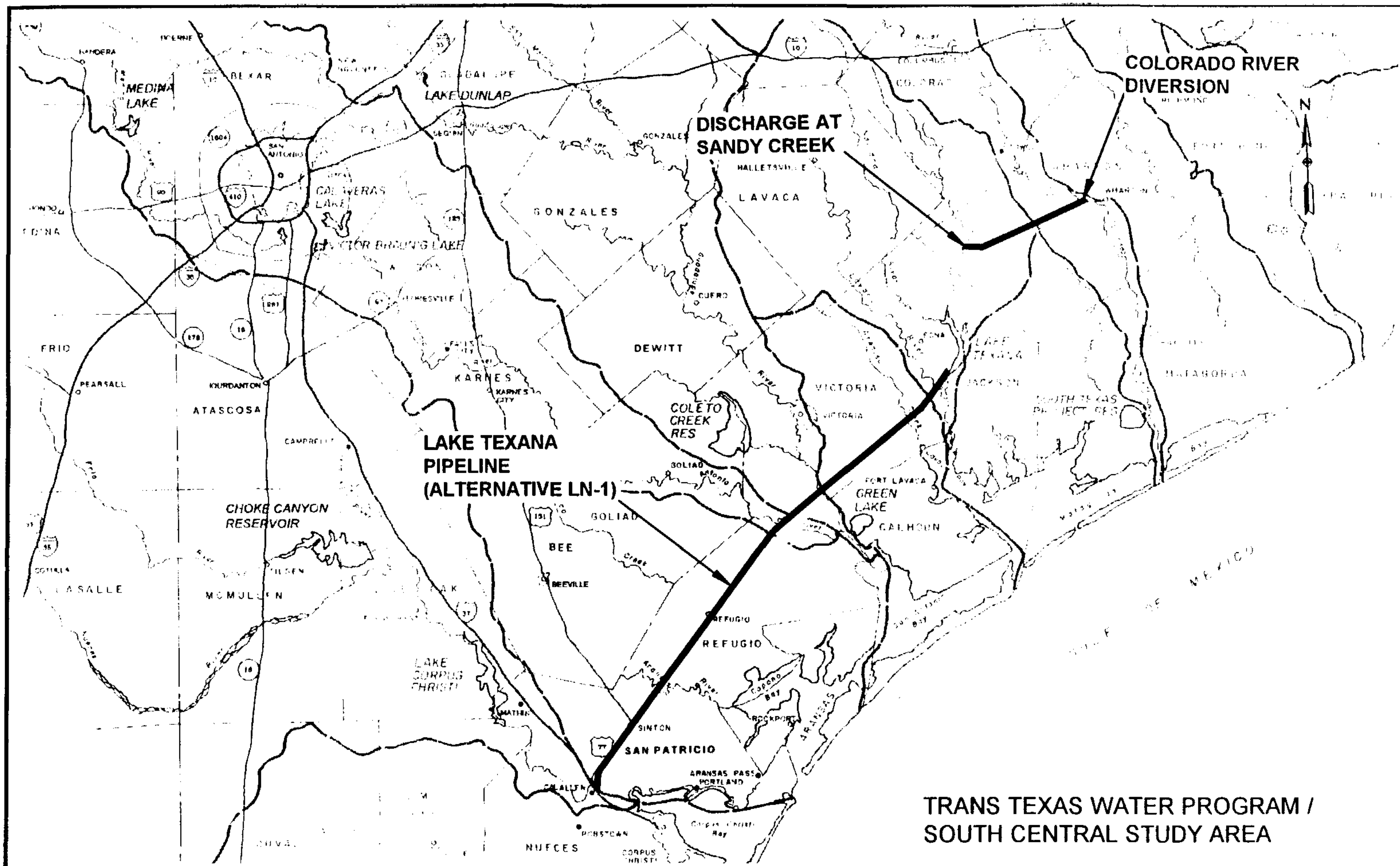
a) LCRA run-of-river rights recently purchased from Pierce Ranch. Certificate of Adjudication 14-5477B authorizes LCRA to divert up to 55,000 acft/yr from the Colorado River for irrigation and municipal purposes. The diversion location is not specified and LCRA must request an amendment to CA 14-5477B to change the place of use and point of diversion prior to using this right. Additionally, this right is subordinated to the 55,000 acft/yr diversion rights retained by Pierce Ranch.

b) LCRA stored water from the Highland Lakes. Based on findings presented to the TNRCC, the LCRA also has approximately 50,000 acft/yr of uncommitted firm water potentially available from the combined firm yield of Lake Travis and Lake Buchanan[1].

c) Pierce Ranch run-of-river rights. Pierce Ranch holds 55,000 acft/yr run-of-river rights which are senior to LCRA's rights purchased from Pierce Ranch. Pierce Ranch has converted 10,000 acft/yr to municipal use and 5,000 to industrial use (CA 5477A, March, 1993) with a diversion point at Wharton. Point of use is within the boundaries of the Pierce Ranch service area and an amendment would be required to transfer the water to Corpus Christi.

For purposes of this study, it was assumed that some combination of water from the above sources would be made available for purchase by the City of Corpus Christi. For either source, it was assumed that the point of diversion would be near the Pierce Ranch irrigation pump station upstream of Wharton, Texas, and delivered to Lake Texana, blended with Lake Texana water and delivered to Corpus Christi through an up-sized Texana Pipeline. The diversion location and pipeline route are shown on Figure 3.20-1. A low head dam, intake, and pump station would be constructed on the Colorado River and a 24 mile pipeline would be constructed to Sandy Creek at

[1] Texas Water Commission, "Order Approving LCRA's Water Management Plan and Amending Certificates of Adjudication Nos. 14-5478 and 14-5482," September 7, 1989.



Legend

Basin Divide

Possible Pipeline Route

0 10 20 Miles

Scale

HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

PURCHASE OF COLORADO RIVER WATER ALTERNATIVE C-2

FIGURE 3.20-1

a location upstream of Lake Texana in the Navidad River Basin. The purchased water would flow approximately 12 miles in Sandy Creek to Lake Texana where it would mix with stored water until being pumped to Corpus Christi. (Note: If this alternate moves forward, it may be possible that a discharge location other than Sandy Creek and closer to Wharton would be suitable, thereby shortening the required transfer pipeline.) From Lake Texana, the combined stored water would be diverted into the intake structure at the dam and pumped to the O.N. Stevens Water Treatment Plant near Calallen through an up-sized Texana Pipeline (the Texana Pipeline is described in Section 3.13).

3.20.2 Available Yield

A water purchase quantity for this alternative was chosen which resulted in a Lake Texana net yield increase of 29,000 acft/yr. To make up for channel and evaporation losses in Sandy Creek and Lake Texana, about 32,000 acft/yr must be purchased. It was assumed that this water would originate from a combination of either LCRA's or Pierce Ranch's run-of-river municipal rights firmed up from stored water in the Highland Lakes. An annual uniform pumping rate at the diversion point was selected for analysis to minimize the size and cost of the pumping and pipeline facilities. It is assumed that the purchased water would be available at the Pierce Ranch diversion location with LCRA providing for any channel losses on the release of stored water which occur between Lake Travis and the diversion point.

To determine how much water might be lost to channel losses in Sandy Creek, a channel loss study was performed in the fall of 1992 and a copy of the memorandum describing the results of the investigation is included in Appendix B. The channel loss study indicated that average losses would range between 5 and 10 percent. Actual channel losses will vary with streamflow, pumping rate, seasons, and other hydrologic conditions. Although these losses could be eliminated by constructing additional transmission pipeline, the cost of the additional pipeline is not economical based on the quantity of water saved. For the Garwood water rights purchase (Alternative C-1, Section 3.16.2), it was estimated that channel and evaporation losses would be about 9 percent on the average for a uniform pumping scenario. Applying this same loss rate to the potential purchase from LCRA requires a purchase of 32,000 acft/yr to obtain a net benefit of 29,000 acft/yr.

3.20.3 Environmental Issues

Introduction

Potential environmental issues related to transferring water from the Colorado River through Lake Texana can be categorized as follows:

- Effects of construction and operation of a small diversion dam on the Colorado River;
- Streamflow changes in the Colorado River below the diversion and inflows to the Lavaca-Colorado Estuary;
- Effects on Sandy Creek, Lake Texana, and the river below Lake Texana;
- Increased inflows to the Nueces Estuary; and
- Effects of pipeline construction and maintenance between the Colorado River and Sandy Creek.

This water supply alternative, if implemented, would be a combined project with the Lake Texana pipeline (Alternative LN-1). Although a stand-alone supply from the purchase of water at the Colorado River delivered to Corpus Christi is possible, to reduce environmental impacts as well as costs the yield from this project would be blended in Lake Texana and delivered through an up-sized Lake Texana pipeline. Methods used to develop this section, including mapping, searches of the available literature and databases, and a reconnaissance survey are described in the Environmental Overview (Section 3.0.2).

The Affected Environment

Regional Setting

The project area lies within Wharton and Jackson Counties. Both counties have hot and humid summers relieved by occasional thundershowers. Average growing seasons are 266 days and 290 days respectively.[2] Mean precipitation averages about 41 inches annually. Both counties are major rice-growing areas with oil production also being economically important. Wharton and Jackson Counties lie entirely within the Gulf Coastal Plain and exhibit great physiographic and vegetational similarity. Both counties consist of alluvial plains dissected by low gradient streams with broad, heavily vegetated floodplains (Section 3.0.1). The area between Wharton, on the

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[2] Griffiths, J. and J. Bryan. 1987. The Climates of Texas Counties. Natural Fibers Information Center, The University of Texas in cooperation with Office of the State Climatologist, Texas A&M University.

Colorado River, and Lake Texana has undergone intense agricultural development. Upland soils are alluvial, black clay and sandy loam types. The terrain of Jackson county consists of prairie draining into rivers creeks and bays. Soils are loam, clay, and black types. Bottomland soils in the vicinity of the proposed dam and intake structure belong to a Miller-Norwood soil association which consists of soils that have a moderately well drained surface layer with poorly draining lower layers of clay and silt loam. The predominant soils are classified as Vertisol (Lake Charles Clay) with less than 1% slope, Mollisol (Miller Clay) and Entisols (Norwood and Lincoln soils).[3] These bottomland soils are the youngest soils in Wharton County, having been laid down by the meandering Colorado River.

Colorado River, Sandy Creek, Lavaca-Colorado Estuary

Discussions concerning the Colorado River and Lavaca-Colorado Estuary are presented in Sections 3.16.3 and in the Environmental Overview (Section 3.0.2). Sandy Creek, which flows into Lake Texana is described under Alternative C-1, Section 3.16.3

Impact Assessment

Construction Effects

Although several listed endangered or threatened species, and species of special concern, have been reported for Wharton county, the only recent occurrence listed in Natural Heritage Program files is a Bald Eagle nest located in the woodlands on Colorado River floodplain Egypt Plantation upstream of the proposed diversion location (Appendix C, Table 7).[4]

Construction of a diversion and intake structure on the Colorado River will disturb less than one acre of stream bank, and result in the permanent conversion of a few hundred square feet of aquatic and riparian habitat into concrete structures. Outfall construction on Sandy Creek will be of a similar nature. Intake and outfall site selection and construction planning and scheduling would

[3] Plant Communities of Texas (Series Level). Texas Natural Heritage Program, April 1993.

[4] TPWD. 1993. Texas Parks and Wildlife Department National Heritage Program special animal files.

include biological evaluations to minimize potential impacts to endangered species, unique or important habitats and wetlands.

Construction of the 24 mile long pipeline would require a construction ROW 140 feet wide, potentially resulting in disturbance to the soils and vegetation on as much as 407 acres. Approximately 34 acres (8.4 percent) of the construction corridor is wooded. The remaining 91.6 percent (373 acres) is agricultural land used primarily for crops. A 40 foot wide ROW maintained free of woody vegetation for the life of the project will occupy 116 acres, although continued agricultural production can occur on this land. Disturbed areas will be revegetated with grasses acceptable to the landowner. Pipeline construction will impact riparian woodlands at crossings of East Fork Jones Creek, Jones Creek, West Mustang Creek, Gobbler Creek, Porter's Creek and Lookout Creek. If this alternative is carried forward, a wetland evaluation at the stream crossings before setting the final pipeline alignment may aid in minimizing wetland impacts.

The Texas Natural Heritage Program does not report any endangered or threatened species within the pipeline corridor. There is a little bluestem-brownseed paspalum series[5] grassland several miles north of where the proposed pipeline route would cross state highway 71. This is described under Alternative C-1, Section 3.16, and would not be disturbed by this project. Important species and resources potentially affected by implementation of this alternative (C-2) are reported in Appendix C, Tables 7, 10 and 20.

All areas to be disturbed during construction will be first surveyed by qualified professionals for the presence of significant cultural resources. If significant cultural deposits are identified and cannot be avoided additional measures may be required.

Operational Effects

Potential effects on the Colorado River from operation of this alternative include entrainment of Colorado River flora and fauna, and reduction of streamflows below the diversion. Although the numerous long term agricultural diversions in place on this reach suggest that the present riverine community is tolerant of the effects of entrainment, it should be minimized by selection of an intake

[5] Ibid.

location that does not attract fish, and by the use of appropriate screening technology to reduce potential losses to aquatic populations.

While this alternative (C-2) would employ a purchased water right (either run-of-river or stored water), it is unresolved whether it would represent a currently exercised right, or if the proposed diversion would be an additional withdrawal from the Colorado River. Because of channel losses in Sandy Creek, 32,000 acft/yr must be diverted from the Colorado River to obtain an additional 29,000 acft/yr in Lake Texana. The effects on the river system and estuary would depend on the source of the purchased right. The diversion of presently unused run-of-river rights would reduce flow in the Colorado River below the Pierce Ranch diversion. However, the diversions would adhere to instream flow targets. If the diversion involved stored water purchased from LCRA, additional releases from the Highland Lakes to meet the demand would increase instream flows in the reach of the Colorado River downstream to the Pierce diversion. Instream flow below the Pierce diversion would be unchanged. The purchase of currently used run-of-river rights from Pierce Ranch would not change the amount of water diverted from the Colorado River but may involve changes in the distribution of diversions and instream flows.

Alternative C1 (Section 3.16) involves using Sandy Creek to transfer Colorado River water to Lake Texana in a manner comparable to this alternative (C-2). Potential effects to aquatic and riparian communities in Sandy Creek are discussed in Section 3.16.3.

Nueces Estuary

Following use in the Corpus Christi area, a portion of the water would be returned to the Nueces Estuary system as treated wastewater. Based on an increased freshwater supply of 29,000 acft/yr to Corpus Christi and an estimated wastewater discharge to Nueces Bay of 47 percent, projections indicate that this alternative would increase wastewater inflows to Nueces Estuary by 13,630 acft of water annually.[6] This represents an annual increase of approximately 4.6 percent in terms of median freshwater inflows to Nueces Estuary (under CC/LCC Phase II operations, 1995 Agreed Order, and 1990 sediment conditions). Under existing discharge patterns Corpus Christi

[6] HDR Engineering, Inc. 1993. Trans-Texas Water Program. Corpus Christi Service Area. Phase I Interim Report Summary.

Bay and the ship channel would receive 12,267 acft/yr and Nueces Bay/Delta would receive an additional 1,363 acft/yr.

Although increased freshwater flows into Nueces Estuary might be expected to benefit shrimp and other aquatic species, the effect of additional freshwater contributed by this alternative considered alone (an increase of 4.6 percent) would be small. In contrast to alternatives involving the diversion of water from the Nueces River Basin, wastewater returns from this alternative would offset losses to the bay from local alternatives which divert water from the Nueces River.

3.20.4 Water Quality and Treatability

Both Lake Texana and the Colorado River have generally good water quality as indicated by the analysis in Appendix D. The four constituent concentrations (hardness, TDS, chlorides, and sulfates) analyzed for Lake Texana were typically less than one-third of the TNRCC Secondary Drinking Water (SDW) Standards and the Colorado River at Wharton generally had concentration levels less than one-half the SDW Standards (see Table D-1). Since this option would include the mixing of 29,000 acft/yr of Colorado River water into Lake Texana, which has an average annual inflow of 517,000 acft, the resultant concentrations of the water quality constituents of the water diverted to Corpus Christi would be very nearly equal to the water quality of the Lake Texana water (refer to Appendix E for more a detailed consideration of treatment issues).

3.20.5 Engineering and Costing

The water supply alternative as presented here is a combined project with the Lake Texana Pipeline (Alt. LN-1). A stand-alone project from the Colorado River to Corpus Christi is possible, but the unit costs of water would be significantly higher.

Purchased water would be diverted at a uniform rate of 2,670 acft/month (or about 30 mgd assuming 5 percent downtown of the pumps) through an intake at a small diversion structure to be located near Wharton on the Colorado River. A pump station at the intake structure would pump the water through a 42-inch diameter transmission pipeline to a discharge structure on Sandy Creek. After flowing down Sandy Creek and mixing with water in Lake Texana, the water would be diverted through the intake structure at the dam and pumped through the Texana pipeline to the

O.N. Stevens Water Treatment Plant near Calallen. The major facilities required to implement this alternative are:

Small Diversion Structure on Colorado River
Surface Water Intake and Pump Station
Transmission Pipeline from Colorado River to Sandy Creek
Discharge Structure at Sandy Creek
Pump Station at Lake Texana
Upsized Transmission Pipeline from Lake Texana to Corpus Christi
Booster Pump Stations
Tie-in to O.N. Stevens Water Treatment Plant

From Lake Texana to Corpus Christi, facility and operation costs are estimated for a combined water delivery of 60,440 acft/yr. When channel and evaporation losses are taken into account, the diversion of 32,000 acft of Colorado River water would result in the delivery of 29,000 acft/yr into Lake Texana. This quantity added to the 31,440 acft/yr that the City of Corpus Christi has purchased from LNRA on a permanent basis from the yield of Lake Texana would give a total of 60,440 acft/yr. The 60,440 acft/yr would be delivered to the O.N. Stevens Water Treatment Plant at a uniform rate of 5,037 acft/month throughout the year. Assuming five percent down time for the pumping equipment, the pumping rate would be about 57 mgd and the pipeline size would be 60 inches diameter. Project costs for purchase and delivery of the water purchased from LCRA are summarized in Table 3.20-1, costs of the Texana Pipeline to Corpus Christi are summarized in Table 3.20-2, and a summary cost table is provided in Table 3.20-3. Rates for the sale of water by LCRA are set by the LCRA Board of Directors and are periodically adjusted. The rates are partially based on cost of service and conceivably can vary up or down, depending on the quantity of water sold. Currently, the annual cost to purchase stored water from LCRA is $105 per acft, or $3,360,000 per year for 32,000 acft and this purchase price was used in this preliminary cost analysis. (Note: It may be possible that an alternative purchase agreement with Pierce Ranch or LCRA for run-of-river water could reduce this cost.) Financing the Colorado River water portion of the project over 25 years at an 8 percent annual interest rate results in an annual expense of $6,880,000 (Table 3.20-3). Operation and maintenance costs, including power, total $2,951,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $13,191,000. The resulting annual cost of the additional yield of 29,000 acft/yr delivered to O.N.

Table 3.20-1
Cost Estimate for Pipeline to Lake Texana (Sandy Creek) (C-2)
Pumping All Year, Flow = 32,000 acft/yr; 30 mgd
(Mid-1995 Prices)

Item	Estimated Cost
Capital Cost	
Diversion Dam	$2,120,000
Pump Station	1,900,000
Pipeline (42-inch)	11,940,000
Subtotal	$15,960,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	4,990,000
Subtotal	$20,950,000
Environmental Studies and Mitigation	200,000
Land Easements	180,000
Subtotal	$21,330,000
Interest During Construction	430,000
Total Project Cost	$21,760,000
Annual Cost	
Annual Debt Service	$2,040,000
Annual Operation and Maintenance (Excluding Power)	180,000
Annual Power	675,000
Annual Payment for Water[1]	3,360,000
Total Annual Cost	$6,255,000

(1) Based on current purchase cost of stored water from LCRA of $105 per acft/yr.

Table 3.20-2
Cost Estimate for Lake Texana Pipeline to Corpus Christi (C-2)
Flow = 60,440 acft/yr (60" diameter)
(Mid-1995 Costs)

Item	**Estimated Cost**
Capital Cost	
Pump Station	$ 4,010,000
Booster Station	2,770,000
Booster Station	3,490,000
Pipeline	70,060,000
Tunneling at Environmental Features	2,110,000
Subtotal	$82,440,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	21,110,000
Subtotal	$103,550,000
Environmental Studies and Mitigation	340,000
Land Easements	550,000
Subtotal	$104,440,000
Interest During Construction	3,130,000
Total Project Cost	$107,570,000
Annual Cost	
Annual Debt Service	$10,080,000
Annual Operation and Maintenance (Excluding Power)	1,093,000
Annual Power	3,273,000
Annual Cost of Water[(1)]	2,071,000
Total Annual Cost	$16,517,000

(1) From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.

Table 3.20-3
Summary Cost Estimate for Purchase of Colorado River Water (C-2)
(mid-1995 Costs)

Annual Delivery to Corpus Christi[1]:	60,440 acft/yr
Delivery Rate at Corpus Christi:	57 mgd
Pipe Diameter (Texana to Corpus Christi):	60 inches
Pipeline Length:	104 miles
Annual Diversion from Colorado River:	32,000 acft/yr
Annual Yield Increase at Texana:	29,000 acft/yr
Delivery Rate from Colorado River[2]:	30 mgd
Pipeline Diameter (Colorado River to Lake Texana):	42 inches
Pipeline Length:	24 miles

Capital Cost Summary	**Total Project**	**LNRA (Texana) Portion[3]**	**Cost for this Alternative**
Pump Station and Channel Dam On Colorado and Pipeline to Texana:	$21;760,000	- -	$21,760,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi:	107,570,000	55,936,000	51,634,000
Total Capital Costs	$129,330,000	$55,936,000	$73,394,000

Annual Cost Summary	**Total Project**	**LNRA (Texana) Portion[3]**	**Cost for this Alternative**
Estimated Annual Debt Service:	$12,120,000	$5,240,000	$6,880,000
Estimated Annual O&M:	5,221,000	2,270,000	2,951,000
Annual Payment for Water:	5,431,000	2,071,000[4]	3,360,000[5]
Total Annual Costs	$22,772,000	$9,581,000	$13,191,000
Average Annual Cost for Each Acre-Foot Delivered at Corpus Christi:	$377	$305	$454

(1) Consists of 31,440 acft/yr of LNRA water (52%) and 29,000 acft/yr of Colorado water (48%).
(2) Rate is based on uniform diversion of 32,000 acft/yr and 5 percent pump downtime.
(3) Calculated as 52% of Texana Pipeline costs for delivery of 60,440 acft/yr; from Table 3.20-2.
(4) From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.
(5) Based on current purchase cost of stored water from LCRA of $105 per acft/yr.

Stevens WTP is $454 per acft. Implementation of this alternative as a stand-alone project would result in significantly higher cost.

3.20.6 Implementation Issues

As formulated here, this alternative is combined with the Texana Pipeline (Alt. LN-1) and an agreement with the Lavaca-Navidad River Authority would be necessary for use of any of their pipeline or pumping facilities and for the use of Lake Texana for temporary storage of the water.

Requirements Specific to Purchase and Diversion of Stored Water

The LCRA policy on interbasin transfers states that LCRA will oppose future interbasin transfers unless it is demonstrated that the transfer will have no detrimental effect on the LCRA ten-county statutory district and that the receiving basin is prudently using and conserving existing water resources and aggressively planning and developing needed additional local water supplies. The LCRA Board Policy on interbasin transfers is included in Appendix K.

1. It will be necessary to obtain these permits:
    a. Permit amendment from TNRCC.
    b. TNRCC Interbasin Transfer Approval.
    c. Coastal Coordinating Council review.
    d. TPWD Sand, Gravel, and Marl permit.
    e. GLO Sand and Gravel Removal permit.

2. Permitting, at a minimum, will require these studies:
    a. Instream flow issues and impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.

3. Land will need to be acquired by negotiations or condemnation.

4. Water purchase agreement will need to be negotiated with LCRA and/or Pierce Ranch.

5. Additional hydrologic modeling is necessary to determine the volume of stored water necessary to firm-up run-of-river rights.

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.
   d. TPWD Sand, Gravel and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

4. If this alternative moves forward in conjunction with the Garwood purchase and the Lake Texana pipeline, the additional cost savings features should be considered, such as a single pipeline from the Colorado River to transport both this water and the Garwood water to Lake Texana as well as an upsized Texana pipeline (66 or 72-inch diameter) to transport the three combined sources of water to the Corpus Christi area which could transport from 77,440 acft/yr up to 92,440 acft/yr of firm water.

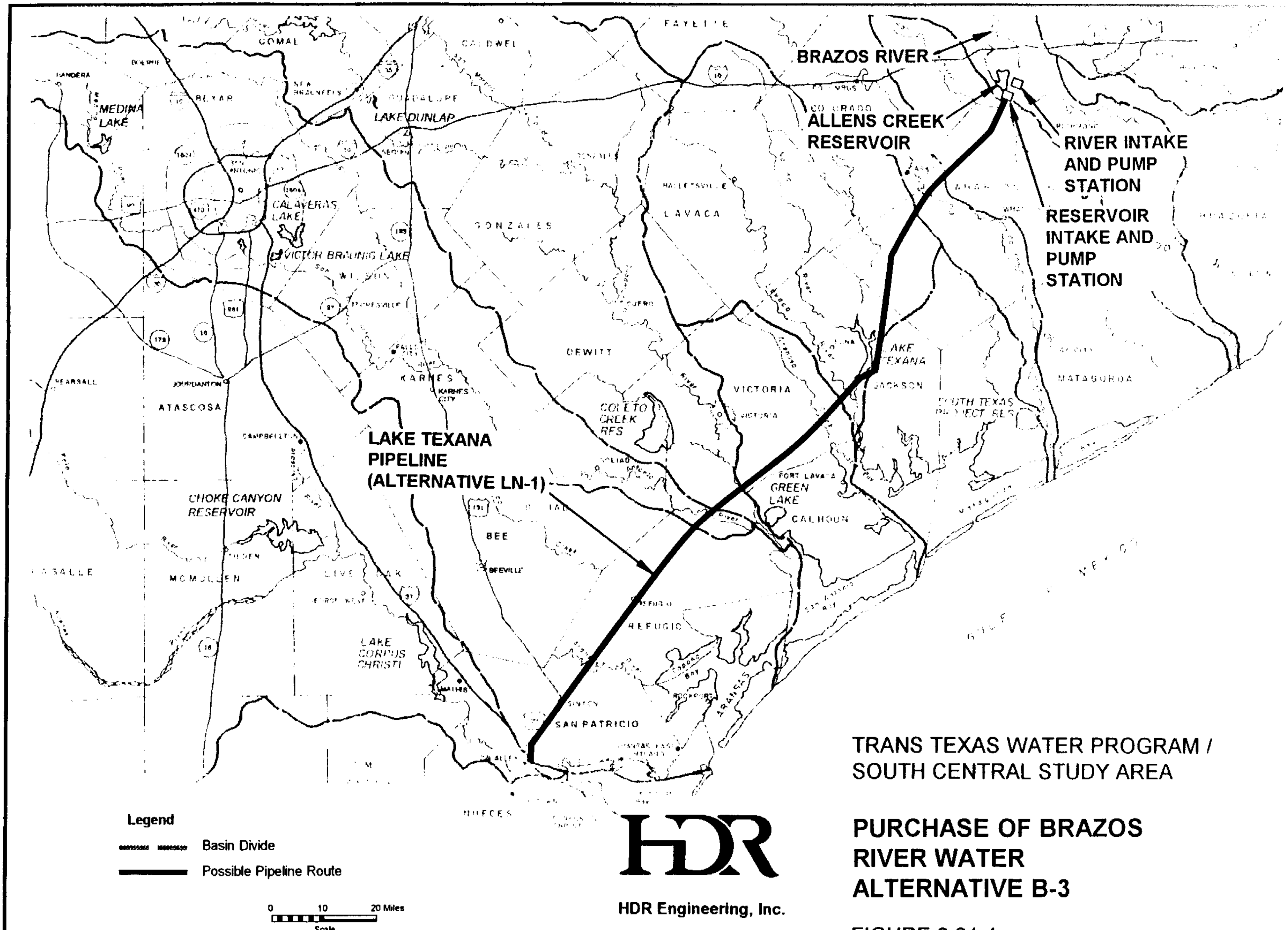
3.21 Purchase of Brazos River Water (B-3)

3.21.1 Description of Alternative

This alternative considers the potential purchase of Brazos River water from the proposed Allens Creek Project for delivery to Corpus Christi in conjunction with the use of Lake Texana water as described in Section 3.13. Allens Creek Reservoir is a proposed off-channel reservoir located on Allens Creek, a small tributary of the Brazos River in Austin County. The reservoir site is located two miles north of the town of Wallis, Texas, and is shown on Figure 3.21-1. The project would impound water available from the Allens Creek watershed as well as water diverted and pumped from the Brazos River during periods of flow in excess of downstream needs. Water from this project would be diverted at Allens Creek Reservoir and pumped through a 69 mile pipeline to a junction with the Lake Texana Pipeline south of Edna, Texas, for delivery to Corpus Christi through an up-sized Texana Pipeline. Because Brazos River water periodically has somewhat higher levels of chlorides and total dissolved solids than Lake Texana water, water from Allens Creek Reservoir would not be pumped into Lake Texana, but would be blended with water from Lake Texana in the Texana Pipeline. The pipeline route would cross the Colorado River near Garwood and the option exists to consider a combined project with the purchase of Colorado River water. (Note: Another potential option is to discharge the Allens Creek Reservoir water into the Colorado River to replace, to the extent necessary, water withdrawn from the Colorado River for interbasin transfers. However, this would require consideration of differences in water quality between the two streams.) The combined Lake Texana and Allens Creek Reservoir water would be pumped to the O.N. Stevens Water Treatment Plant near Calallen through an up-sized Texana Pipeline (the Texana Pipeline is described in Section 3.13).

The Allens Creek Reservoir project was originally proposed by Houston Lighting and Power Co. (HL&P) as a cooling lake for an electric power plant and the site was studied in 1974 by URS/Forrest and Cotton[1]. URS made a second study in 1977 with a different dam alignment

[1] URS/Forrest and Cotton, "Allens Creek Dam and Reservoir on Allens Creek, Brazos River Basin, Austin County, Texas" (prepared for Houston Lighting and Power Company), January 1974.



TRANS TEXAS WATER PROGRAM / SOUTH CENTRAL STUDY AREA

PURCHASE OF BRAZOS RIVER WATER ALTERNATIVE B-3

FIGURE 3.21-1

and smaller reservoir[2]. HL&P eventually abandoned plans for a power plant at the Allens Creek site and subsequently the Brazos River Authority (BRA) obtained an option to purchase the reservoir site from HL&P. In 1988, BRA retained Freese & Nichols to study the yield and cost of the proposed reservoir[3]. As part of the Trans-Texas Water Program, Freese & Nichols and Brown & Root re-evaluated the yield of the reservoir with the application of the Trans-Texas Environmental Criteria.[4]

The dam configuration studied by Freese & Nichols is the layout from the 1974 URS report, with minor changes. The dam would be a 26,200-foot earthfill embankment with a top width of 20 feet and 3-to-1 side slopes on both the upstream and downstream sides. The top of the embankment would be at elevation 136.5 feet; the probable maximum flood elevation in the reservoir would be 129.2 feet; and the top of the conservation pool would be elevation 118.0 feet with a surface area of 8,250 acres. Approximately six miles of stream channel along Allen's Creek would be inundated by the reservoir.

The outlet works consist of a 60-inch diameter pipe in the spillway, and a 500-foot uncontrolled concrete ogee spillway with a crest elevation of 118.0 feet. Because the Brazos River would reach the embankment under high flow conditions, slope protection would be needed to protect the downstream face of the dam below elevation 120.0 feet as well as the entire upstream face. The design flood on the Brazos River exceeds the spillway elevation and the spillway would be designed to accommodate flow from the river into the reservoir. Two small dikes of compacted earthfill on the southern shore of the reservoir would be needed to raise the shoreline above the elevation of the Allens Creek probable maximum flood.

Diversion facilities on the Brazos River would include a gated intake channel, pump station, two parallel pipelines to the reservoir, and a discharge structure in the reservoir.

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[2] URS/Forrest and Cotton, "Allens Creek Dam and Reservoir on Allens Creek, Brazos River Basin, Austin County, Texas" (prepared for Houston Lighting and Power Company), July 1977.

[3] Freese & Nichols, Inc., "Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir", February 1989.

[4] Brown & Root, Inc. and Freese & Nichols, Inc., "Trans-Texas Water Program, Southeast Area Phase I Report", March 1994.

3.21.2 Available Yield

The Allens Creek drainage area controlled by the reservoir would be 58.3 square miles and water available from the local watershed during the critical drought period was estimated to be only 3,407 acft/yr. To create a more significant project yield, water must be pumped into the reservoir from the Brazos River during times when flow in the river exceeds the needs of senior downstream water rights. The volume of unappropriated Brazos River water that could be diverted and stored in Allens Creek Reservoir is limited by the capacity of the diversion pumps and by the daily flow in the Brazos River, as well as by the reservoir storage volume. Freese & Nichols[5] reports that the TNRCC estimated the volume of unappropriated water in the Brazos at the proposed diversion to be an average of 3,137,000 acft/yr, with a minimum annual volume of 40,800 acft (1956), and a maximum annual volume of 8,854,000 acft (1957). During the critical drought period from March, 1954 through February 1957, an average of 174,756 acft/yr would be available. These estimates were computed on a monthly basis, using historical flows between 1947 and 1976 adjusted to reflect watershed conditions and existing water rights as of June 30, 1986.

In 1994, Freese & Nichols/Brown & Root[6] updated previous yield studies of Allens Creek Reservoir considering application of the Trans-Texas Environmental Criteria for In-Stream flows and recent water rights granted. They estimated that for a diversion rate of 820 cfs, the project firm yield would be 57,800 acft/yr and for a diversion rate of 1,900 cfs, the firm yield would increase to 85,000 acft/yr. For purposes of this study, the river diversion rate was set at 820 cfs for a firm yield of 57,800 acft/yr.

A water purchase quantity for the Allens Creek alternative was chosen which resulted in a net yield increase of 29,000 acft/yr. It is assumed that the remainder of the Allens Creek Reservoir firm yield (i.e., 28,800 acft/yr) would be purchased by other entities.

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[5] Freese & Nichols, Inc., "Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir", February 1989.

[6] Brown & Root, Inc. and Freese & Nichols, Inc., "Trans-Texas Water Program, Southeast Area Phase I Report", March, 1994.

3.21.3 Environmental Issues

Introduction

Potential environmental issues related to transferring water from the Allens Creek Reservoir project can be categorized as follows:

- Effects due to the construction and operation of the Allens Creek Reservoir project;
- Effects with respect to the Nueces Estuary; and
- Effects along the pipeline ROW.

This water supply alternative, if implemented, would be a combined project with the Lake Texana pipeline (Alternative LN-1). Although a stand-alone supply from the purchase of Brazos River water delivered to Corpus Christi is possible, to reduce environmental impacts, as well as costs, the yield from this project could be blended with Lake Texana water in an up-sized pipeline and delivered to Corpus Christi. Methods used to develop this section, including mapping, searches of existing literature and databases, and a reconnaissance survey are described in the Environmental Overview (Section 3.0.2).

The Affected Environment

Regional Setting

The proposed Allens Creek Reservoir is located in the southern tip of Austin County adjacent to the Brazos River near Wallis, Texas. Winters in the area are mild and summers are hot and humid with a growing season of 282 days. Livestock, poultry, cotton, grain, and peanuts are important economic factors. Austin County's terrain is gently rolling prairie and farmland with the Brazos River forming the county's eastern boundary. The soil is black and rich, and there is oil and gas production. The proposed pipeline route would pass westerly through Wharton and Jackson Counties. A description of the biogeography of Wharton and Jackson Counties is presented in the Environmental Overview (Section 3.0.2).

Soils within the Western Coastal Plain are primarily vertisols. The two dominant soil types found in the area to be inundated by the proposed reservoir consist mainly of Brazoria Clays[6]. Brazoria Clay with less than 1 percent slope, and the Brazoria Clay depressional, are both deep level soils on flood plains adjacent to the Brazos River. Brazoria clay is moderately alkaline and calcareous, poorly drained, surface runoff is slow, permeability is low, the available water capacity is high and the likelihood of erosion is slight. This soil is used mainly for pasture and crops and is well suited to growing corn, soybeans, and forage sorghums. Brazoria depressional soil is slightly lower than surrounding soils and is subject to flooding for short periods. This soil is slightly alkaline and calcareous, poorly drained, surface runoff is slow, permeability is very slow and erosion hazard is slight. Brazoria Clay depressional soil is used mainly for pasture and range with some areas being cropland. Because of the hazard of flooding, both of these soils are poorly suited to urban use.

Impact Assessment

Reservoir

Direct impacts of the proposed reservoir include construction of the dam, inundation of 8,250 acres of primarily bottomland hardwood habitat and cropland, and the withdrawal of water from the Brazos River. The riparian vegetation consists of cedar elm, black willow, hackberry, soapberry, pecan, ash, and poison oak. The area that will be inundated by the proposed reservoir is a complex mosaic of woodlands, grasslands and croplands which have a steady water supply and together provide a high quality habitat for a wide variety of species. Alligator Hole, a 650 acre area of bottomland hardwood surrounding a pond, is located within the conservation pool. This bottomland hardwood community appears to be frequently inundated by flood flows and is considered to be wetland habitat (USGS, Wallis Quad) which will probably require mitigation. Wetland mapping has not been completed for this area, thus a detailed inventory of wetland types is not available for this assessment. An on site survey to delineate wetlands will be required in future phases of the Trans Texas Water Program.

Although no threatened or endangered species are reported by the Texas Natural Heritage Program within the area that would be inundated, a little bluestem-brown seed paspalum series prairie (see Section 3.16.3 for a description of this plant community) and the western smooth green snake (*Ophedrys vernalis blancharidi*) are noted on the Wallis Quadrant within two miles of the reservoir site. This prairie would not be affected by construction or operation of the reservoir. The smooth green snake is not listed under the U.S. Endangered Species Act, however, it is listed by TPWD as S1, "Critically imperiled in state, extremely rare, very vulnerable to extirpation, 5 or fewer occurrences," and endangered.[7] In Texas the Western smooth green snake is known from fewer than 10 specimens, all collected on the coastal plain in Austin, Chambers, Harris, and Matagorda counties.[8] The western smooth green snake inhabits meadows, grassy marshes and moist grassy fields along forest edges.[9] Other important species potentially occurring in the counties of the project area are listed in Appendix C, Tables 7, 10 and 20. Habitats capable of supporting some of these may occur in the immediate vicinity of the project (Table 3.21-1).

Table 3.21-1
Water Quality of Lower Brazos River[1]

Constituent	Average Annual Concentration, 1988 to 1993 (mg/l)	Maximum Monthly Concentration[2], 1988 to 1993 (mg/l)
Dissolved Chlorides	81	240
Total Dissolved Solids	334	737
Dissolved Sulfates	57	150
Hardness (Ca, Mg)	164	280

1 Source: USGS, Water Resources Data Reports, Water Years 1988 to 1993. Brazos River at Richmond, Gage No. 08114000
2 Maximum monthly specific conductance in past six years occurred November, 1992.

The Brazos River has already filled its Pleistocene river valley with sediments, so that its estuary consists only of the lower few miles of channel before it discharges into the Gulf of Mexico. Potential firm yield has been estimated based on compliance with the Trans-Texas criteria for maintaining inflows to estuarine areas. Diverting 29,000 acft/yr under this alternative represents only 1 percent of the estimated 3,137,000 acft/yr of unappropriated water

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[7] TPWD. 1993. Texas Natural Heritage Program. Special Animal List. 06 October 1993.

[8] Tennant, A. 1985. A Field Guide to Texas Snakes. Texas Monthly Press.

[9] Behler, J.L. 1979. The Audubon Society Field Guide to North American Reptiles and Amphibians. Alfred A. Knopf, New York.

in the Brazos River at the proposed diversion. The remainder of the firm yield of Allens Creek Reservoir would represent another 1 percent of the unappropriated water.

The Pipeline ROW

Construction of the 70 mile long transmission line from Allens Creek to the Lake Texana pipeline would require a construction ROW 140 feet wide affecting a total area of 1194 acres. A mowed ROW of 341 acres (40 feet wide) would be maintained for the life of the project. The largest habitat types that would be impacted by construction are cropland and pasture (1132 acres, 95 percent of the total area) and woodland (62 acres, 5 percent) which is primarily associated with river and creek crossings. The construction of the pipeline would require the clearing and removal of woody vegetation, however, the woodland acreage given above may be viewed as a maximum value. The woodland acreage impacted could be reduced by judicious placement of the final pipeline alignment. Impacts on wildlife habitats can generally be avoided by locating the pipeline ROW in previously disturbed areas, such as cropland and pasture. A cleared pipeline ROW through a woodland or brushy habitat could be beneficial to some wildlife by providing edge habitat, except in situations where the habitat is already highly fragmented. Major rivers and streams crossed by the proposed pipeline include the San Bernardo and Colorado Rivers, and Mustang Creek.

Although the Texas Natural Heritage Program does not report any endangered or threatened species within the pipeline corridor, a rare prairie remnant community and rare species have been confirmed and located within several miles of the proposed pipeline corridor. These include the little bluestem-brownseed paspalum series (on Highway 71, a quarter of a mile north of where the proposed pipeline route crosses the highway), the western smooth green snake (*Ophedrys vernalis blancharidi*) on the Wallis Quadrangle, Attwater's greater prairie chicken (*Cupido tympanicus attwateri*) on the Lissie Quadrangle, and Guadalupe bass (*Micropterus treculi)* in the Colorado River on the Bonus Quadrangle.

The transmission line at Allens Creek Reservoir is approximately 2 miles east from the closest confirmed observation of Attwater's prairie chicken. Attwater's prairie chicken is dependent upon areas that are composed of more than 50% tall grass prairie climax species, such as big and little bluestem, Indian grass and brownseed Paspalum. The effects of the construction on this habitat would be minimal if a proper corridor is chosen. If appropriate revegetation and management procedures are employed within the transmission line ROW the habitat could be managed for the benefit of the Attwater's prairie chicken. Implementation of this alternative is expected to require field surveys for protected species, vegetation, habitats, and cultural resources during ROW selection to avoid or minimize adverse impacts.

3.21.4 Water Quality and Treatment

Average annual and maximum monthly concentrations of four water quality parameters for the Brazos River at Richmond are presented in Table 3.21-1 for a six year period. The TNRCC standard for chlorides and sulfates is 300 mg/l and for total dissolved solids is 1,000 mg/l Table 3.21-1 indicates that the average annual concentration was 81 mg/l for chlorides, 57 mg/l for sulfates and 334 mg/l for total dissolved solids. Maximum monthly concentrations over the past six years has been 240 mg/1 for chlorides and 737 mg/1 for total dissolved solids. For comparison, the median chloride concentrations of water from Lake Texana and the Nueces River at Mathis are 21 mg/l and 73 mg/l, respectively (Appendix D, Figure D-4). The median total dissolved solids concentrations at Lake Texana and Nueces River at Mathis are 132 mg/l and 341 mg/l, respectively.

During periods of low flow the Brazos River has exhibited much higher concentrations of chlorides and TDS, ranging as high as 1,690 mg/l TDS[10]. If the importation of Brazos River water should continue to be considered as an alternative water supply for Corpus Christi, specific water quality assessments should be completed in later phases of the study, (refer to Appendix E for more a detailed consideration of treatment issues).

3.21.5 Engineering and Costing

The water supply alternative as presented here is a combined project with the Lake Texana Pipeline (Alt. LN-1). A stand-alone supply from Allens Creek Reservoir delivered to Corpus Christi is possible, but the costs would be significantly higher. Additionally, it is

[10] USGS, Brazos River at Richmond, Gage 08114000, specific conductance of 2,600 microsiemens on 9/4/78, TDS calculated as 65 percent of specific conductance.

assumed for preliminary costing purposes that the Allens Creek Reservoir would be constructed as a stand-alone reservoir by the Brazos River Authority (BRA) or another entity. As such, water from the reservoir would not be priced at BRA's system rate. If, however, it is determined that the Allens Creek Reservoir could be constructed by BRA as part of their system, then the cost presented herein needs to be recalculated.

The stored water purchased from the Allens Creek Reservoir project would be diverted at a uniform rate of 2,420 acft/month (or about 27 mgd assuming 5 percent downtime of the pumps) through an intake at the reservoir. A pump station at the intake structure would pump the water through a 42-inch diameter transmission pipeline to a junction with the Texana Pipeline south of Edna. At this location, the Allens Creek water would be combined with water from Lake Texana and pumped to the O.N. Stevens Water Treatment Plant near Calallen. The major facilities required to implement this alternative are:

River Diversion, Intake, and Pump Station on the Brazos River
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Transmission Pipeline from Allens Creek Reservoir to Texana Pipeline
Up-sized Transmission Pipeline from Lake Texana to Corpus Christi
Booster Pump Stations
Tie-in to O.N. Stevens Water Treatment Plant

The cost estimate for the reservoir and dam is an update of the estimate prepared by Freese & Nichols, in which they estimated the reservoir and dam to cost $57 million in 1988 dollars, including permitting and environmental mitigation; the cost estimate for the river diversion, pump station, and pipeline was $15.9 million. The 1988 cost estimate for each of the project components was updated by multiplying the individual cost components of the estimate by the relevant ENR CCI or USBR construction cost index ratios (1995/1988). The mid-1995 estimated total project cost for the dam and reservoir plus other facilities including the river intake and pump station sized to deliver 820 cfs into Allens Creek Reservoir through two 120-inch diameter pipelines, totals $192,680,000. The cost of the dam and reservoir is pro-rated 50 percent to this alternative as shown in Table 3.21-2, with the remaining pro-rata cost to be borne by other entities purchasing the remaining project yield.

Table 3.21-2 Cost Estimate for Allens Creek Reservoir and Pipeline to Texana Pump Station (B-3) Pumping All Year, Flow = 29,000 acft/yr; 27 mgd (Mid-1995 Prices)		
Item	**Estimated Cost**	
	Complete Project	**Pro-Rata Cost for This Alternative**[1]
Capital Cost		
Dam, Reservoir, and River Intake	$63,800,000	$31,900,000
Reservoir Intake and Pump Station	2,050,000	2,050,000
Transmission Pipeline and Booster Pump Station to Lake Texana	35,400,000	35,400,000
Subtotal	$101,250,000	$69,350,000
Engineering, Legal and Contingencies (Pipelines 30%; Other Facilities 35%)	33,530,000	22,500,000
Subtotal	$134,780,000	$91,850,000
Environmental Studies and Mitigation	21,860,000	10,930,000
Land Easements	26,150,000	13,075,000
Subtotal	$182,790,000	$115,855,000
Interest During Construction	9,890,000	6,950,000
Total Project Cost	$192,680,000	$122,805,000
Annual Cost		
Annual Debt Service	$18,054,000	$11,507,000
Annual Operation and Maintenance (Excluding Power)	1,654,000	827,000
Annual Power	1,182,000	1,182,000
Total Annual Cost	$20,890,000	$13,516,000

(1) Pro-rata cost corresponding to 29,000 acft/yr of reservoir total yield. Pro-rata portion is calculated as 29,000/57,800 = 0.50

From Lake Texana to Corpus Christi, facility and operation costs are estimated for a combined water delivery of 60,440 acft/yr. This is the quantity resulting from the purchase of 29,000 acft/yr stored water from Allens Creek Reservoir added to the 31,440 acft/yr that the City of Corpus Christi has purchased from LNRA on a permanent basis from the yield of Lake Texana. The 60,440 acft/yr would be delivered to the O.N. Stevens Water Treatment Plant at a uniform rate of 5,037 acft/month throughout the year. Assuming five percent down time for the pumping equipment, the pumping rate would be about 57 mgd and the pipeline size would be 60 inches diameter. Project costs for purchase and delivery of the water from Allens Creek Reservoir are summarized in Table 3.21-2, costs of the Texana Pipeline to Corpus Christi are summarized in Table 3.21-3, and summary cost table is provided in Table 3.21-4. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $16,325,000 for the portions of the project associated with delivery of Allens Creek Reservoir water to Calallen (Table 3.21-4). Operation and maintenance costs, including power, total $4,105,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $20,430,000. The resulting annual cost of the additional 29,000 acft/yr delivered to Calallen is $704 per acft. Implementation of this alternative as a stand-alone project would result in significantly higher cost.

3.21.6 Implementation Issues

As formulated here, this alternative is combined with the Texana Pipeline (Alt. LN-1) and an agreement with the Lavaca-Navidad River Authority would be necessary for use of any of their pipeline and pumping facilities. Since water under this alternative would not be stored in Lake Texana an agreement for use of storage space in Lake Texana would not be required.

<u>Requirements Specific to Dams and Reservoirs</u>

1. It will be necessary to obtain these permits:
    a. TNRCC Water Right and Storage permits.
    b. TNRCC Interbasin Transfer Approval.
    c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
    d. GLO Sand and Gravel Removal permits.
    e. GLO Easement for use of state-owned land.
    f. Coastal Coordination Council review.
    g. TPWD Sand, Gravel, and Marl permit

2. Permitting, at a minimum, will require these studies:
    a. Bay and estuary inflow impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.

Table 3.21-3 Cost Estimate for Lake Texana Pipeline to Corpus Christi (B-3) Flow = 60,440 acft/yr (60" diameter) (Mid-1995 Costs)	
Item	**Estimated Cost**
Capital Cost	
Pump Station	$ 4,010,000
Booster Station	2,770,000
Booster Station	3,490,000
Pipeline	70,060,000
Tunneling at Environmental Features	2,110,000
Subtotal	$82,440,000
Engineering, Legal and Contingencies (Pipelines 25%; Other Facilities 30%)	21,110,000
Subtotal	$103,550,000
Environmental Studies and Mitigation	340,000
Land Easements	550,000
Subtotal	$104,440,000
Interest During Construction	3,130,000
Total Project Cost	$107,570,000
Annual Cost	
Annual Debt Service	$10,080,000
Annual Operation and Maintenance (Excluding Power)	1,093,000
Annual Power	3,273,000
Annual Cost of Water[1]	2,071,000
Total Annual Cost	$16,517,000

(1) From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.

3. Land will need to be acquired by negotiations or condemnation.

4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

5. The project will require a sponsoring agency to obtain permits, financing, and construct the project. Additionally, the sponsoring agency will need to find purchasers for the yield of the reservoir not purchased by Corpus Christi, or have other uses for remaining yield. Corpus Christi would need to enter into a water purchase agreement with the sponsoring agency.

Table 3.21-4
Summary Cost Estimate for Purchase of Brazos River Water (B-3)
(mid-1995 Costs)

Annual Delivery to Corpus Christi(1):		60,440 acft/Yr	
Delivery Rate at Corpus Christi:		57 MGD	
Pipe Diameter (Texana to Corpus Christi):		60 Inches	
Pipeline Length from Texana to O.N.Stevens:		104 Miles	
Annual Diversion from Brazos River Basin:		29,000 acft/yr	
Annual Yield Increase:		29,000 acft/yr	
Delivery Rate from Allens Creek Reservoir(2):		27 MGD	
Pipeline Diameter (Allens Creek Reservoir to Texana Pump Station):		42 Inches	
Pipeline Length from Allens Creek Reservoir to Texana Pump Station:		69 Miles	
Capital Cost Summary	**Total Project**	**LNRA (Texana) Portion(3)**	**Cost for this Alternative**
Allens Creek Dam and Reservoir(4), including Intake, Pump Station, and Pipeline to Texana:	$122,805,000	- -	$122,805,000
Pump Station at Texana and Booster Stations and Pipeline to Corpus Christi:	107,570,000	55,936,000	51,634,000
Total Capital Costs	$230,375,000	$55,936,000	$174,439,000
Annual Cost Summary	**Total Project**	**LNRA (Texana) Portion(3)**	**Cost for this Alternative**
Estimated Annual Debt Service:	$21,590,000	$5,240,000	$16,350,000
Estimated Annual O&M:	6,375,000	2,270,000	4,105,000
Annual Payment for Water:	2,071,000	2,071,000(5)	0
Total Annual Costs	$30,036,000	$9,581,000	$20,455,000
Average Annual Cost for Each Acre-Foot Delivery at Corpus Christi:	$497	$305	$704

(1) Consists of 31,440 acft/yr of LNRA water (52%) and 29,000 acft/yr of Colorado water (48%).
(2) Rate is based on uniform diversion of 32,000 acft/yr and 5 percent pump downtime.
(3) Calculated as 52% of Texana Pipeline costs for delivery of 60,440 acft/yr; from Table 3.21-3.
(4) Pro-rata portion of Allens Creek Reservoir capital cost corresponding to purchase of 29,000 acft/yr.
(5) From Table 3.13-1 for purchase of 31,440 acft/yr from LNRA.

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 Coordination Council review.
   d. TPWD Sand, Gravel and Marl permit for river crossings.

2. Right-of-way and easement acquisition.

3. Crossings:
   a. Highways and railroads
   b. Creeks and rivers
   c. Other utilities

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4.0 INTEGRATED WATER SUPPLY PLANS

4.1 Objectives

Alternative integrated water supply plans have been developed to assist the City of Corpus Christi in acquiring sufficient water supplies to meet the projected demands of the area through the year 2050. In developing the plan, long-term dependability and availability, water quality, environmental impact, and affordability have been paramount concerns. The plans presented here provide a framework for the City to periodically assess whether the TWDB demand projections made in 1992 are reasonably on target or whether the implementation of the plan should be expedited (i.e., the demand growth is exceeding projections) or postponed (i.e., the demand growth is lower than the projections). Thus, the plans allow for a large degree of flexibility with respect to the timing of implementation of alternatives.

Specifically, the integrated water supply plans meet the following needs for additional water supplies by either adding additional supply from available alternatives or by reducing demands through water conservation measures:

Year	Additional Water Supply Needed (acft/yr)
2000	0
2010	14,500
2020	34,500
2030	56,500
2040	78,500
2050	100,500

4.2 Comparisons and Grouping of 22 Alternatives

A total of 22 water supply alternatives were investigated during the course of the Phase I and II studies. These alternatives are summarized in Table 4.2-1. These 22 water supply alternatives were screened with respect to four critical concerns: (a) unit cost; (b) additional water supply quantity; (c) total acres of land impacted; and (d) water quality. A comparison of how each alternative compares to the others with respect to these four critical concerns is shown in Figure 4.2-1. This comparison resulted in a relative ranking of alternatives. These rankings together with other issues (such as degree of certainty, willingness of others to sell water rights, basin of origin supply/demand balances, and back-up supplies in case of a more severe drought), resulted in grouping the twenty-two alternatives into four categories or groups. These four groups are discussed here:

Group 1 Alternatives include those that are reasonably developable and that provide a permanent, dependable and affordable source of good quality water to the area, with minimal environmental impacts (Table 4.2-2). Group 1 includes four alternatives: modifications of the Choke Canyon/Lake Corpus Christi Reservoir Operating Policy to incorporate the TNRCC 1995 Agreed Order, Accelerated/Additional Conservation, the Lake Texana Pipeline, and the Purchase and Diversion of Garwood Water Rights via Garwood/Colorado Pipeline. The combined supply available from this group totals 82,940 acft/yr or about 83 percent of the projected 2050 additional water needs of the area.

Table 4.2-2
Group 1 Alternatives
(Dependable, Permanent, & Affordable Options)

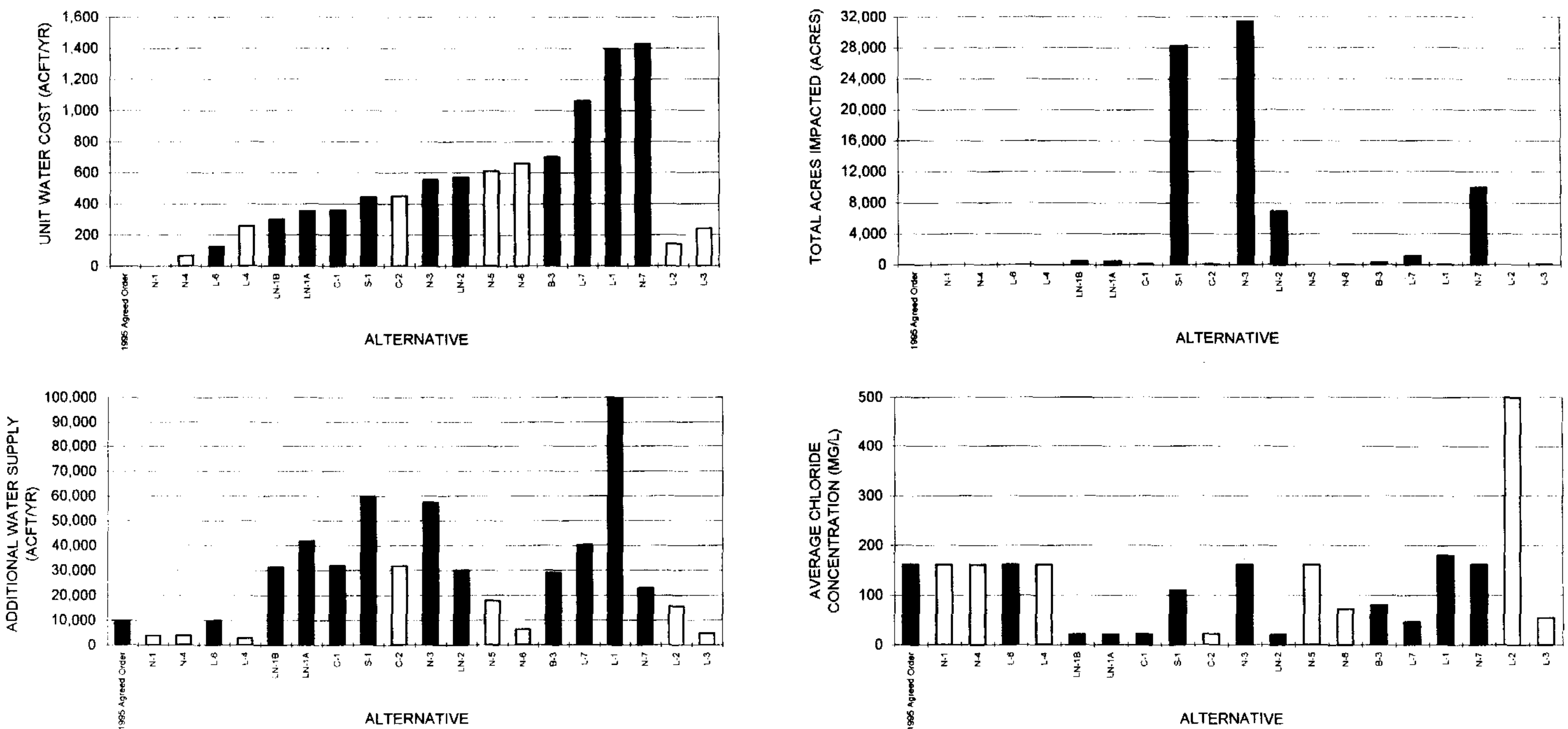
Alternative	Long-Term Permanent Supply (acft/yr)
Modification of Choke Canyon/Lake Corpus Christi Reservoir Operating Policy to incorporate 1995 Agreed Order (N-1)	9,500[1]
Accelerated and Additional Conservation (L-6)	10,000[2]
Lake Texana Pipeline (LN-1)	31,440[3]
Purchase and Diversion of Garwood Water Rights via Garwood/Colorado Pipeline (C-1)	32,000[3]
TOTAL	82,940

[1] The 1995 Agreed Order was issued by the TNRCC on 4/28/95. This order resulted in releases from the City's reservoirs being limited to measured monthly reservoir inflows thereby increasing the system yield. Under 1990 sediment conditions, the yield is increased by 13,500 acft/yr and under 2050 sediment conditions, the yield is increased by 9,500 acft/yr under the City's Phase II reservoir operating policy.
[2] Start in 1996 and fully effective by 2020.
[3] Garwood diversion of 35,000 acft/yr would yield 32,000 acft/yr at Lake Texana, of which 10,400 acft/yr could be used to replace the Lake Texana water reserved for potential future water demands of Jackson County (10,400 acft/yr) resulting in a combined availability of 63,440 acft/yr considering both sources for delivery to Corpus Christi through the Lake Texana Pipeline.

Table 4.2-1 - Summary of Potential Water Supply Alternatives for Corpus Christi Service Area

Alternative	Additional Water Supply (acft/yr)	Unit Cost of Additional Water ($ per acft/yr)	Environmental Issues/Special Concerns
Group 1 Alternatives: Dependable, Permanent, and Affordable Supply Options			
N-1 Modify Reservoir Operating Policy 1995 Agreed Order	9,500	$0	City is in process of implementing this alternative.
L-6 Accelerated and Additional Municipal Water Conservation	10,000	$128	Degree of participation uncertain/reduction of wastewater flow will require additional reservoir releases and/or reduce freshwater inflows to estuary.
L-5 Industrial Water Conservation	--	--	Corpus Christi industries lead the State in water conservation measures already implemented/future conservation effects are included in water demand projections.
LN-1 Lake Texana Pipeline to Corpus Christi A. Total LNRA Contract Quantity (stand-alone) B. Permanent LNRA Contract Quantity (combined with other alternatives)	 41,840 31,440	 $355 $305	504 acres for permanent easement/interbasin transfer/permit contains final release provisions for Lavaca Estuary inflow/increase in Nueces Estuary inflows/existing reservoir with long-term water available/good quality water available for blending with other water sources.
C-1 Purchase and Diversion of Garwood Water Rights to Corpus Christi Existing Garwood water (combined with LN-1B)	 32,000[1]	 $360	Additional 144 acres for permanent easement/interbasin transfer/reduction of Colorado Estuary inflow/increase in Nueces Estuary inflows.
Group 2 Alternatives: Stand-By Water Supply Options			
L-2 Local Groundwater Options (Gulf Coast Aquifer) A. Existing Wells Near LCC B. New Sinton Well Field	 15,600[2] 33,600[2]	 $142-314[3] $285-998[3]	Potential for degradation of water quality and saltwater intrusion could limit long-term dependability/possible subsidence/brine disposal/ability to secure lease rights to develop well field/ impact on neighboring wells/ uncertain dependability/continue to use as emergency back-up.
L-3 Use of Groundwater from Campbellton Wells (Carrizo Aquifer)	4,800	$250	118 acres for permanent easement/lowering of groundwater levels near Campbellton.
Group 3 Alternatives: Potentially Dependable, Permanent, and Affordable Options (need further investigation)			
N-1 Modify Reservoir Operating Policy Lower LCC Target from 88 ft-msl to 87 ft-msl (60 days of storage)	 4,000	 $0	Impact to Recreational Users from following average lake level changes: - 2 inches @ Lake Corpus Christi and +9 inches @ Choke Canyon Reservoir.
N-4 Purchase of Existing Water Rights in Nueces Basin A. Lower Basin Rights; purchase of 4,940 acft/yr B. Upper Basin Rights; purchase of 34,000 acft/yr	 3,260 3,500	 < $70 $431	Uncertainty of owner's willingness to sell rights/value of rights vary depending on location relative to CC/LCC System/relatively small increase in system yield.
N-5 Pipeline from Choke Canyon to Lake Corpus Christi	18,000	$633	145 acres for permanent easement/reduction in Nueces River flows below Choke Canyon Reservoir.
N-6 Pipeline from Lake Corpus Christi to O.N. Stevens W.T.P.	6,500	$686	113 acres for permanent easement/reduction in Nueces River flows below Lake Corpus Christi.
L-4 Municipal Wastewater Reuse (Nueces Delta)	1,100-5,500[4]	$197-710[4]	Degree of credit for diversions to Nueces Bay and Delta are highly uncertain/wastewater permitting requirements uncertain/data needed from demonstration projects.
C-1 Purchase Additional Colorado River Water and Deliver through upsized Garwood and Lake Texana pipelines (combine with LN-1.B)	14,000	$333	No additional easement required/interbasin transfer/reduction of Colorado Estuary inflow/increase in Nueces Estuary inflow
C-2 Purchase of Colorado River Water other than Garwood (combine with LN-1.B)	29,000[1]	$454	Additional 116 acres for permanent easement/interbasin transfer/reduction of Colorado Estuary inflow/increase in Nueces Estuary inflows.
Group 4 Alternatives: Potential Future Options			
N-2 Diversion from Nueces River to Choke Canyon	900	$3,488	No significant increase in system yield.
N-3 R&M Reservoir	57,500	$557	Large environmental impact with 31,400 acres inundated/reduction of Nueces Estuary inflow.
N-7 Dredging Lake Corpus Christi A. Maintenance Program (25-years) B. Accelerated Program (25-years)	 7,200 23,000	 $1,667 $1,430	Cost prohibitive/permit needed for spoil disposal/disposal area will cover 6,800 acres to 20,000 acres, depending on depth.
L-1 Desalination of Seawater	5,000-100,000	$1,400-2,000	Cost prohibitive based on cost data from few existing U.S. plants/permitting for large brine disposal uncertain/very high plant maintenance and replacement costs.
S-1 Goliad Reservoir	0-60,000	$447	Large environmental impact with 28,000 acres inundated/reduction of Guadalupe Estuary inflows/347 acres for easements/water quality studies needed/interbasin transfer/increase in Nueces Estuary inflows/ future San Antonio in-basin needs exceed available supplies.
GS-1 Diversion from Guadalupe & San Antonio Rivers (McFaddin Reservoir)	0	--	1,200 acres inundated/interbasin transfer/future San Antonio-Guadalupe in-basin needs exceed available supplies/reduction of Guadalupe Estuary inflow/increase in Nueces Estuary inflows.
LN-2 Palmetto Bend (Phase II) Reservoir (combined with LN-1.B)	30,000	$575	6,900 acres inundated/permit contains provisions for Lavaca Estuary inflow/increase in Nueces Estuary inflow/interbasin transfer.
LN-3 Diversion from Lavaca River to Lake Texana	<3,000	--	No significant increase in system yield.
L-7 Groundwater Recharge and Recovery (Carrizo/Wilcox Aquifer)	40,300	$1,066	Permit needed from Evergreen Underground Water District and TNRCC/ownership of recharge water and effect of ownership rights on other well owners in recharge area is uncertain.
B-3 Purchase of Brazos River Water (combined with LN-1.B)	29,000	$704	Additional 335 acres for permanent easement/interbasin transfer/reduction of Brazos Riverine Estuary inflow/increase in Nueces Estuary inflows/water quality studies needed.

[1] Costs for Alternative C-1 and C-2 are for diversion of water from the Colorado River to Lake Texana delivered through 12-mile reach of Sandy Creek.
[2] Additional water supply amount listed is only for a two-year drought period and is not a sustainable amount.
[3] Approximate range with minimum cost indicating cost if groundwater is blended with good quality surface water. If treatment of groundwater is required to remove dissolved minerals then the cost would be closer to the maximum cost indicated.
[4] Additional water supply and unit costs are dependent on degree of credits for diversions to Nueces Delta.



Group 1: Dependable, Permanent, and Affordable Supply Options

Group 2: Stand-by Water Supply Options (Two-Year Drought Supply)

Group 3: Potentially Dependable, Permanent, and Affordable (Needs Further Investigation)

Group 4: Potential Future Supply Options

L-1 Desalination
L-2 Local Groundwater - Gulf Coast Aquifer
L-3 Use of Groundwater from Campbellton Wells- Carrizo Aquifer
L-4 Municipal Wastewater Reuse
L-6 Accelerated/Additional Municipal Water Conservation
L-7 Groundwater Recharge and Recovery (Carrizo/Wilcox Aquifer)
N-1 Modify Reservoir Operating Policy
N-3 R & M Reservoir
N-4 Purchase of Existing Water Rights in Nueces Basin
N-5 Pipeline from Choke Canyon to Lake Corpus Christi
N-6 Pipeline from Lake Corpus Christi to O N Stevens W T P
N-7 Dredging of Lake Corpus Christi
LN-1A Lake Texana Pipeline (Stand-Alone)
LN-1B Lake Texana Pipeline (Combined w/other Alternatives
LN-2 Palmetto Bend (Phase II) Reservoir
S-1 Goliad Reservoir
C-1 Garwood Irrigation Water (w/ LN-1)
C-2 Purchase of Colorado River Water (w/ LN-1)
B-3 Purchase of Brazos River Water (w/ LN-1)

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UNIT WATER COSTS, ADDITIONAL WATER SUPPLY, TOTAL ACRES IMPACTED AND WATER QUALITY FOR WATER SUPPLY ALTERNATIVES

HDR

FIGURE 4.2-1

Group 2 Alternatives are stand-by supplies available to meet emergency conditions. These consist of affordable groundwater supplies which are presently or potentially available to the area in the event a drought more severe than previous droughts were to occur. These alternatives generally have low environmental impacts, provided pumpage of groundwater is limited so as to not overdraft the aquifer systems. The water quality associated with these alternatives is generally poorer than existing surface water supplies, but is acceptable for drinking purposes if blended with the better quality surface water. Included in this group are the existing wells near Lake Corpus Christi, the Campbellton Well Field, and a potential new well field north of Sinton. Table 4.2-3 lists the water supply alternatives included in Group 2, as well an estimate of the annual water supply that could be obtained from each option during a 2-year drought period.

Table 4.2-3
Group 2 Alternatives
(Stand-By Options)

Alternative	**Two-Year Drought Supply** (acft/yr)
Existing Wells near Nueces River and Lake Corpus Christi[(1)] (L-2)	15,600
Potential New Sinton Well Field[(2)] (L-2)	33,600
Existing Campbellton Wells (L-3) - Delivered to Choke Canyon Reservoir via pipeline	4,800[3]

[1] Could be combined with proposed pipeline from LCC to O.N. Stevens WTP (i.e., Alternative N-6), if pipeline were constructed.
[2] Potential stand-by option for either San Patricio County or Nueces County entities. However, considerable additional study is needed to further determine the feasibility of this alternative.
[3] Sustainable beyond 2 years.

Group 3 Alternatives include water supply options that, with additional investigation, could potentially become part of the Group 1 Alternatives and provide a permanent, dependable, and affordable water supply. However, these options require a significant additional planning, permitting, or implementation effort. Generally these alternatives have reasonably small to moderate environmental impacts relative to the other alternatives in this study. Table 4.2-4 lists the possible long-range options comprising Group 3, the estimated range of additional annual supply available, as well as a list of

Table 4.2-4 Group 3 Alternatives (Potentially Dependable, Permanent, and Affordable Options)		
Alternative	**Range of Potential Long-Term Permanent Supply** (acft/yr)	**Issues Needing Additional Investigation**
Modification of Choke Canyon/Lake Corpus Christi Reservoir Operating Policy (N-1)	4,000	Reservoir Sedimentation Survey and Water Delivery Loss Study
Purchase of Existing Water Rights in Nueces River Basin (N-4) A. Lower Basin Rights B. Upper Basin Rights	 0 - 3,261 0 - 3,500	Willingness of owners to sell water rights
Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5)	18,000 ±	Water Delivery Loss Study
Pipeline from Lake Corpus Christi to O.N. Stevens Water Treatment Plant (N-6)	6,500 ±	Water Delivery Loss Study and Water Quality Evaluation
Municipal Wastewater Reuse (L-4) (Diversions to Nueces Delta)	1,100 - 5,500	Establishment of Biological Productivity Credits and Relief of TNRCC Effluent Standards
Purchase and Diversion of Additional Garwood Water Rights and/or other Colorado River Water through upsized Garwood Pipeline (C-1) and (C-2)	14,000	Willingness of owners to sell water rights and other water rights issues.
Purchase of Colorado River Water (other than Garwood) (C-2)	32,000	Willingness of owners to sell water rights and other water rights issues.

issues needing additional investigation. Included in this group are: Modification of the Choke Canyon/Lake Corpus Christi Reservoir Operating Policy to use a Lake Corpus Christi lake level at elevations below 88 ft-msl; Purchase of Existing Water Rights in the Nueces River Basin; Pipelines from Choke Canyon Reservoir to Lake Corpus Christi and from Lake Corpus Christi to the O.N. Stevens Water Treatment Plant; Diversions of Municipal Wastewater to the Nueces Delta; and Purchase and Diversion of Additional Garwood Water Rights and/or other Colorado River Water.

Group 4 Alternatives include potential future water supply options that have one or more significant issues that limit present feasibility. Limiting issues include a large degree of uncertainty, limited permanent water available, high costs, and/or significant environmental impacts as compared to the other alternatives. Table 4.2-5 lists the potential future supply options of Group 4, the estimated range of additional water supply available, as well as a listing of the present limiting issue(s) for each option. The following options are included in this group: Diversion from Nueces River to Choke Canyon Reservoir; R&M Reservoir; Desalination of Seawater; Goliad Reservoir (San Antonio River Basin); Diversion from Guadalupe/San Antonio rivers (with or without McFaddin Reservoir); Palmetto Bend (Stage II) Reservoir; Diversion from Lavaca River to Lake Texana; Groundwater Recharge and Recovery (Carrizo/Wilcox Aquifer); Dredging Lake Corpus Christi; and Purchase of Brazos River Water.

Some of the alternatives in Group 4 could potentially become viable alternatives if limiting issues are resolved in the future. For example, if significant technological breakthroughs occur in desalination processes, it may be appropriate to move this option, or others, into Group 3 for additional investigations.

4.3 Development of Integrated Water Supply Plans

From a review of the four alternative water supply groups, two potential integrated water supply plans have been formulated, each of which will provide an additional 100,500 acft/yr by 2050. Each plan includes alternatives which have a high degree of certainty, and provide permanent, dependable and affordable good quality water to the area, with minimal environmental impacts. Each plan includes the four alternatives contained in Group 1. These alternatives are: Modification of Choke Canyon/Lake Corpus Christi Reservoir Operating Policy to incorporate TNRCC 1995 Agreed Order; Accelerated and Additional Conservation (start in 1996 and fully effective by 2020); Lake Texana Pipeline; and Purchase and Diversion of Garwood Water Rights via Garwood/Colorado Pipeline.

These alternatives provide a total permanent supply of about 83,000 acft/yr which is about 17,500 acft/yr short of the year 2050 projected demand of 100,500 acft/yr. Considering

Table 4.2-5 Group 4 Alternatives (Potential Future Options[1])		
Alternative	**Range of Potential Long-Term Permanent Supply** (acft/yr)	**Present Limiting Issues**
Diversion from Nueces River to Choke Canyon Reservoir (N-2)	900	Supply limited; high cost.
R & M Reservoir (N-3)	57,000±	High costs and large environmental impact.
Desalination of Seawater (L-1)	5,000 - 100,000	Very high cost.
Goliad Reservoir (S-1) (San Antonio River Basin)	0 - 60,000	Large environmental impact; highly uncertain water rights issues.
Diversion from Guadalupe/San Antonio Rivers (GS-1) (with or without McFaddin Reservoir)	0 - 39,500	Highly uncertain water rights issues.
Palmetto Bend (Stage II) Reservoir (LN-2)	30,000	Quantification of estuary releases.
Diversion from Lavaca River to Lake Texana (LN-3)	< 3,000	Supply limited.
Groundwater Recharge and Recovery (L-7) (Carrizo/Wilcox Aquifer)	40,300	Uncertain legal issues; high cost.
Dredging Lake Corpus Christi (N-7)	7,200 - 23,000	High cost; uncertain environmental permitting issues.
Purchase of Brazos River Water (B-3)	29,000	High cost.

[1] Includes options which have either a large degree of uncertainty, high environmental impact, high unit costs or provide limited firm water supply.

the six alternatives from Group 3 (see Table 4.2-4), it was decided that alternatives from this group with the highest degree of certainty and reasonable cost would be included in the two plans. For Plan A, this included the Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (Alternative N-5) which is estimated to supply about 18,000 acft/yr as indicated on Table 4.2-4. For Plan B, Modifications of the Choke Canyon/Lake Corpus Christi Reservoir Operating Policy (Alternative N-1) which would supply an estimated additional 4,000 acft/yr

(2050 conditions) as well as the Purchase and Diversion of Additional Colorado River water (either Alternatives C-1 or C-2) which would supply an additional 14,000 acft/yr were included.

Under Plan B it would be necessary to upsize the Lake Texana pipeline and the Garwood/Colorado pipeline to convey the additional 14,000 acft/yr of future supply. For the Lake Texana pipeline, this means upsizing from a 60-inch diameter line to a 66-inch diameter line. For the Garwood/Colorado pipeline this means upsizing from a 48-inch diameter line to a 60-inch diameter line, although the diameter of this line is subject to change depending on the final outcome of the Garwood water rights permit amendment process.

The dates at which each of the individual water supply or demand management components of each plan needs to be available are indicated in Table 4.3-1. These dates are flexible depending on actual growth. For example, if growth exceeds the projected rates, the components of each plan need to be brought on-line sooner and if growth is less than projected, then the implementation of some projects can be delayed. However, one of the most significant items that affects the ultimate cost of each alternative is the interest rate on the necessary bond issue. It would be prudent to allow ample flexibility in the timing of construction so that financing for each project can be obtained at the lowest possible interest rate. The approximate dates each alternative needs to be on-line are shown graphically on Figure 4.3-1 for Plan A and on Figure 4.3-2 for Plan B.

As shown in both Figures 4.3-1 and 4.3-2, implementation of the new 1995 Agreed Order occurs in 1995 while Accelerated/Additional Conservation efforts begin in 1996. Construction of the Lake Texana Pipeline would need to begin no later than 2004 in order to have the project on line by 2007. The Garwood/Colorado pipeline would be needed by about 2029 if growth occurs as projected. For Plan A the pipeline from Choke Canyon Reservoir to Lake Corpus Christi would be needed by about 2039. And for Plan B, by 2039 either the modification of the operating policy of the two reservoirs needs to occur, or additional Colorado water brought in via the Garwood/Colorado and Lake Texana pipeline.

In some water supply systems it has been shown to be feasible to delay construction by tieing implementation of a major water transmission pipeline to drought conditions based on key reservoir levels and water demands. However, in the case of the Corpus Christi System, this type of triggering mechanism would probably not be prudent due to a combination of several

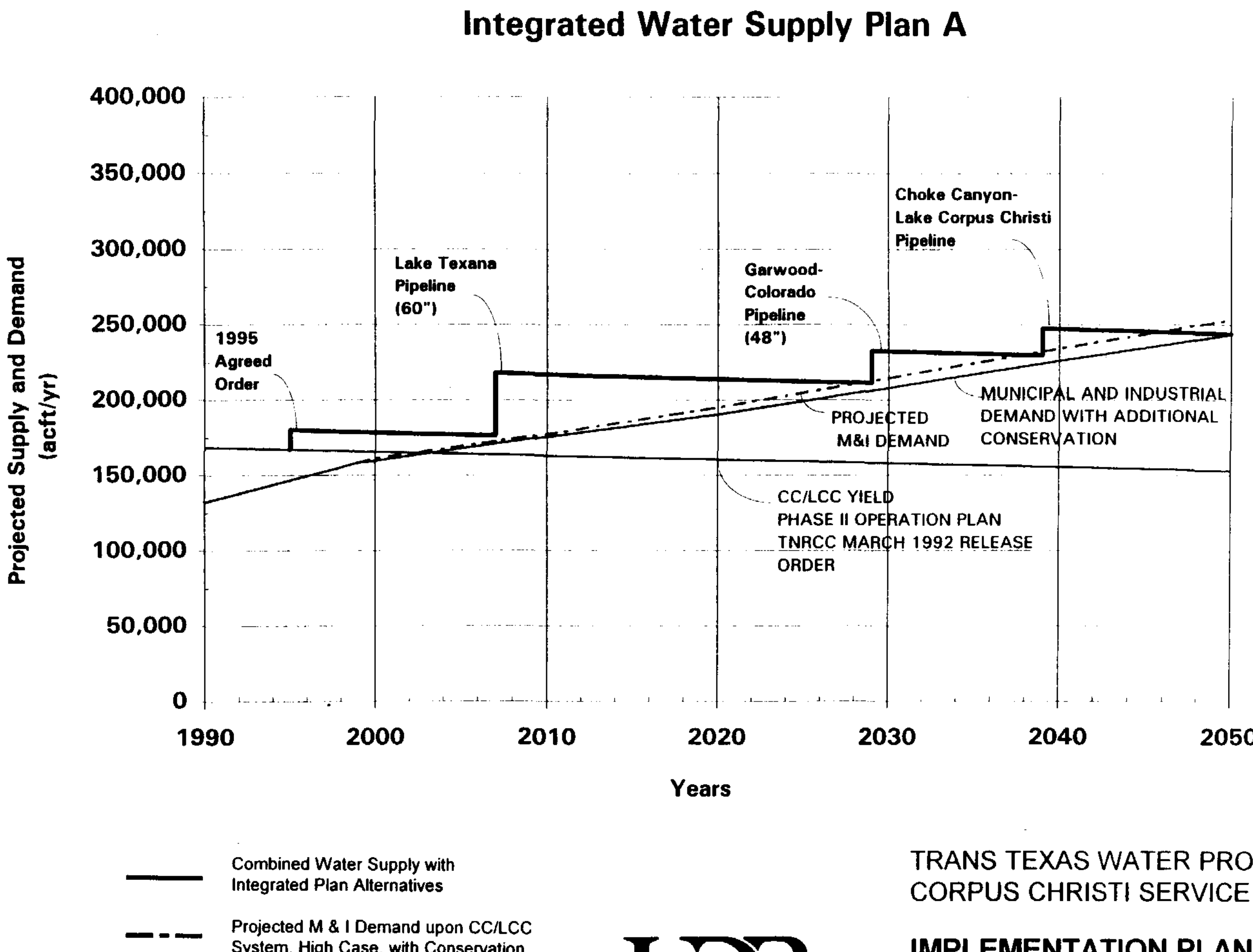
Table 4.3-1 Integrated Water Supply Plans Corpus Christi Service Area		
Plan and Alternatives Included	**Year 2050 Permanent Supply (acft/yr)**	**Estimated Year Water Needs to be Available**
Plan A		
• Modification of Choke Canyon/Lake Corpus Christi: Operating Policy to incorporate 1995 Agreed Order	9,500	1995
• Accelerated/Additional Conservation (L-6)	10,000	1996[3]
• Lake Texana Pipeline (60") (LN-1)	41,840[1]	2007
• Garwood-Colorado Pipeline (C-1)	21,600[1]	2029
• Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5)	18,000	2039
Total	100,940	
Plan B		
• Modification of Choke Canyon/Lake Corpus Christi: Operating Policy to incorporate 1995 Agreed Order	9,500	1995
• Accelerated/Additional Conservation (L-6)	10,000	1996[3]
• Lake Texana Pipeline (66") (LN-1)	41,840[1]	2007
• Garwood-Colorado Pipeline (60") (C-1)	21,600[1]	2029
• Additional Garwood or Colorado River Water (C-1 or C-2)	14,000[2]	2039
• Modification of Choke Canyon/Lake Corpus Christi Operating Policy by changing LCC Target Elevation to 87 ft-msl (N-1)	4,000	2046
Total	100,940	

[1] Corpus Christi has acquired 41,840 acft/yr of Lake Texana water, which includes 10,400 acft/yr reserved for potential future demands in Jackson County. The 41,840 acft/yr will meet projected demands of the Corpus Christi Service Area until 2029, at which time additional quantities will be needed. The completion of facilities in 2029 to begin the transfer of 35,000 acft/yr of Colorado River water purchased from Garwood Irrigation Company would yield about 32,000 acft/yr at Lake Texana, of which 10,400 acft/yr would be available to replace the 10,400 acft/yr of Lake Texana water reserved for potential future demands of Jackson County. This is a reasonable "worst case" assumption as water demand projections for Jackson County show that this water will not be needed before 2050. Under these assumptions, the combined availability of Lake Texana and Garwood water for delivery to the Corpus Christi Service Area after 2029 would be 63,440 acft/yr (41,840 + 32,000 - 10,400 = 63,440). If the 10,400 acft/yr is not needed in Jackson County, then implementation of subsequent alternatives could be delayed.

[2] Additional Colorado River water rights would need to be purchased from either Garwood, LCRA, Pierce Ranch, or others.

[3] Date to begin, with full implementation by 2020.

factors. While the length of the critical drought for the CC/LCC System is only about 42 months, obtaining financing, bidding and construction of the pipeline could require between 18 and 30 months or more. This means that construction would need to start with the Lakes



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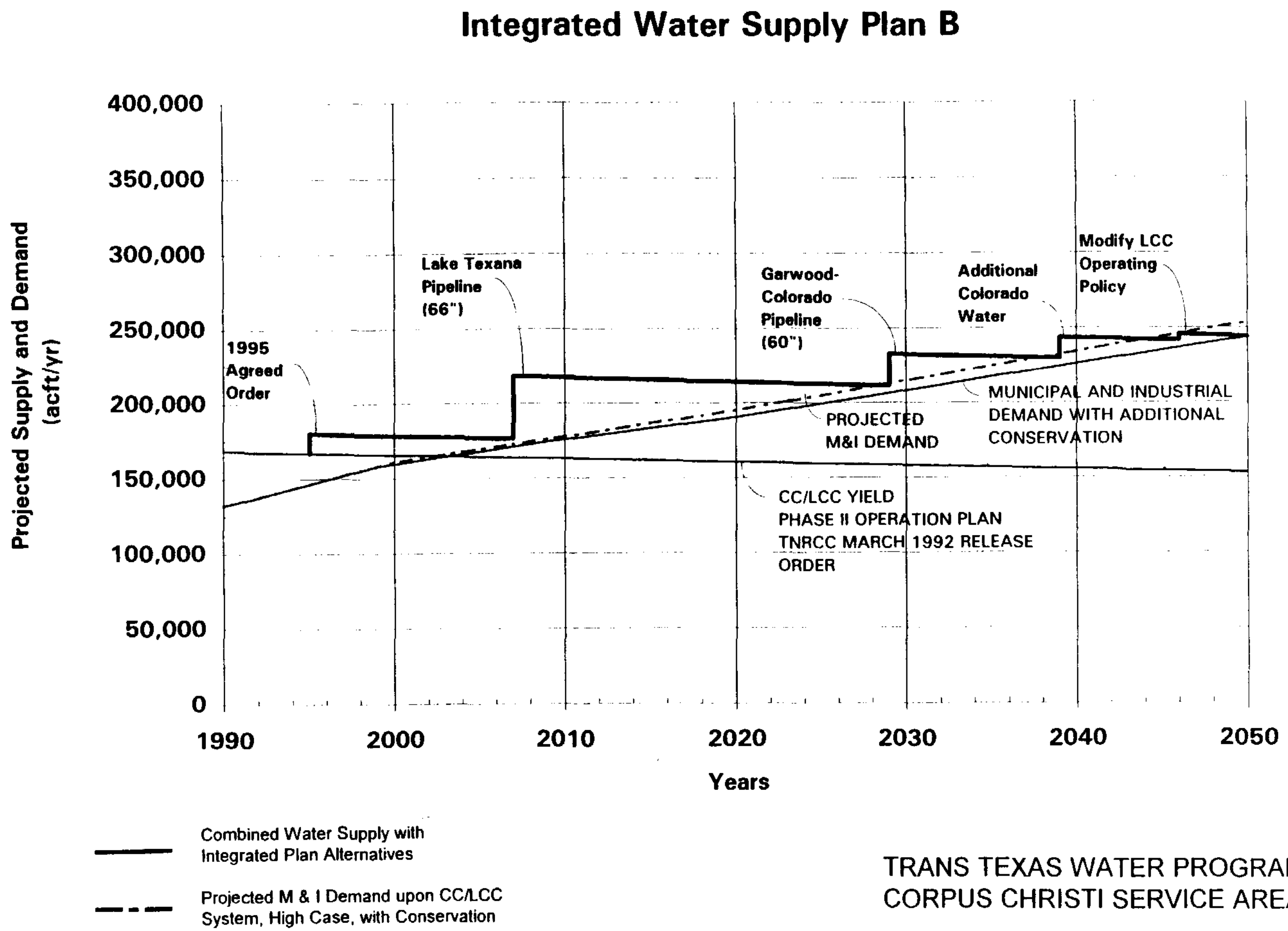
IMPLEMENTATION PLAN FOR INTEGRATED WATER SUPPLY PLAN A

FIGURE 4.3-1



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IMPLEMENTATION PLAN FOR INTEGRATED WATER SUPPLY PLAN B

FIGURE 4.3-2

relatively full in order to have water available from the pipeline (which will then be delivering less than 25 percent of the service area's demands) for a meaningful length of time during the drought. A more appropriate way to time construction of the Lake Texana pipeline is to periodically review records of actual water demands and project these demands forward in time on the basis of estimates of future growth. When these projections indicate that demands are likely to exceed available supply within a 10-year timeframe, then a financing plan for construction should be initiated. As soon as favorable market conditions occur (i.e., low interest rates), financing should be procured, bids obtained, and construction initiated. This type of managed approach will result in minimizing the cost of the pipeline to rate payers in the service area while maintaining a reasonable degree of system reliability. A discussion of each alternative contained in the two water supply plans is included in the following sections.

4.4 1995 Agreed Order for Bay and Estuary Releases

In April, 1995, TNRCC adopted a new bay and estuary release order (1995 Agreed Order) governing fresh water release requirements to the Nueces Estuary that effectively provides about the same quantities of water to the bays and estuary as the 1992 Interim Order, but significantly increases the firm yield of the CC/LCC system (see Appendix O). The major differences between the new 1995 Agreed Order and the 1992 Interim Order are as follows:

1) The water released from the CC/LCC System to satisfy the TNRCC bay and estuary release requirement in a given month is limited to no more than the inflow to LCC as if Choke Canyon Reservoir did not exist.

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 LCC. When the system storage is less than 70 percent, but more than 40 percent, the target schedule is reduced so as to provide 97,000 acft/yr to Nueces Bay/Delta. 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 may be suspended when the City and its customers implement Condition III of the Plan.

The 1995 Agreed Order, like the 1992 Interim Order, provides for relief from bay and estuary release requirements when salinity criteria in Nueces Estuary are met and when spills in the previous month are more than that month's release requirement.

The limiting of releases under the new order increases the firm yield of the CC/LCC System under Phase II Operations Policy by approximately 13,500 acft/yr under 1990 sediment conditions and 9,500 acft/yr under 2050 sediment conditions. A comparison of the firm yields between the 1992 Interim Order and the 1995 Agreed Order is provided in Table 4.4-1.

Table 4.4-1
Comparison of CC/LCC System Firm Yields
Under the 1992 and 1995 TNRCC Release Orders

Reservoir Sedimentation Year	1992 Interim Order Firm Yield Under Phase II Policy (acft/yr)	1995 Agreed Order Firm Yield Under Phase II Policy (acft/yr)	Increase in Firm Yield Due to New Release Order (acft/yr)
1990	168,000	181,500	13,500
2050	153,000	162,500	9,500

The costs to implement this alternative have already been incurred by the City of Corpus Christi. Therefore, no cost for this alternative has been carried forward into either of the two Integrated Water Supply Plans.

4.5 Accelerated and Additional Municipal Water Conservation

The municipal water demand projections in Section 2.0 take into account the conservation effects that will occur due to the legislation of 1991 that specifies that only low flow plumbing fixtures can be sold in Texas after January 1, 1993. The estimated conservation resulting from the installation of low flow plumbing fixtures in new construction and in remodelling and repair of plumbing fixtures in existing dwellings, commercial establishments, and institutions is about 18 to 22 gallons of water per person per day over about a 20-year period. The municipal water demand projections of Section 2.0 include this effect.

An evaluation of conservation methods to accelerate the rate of municipal water conservation, as described above, plus the use of cost-effective methods to obtain conservation in addition to that expected from the use of low flow plumbing fixtures has resulted in a combination of water conservation methods being included in both Integrated Water Supply Plans. These methods or programs include:

1. Public information;
2. Water audits and efficient irrigation plans for areas of one acre and larger;
3. Plumbing retrofit kits consisting of low flow shower heads, faucet aerators, and toilet tank displacement bags provided at no cost to homeowners, with homeowners performing installation; and
4. Landscape standards for new development, with standards designed to reduce lawn and landscape irrigation demands.

The combination of the above methods are estimated to achieve savings in municipal water of 1,520 acft/yr by year 2000, 1,970 acft/yr by year 2010, and 4,585 acft/yr by 2020, and 10,000 acft/yr by 2050 (Table 4.5-1). The public information and water audits are comparatively low cost per acft yield, but have a relatively low, although continuous potential yield. Thus, these methods should be organized in the immediate future and in full operation by year 2000.

Table 4.5-1
Accelerated Additional Water Conservation Program
Corpus Christi Service Area--Trans Texas Water Program

Conservation Practice		Year					
		2000	2010	2020	2030	2040	2050
(1) Public Information	acft $/acft	760 298	878 298	980 298	1,088 298	1,193 298	1,298 298
(2) Water Audits	acft $/acft	442 130	456 130	509 130	565 130	619 130	675 130
(3) Plumbing Retrofit Kits	acft $/acft	318 67	636 67	0 0	0 0	0 0	0 0
(4) Landscape Standards New Development	acft $/acft	0 0	0 0	3,096 100	4,905 100	6,290 100	8,027 100
Total	acft $/acft	1,520 200	1,970 184	4,585 146	6,558 134	8,102 131	10,000 128

The plumbing retrofit kit program is also a relatively low cost program, but also with low yield potential due to the fact it addresses only showers, faucets, and toilet tanks of existing plumbing. It also has a modest acceptance rate (approximately 39 percent installation rate in a 1994 Corpus Christi study).[1] Thus, this program could make a limited, but low cost contribution between now and 2020, at which time most of the existing plumbing fixtures will have been replaced or phased out.[2]

Landscape standards for new development have potentials to reduce peak demands for lawn watering, but would only be effective as new construction is done, which is largely dependent upon growth. Such a program would be essentially regulatory in nature, with the costs of regulation falling on city departments that administer building functions. However, this type of program would require extensive study and development, since it could significantly alter appearances, densities (for example, smaller lot sizes with less lawn area), and physical and social relationships within new subdivisions. Thus, it is estimated that a program of landscape standards for new development would require some time to be fully implemented and is therefore not included in either Plan before 2010. If adopted, this program would phase in as new development occurs.

In summary, an accelerated municipal water conservation program consisting of public information, water audits and efficient irrigation plans for large areas, plumbing retrofit kits, and landscape standards for new development could produce about 10,000 acft/yr of municipal water supply equivalent by the year 2050. The effects of these demand reductions have been included in both Integrated Water Supply Plans. The combined average costs per acft vary from $200 for 1,520 acft in 2000 to $146 per acft in 2020 for 4,585 acft/yr, and as plumbing retrofit is

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[1] "Retrofit Study of Summer Water Use in Single-Family Households, Corpus Christi, Texas," Prouty, Jennifer S., Edward R. Jones, and Gale S. Ketchum, Texas A&M University--Corpus Christi, corpus Christi, Texas, March 1995.

[2] Full scale plumbing retrofit, with low flow shower heads, faucet aerators, and replacement of commodes and urinals with low flush types, and lawn grass replacement are among the most expensive means to save water. Plumbing retrofit and replacement of lawn grass are estimated to have comparable costs of about $1,000 per acft of water saved. Such programs could be initiated at any time, if needed. However, since water saved through plumbing retrofit is high cost in comparison to other alternatives, and since replacement of existing plumbing fixtures will be taking place as remodelling and repair is done, in this analysis neither a full scale plumbing retrofit nor a lawn grass replacement program are included. Refer to Section 3.17 of this report for additional background information.

completed and more of the water savings are obtained through landscape standards for new development, the cost per acft declines to $134 in 2030 and $128 in 2050 (Table 4.5-1). The above costs have been included in both Integrated Water Supply Plans.

4.6 Combined Operation of Lake Texana and Garwood Pipelines with CC/LCC Reservoir System

Under either Plan A or Plan B, the implementation of the Lake Texana pipeline should be completed two years before additional water is projected to be needed in the CC/LCC service area. The pipeline included in Plan A would be 60 inches in diameter and would have capacity to deliver up to 63,440 acft/yr from Lake Texana. This includes water purchased from the Garwood Irrigation Company and transferred to Lake Texana. The pipeline included in Plan B would be 66 inches in diameter and is sized to deliver an additional 14,000 acft/yr purchased from either the Garwood Irrigation Company or owners of other water rights on the Colorado River. When the pipeline becomes operational, the City will have an opportunity to further maximize utilization of the existing CC/LCC System for water supply purposes because the pipeline to Lake Texana provides a dependable, high-quality alternative water source.

4.6.1 Description of Combined Operation

Although the pipeline will be capable of delivering 63,440 to 77,440 acft/yr as soon as it is completed, it will take some time for water demands to grow to a point necessitating continuous operation. During these interim years, while water demands increase, the City will likely strive to minimize pumping costs while attempting to manage the combined system to obtain a reasonable stable blended water quality. One means of minimizing pumping costs would be to maximize utilization of supplies from the CC/LCC System, which can be delivered by gravity, and limit deliveries via pipeline from Lake Texana to avoid power costs associated with pumping. It would be impractical, however, to leave the pipeline idle because water from Lake Texana is much higher quality than that of the CC/LCC System, and thus would be beneficial to the City's residential and industrial customers. Furthermore, the pump stations and pipeline must be "exercised" periodically to ensure dependable operation when water deliveries are needed.

An optimum operation of the two water sources can be accomplished by setting CC/LCC System storage triggers which would allow the majority of water demands to be satisfied by use of the CC/LCC System (except for water quality management purposes and exercise of the pipeline pumps). Once CC/LCC System storage falls below the trigger during drought, the pipeline would be operated at full capacity, significantly reducing diversions from the CC/LCC System at a time when water quality from the Nueces River is most likely to be relatively low and channel losses in the Nueces River are most likely to be relatively high. Combined operation of the CC/LCC System and the pipeline in this way will not only minimize overall power costs and produce an improved, blended water quality, but will increase the firm yield of the CC/LCC System by amounts as much as twice the average annual pipeline delivery volume during the interim years. This potential management method is illustrated in the following example.

4.6.2 Example of Combined Operation

The potential benefits of combined operation of the CC/LCC System and the pipeline from Lake Texana during the interim years after the pipeline is completed, but before water demands necessitate deliveries approaching the maximum pipeline capacity are best illustrated by example. This example is based on Integrated Water Supply Plan A and assumes CC/LCC System operations under the Phase II policy and a 60-inch pipeline from Lake Texana sized to deliver up to 63,440 acft/yr purchased from the Lavaca-Navidad River Authority and Garwood Irrigation Company. Maximum monthly deliveries were set equal to the capacity of the pipeline or 5,800 acft per month. Minimum monthly deliveries were assumed equal to one-twelfth of 10 percent of the annual maximum delivery or 530 acft to allow for maintenance and exercising of the pumps to ensure dependability. The Lower Nueces River Basin & Estuary Model was modified to simulate combined operations subject to CC/LCC System storage triggers for full-capacity deliveries from Lake Texana as well as to compute monthly power costs associated with pipeline deliveries.

Table 4.6-1 and Figure 4.6-1 summarize the potential results of combined operation for CC/LCC System storage triggers ranging from 5 to 100 percent of capacity subject to estimated sediment accumulation for the year 2010. In addition, Figure 4.6-2 illustrates that there is an optimum CC/LCC System storage trigger (about 20 percent of capacity) with respect to the power cost per unit firm yield increase attributable to the Lake Texana pipeline. The following potential scenarios illustrate the interpretation and use of the information presented in Table 4.6-1 and Figures 4.6-1 and 4.6-2:

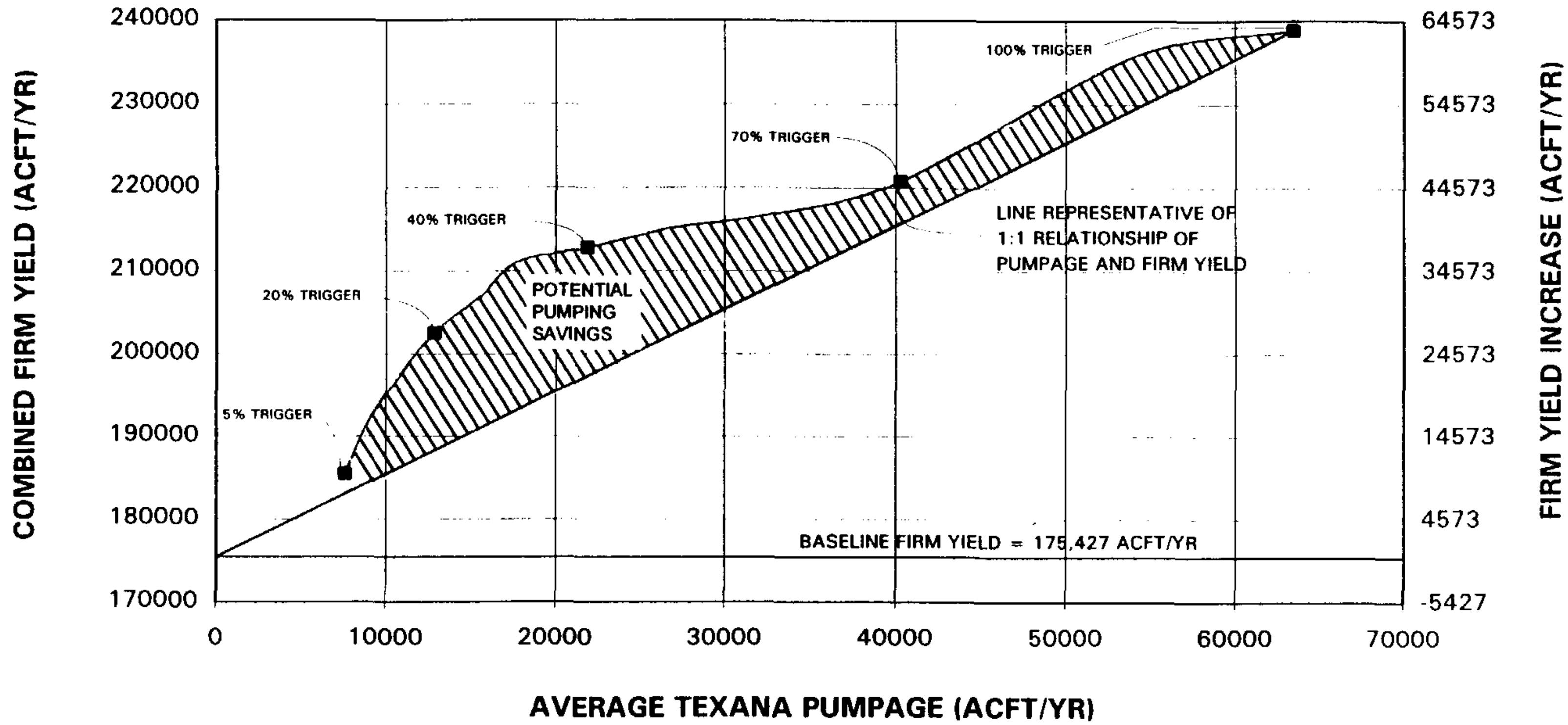
Table 4.6-1
Combined Operation Summary

CC/LCC System Storage Trigger[1] (percent)	**Total Firm Yield**[2] (acft/yr)	**Firm Yield Increase** (acft/yr)	**Average Pipeline Delivery** (acft/yr)	**Average Annual Delivery** (percent of firm yield increase)
100	238,852	63,425	63,440	100%
70	220,810	45,383	40,237	89%
40	212,753	37,326	21,871	59%
20	202,502	27,075	12,814	47%
5	185,420	9,993	7,589	76%

[1] Percentage of CC/LCC System storage capacity below which Texana pipeline is operated at full capacity.
[2] Combined yield of the CC/LCC System under the Phase II operation policy and 2010 sediment accumulation and 60-inch pipeline from the Lake Texana capable of delivering up to 63,440 acft/yr.

Scenario 1 - When water demands reach 202,000 acft/yr, additional firm yield of about 26,000 acft/yr will be required. Assuming a CC/LCC System storage trigger of about 20 percent of capacity, the necessary increase in firm yield can be ensured with an average pipeline delivery of about 13,000 acft/yr and a resulting savings in power costs. Under this scenario, the pipeline will need to be operating at full capacity only about 12 percent of the time to obtain the needed yield, although it could be operated more frequently to maintain a stable blended water quality.

Scenario 2 - When water demands reach 221,000 acft/yr, additional firm yield of about 45,000 acft/yr will be required. Assuming a CC/LCC System storage trigger of about 70 percent of capacity, the necessary increase in firm yield can be ensured with an average pipeline delivery of about 40,000 acft/yr and a resulting savings in power costs. Under this scenario, the pipeline will need to be operating at full capacity about 56



* Trigger represents percentage of CC/LCC system storage capacity below which Lake Texana pipeline is required to operate at full capacity.

60" Pipeline, 2010 Conditions

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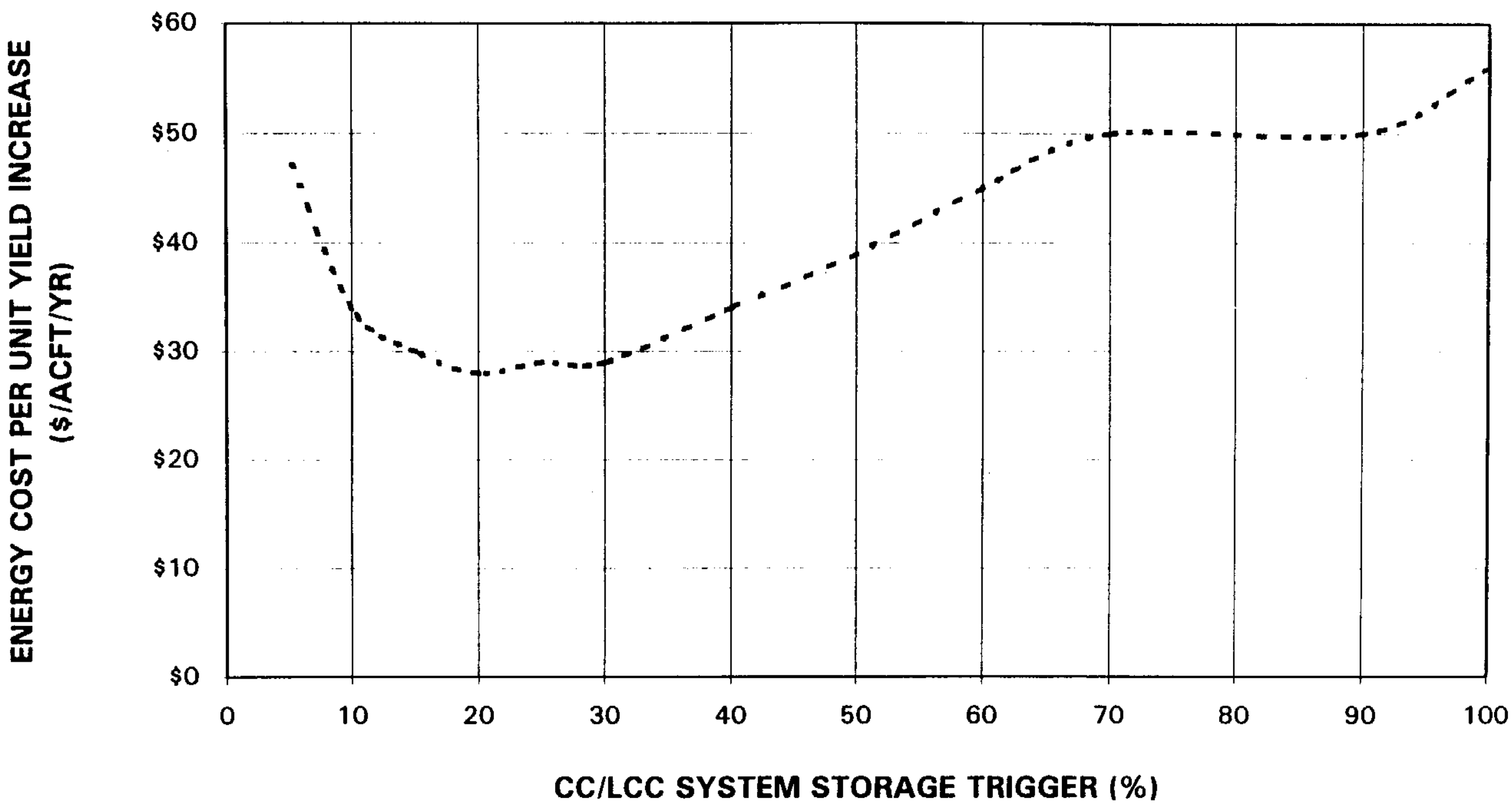
CC/LCC SYSTEM YIELD INCREASE FOR COMBINED OPERATION WITH TEXANA PIPELINE

FIGURE 4.6-1



60" Pipeline, 2010 Conditions

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ENERGY COST PER UNIT YIELD INCREASE FOR COMBINED OPERATION OF CC/LCC SYSTEM AND TEXANA PIPELINE

FIGURE 4.6-2

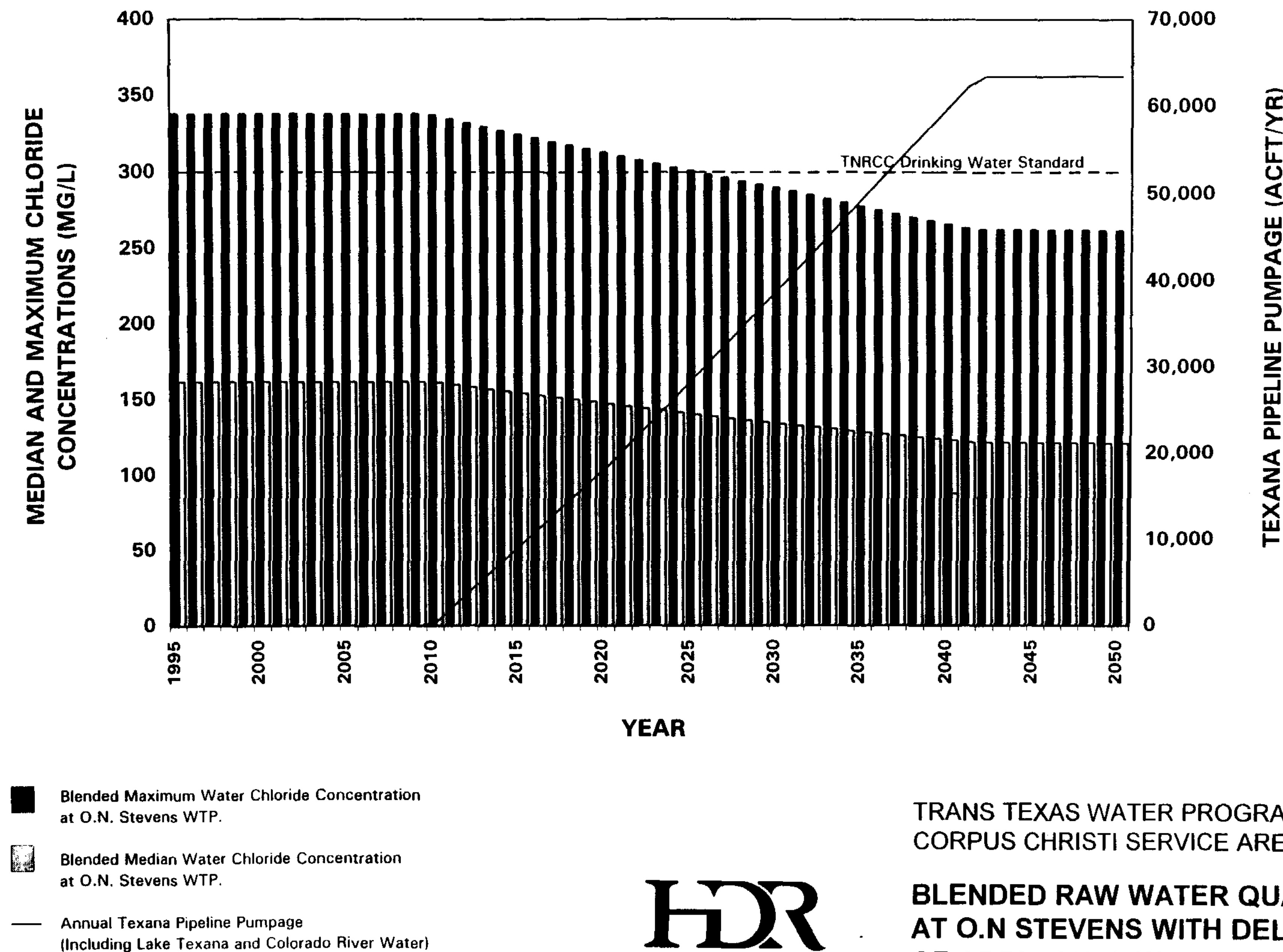
percent of the time solely for yield enhancement purposes.

Scenario 3 - When water demands reach 239,000 acft/yr, additional firm yield of about 64,000 acft/yr will be required. In order to ensure this increase in firm yield, thepipeline will need to be operating at full capacity whenever CC/LCC System storage falls below 100 percent of capacity or Lake Corpus Christi is not spilling.

These scenarios clearly illustrate that combined operations based on tracking water demands and adjusting CC/LCC System storage triggers accordingly can result in firm yield increases well in excess of the amounts delivered through the Texana pipeline until additional water demands reach the full capacity of the pipeline. It should be noted, however, that factors other than minimization of power costs may affect selection of CC/LCC System storage triggers or other mechanisms for initiating pipeline deliveries. Two of these factors include desired stability of blended water quality and maximization or stabilization of Lake Corpus Christi and/or Choke Canyon Reservoir levels, and/or potential reductions in CC/LCC spills and inflows to Nueces Bay.

4.6.3 Blended Water Quality

Upon operation of the Texana Pipeline, raw water quality at the O.N. Stevens WTP will be improved by blending with the Lake Texana and Colorado River water. Median chloride concentration of Nueces River water at Calallen is 162 mg/l and the maximum observed chloride level is 338 mg/l. The median chloride concentration at Lake Texana is 21 mg/l and after Colorado River water is routed through Lake Texana, concentrations will average about 23 mg/l for chlorides. Figure 4.6-3 is a graph showing the projected delivery of Lake Texana water to the O.N.Stevens Water Treatment Plant and the resulting improvement of the blended water quality as Texana deliveries increase. By year 2040, the median chloride concentrations of blended raw water will be about 123 mg/l, about a 25 percent reduction from historical levels. Maximum chloride concentrations will be well below 300 mg/l, which is the TNRCC drinking water standard. Additionally, hardness levels are expected to decrease by about 12 percent over the same timeframe.



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BLENDED RAW WATER QUALITY AT O.N STEVENS WITH DELIVERY OF ADDITIONAL WATER SUPPLY

FIGURE 4.6-3

4.7 Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5)

This alternative has been included as one of the elements of Plan A to potentially meet a portion of the long-term water needs of the service area. Channel losses in streams that deliver water from Choke Canyon Reservoir to Lake Corpus Christi are estimated to be as high as 29 percent and consequently reduce the yield of the CC/LCC System. However, water delivered by pipeline that bypasses the stream channel between the lakes would not be subjected to these losses and could potentially increase the system yield by 18,000 acft/yr. Implementation of this alternative would involve construction of a 30-mile, 96-inch diameter pipeline.

Before this alternative is considered for implementation, the impending sediment survey of Lake Corpus Christi needs to be completed, as well as detailed channel loss studies on the river reach between the reservoirs to fully understand the seasonality and variability of the losses with respect to release rates. Additionally, the reservoir operating policy of the CC/LCC System could potentially affect the yield and cost of this option. An implementation issue which would need to be addressed is the impact of the reduced flows in the Nueces River downstream of Choke Canyon Reservoir.

4.8 Modification of Choke Canyon/Lake Corpus Christi Reservoir Operation Policy

This alternative has been included as one of the elements of Plan B to potentially meet a part of the long-term needs of the area. Because of the historically high rate of sedimentation of Lake Corpus Christi, the year 2050 gain in yield from lowering the Lake Corpus Christi target level to a minimum 60-day supply of water to maintain water quality is estimated to be approximately 4,000 acft/yr. Changing the 88 ft-msl target to about 87 ft-msl would be necessary to produce this increase in yield. Changing the target level by 1 ft would not require significant modifications to the existing intakes in Lake Corpus Christi and no costs have been included in the Integrated Water Supply Plan for this alternative. Before this alternative is considered for implementation, the impending sediment survey of Lake Corpus Christi needs to be completed as well as additional channel loss studies on the river reaches between the reservoirs. Any new operating policy must consider losses from all sources in order to fully maximize the yield of the system while maintaining water quality and minimizing the impacts to recreational users.

4.9 Financial Considerations

Annual costs for the period 1995 to 2050 for each of the potential water supply plans were estimated and a schedule of expenditures for each of the component costs was developed to bring the plan on-line and meet the projected need for new water supplies. For alternatives requiring construction, the implementation schedule brings the project on-line two years prior to the date a projected shortfall of water supply would occur without the project.

Cost Components

The costs to implement the 1995 Agreed Order have already been incurred by the City of Corpus Christi. Therefore, no costs for this alternative have been carried forward into either of the two integrated plans. Costs for the Accelerated/Additional Conservation alternative were included in both plans and include recommended programs for public information, water audits, partial plumbing retrofits, and landscaping regulations. These costs are summarized in Table 4.5-1.

For the Texana Pipeline (LN-1), water purchase costs begin in 1995 with engineering and permitting costs scheduled to begin in 1996. Easement acquisition would begin in 1997. Debt service payments on the capital improvements are estimated to begin with project operation in 2007. After the Corpus Christi/LNRA water purchase contract expires in 2035, payments to LNRA continue for reimbursement of a portion of the operation and maintenance costs of Lake Texana (payments estimated to be $635,000 annually). O&M costs for the pipeline begin in 2007 and power costs have been conservatively estimated to be proportional to the amount of annual pumpage to meet projected demands. The overall project cost estimate, including O&M and power costs, is provided in Table 3.16-15 (Section 3.16) for the 60-inch diameter pipeline (Plan A) and in Table 3.16-21 for the 66-inch diameter pipeline (Plan B).

For the purchase of Garwood Water Rights (C-1), water purchase costs begin in 1996 and are estimated to be financed for 25 years. Permitting and preliminary engineering costs begin in 1996. Easement acquisition and final engineering would need to be completed by 2025. Debt service on the pipeline would begin in 2027 and O&M costs in 2029. Power costs are estimated to be proportional to the amount of annual pumpage to meet projected demands. An overall project cost estimate, including O&M and power costs, is provided in Table 3.16-14

(Section 3.16) for both the 48-inch (Plan A) and 60-inch (Plan B) diameter pipelines.

For Plan A, the last alternative to be implemented is the pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5). Engineering and permitting would begin in year 2037 and continue for two years followed by a one-year construction period prior to project operation in year 2039. O&M costs begin in 2039 and power costs have been estimated to be proportional to the amount of annual pumpage to meet projected demands. The overall project cost estimate, including O&M and power costs, is provided in Table 3.5-3 (Section 3.5).

For Plan B, additional water from the Colorado River (Alternative C-2) must be purchased for delivery through an up-sized Garwood pipeline (i.e., 60-inch) and Texana pipeline (i.e., 66-inch). The water could potentially be purchased from several sources as described in Section 3.19. A purchase agreement could be in place by 2006 with a lease-back arrangement to current uses of the water, thereby avoiding long-term payments for unused water. Under this arrangement, payment for the water is scheduled to begin upon actual diversion to meet projected needs, or about 2039. Engineering, permitting, and construction costs for this alternative are included in the up-sized Garwood and Texana pipeline project costs and debt service on these higher costs would begin in years 2007 and 2029, respectively. O&M costs for the larger pipelines also begin in 2007 and 2029, respectively, for the Texana and Garwood pipelines. Power costs to pump the additional Colorado water begin in 2039 and are proportional to the amount of annual pumpage to meet projected demands. The overall project cost estimate summary for the up-sized Garwood pipeline is provided in Table 3.16-14 and the cost summary for the up-sized Texana pipeline is in Table 3.16-21, both found in Section 3.16.

For Plan B, the last alternative to be implemented is the Modification of the Lake Corpus Christi Operating Policy (N-1). This alternative is projected to be needed by about 2046. No implementation costs are anticipated for this alternative.

Treatment Plant Expansion Requirements

Cost components for water treatment plant expansions are the same for each of the integrated water supply plans. Upon completion of the current upgrade of O.N. Stevens WTP begun in 1995, the plant will have a capacity of 196 mgd. In 1993, about 70 percent of water demand from the CC/LCC System was for treated water and this percentage was applied to the projected 2050 total demand, resulting in a projected 2050 demand for treated water of 170,450 acft/yr (includes demand reduction due to accelerated/additional conservation). For a peak day demand to annual average demand peaking factor of 1.75, the projected water treatment plant capacity needed in 2050 is 266 mgd, or about 70 mgd more than presently available. Therefore, treatment plant expansions totaling 70 mgd are included in Plans A and B. The implementation plan for the additional treatment capacity is the same for each integrated water supply plan as follows: the capacity expansion is divided into two equal increments of 35 mgd each; the first 35 mgd expansion is planned for operation in 2021 with engineering and permitting costs beginning in 2019; the second 35 mgd expansion is projected to be needed in about 2040. The need and schedule for the treatment plant expansions is not tied to any specific water supply alternative in the integrated supply plans, but rather is in response to the projected demand for treated water. The implementation date for the first treatment plant expansion occurs 12 years after the Texana pipeline becomes operational and 10 years before the Garwood pipeline is needed. This implementation schedule has two advantages. First, the financing requirements on Corpus Christi will closely match the growth of the customer base and the initial years of debt service for the treatment plant expansion will not occur simultaneously with the major elements of either of the integrated supply plans. Secondly, sufficient time is allowed after each of the major supply alternatives are on-line for Corpus Christi to assess water demand trends and appropriately adjust the implementation schedule of subsequent projects and treatment upgrades.

The estimated cost of each 35 mgd expansion to the O.N. Stevens WTP is $28,800,000 (mid-1995 costs), including engineering, permitting and contingencies. For 25 year financing at 8 percent interest, the annual cost will be $2,700,000. Operation and maintenance costs are estimated to be $2,800,000 when the expansion is fully used. In early years of operation, the O&M costs are reduced proportionally to water demands. The need for the second expansion occurs 21 years after the first expansion is brought on-line and creates a 4-year overlap in debt service payments before the first plant's debt is paid off at the end of 25 years. As will be discussed later, for a level debt service payment schedule, this overlap creates a somewhat higher rate impact for 4 years that could possibly be avoided by either phasing in a slightly larger initial plant expansion and delaying the need for the second expansion by 4 years or by structuring the financing plan to avoid the overlap.

4.9.1 Summary of Annual Costs and Impacts on Water Rates

Cost increases necessary to pay for the integrated plans are calculated assuming actual water sales will be only a portion of the total projected water demand. Estimated sales are reduced below total projected demand to account for three factors: (1) In years of average or high rainfall, water sales will be less than the high case dry year projected demands; (2) projected water demands include distribution system losses; and (3) estimates of water sales are uncertain and generally require a reserve fund for bond coverage. Considering all of these factors, water sales were estimated based on 70 percent of projected total municipal and industrial water demand, as presented in Section 2.0. For example, in year 2010, total projected dry year water demand, with accelerated conservation, is 175,530 acft/yr which is estimated to generate at least 122,871 acft of metered water sales[3] to retail and wholesale customers if average weather conditions occur. The annual costs of the integrated plans are therefore divided by the projected average annual sales to estimate increased water costs. In 1993, about 70 percent of total water demand was treated water and this percentage is applied throughout the 1995 to 2050 period to the total annual estimated water sales for calculation of the rate increases for treated water unit costs. All costs are in 1995 dollars.

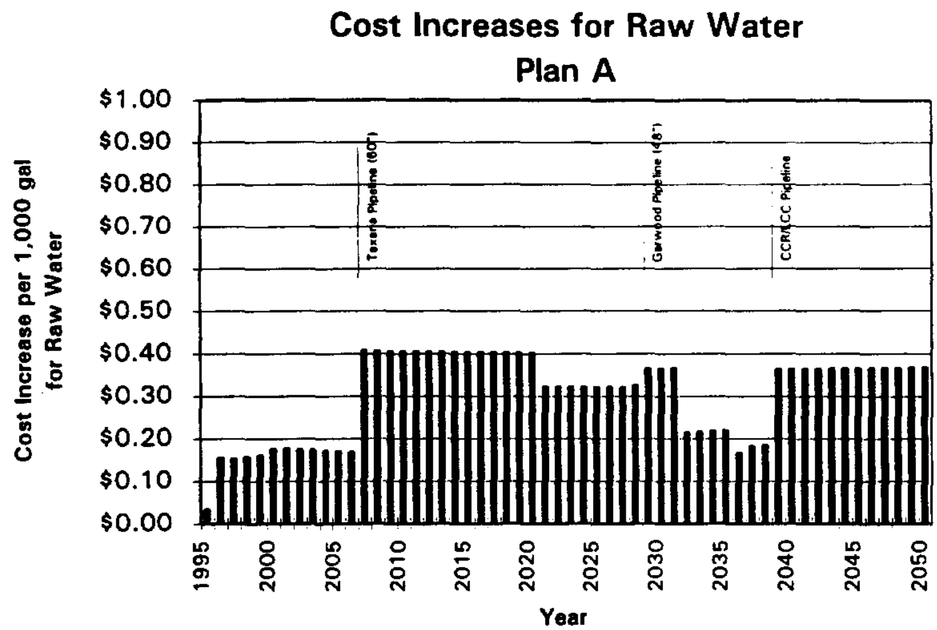
For the period 1996 to 2006 (prior to the Texana Pipeline coming on-line), the average cost increase for raw water under Plan A is $0.17 per 1,000 gallons and is $0.18 per 1,000 gallons under Plan B (Table 4.9-1 and Figure 4.9-1). For the 2007 to 2030 period, the average cost increase above 1995 rates for raw water under Plan A is $0.38 per 1,000 gallons and $0.43 per 1,000 gallons under Plan B. For the last 20 years of the planning period, the average cost increase above 1995 rates for raw water under Plan A is $0.32 per 1,000 gallons, and for Plan B is $0.20 per 1,000 gallons above 1995 rates (Table 4.9-1 and Figure 4.9-2). The unit costs for both Plan A and Plan B in the 2031 to 2050 period actually decrease for raw water compared to the 2007 to 2030 cost.

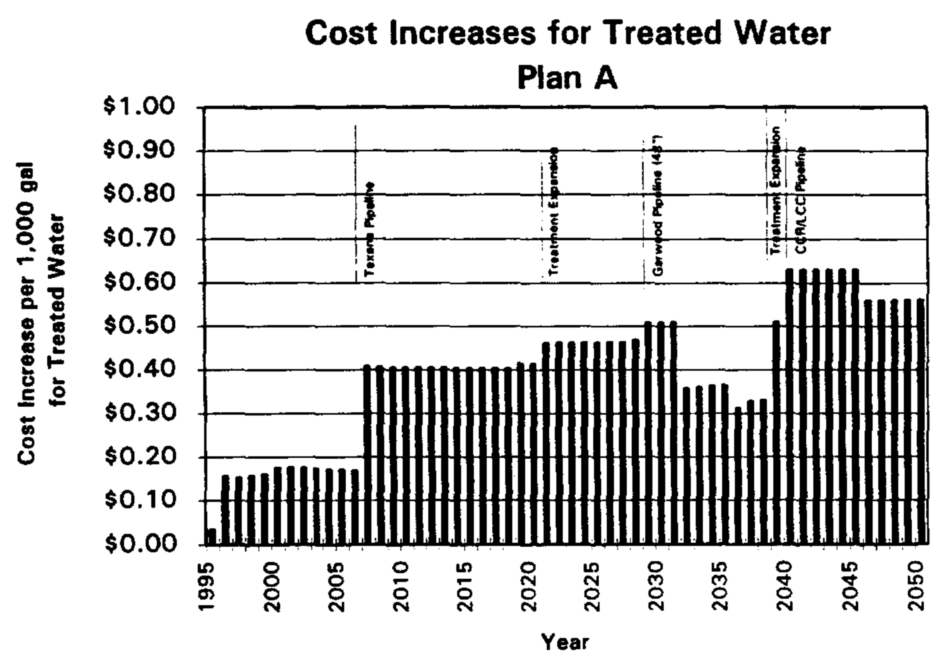
[3] 122,871 acft/yr is 40.0 billion gallons, or 40.0 million billing units of 1,000 gallons per billing unit.

Table 4.9-1 Cost Increases for Integrated Water Supply Plans[1]				
RAW WATER[2]				
	Plan A		Plan B	
Time Period	Incremental Cost Increase[3] ($ per 1,000 gal)	Average Cost Increase Above 1995 Rates[4] ($ per 1,000 gal)	Incremental Cost Increase[3] ($ per 1,000 gal)	Average Cost Increase Above 1995 Rates[4] ($ per 1,000 gal)
1996--2006	$0.168	$0.168	$0.179	$0.179
2007--2030	$0.207	$0.375	$0.250	$0.429
2031--2050	($0.053)	$0.322	($0.231)	$0.198
TREATED WATER[5]				
	Plan A		Plan B	
Time Period	Incremental Cost Increase[1] ($ per 1,000 gal)	Average Cost Increase Above 1995 Rates[2] ($ per 1,000 gal)	Incremental Cost Increase[1] ($ per 1,000 gal)	Average Cost Increase Above 1995 Rates[2] ($ per 1,000 gal)
1996--2006	$0.168	$0.168	$0.179	$0.179
2007--2030	$0.226	$0.434	$0.310	$0.489
2031--2050	$0.094	$0.528	($0.095)	$0.394

[1] Based on total projected M&I demand adjusted for average and wet conditions (0.85 factor), distribution system losses (0.88 factor) and bond coverage (0.935 factor). Net factor = 0.70.
[2] Raw water demand is about 28 percent of total demand.
[3] Average cost increase per 1,000 gallons needed in the time period to pay for implementation of the integrated plan.
[4] Corpus Christi schedule of water rates is provided in Table 3.17-6, Section 3.17.
[5] Treated water demand is about 72 percent of total demand.

For the period 1996 to 2006 (prior to the Texana Pipeline coming on-line), the average cost increase for treated water under Plan A is $0.17 per 1,000 gallons and is $0.18 per 1,000 gallons under Plan B (Table 4.9-1). For the 2007 to 2030 period, the average cost increase above 1995 rates for treated water under Plan A is $0.43 per 1,000 gallons and $0.49 per 1,000 gallons under Plan B. For the last 20 years of the planning period, the average cost increase





1. Debt service component calculated for 25 years at 8% interest.
2. Cost increases are 1995 dollars.
3. Revenue requirement increase needed per year to pay for integrated plan.

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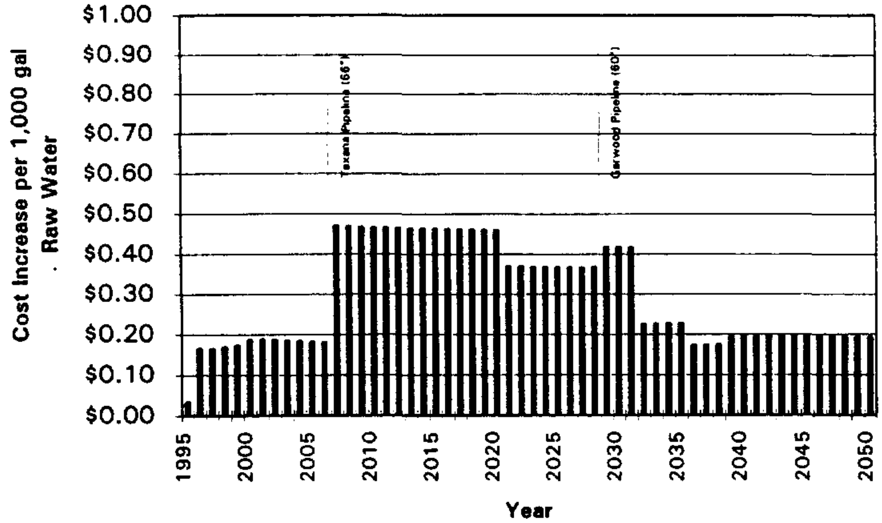
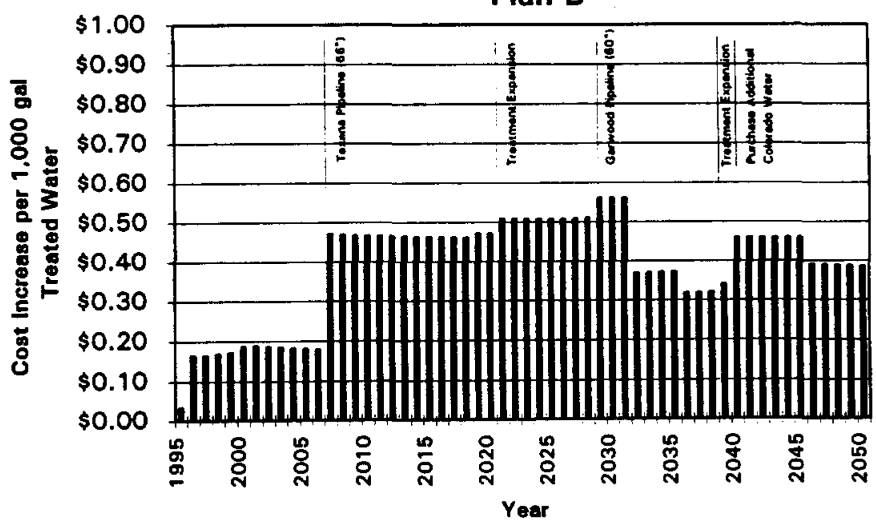
INCREASED COST OF WATER WITH INTEGRATED WATER SUPPLY PLAN A

FIGURE 4.9-1

Cost Increases for Raw Water
Plan B



Cost Increases for Treated Water
Plan B



1. Debt service component calculated for 25 years at 8% interest.
2. Cost increases are 1996 dollars.
3. Revenue requirement increase needed per year to pay for integrated plan.

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INCREASED COST OF WATER WITH INTEGRATED WATER SUPPLY PLAN B

FIGURE 4.9-2

for treated water under Plan A is $0.53 per 1,000 gallons above 1995 rates, and for Plan B is $0.39 per 1,000 gallons above 1995 rates. The unit cost increase for Plan B in the 2031 to 2050 period ($0.39/1,000 gal) actually decreases compared to the 2007 to 2030 cost ($0.49/1,000 gal). Incremental and accumulated cost increases for each of the integrated plans for three time periods are provided in Table 4.9-1.

Potential effects on typical monthly water bills for residential, commercial, and wholesale customers from implementing the integrated plans is demonstrated in Table 4.9-2 for Plan A and Table 4.9-3 for Plan B. As shown in Table 4.9-2, implementation of Plan A will increase the average residential water bill (for 9,000 gal/month consumption in-city) from $16.38 in 1995 to $20.29 in 2007 (1.8 percent per year increase), and to $21.14 by 2031 (in 1995 dollars), or a total increase of 29 percent. A commercial in-city bill for 70,000 gal/month would increase from $202.03 under Plan A to $232.41 in 2007 (1.2 percent per year increase), and to $238.99 by 2031 for a total increase of 18 percent. A wholesale industrial raw water bill for 10,000,000 gal/month would increase from $2,080.43 to $5,300.43 in 2050 (1995 dollars) for a total increase of 155 percent. On an annual basis, the wholesale water rate increase would average about 9.0 percent for the 1995 to 2007 period, and would essentially be stable for the remainder of the planning period for Plan A.

As shown in Table 4.9-3, implementation of Plan B will increase the average residential water bill (for 9,000 gal/month consumption, in-city) from $16.38 in 1995 to $20.78 in 2007 (2.0 percent per year increase), and would reduce to $19.93 by 2031 (in 1995 dollars), for a total increase of 21 percent. A commercial in-city bill for 70,000 gal/month would increase from $202.03 under Plan B to $236.26 in 2007 (1.3 percent per year increase) and would decrease to $229.61 by 2031 for a total increase of 14 percent above 1995 rates. A wholesale industrial raw water bill for 10,000,000 gal/month would increase from $2,080.43 to $4,060.43 (1995 dollars) or a total increase of 95 percent. On an annual basis, the wholesale water increase would be 9.8 percent per year for the 1995 to 2007 period, and would decrease slightly throughout the remainder of the planning period for Plan B.

Table 4.9-2
Typical Monthly Water Bills for Plan A

Rate Category	Monthly Use (gal)	Present Monthly Bill(2)	Estimated Monthly Bill[1] 1995-2006 Percent Increase (per year)	2007-2030 Average Total Bill (per year)	2031-2050 Average Total Bill (per year)
Residential In-City	4,000 9,000	$7.81 $16.38	1.69% 1.80%	$9.55 $20.29	$9.92 $21.14
Residential Out-of-City	4,000 9,000	$15.39 $31.23	1.71% 1.88%	$18.86 $39.04	$19.61 $40.73
Commercial/Industrial In-City	70,000 200,000 400,000	$202.03 $366.67 $654.59	1.17% 1.79% 1.98%	$232.41 $453.47 $828.19	$238.99 $472.27 $865.79
Commercial/Industrial Out-of-City	200,000 400,000	$826.92 $1,560.37	1.60% 1.69%	$1,000.52 $1,907.57	$1,038.12 $1,982.77
Wholesale Treated Water	1,000,000 10,000,000	$1,367 $10,184	2.32% 3.00%	$1,800.86 $14,523.71	$1,894.86 $15,463.71
Wholesale Raw Water (Industrial)	1,000,000 10,000,000	$370.43 $2,080.43	6.00% 8.97%	$745.43 $5,830.43	$692.43 $5,300.43

[1] Values are 1995 dollars.
[2] Corpus Christi schedule of water rates is provided in Table 3.17-6, Section 3.17.

Table 4.9-3
Typical Monthly Water Bills for Plan B

Rate Category	Monthly Use (gal)	Present Monthly Bill(2)	Estimated Monthly Bill[1] 1995-2006 Percent Increase (per year)	2007-2030 Average Total Bill (per year)	2031-2050 Average Total Bill (per year)
Residential In-City	4,000 9,000	$7.81 $16.38	1.88% 2.00%	$9.77 $20.78	$9.39 $19.93
Residential Out-of-City	4,000 9,000	$15.39 $31.23	1.91% 2.09%	$19.30 $40.03	$18.54 $38.32
Commercial/Industrial In-City	70,000 200,000 400,000	$202.03 $366.67 $654.59	1.31% 1.99% 2.20%	$236.26 $464.47 $850.19	$229.61 $445.47 $812.19
Commercial/Industrial Out-of-City	200,000 400,000	$826.92 $1,560.37	1.79% 1.88%	$1,022.52 $1,951.57	$984.52 $1,875.57
Wholesale Treated Water	1,000,000 10,000,000	$1,367 $10,184	2.58% 3.32%	$1,855.86 $15,073.71	$1,760.86 $14,123.71
Wholesale Raw Water (Industrial)	1,000,000 10,000,000	$370.43 $2,080.43	6.62% 9.77%	$799.43 $6,370.43	$568.43 $4,060.43

[1] Values are 1995 dollars.
[2] Corpus Christi schedule of water rates is provided in Table 3.17-6, Section 3.17.

Because Plan B includes up-sized facilities to be built early in the plan to transport future water from the Colorado River, the impact on water rates early in the plan are higher when compared to Plan A. However, Plan B has a lower potential impact on water rates at the end of the planning period when the plan facilities become fully utilized. For instance, for the 2007 to 2030 period, the average cost increase for treated water under Plan B is $0.06 per 1,000 gallons higher than Plan A, a difference of 11 percent (Table 4.9-1). However, for the 2031 to 2050 period, cost increases for Plan B are $0.14 lower than Plan A, a difference of 34 percent.

4.9.2 Potential Effect of Interest Rate on Integrated Plan Costs

A significant item affecting the magnitude of rate increases associated with either Plan A or Plan B is the interest rate on bonds issued to pay for construction. For the Texana Pipeline project, about 65% of the annual cost goes toward retirement of the debt. Project cost estimates in this report are all made with the interest rate set at 8 percent, which is currently above the market rate for municipal bonds in mid-1995. If the interest rate on bonds issued for the integrated plans is actually 6 percent, then the debt service payments will be 17 percent lower. These lower debt service payments could lower the cost of the project and resulting increase in water rates by about 11 percent. Conversely, if the integrated plan is implemented during an unfavorable bond market, then cost increases could be higher. Debt service payments for 10 percent interest would be about 17 percent higher and overall plan costs would be about 11 percent higher than for those calculated with interest rates at 8 percent.

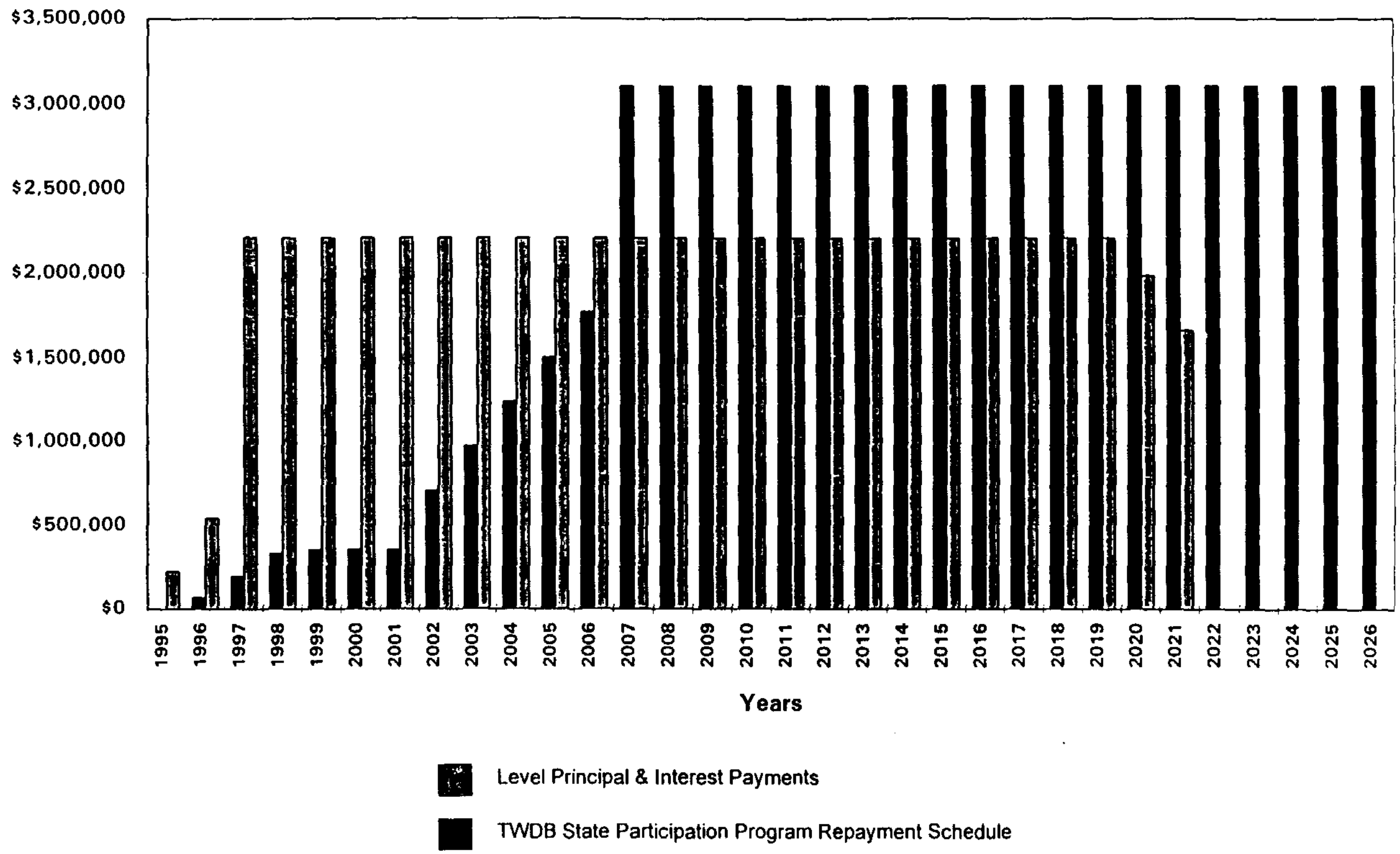
4.9.3 Potential Effects of Financial Participation by TWDB

Annual debt service costs for integrated supply Plans A and B have been estimated based on level debt service payments for a 25 year financing period. However, alternate financing arrangements are available which could potentially lower water rate increases. One potential financing arrangement is offered by the Texas Water Development Board (TWDB) to assist in paying for projects sized for future requirements. The TWDB State Participation Program allows deferral of a portion of the interest on project bonds, thereby requiring lower payments in the early years of a project. The deferred interest is repaid later in the project after the customer rate base has increased.

Figure 4.9-3 contains the results of a comparison for two repayment schedules for a loan amount of $26,450,000. The lightly shaded bars on Figure 4.9-3 show a plot a level repayment schedule similar to those used in this study, for three bond issues totaling $26,450,000 for a 25 year financing period, at interest rates varying from 6.4 percent to 6.75 percent. For this case, the annual payment is $2.21 million and the total of all payments throughout the loan period is $53.4 million.

The solid black bars show payments for the same loan amount using a TWDB State Participation Repayment Schedule. The cumulative loan period is 32 years and the interest rate varies from 6.4 percent to 6.75 percent. The payments start low and increase for the first twelve years of the program, allowing the project to become more fully utilized before the higher payments are due. The average of the first twelve annual payments is $655,000, or about 70 percent lower than a level repayment schedule. From year 13 to 32, the payments are $3.1 million, or about 40 percent above the level payment schedule. The total of all payments throughout the financing period is $70.0 million (31 percent higher), but the average annual payment over the 32 year period is $2.19 million, or about the same as the level repayment schedule. If this type of financing were used to finance the Lake Texana pipeline, the average annual rate increases calculated for this study could be reduced significantly for the years 1996 through 2009.

In addition to the State Participation Program, the TWDB has water development loan funds to which Texas cities and water authorities may apply for loans to finance water supply projects, such as the Lake Texana Pipeline, water treatment plant expansions or the purchase of water rights. The interest rates for TWDB water supply loans are based upon the rates that TWDB has to pay when it issues bonds in the open market, plus one-half of one percent that is applied to TWDB's cost of bond issuance and administration of this loan program. In many instances, the interest rates charged by TWDB are less than the rates that an individual city or water authority would have to pay if it were to issue its own bonds in the marketplace, since the TWDB issues high quality bonds backed by the full faith and credit of the State of Texas, as authorized by the Texas Constitution, and as a matter of policy, TWDB uses its water supply loan program to encourage regional water supply development, such as supplies for the South



Repayment of $26,450,000 bond issue at interest rate varying from 6.4% to 6.75%.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

HDR Engineering, Inc.

ALTERNATVE TWDB FINANCING SCENARIOS

FIGURE 4.9-3

Central Trans-Texas Region. Therefore, it is recommended that Corpus Christi consider the TWDB as potential lender when its water supply financing plans are being developed. At any given time, it may be able to obtain lower interest rates from TWDB than from the market.

4.10 Environmental Issues

In terms of acreage affected, streamflows, bay and estuary inflows, and wastewater return flows to Nueces Estuary, effects of implementing either plan will be additive, and will accumulate sequentially as the separate alternatives are implemented over time. The effects of installing water pipelines will be greatest on terrestrial habitats during construction. However, agricultural land can be returned to its original use following construction. The total acreage of terrestrial habitats affected by Plan A (Figure 4.3) during construction would be 2,545 acres, of which 1,804 acres (71%) is grass or cropland. About 666 acres would be maintained ROW after the projects are constructed. Where the pipelines cross brushlands, brush can be expected to become established in areas outside the maintenance ROW in about 10 years. About 190 acres that were formerly brushland would be maintain as a mowed ROW. The combined alternatives would impact approximately 65 acres of woodland, mostly along river and creek banks. Wetlands in the proposed ROWs total about 145 acres, however, tunneling under several major rivers is expected to significantly reduce impacts below this amount.

The effects of Plan B on terrestrial habitats are similar to those of Plan A. The construction and maintenance ROWs for Plan B would involve about 2,443 acres and 698 acres, respectively. Impacts to woodlands would be greater by about 34 acres, but impacts to brushland would be less by about 431 acres. Cropland crossed by a proposed pipeline to the Colorado River near Wharton accounts for the remaining difference.

Implementing Plan A will reduce flows, below the Garwood diversion point on the Colorado River, and in the Nueces River between Choke Canyon Reservoir and Lake Corpus Christi. Freshwater inflow resulting from interbasin transfer considered alone would increase freshwater inflow to Nueces Estuary 10 percent (29,800 acft/yr assuming a water supply of 63,440 acft/yr). For Plan B, water diverted from the Colorado River near Wharton, in addition to water diverted from Garwood, is substituted for the pipeline from Choke Canyon Reservoir to Lake Corpus Christi. Thus, Plan B would divert more water from the Colorado River (an additional 14,000 acft/yr). Return flows resulting from this interbasin transfer would further increase freshwater inflow to Nueces estuary. Local alternatives common to both plans (Modification of Choke Canyon/Lake Corpus Christi, Accelerated and Additional Conservation) and Modification of Choke Canyon/Lake Corpus Christi Operating Policy by changing to a target elevation of 87 ft-msl in Plan B would appear to result in only minor deviations in inflows from that expected from the interbasin transfers.

Increasing freshwater inflow to Nueces Estuary can be expected to have generally positive effects on the ecology of the estuary. Increasing flow to Nueces Estuary would mitigate against the historical trend of reducing freshwater inflows for human use and increased flows. Also, increased freshwater inflows may benefit estuarine shellfish and finfish fisheries.[4,5] With respect to the interbasin transfer of organisms, neither plan would appear to present problems, since Colorado River Water has been transferred to the Lavaca Basin annually since the early 1900's, and under each of the integrated plans, water from the Colorado and Lavaca Basins would be piped directly from Lake Texana to the O.N. Stevens Water Treatment Plant. Although this issue continues to be studied,[6] appropriate engineering practices and treatment at the O.N. Stevens W.T.P. would greatly reduce the likelihood of transferring organisms to intervening river basins. Furthermore, the close proximity of the Colorado River Basin and the Lavaca-Navidad River in Wharton, Matagorda, and Jackson Counties makes it unlikely that species inhabiting either basin are isolated from the other basin. In addition to species transfers due to human activities, natural events such as large storms which lower estuarine salinities provide a corridor favorable for the natural interbasin transfer of organisms.

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[4] Texas Department of Water Resources. 1981. Nueces and Mission-Aransas Estuaries: A Study of the Influence of Freshwater Inflows. LP-108. TDWR. Austin, Texas.

[5] Longley, W.L. ed. 1994. Freshwater Inflows to Texas Bays and Estuaries: Ecological Relationships and Methods for Determination of Needs. TWDB and TPWD. Austin, Texas.

[6] U.S. Army Corps of Engineers. 1995. Technical Memorandum, Potential Ecological Effects of Two Proposed Interbasin Transfers in the South-Central Study Area. Fort Worth District.

4.11 Implementation Issues

The implementation of the components of the water supply plans described in Section 4.3 will require permits from state and federal agencies, and may encounter legal and institutional issues that will need to be resolved. Legal requirements that could arise during implementation of the integrated water supply plans can be grouped into three general categories: (1) contractual requirements; (2) water rights issues; and (3) construction-related permit requirements, both state and federal. Each is discussed below and specific permits and issues associated with Plan A and Plan B are identified in subsections 4.11.5 and 4.11.6.

For some sources of water to be included in the water supply plan, the City of Corpus Christi, or other operating agency, may need to have valid water supply contracts. In the case of Alternative LN-1 (Lake Texana Pipeline to Corpus Christi), on December 14, 1993, the City of Corpus Christi and the Lavaca-Navidad River Authority executed a contract which addresses the construction and financing of the project; the ownership, operation, and maintenance of its structures, and the water supply can begin under the contract once the project is complete. The Third Court of Appeals upheld the contract's validity on July 12, 1995. Similar contractual arrangements may be needed for other alternatives included in the Plans.

For each source of water to be included in the water supply plan, the City of Corpus Christi, or other operating agency, may need to obtain water rights, as appropriate and the necessary permits for interbasin transfer and use of surface water for those sources or options for surface water located in neighboring river basins, and for any groundwater sources, the ownership in or permission from landowners to install wells and withdraw and transfer water from the well sites to the service area. In the former case, existing water rights may need to be amended to permit interbasin transfer and use of the water. For example, in the case of Alternative LN-1, since the contract between the Lavaca-Navidad River Authority (LNRA) and Corpus Christi involves the sale of water for use outside the area currently authroized in the Lake Texana water right, LNRA must apply to the Texas Natural Resource Conservation Commission (TNRCC) for an amendment to certificate of Adjucation No. 16-2095 (CA16-2095).[7] No deliveries or diversions can be made under the Corpus Christi/LNRA contract

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[7] 31 TAC § § 297.101, 297.102(a). See also: Tex. Water Code Ann. § 1.144 (Vernon 1988) (Amendment required before changing any reservoir or diversion work.)

unless and until the certificate of adjucation is amended,[8] Applications for interbasin transfers are submitted to and considered by the TNRCC in the same manner as applications for water rights in general, although they must specifically state that a transbasin diversion is being sought.[9]

In addition to its usual considerations, the TNRCC must determine that the interbasin transfer will not work "to the prejudice of any person or property" in the basin of origin.[10] However, the Texas Supreme Court has determined that this provision requires the TNRCC to prohibit an interbasin transfer to the extent it will impair existing water rights in the basin of origin.[11] If existing water rights will not be impaired, and if the benefits to the recipient basin outweigh the detriments to the basin of origin, the interbasin transfer should be allowed.[12]

Additionally, Article III, Section 49-d of the Texas Constitution prohibits the use of state funds to finance a project "which contemplates or results in the removal from the basin of origin of any surface water necessary to supply the reasonable foreseeable future water requirements for the next ensuing fifty-year period within the river basin of origin, except on a temporary, interim basis."[13] This provision should not be an obstacle to implementation of any parts of Plans A or B, since only water that is surplus to the needs of the basins of origin are considered.

In addition to permits to use state water, the permits must show place of use, purpose of use, diversion point(s), diversion rate(s), and delivery point(s).[14] In addition, the TNRCC will assess the effects of the water right on the bays and estuaries of the state,[15] and the effect

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[8] Tex. Water Code Ann. § 11.121 (Vernon 1988); 31 TAC § § 297.101(a).

[9] Tex. Water Code. Ann. § 11.085(b); 31 TAC §§ 295.13, 297.71.

[10] Tex. Water Code Ann. § 11.085(a).

[11] San Antonio v. Texas Water Commission, 407 S.W.2d 752, 758 (Tex. 1966).

[12] 407 S.W.2d at 759.

[13] Tex. Const. Art. III, sec. 49-d.

[14] Texas Water Code Ann. § 11.122(a).

[15] Tex. Water Code Ann. § 11.147(b) (Vernon 1988); 31 TAC § 297.52 and 297.56. TNRCC rules apply statutory provisions concerning bay and estuary requirements, instream flow requirements, and mitigation to water right amendment applications. Statutory provisions, on the other hand, expressly apply to only permit applications. No case

of granting the permit or a permit amendment on existing instream uses, which include water quality and fish and wildlife habitats.[16] Each applicant must include a water conservation plan with its application to obtain and use state water.

4.11.1 State Permits, Approvals and Authorizations

A. Sand, Shell and Gravel Permits: These permits must be obtained from the Texas Parks and Wildlife Department (TPWD) to the extent that the water supply project will disturb sedimentary materials lying in the public waters of the State.[17] "Sedimentary materials" include marl, sand, gravel, shell, or mudshell.[18]

To initiate the process, a permit application must be filed with the TPWD's executive director setting forth the location, quantity, and types of sedimentary materials to be removed, as well as the type of equipment to be used and the operation's projected duration.[19]

A permit may be denied on any reasonable basis.[20] However, in making a determination, the executive director *must* consider the following:

- Whether the operation under the proposed permit will damage or injuriously affect oysters, oyster beds, or related fish-inhabiting waters;
- Whether the operation will damage or injuriously affect any island, reef, bar, channel, river creek, or bayou used for frequent or occasional navigation;
- Whether the operation will change or otherwise injuriously affect any current navigation; and,

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has tested TNRCC's authority to expand the application of these requirements to amendments. For purposes of this analysis, the provisions will be assumed to apply also to amendments of water rights as specified in TNRCC rules.

[16] Tex. Water Code Ann. §§ 11.147(d), 11.147(e), 11.150, 11.152 (Vernon 1988); 31 TAC §§ 297.49, 297.50, 297.52, 297.56.

[17] Tex. Parks & Wildlife Code Ann. § 86.002(a) (Vernon 1991); 31 TAC §§ 57.61, et. seq.

[18] 31 TAC § 57.62. See also: Tex. Parks & Wildlife Code Ann. § 86.002(a).

[19] Tex. Parks & Wildlife Code Ann. § 86.003; 31 TAC § 57.65.

[20] 31 TAC § 57.68(a).

- The requirements of industry for the sedimentary materials and their value to State for commercial use.[21]

The executive director *may* also consider the following:

- The applicant's past performance with respect to it obedience to and strict compliance of the terms of past permits;
- Whether the applicant shows evidence of financial responsibility;
- The applicant's ability to operate;
- The existence of sedimentary materials in the area applied for;
- Whether the permit will have a material adverse effect on recreation or the seafood industry, including commercial fishing; and,
- Whether the permit will affect navigation.[22]

If a permit is issued, the permittee must pay the TNRCC for the sedimentary materials that it removes at prices established by the TNRCC and approved by the Governor.[23] To secure payment, the applicant must make a good and sufficient bond payable to the TNRCC.[24] In addition, the permit will prohibit the permittee from interfering with state or federal improvements, navigation, fish life, or riparian water rights.[25]

Sand, shell and gravel permits cannot grant an exclusive right to remove sedimentary material,[26] and they cannot be issued for periods of longer than one year.[27]

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[21] 31 TAC § 57.68(b). See also: Tex. Parks & Wildlife Code Ann. §§ 86.004, 86.005.

[22] 31 TAC § 57.68(a).

[23] 31 TAC § 57.71(d). It may be worth noting that "[s]and other deposits having no commercial value may be taken from Corpus Christi and Nueces bays for filling and raising the grade of . . . the lowlands lying north of the north boundary line of the city of Corpus Christi, in Nueces County, and south of the south boundary line of the city of Portland, in San Patricio County, without making payments for it to the commission." Tex. Parks & Wildlife Code Ann. § 86.015 (Vernon 1991).

[24] 31 TAC § 57.71(b).

[25] 31 TAC § 57.71(e).

[26] 31 TAC § 57.72(a)

[27] 31 TAC § 57.70

B. Easements from the Land Commissioner: An easement for a right-of-way also must be obtained from the Texas Land Commissioner for each location where a water supply pipeline will span, cross through, or tunnel under a navigable stream.[28]

The process is started by filing an application,[29] and since the Land Commissioner can grant no more than two separate rights-of-way in each easement contract,[30] it is likely that an applicant will have to file more than one application.[31] If an application for a Corps of Engineers permit (e.g., Section 10 or Section 404) requires public notice, the Land Commissioner can postpone his decision on the easement application until 30 days after public notice of the Corps application is received.[32]

The Land Commissioner is authorized to establish the terms and conditions of the easement.[33] Several standard provisions are automatically included in pipeline easements on submerged lands, unless the Land Commissioner waives them. These conditions address: the pipeline's depth below or height above the navigable stream; the materials, techniques and testing to be used in its construction; erosion prevention; and sites and conditions to be avoided.[34]

If an easement is granted, the applicant must pay in advance for its use of the easement. Under the current rate schedule, the fee for a ten year easement will probably be $21.00 per lineal rod with a $500.00 minimum.[35]

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[28] Tex. Nat. Res. Code Ann. §§ 51.291, 51.302 (Vernon Supp. 1994). These easements from the Land Commissioner are in addition to the sand, shell and gravel permits that must be obtained from the Texas Parks & Wildlife Department. Tex. Nat. Res. Code Ann. § 51.291(b) (Vernon Supp. 1994).

[29] 31 Tex. Admin. Code § 13.11(a).

[30] 31 T.A.C. § 13.11(b).

[31] If an individual, rather than a nationwide, Section 404 permit is required for the project, the Land Commissioner can postpone his decision on the easement applications until thirty days after he receives the Corps of Engineers' public notice of the Section 404 application. 31 Tex. Admin. Code § 13.11(c).

[32] 31 TAC § 13.11(c). The Corps must issue public notice within 15 days of its receipt of all information required to be submitted by the applicant. 33 C.F.R. § 325.2(d)(1).

[33] Tex. Nat. Res. Code Ann. § 51.295 (Vernon 1978).

[34] 31 TAC § 13.12(b)(1).

[35] 31 TAC § 13.17, Table 1. This rate is based upon a pipeline that has an outside diameter of 13 inches. If for some reason a smaller pipeline is installed, the rate would be considerably less. In addition to the easement fee, the applicant also must record the easement in the county clerk's office of the county in which the land is located, pay the recording fee, and furnish a certified copy of the easement to the Land Commissioner. Tex. Nat. Res. Code Ann. § 51.297 (Vernon 1978 & Vernon Supp. 1994); 31 Tex. Admin. Code 13.12(a)(5).

The current Commissioner does not grant an easement for a term of more than ten years as a matter of policy, although he is authorized to grant water pipeline easements for any term that is "in best interest of the State."[36] Easements are renewed automatically for an additional ten-year term upon the filing of a renewal application and the payment of an amount equal to 50% of the rate at which the easement was granted or renewed.[37] Although renewal applications dispense with most of the requirements for new easements, they subject the applicant to the rules in effect at the time the renewal application is filed.[38]

C. Written Authorization to Adversely Affect Historic Structures or Property: The applicant must obtain written permission from the Texas Historical Commission (THC) before demolishing or adversely affecting the structural, physical, or visual integrity of an historic structure or property.[39]

An "historic structure or property" means any structure or property that has been designated as historic by a political subdivision of the state, the state, or the federal government.[40]

D. Texas Antiquities Permits: Permits from the Texas Antiquities Committee (TAC) may also be required, because state archaeological landmarks, including those on private land, cannot be altered, damaged, destroyed, or excavated without a permit or a contract from the TAC.[41]

E. Compliance with the Coastal Management Plan: During the 1995 legislative session, the Texas Legislature significantly revised the enabling statute for the State's Coastal Management Plan. New rules will be promulgated. The impact of this program cannot be evaluated at this time.

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[36] Tex. Nat. Res. Code Ann. § 51.296(a) (Vernon Supp. 1994).

[37] 31 TAC §§ 13.13(a), 13.17(c).

[38] 31 TAC § 13.13(a).

[39] Tex. Gov. Code Ann. § 442.016(b)(2) (Vernon Supp. 1994).

[40] Tex. Gov. Code Ann. § 442.106(a) (Vernon Supp. 1994). See also: Tex. Gov. Code Ann. § 442.001 (Vernon 1990) (definition of "historic structure," which includes state archeological landmarks and structures on the National Register of Historic Places).

[41] Tex. Nat. Res. Code Ann. §§ 191.053, 191.054, 191.093, 191.131(b) (Vernon 1993); 13 TAC §§ 43.241-242. See also: Tex. Nat. Res. Code Ann. §§ 191.091-.092 (defining "state archeological landmarks"), 191.095 (r.e. landmarks on private lands).

4.11.2 Federal Permits, Approvals and Authorizations

A. Section 10 and Section 404 Permits: Pipeline crossings of rivers, streams, and adjacent wetlands will likely require permits from the U.S. Army Corps of Engineers ("Corps").

Two types of Corps permits are potentially applicable to pipeline projects of Plan A and B: Section 10 permits and Section 404 permits.[42]

Section 10 permits authorize structures and work, such as construction or dredging, in navigable waters,[43] and Section 404 permits authorize the use of dredged or fill material in streambeds.[44] The purview of both permits is limited to the "waters of the United States;" however, each assigns a different definition to the phrase.[45] Section 10 permits only apply to waters that are navigable in the traditional sense (e.g., waters that are susceptible to use in interstate or foreign commerce),[46] while Section 404 permits apply, not only to navigable waters, but also to their tributaries and adjacent wetlands.[47]

1. General Permits: The Corps is authorized to issue "general permits" to regulate categories of similar activities which cause minimal environmental impacts, either

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[42] Rivers and Harbors Act of 1899, ch. 425, § 10, 30 Stat. 1151 (1899) (current version at 33 U.S.C § 403) ("Section 10"); Federal Water Pollution Control Act, ch. 758, Title IV, § 404 (1948) (current version at 33 U.S.C. § 1344) ("Section 404"). Occasionally, both permits are required for the same activity. 33 C.F.R. §§ 322.1, 323.1.

[43] 33 C.F.R. §§ 320.1(b)(3), 320.2(b), 322.3(a). See also: California v. Sierra Club, 451 U.S. 287 (1981) (regarding the test for a Section 10 permit).

[44] 33 C.F.R. §§ 320.1(b)(5), 320.2(f), 323.3(a). "Dredged material" is any material that is dredged or excavated from the waters of the United States, and "fill material" includes materials as common as rock, sand and dirt. 33 CFR § 323.2(c),(e); 40 CFR 232.2.

[45] Compare 33 C.F.R. § 322.2(a) & part 328 (defining "waters of the United States" for purposes of Section 404) with 33 C.F.R. § 323.2(a) & part 329 (defining "navigable waters of the United States" for purposes of Section 10). See also: 33 C.F.R. § 320.1(d) (it is important to know the difference between the two definitions).

[46] Section 10 actually applies to "navigable waters of the United States." The Section 10 regulations define "navigable waters of the United States" as follows: Generally, they are those waters of the United States that are subject to the ebb and flow of the tide shoreward to the mean high water mark, and/or are presently used, or may be susceptible to use to transport interstate or foreign commerce. 33 C.F.R. § 322.2(a). Even though Section 10 only applies to traditional navigable waters, its coverage does include canals and other artificial waterways connected to navigable waters. 33 C.F.R. § 322.5(g).

[47] 33 C.F.R. § 328.3(a)(5); 40 C.F.R. § 232.2. The "waters of the United States" covered by Section 404 permits include: tide waters, interstate waters (e.g., the Gulf of Mexico), intrastate waters having a nexus to interstate or foreign commerce (e.g., water used for recreation by interstate or foreign travelers or for industrial purposes in interstate commerce). 33 CFR §§ 323.2(a), 328.1-328.5; 40 CFR § 232.2.

cumulatively or separately.[48] They are promulgated like a rule. Once the Corps issues a general permit, anyone can engage in the activity authorized without filing an application.[49] It is customary to file an application to obtain the Corps' verification that a general permit does in fact apply.[50]

There are two categories of general permits: nationwide permits and regional permits.[51] Nationwide permits are issued by the Chief of Engineers at the Corps' headquarters in Washington, D.C. and have nationwide applicability.[52] Regional permits are issued by district or division engineers and are applicable only within the district or division.[53]

a. Nationwide Permit No. 12: At least one nationwide permit could apply to the stream crossings used in the water supply options for Plan A and B--Nationwide Permit No. 12, which is a Section 404 permit that authorizes discharges of backfill and bedding material for utility line projects.[54] Water pipelines are included in the permit's definition of "utility lines."[55]

Nationwide Permit No. 12 allows material resulting from trench excavation to be temporarily sidecast into the waters of the United States for up to three months, provided the material is not dispersed by currents or other forces.[56] In addition, Nationwide Permit No. 12 contains four limiting conditions: 1) the area of waters disturbed by the project must be limited to the minimum necessary to

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[48] 33 U.S.C. 1344(e)(1), 33 C.F.R. § 323.2(h) (Section 404); 33 C.F.R. §§ 322.2(f), 322.5(a) (Section 10); 33 C.F.R. §§ 325.5(c), 330.1(g) (Corps permits generally).

[49] 33 C.F.R. §§ 320.1(c), 325.5(c), 330.1(e)(1). The applicability of a general Corps permit does not obviate the need to obtain any other federal, state, or local permit, approval, or authorization that is required by law. 33 C.F.R. 330.4(b)(2).

[50] The Corps' district engineers are instructed to review all incoming applications to determine if a general permit applies. If a general permit is found to apply, the district engineer will verify the authorization and provide the applicant with written notification of the verification. 33 C.F.R. § 330.1(f).

[51] 33 C.F.R. § 325.5(c).

[52] 33 C.F.R. §§ 325.5(c)(2), 330.1(b).

[53] 33 C.F.R. §§ 320.1(c), 325.5(c)(1).

[54] 33 C.F.R. pt. 330, app. A, § B(12). A Section 10 permit will also be required if the pipeline obstructs the navigable waters of the United States.

[55] Ibid. ("A 'utility line' is defined as any pipe or pipeline for the transportation of any . . . liquid.").

[56] Ibid.

construct the utility line; 2) the bed and banks must be returned to their preconstruction contours; 3) exposed slopes and streambanks must be stabilized; and, 4) excess material must be removed to upland areas.[57]

Nationwide Permit No. 12 also incorporates the general conditions that apply to all nationwide permits,[58] as well as the restrictions for Section 404 permits.

The duration of general permits is limited to a maximum of five years.[59] Nationwide Permit No. 12's effective date was January 21, 1992;[60] therefore, it will expire on or before January 21, 1997. Any permitted activity that has commenced or is under contract to commence on the expiration date will remain authorized, provided the activity is completed within twelve months of that date, unless the Corps exercises its discretion to modify, suspend or revoke the authorization.[61]

b. Regional permit for pipelines placed by directional drilling: The Corps' Galveston District has a regional Section 10 permit which authorizes the placement of pipelines by directional drilling in all navigable waters within the Galveston District. The permit is referred to as "General Permit No. 14114,"[62] and it can be used to authorize an applicant to tunnel the pipeline under any navigable stream.[63]

To obtain authorization to operate under General Permit No. 14114, a standard application form must be completed and submitted to the district engineer and the U.S. Coast Guard at least two weeks prior to the commencement of any work that is subject to the permit. If authorization is received, as it is routinely, the applicant has two years to complete the authorized work.

General Permit No. 14114 has several special conditions, including:

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[57] Ibid.

[58] 33 C.F.R. Pt. 330, App. A(C).

[59] 33 U.S.C. § 1344(e)(2); 33 C.F.R. § 330.6(b).

[60] 56 Fed. Reg. 59110 (1991).

[61] 33 C.F.R. § 330.6(b).

[62] Regional permits are often referred to as "general permits," even though general permits actually refers to nationwide permits as well.

[63] "For purposes of a Section 10 permit, a tunnel or other structure or work under or over a navigable water of the United States is considered to have an impact on the navigable capacity of the waterbody." 33 C.F.R. § 322.3(a).

- All existing pipelines in the immediate vicinity of the proposed work must be identified and their owners must be notified of the proposed activity;

- Discharges of dredged or fill material and dredging are prohibited for purposes of the work done under the permit;

- The disturbance of adjacent wetlands, submerged vegetation, and reefs must be avoided;

- Individual actions under the permit must be reviewed for potential impacts to historic properties; and,

- The activity cannot affect a threatened or endangered species or adversely modify their critical habitat.

It also requires that a pipeline be placed at a certain depth, depending on the characteristics of the navigable stream that it passes under.

General Permit No. 14114 will not expire until December 31, 1996.

2. Individual Permits: If the stream crossings involved in the project are not covered by Nationwide Permit No. 12, General Permit No. 14114, or any other general permit an individual permit may be required. To obtain an individual permit, an application must be filed that includes a complete description of the proposed project and its related activities and sufficient information to demonstrate compliance with the requisite guidelines. The applicant is not required to specify the type of permit that is needed, because the district engineer will make that determination.[64]

An individual permit may be issued as a standard permit or as a Letter of Permission (LOP).[65] A standard permit is one processed through the typical review procedure,

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[64] The same forms are used whether a Section 10 or a Section 404 permit is requested. See: 33 C.F.R. §§ 325.1(c) (application form: ENG Form 4345), 325.5 (permit form: ENG Form 1721). According to the instructions that accompany the application, routine applications involving public notice generally take two to three months to process. Applications for large or complex activities may take longer, and for them, the Corps recommends pre-hearing consultations or informal meetings during the project's early planning stages. A joint processing meeting is held at the Corps' district office in Galveston every two weeks. These meetings attempt to coordinate the efforts of federal and state agencies that review permit applications. The agencies that participate include: the Corps, U.S. Fish and Wildlife Service, the Texas General Land Office, and the Texas Parks and Wildlife Department. EPA does not participate at this time.

[65] According to the instructions that accompany the application, only three percent of all requests for permits are denied.

which includes public notice and comment and an opportunity for a public hearing.[66] LOPs are issued through an abbreviated procedure.[67] If the Corps issues either, it probably will be a Section 10 authorization, because constructing a pipeline across streams and rivers is not likely to disturb the streambed enough to warrant a Section 404 authorization for discharges of dredged or fill material.[68]

Whether a Section 10 or a Section 404 authorization is sought, the Corps will conduct a public interest review, which balances the proposed activity's reasonably foreseeable benefits against its reasonably foreseeable detriments.[69] When conducting this review, the Corps will evaluate:

- The relative extent of the public and private need for the proposed activity;
- The practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed activity; and,
- The extent and performance of the beneficial and/or detrimental effects which the proposed activity is likely to have on the public and private uses to which the area

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[66] Public notice will be issued within 15 days of the Corps' receipt of all required information. 33 C.F.R. §§ 325.2(a)(2), 325.2(d)(1). See also 33 C.F.R. § 325.3 (regarding the content and distribution of the notice). If it is determined that the application is for a Section 404 permit, the Corps and the TNRCC will issue a joint public notice, notifying the public that the application has been filed and that the TWC will be evaluating it for compliance with the State's Section 401 water quality standards. See 33 C.F.R. § 325.2(e)(3) (r.e. joint procedures). The comment period will extend no more than 30 days nor less than 15 days from the date of notice. 33 C.F.R. § 325.2(d)(2). If the application is for a Section 404 permit, there will be a 30-day comment period, at least as to the TNRCC's Section 401 compliance evaluation. The district engineer may specify in the public notice that a public hearing will be held, or any person may request a public hearing in writing during the comment period. 33 C.F.R. § 327.4(a) & (b). If a public hearing is requested, the district engineer will grant the request, unless he determines that the issues raised are insubstantial or there is otherwise no valid interest to be served. 33 C.F.R. § 327.4(b). The Corps' goal is to decide whether to issue or deny the permit within 60 days of from the date on which all required information is received. However, when public hearings or complex activities, issues, or legal requirements are involved, the district engineer often needs more time. 33 C.F.R. § 325.2(d)(3). Most applications involving public notice are completed within four months.

[67] The LOP procedure involves coordination with Federal and state fish and wildlife agencies, as required by the Fish and Wildlife Coordination Act, and a public interest evaluation , but without the publishing of an individual notice. 33 C.F.C. § 325.2(e)(1)(i).

[68] With respect to a Section 10 authorization, a LOP may be issued, rather than a standard permit, if the district engineer determines that the project "would be minor, would not have significant individual or cumulative impacts on environmental values, and should encounter no appreciable opposition." 33 C.F.C. § 325.2(e)(1)(i). The analysis for Section 404 LOPs is a little more complicated. See 33 C.F.R. 325.2(e)(1)(ii).

[69] 33 C.F.R. § 320.4(a). The Corps' public interest review regulations were promulgated initially to implement Section 10 of the Rivers and Harbors Act; however, they also are considered for permits issued pursuant to Section 404. This is so, even though the Section 404 regulations indicate that a permit will be granted if the Section 404(b)(1) guidelines are met. See 33 C.F.R. § 323.6.

is suited.[70]

Factors which may be relevant to the proposed activity must be weighed, including: economics, aesthetics, general environmental concerns, historic and cultural values, fish and wildlife values, flood hazards and floodplain values, land use, navigation, recreation, water supply and quality, conservation, food and fiber production, and, in general, the needs and welfare of the people.[71]

If a Section 404 authorization is sought, the Corps will conduct an additional review. Unlike Section 10, Section 404 requires consideration of, what are commonly referred to as, the "Section 404(b)(1) guidelines."[72] The Section 404(b)(1) guidelines prohibit the issuance of a permit:

- When there is "a practicable alternative to the discharge which would have less adverse impact on the aquatic ecosystem"[73];
- When there will be a significant degradation of the waters of the United States;[74]
- When reasonable mitigation is necessary, but not employed;[75] and,

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[70] 33 C.F.R. § 320.4(a)(2).

[71] 33 C.F.R. § 320.4(a)(1).

[72] See 40 C.F.R. Pt. 230. The Section 404(b)(1) guidelines are promulgated by the EPA, rather than the Corps. Moreover, the EPA determines a property's wetland status. See In re Alameda County Assessors' Parcels Nos. 537-801-2-4 and 537-850-9, 672 F.Supp. 1278 (N.D. Cal. 1987). A Section 404 permit cannot be issued unless the guidelines are satisfied. 33 C.F.R. § 323.6. The Section 404(b)(1) criteria are considered to be binding substantive rules, even though they are referred to as "guidelines." Buttrey v. United States, 690 F.2d 1170, 1180 (5th Cir. 1982).

[73] 40 C.F.R. § 230.10(a). When considering practicable alternatives, the Corps can consider costs, existing technologies, and logistics, in light of the project's overall purposes. 40 C.F.R. § 230.10(a)(2). There is a rebuttable presumption that practicable alternatives which do not involve a discharge into a wetland have less adverse impact on the aquatic ecosystem. 40 C.F.R. § 230.10(a)(3). In addition, if the project is water-dependent, there is another rebuttable presumption that some practicable upland alternative exists. 40 C.F.R. § 230.10(a)(3).

[74] 40 C.F.R. § 230.10(c). Effects contributing to significant degradation include adverse effects on humans, aquatic and other wildlife, aquatic ecosystems, recreation, aesthetics, and economics. Ibid.

[75] 40 C.F.R. § 230.10(d). An applicant has the duty to mitigate the impact of the discharge, even though it may be acceptable under the guidelines. Ibid. In fact, mitigation is not even considered until after the permit application is determined to meet other relevant criteria. Mitigation MOA, Part II(C). If the TNRCC requires mitigation of any adverse impacts on fish and wildlife habitats, it must offset it against any mitigation required by the U.S. Fish and Wildlife Service under a Section 404 permit. Tex. Water Code Ann. § 11.152; 31 TAC § 297.49.

- When other statutory violations will occur.[76]

The Corps will vary its evaluation of these requirements to reflect the seriousness of the potential for adverse impacts posed by the activity.[77]

Another difference between Section 10 and Section 404 permits is their duration. Permits that authorize the existence of permanent structures, such as pipelines, usually cite no expiration date and are of indefinite duration.[78] On the other hand, permits that authorize activities, such as the discharge of dredge or fill material, generally specify a time limit for completing the activity and often specify a date by which the activity must commence (normally one year from the date of issuance).[79] Section 10 permits fall in the former category, and Section 404 permits fall in the latter.

B. Easement from the Bureau of Reclamation: The land surrounding Lake Texana (Alternative LN-1) is under the Bureau of Reclamation's jurisdiction, and before any part of the pipeline can be constructed there, the Secretary of Interior must grant an easement to L-NRA.[80] The Secretary can issue the easement with or without limitation as to the period of time.[81]

4.11.3 Issues Associated With Plan A Implementation: The permits and the issues involving Plan A are listed below.

Alternative N-1: Modification of Choke Canyon/Lake Corpus Christi Operating Policy to Incorporate 1995 Agreed Order: The TNRCC Order which requires the City to operate the reservoirs to insure water for the Nueces Estuary was issued in April, 1995. The City has implemented this order.

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[76] The guidelines require the activity to comply with the following: 1) Any applicable State water quality standard under Section 401 of the Clean Water Act; 2) Any toxic effluent standard or prohibition under Section 307 of the Clean Water Act; The Endangered Species Act; and, 3) Any requirement imposed to protect a marine sanctuary pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act. 40 C.F.R. § 230.10(b).

[77] 40 C.F.R. § 230.10.

[78] 33 C.F.R. § 325.6(b).

[79] 33 C.F.R. § 325.6(c).

[80] 43 U.S.C. § 387.

[81] Ibid. However, with respect to Alternative LN-1, if LNRA is still under a contract obligation to repay the any costs associated with the reservoir's construction, its governing board must approve any term that exceeds twenty-five years. Ibid.

Alternative L-6: Accelerated/Additional Municipal Water Conservation: Major issues include public acceptance and willingness to:

- Replace plumbing fixtures in their homes, workplaces, and institutions;
- Change landscaping at homes and public places, including recreation areas; and
- Become more conscious of and directly involved with management of personal water using functions.

The replacement of plumbing fixtures would be a temporary inconvenience; water conservation landscaping would result in views of different types of grasses and plants, and during the dry times more brown and less green lawns and public areas. A water conscious public would increase care with which plumbing fixtures, water using appliances, and irrigation equipment is used. For some actions under this alternative, the City Council will need to issue new ordinances dealing with specific issues such as landscape requirements for new subdivisions.

Alternative LN-1: Lake Texana Pipeline to Corpus Christi Service Area: The following permits and actions will be needed:

- TNRCC amendment of Lake Texana Permit, authorizing transfer of water from Lake Texana to the Corpus Christi service area;
- Coastal Coordinating Council review;
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for pipeline crossings of streams classified as navigable waters of the U.S.;
- Texas General Land Office Sand and Gravel Removal permits and stream crossings;
- Texas Parks and Wildlife Sand, Gravel, and Marl permits for river crossings;
- Environmental studies;
- Cultural resource studies;
- Right-of-way and easement acquisition;
- Affected Agency approvals for pipeline crossings:
  - Texas Department of Transportation;
  - County Commissioners' Courts;

- Cities;
- Railroads;
- River Authorities;
- Gas and electric utilities;
- Water Utilities;
- Oil and gas pipeline companies; and
- Other owners of pipelines; and

- Habitat Mitigation Plan.

Alternative C-1: Purchase of Garwood Water Rights: Pipeline from Colorado River downstream of Garwood to Lavaca Basin, with transfer of Garwood Water through Lake Texana and via the Lake Texana pipeline (LN-1) to the Corpus Christi Service Area. The following permits and actions will be needed:

- TNRCC Amendment of Garwood Irrigation Company Water rights permit authorizing transfer of water from the Colorado River through Lake Texana to the Corpus Christi service area:

- Coastal Coordinating Council review;

- Agreements with the Lavaca-Navidad River Authority (LNRA) for temporary storage of Colorado River water in Lake Texana and any use of LNRA facilities;

- U.S. Army Corps of Engineers Section 10 and 404 dredge and fill permits for pipeline crossings of streams classified as navigable waters of the U.S.;

- Texas General Land Office Sand and Gravel Removal permits and stream crossings;

- Texas Parks and Wildlife Sand, Gravel, and Marl permits for river crossings;

- Environmental studies;

- Cultural resource studies;

- Right-of-way and easement acquisition;

- Affected Agency approvals for pipeline crossings:
  - Texas Department of Transportation;
  - County Commissioners' Courts;
  - Cities;
  - Railroads;
  - River Authorities;
  - Gas and electric utilities;

- Water Utilities;
- Oil and gas pipeline companies; and
- Other owners of pipelines; and

- Habitat Mitigation Plan.

Alternative N-5: Pipeline from Choke Canyon Reservoir to Lake Corpus Christi:

The following permits and actions would be needed:

- Study of impacts of reduced flows in the Nueces River between Choke Canyon Reservoir and Lake Corpus Christi upon river habitat, instream uses, and channel losses;

- Coastal Coordinating Council Review;

- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for pipeline crossings of streams classified as navigable waters of the U.S.;

- Texas General Land Office Sand and Gravel Removal permits and stream crossings;

- Texas Parks and Wildlife Sand, Gravel, and Marl permits for river crossings;

- Environmental studies;

- Cultural resource studies;

- Right-of-way and easement acquisition;

- Affected Agency approvals for pipeline crossings:
  - Texas Department of Transportation;
  - County Commissioners' Courts;
  - Cities;
  - Railroads;
  - River Authorities;
  - Water Utilities;
  - Oil and gas pipeline companies; and
  - Other owners of pipelines; and

- Habitat Mitigation Plan.

4.11.4 Issues Associated With Plan B Implementation: The permits and implementation issues for each alternative of Plan B are listed below, with alternatives common to Plan A, so noted.

Alternative N-1: Modification of Choke Canyon/Lake Corpus Christi Operating Policy to incorporate 1995 Agreed Order (same as Plan A).

Alternative L-6: Accelerated and Additional Municipal Water Conservation (same as Plan A).

Alternative LN-1: Lake Texana Pipeline (included in Plan A as 60" pipeline): Under Plan B, this option is for a 66" pipeline. However, the permits and actions needed are the same as for the 60" pipeline, and are included in Plan A.

Alternative C-1: Purchase of Garwood Water Rights: Pipeline from Colorado River downstream of Garwood to Lavaca Basin, with transfer of Garwood water through Lake Texana and via the Lake Texana pipeline (LN-1) to the Corpus Christi Service Area (included in Plan A as a 48-inch pipeline). Under Plan B, this option is for a 60-inch pipeline. However, the permits and actions needed are the same as for the 48-inch pipeline and are included in Plan A.

Alternative C-2: Additional Garwood or Colorado River Water: Pipeline from Colorado River downstream of Garwood or Pierce Ranch, with transfer of water through Lake Texana and via the Lake Texana pipeline (LN-1) to the Corpus Christi Service area: The following permits and actions will be needed:

- Water purchase agreement with the Garwood Irrigation Company, the Lower Colorado River Authority (LCRA) and/or Pierce Ranch for purchase of about 16,000 acft of water from Colorado River;
- Hydrologic modeling will be needed to determine volume of stored water needed to firm up run-of-river rights, depending on the rights purchased;
- TNRCC Amendment of Garwood Irrigation Company, LCRA and/or Pierce Ranch water rights permits authorizing transfer of water from the Colorado River through

Lake Texana to the Corpus Christi service area;

- Coastal Coordinating Council review;
- Agreements with the Lavaca-Navidad River Authority (LNRA) for temporary storage of Colorado River water in Lake Texana and any use of LNRA facilities;
- U.S. Army Corps of Engineers Section 10 and 404 dredge and fill permits for pipeline crossings of streams classified as navigable waters of the U.S.;
- Texas General Land Office Sand and Gravel Removal permits and stream crossings;
- Texas Parks and Wildlife Sand, Gravel, and Marl permits for river crossings;
- Environmental studies;
- Cultural resource studies;
- Right-of-way and easement acquisition;
- Affected Agency approvals for pipeline crossings:
  - Texas Department of Transportation;
  - County Commissioners' Courts;
  - Cities;
  - Railroads;
  - River Authorities;
  - Gas and electric utilities;
  - Water Utilities;
  - Oil and gas pipeline companies; and
  - Other owners of pipelines; and
- Habitat Mitigation Plan.
- Consider potential cost savings for combined options at Lake Texana Pipeline (LN-1), Garwood Water (C-1) and additional Garwood or Colorado River Water (C-2) through a single pipeline from the Colorado River to transport both this water and the Garwood water to Lake Texana as well as an upsized Texana pipeline to transport the three combined sources of water to the Corpus Christi area.

Alternative N-1: Modification of Choke Canyon/Lake Corpus Christi Operating Policy by changing to a Target Evaluation of 87 ft-msl: This option differs from Alternative N-1, as listed above, in that the operating policy would be to reduce the target levels of Lake Corpus Christi from elevation 88 ft-msl to 87 ft-msl. The following actions will need to be taken:

- Presently, there are no known additional permits required;

- The planned sediment survey of Lake Corpus Christi needs to be completed. This will provide more accurate estimates of the sedimentation rate in the lake, which will result in better estimates of future reservoir capacities. The capacities of the lakes play an important role in the firm yield of the system. If the results of the sedimentation surveys indicate that reservoir sedimentation is continuing at historical rates, then a large percentage of the increases in yield presented herein (estimated for 2010 sediment conditions) are only temporary gains. Following the results of the sediment survey, reservoir system yield should be re-computed for both 2010 and 2050 conditions.

- Additional channel loss studies on the river reaches between CCR and LCC and between LCC and Calallen Dam need to be completed to determine if losses vary significantly with the time of year and the magnitude of the release rates. Any new operating policy must consider losses from all sources in order to fully maximize the yield of the reservoir system while attempting, to the extent possible, to minimize impacts to recreational users.

- If an alternative reservoir operating policy is implemented prior to an alternative water source with better water quality becoming available, a detailed analysis of water quality should be undertaken to determine the degree and extent of water quality changes at Stevens as a result of less frequent water supply releases occurring from Choke Canyon Reservoir.

- Consideration of lower target levels at Lake Corpus Christi should continue to address the need to modify water supply intakes in and around Lake Corpus Christi, especially if target levels below 84 ft-msl are considered.

- Modification of the current City Ordinance describing the implementation of operation policy phases as demands increase will be necessary if alternative operating policies are implemented.

5.0 RECOMMENDATIONS

Either of the two integrated water supply plans provide the Corpus Christi service area with the opportunity to develop economical and reliable water supplies to meet the growing needs of the area, provided that an orderly and flexible implementation plan is followed and key decision points are maintained. Intrinsic to the plan is the flexibility to adjust the implementation schedule as needed to meet the water needs of the service area. The decision-making framework to give the City full advantage of this flexibility is discussed here. However, significant lead times are needed to conduct studies for permitting, answer the public's concerns, obtain financing, obtain easements, and bring the individual plan elements on-line. Long lead times require long-range planning, an orderly progression of recommended actions, and a commitment to periodically update the area growth trends for decision making.

The planning framework set forth below contains the action-item recommendations for implementation of an integrated water supply plan. Figures 5.0-1 and 5.0-2 present bar chart timelines of the recommended implementation schedule for Plan A and Plan B, respectively.

The Trans-Texas Water Program defines the following project phases and these designations are used in the recommended implementation plan and schedule:

Phase I:	Program Initiation/Conceptual Planning (Phase I has been completed)
Phase II:	Feasibility Studies (This report when finalized will conclude the Phase II work on Group 1 alternatives.)
Phase III:	Preliminary Project Design/State and Federal Permitting
Phase IV:	Property Acquisition/Final Design
Phase V:	Project Construction, Start-up, and Operation.

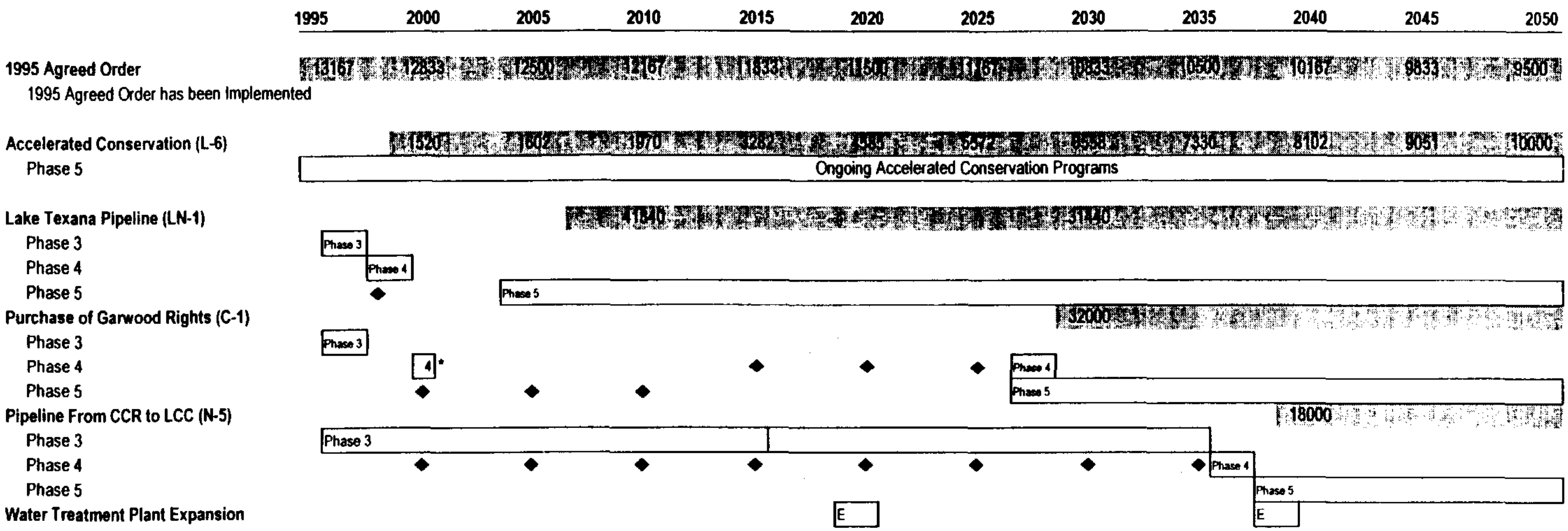
Recommended actions that are included in both Plan A and Plan B are discussed below:

Year 1996 to 2000

1. Accelerated and Additional Municipal Water Conservation (L-6)
   Phase III and IV: These Phases are not applicable to this alternative.
   Phase V:
   a. Continue and Enhance Public Information Program
   b. Begin Water Audit Program
   c. Continue and Enhance Plumbing Retrofit Kit Program
   d. Evaluate potential to revise city ordinances to require the use of drought tolerant grassees and landscaping in new subdivisions.

Integrated Water Supply Plan A

PLAN A - PHASING SCHEDULE



	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Sum of Additional New Water Supplies (acft/yr)	13167	14353	14102	55977	56955	57925	58578	80831	81270	99709	100324	100940
New Water Supply Needed (acft/yr)	0	0	0	14500	24500	34500	45400	56500	67500	78500	89500	100500

Phases of the Trans-Texas Water Program Are:

- Phase 3: Preliminary Design / State and Federal Permitting / Further Investigations
- Phase 4: Final Design / Property Aquisition
- Phase 5: Project Construction, Start-Up, and Operation

Legend:

Numbers in shaded bars indicate new water supply from the alternative.

Outlined areas indicate duration of phase

E 35 MGD Water Treatment Plant Expansion

◆ Milestone review by Corpus Christi to update growth projections, adjust integrated supply plan implementation schedule, and consider milestone decisions.

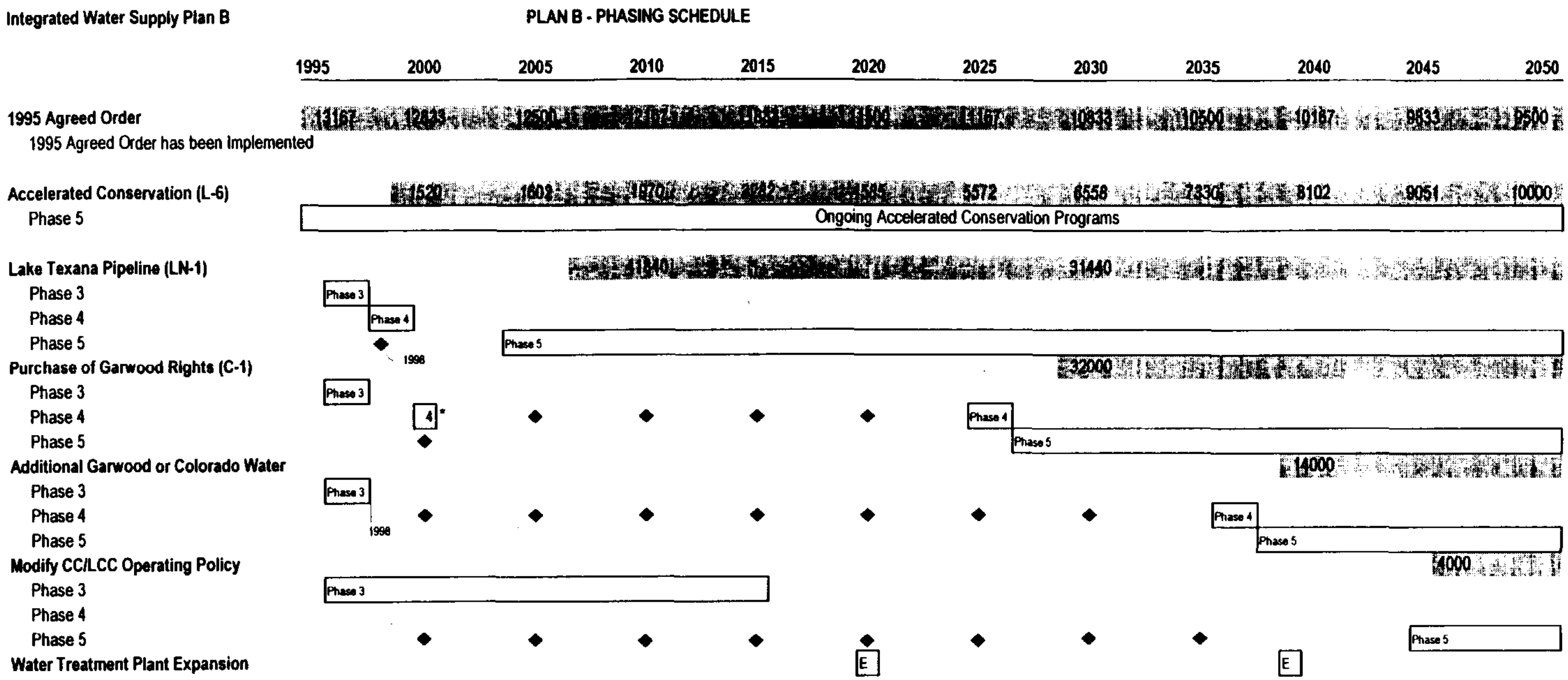
* Easement Acquisition Only

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

PHASING SCHEDULE INTEGRATED WATER SUPPLY PLAN A

FIGURE 5.0-1



	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Sum of Additional New Water Supplies (acft/yr)	13167	14353	14102	55977	56955	57925	58578	80831	81270	95709	96324	100940
New Water Supply Needed (acft/yr)	0	0	0	14500	24500	34500	45400	56500	67500	78500	89500	100500

Phases of the Trans-Texas Water Program Are:

Phase 3: Preliminary Design / State and Federal Permitting / Further Investigations

Phase 4: Final Design / Property Aquisition

Phase 5: Project Construction, Start-Up, and Operation

Legend:

Numbers in shaded bars indicate new water supply from the alternative.

Outlined areas indicate duration of phase

E 35 MGD Water Treatment Plant Expansion

◆ Milestone review by Corpus Christi to update growth projections, adjust integrated supply plan implementation schedule, and consider milestone decisions.

* Easement Acquisition Only

HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / CORPUS CHRISTI SERVICE AREA

PHASING SCHEDULE INTEGRATED WATER SUPPLY PLAN B

FIGURE 5.0-2

2. Lake Texana Pipeline (LN-1)

Initiate Phase III by 1996:

a. Make application to TNRCC for amendment to Lake Texana Permit, authorizing interbasin transfer of water from Lake Texana.
b. Prepare Preliminary Engineering Report.
c. Continue detailed route studies to avoid environmentally sensitive areas, wetlands, and cultural resources.
d. Prepare habitat mitigation plan.

Initiate Phase IV in 1997:

a. Finalize pipeline alignment.
b. Plan easement acquisition.
c. Perform rate sutdy and financing plan.
d. Pursue possible alternative financing with TWDB.

> Decision Milestone: By 1998, using information developed from this and other studies (i.e., rate studies, permitting issues, growth rates, and public input) consider and decide on capacity of Texana Pipeline (i.e. Plan A: 60" pipeline or Plan B: 66" pipeline).

e. Complete Phase IV Final Design by 2000.

3. Purchase of Garwood Water Right (C-1)

Initiate Phase III in 1996:

a. Prepare Preliminary Engineering Report
b. Make application to TNRCC for amendment to Garwood Permit, authorizing transfer of water from Colorado River to the Corpus Christi service area through Lake Texana.
c. Continue detailed route studies to avoid environmentally sensitive areas, wetlands, and cultural resources.
d. Prepare habitat mitigation plan.

> Decision Milestone: Upon obtaining permit amendment, purchase 35,000 acft/yr of Garwood water rights.
>
> a. Financing and payment methods.
> b. Based on decision made for Texana Pipeline capacity, (i.e. Plan A: 60" or Plan B: 66"), consider option to pursue purchase of additional Colorado River water, if favorable.

4. Purchase of Additional Garwood Water or other Colorado River water (C-1) or (C-2)

a. Begin discussions with water right owners by 1996 to determine feasibility of obtaining an option contract for future purchase of an additional 15,000 to 16,000 acft of Colorado River water.

Decision Milestone: By 1998, decide on capacity and size of Texana Pipeline considering the results of efforts to obtain additional Colorado River water under favorable contract terms. If efforts are not successful, then proceed with 60" pipeline.

5. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
   a. Initiate long-term study of channel losses in river reaches and install additional stream gages downstream of Choke Canyon Reservoir and upstream of Lake Corpus Christi.
   b. Perform detailed evaluation of impacts of reduced flows on the by-passed reach

6. Modification of Choke Canyon/Lake Corpus Christi Operating Policy
   a. Complete TWDB Sedimentation Survey of Lake Corpus Christi next time lake fills.
   b. Following completion of Sedimentation Survey, recalculate future estimates of elevation-area-capacity relationships for Lake Corpus Christi and then re-evaluate alternative reservoir operation policies.
   c. Continue channel-loss studies on two reaches (Choke Canyon to Lake Corpus Christi and Lake Corpus Christi to Calallen Dam) of Nueces River to determine how loss rates vary by season and by release rates.

7. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Purchase of water rights in Nueces River Basin (N-4). Contact owners and decide by 1998 on availability of water.
   b. Pipeline from Lake Corpus Christi to O.N. Stevens Water Treatment Plant (N-6); Continue channel loss studies and water quality monitoring to further evaluate project feasibility.
   c. Wastewater Diversions to Nueces Delta (L-4) - Implement demonstration project by 1996 to determine biological productivity factors and pursue relief of higher TNRCC effluent standards.
   d. Use of Campbellton wells (and/or San Antonio river water) delivered to Choke Canyon Reservoir (L-3); Continue negotiations with entities in the San Antonio area concerning the possibility of the joint construction of this project to offset impacts of Edwards Aquifer recharge projects.
   e. Potential New Sinton Well Field (L-2); Consider additional groundwater modeling studies to determine the long-term reliability and stability of the water quality from this potential source.

Year 2000 to 2005

1. Accelerated and Additional Municipal Water Conservation (L-6)
   Phase V items:
   a. Continue Public Information Program
   b. Continue Water Audit Program

c. Continue Plumbing Retrofit Kit Program
d. Implement Landscape Standards for New Development by adoption of appropriate city ordinances.

2. Lake Texana Pipeline (LN-1)
Phase IV items:
a. Obtain construction permits:
U.S. Army Corps of Engineers, Sections 10 and 404 permits
Texas General Land Office Sand and Gravel Removal permit
Texas Parks and Wildlife Department Sand, Gravel and Marl permit
Coastal Coordinating Council review
b. Obtain approvals for river, roads, and utility crossings

Decision Milestone: Project financing needs to be complete and construction of Texana Pipeline needs to be initiated prior to 2004 considering favorable financial markets and projected growth in water demands. Upon favorable conditions:
a. Issue bonds for project financing
b. Initiate construction by 2004

3. Purchase of Garwood Water Right (C-1)
Initial Phase IV in about 2000:
a. Finalize pipeline alignment
b. Plan easement acquisition

4. Purchase of Additional Garwood Water or Other Colorado River Water (C-1) or (C-2)
a. No significant actions required.

5. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
a. Continue channel-loss studies.

6. Modification of Choke Canyon/Lake Corpus Christi Operating Policy (N-1)
a. Perform Sedimentation Survey (if not yet completed)
b. Continue channel-loss studies.

7. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
a. Continue investigations and implement individual alternatives, if appropriate.

Year 2006 to 2020

1. Accelerated and Additional Municipal Water Conservation (L-6)
Phase V items:
a. Continue Public Information Program
b. Continue Water Audit Program
c. Possibly end Plumbing Retrofit Kit Program

d. Continue Landscape Standards for New Development
e. Evaluate New Water Conservation Methods

2. Lake Texana Pipeline (LN-1)
   Phase V: construction to be completed and operation to begin by 2007

3. Purchase of Garwood Water Right (C-1)
   Phase IV: complete any remaining permitting studies and finalize easement acquisition

Decision Milestone: By year 2020, update water demand projections and assess financial markets to plan implementation date for Garwood pipeline.

4. Purchase of Additional Garwood Water or Other Colorado River Water (C-1) or (C-2)
   a. If additional Garwood and/or Colorado River water has been obtained, include amounts in planning of Garwood pipeline in Item 3. above.

5. Pipeline from Choke Canyon Reservoir to Lake Corpus Christi (N-5)
   a. Continue channel-loss studies until about 2015 and when adequate data has been obtained re-evaluate yield increases possible if a pipeline were constructed.

6. Modification of Choke Canyon/Lake Corpus Christi Operating Policy (N-1)
   a. Continue channel-loss studies until about 2015 and when adequate data has been obtained, re-evaluate alternative reservoir operating policies for possible implementation.

7. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Continue investigations and implement individual alternatives, if appropriate (refer to page 5-5 for list of alternatives.)

8. Water Treatment Plant Capacity:

Decision Milestone: Water Treatment Plant Capacity: at years 2010 and 2015, update water demand projections and assess need to increase plant capacity. Decision will be influenced by projected peak demands and financial markets. A 35 mgd expansion is currently projected to be needed by 2020.

Year 2021 to 2025

1. Accelerated and Additional Municipal Water Conservation (L-6)
   Phase V items:
   a. Continue Public Information Program
   b. Continue Water Audit Program
   c. Continue Landscape Standards for New Development
   d. Evaluate New Water Conservation Methods

2. Lake Texana Pipeline (LN-1)
Phase V: Continue project operation

3. Purchase of Garwood Water Right and Possibly Other Colorado River Water (C-1) and (C-2)

Decision Milestone: after assessment of updated water demand projections and financial markets, begin final design for pipeline by 2025 and review construction schedule for Garwood diversion and pipeline.

4. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
Phase III items:
   a. Continue channel loss studies (if not yet conclusive).

5. Modification of Choke Canyon/Lake Corpus Christi Reservoir Operating Policy (N-1)
   a. Periodically assess need to revise reservoir operating policy considering on-going channel loss studies and updated reservoir sedimentation survey data.
   b. Perform new sedimentation survey for Lake Corpus Christi.

6. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Continue investigations and implement individual alternatives, if appropriate. (Refer to page 5-5 for list of alternatives.)

Year 2026 to 2030

1. Accelerated and Additional Municipal Water Conservation (L-6)
Phase V items:
   a. Continue Public Information Program
   b. Continue Water Audit Program
   c. Continue Landscape Standards for New Development
   d. Evaluate New Water Conservation Methods

2. Lake Texana Pipeline (LN-1)
Phase V: Continue project operation

3. Purchase of Garwood Water Rights and Possibly Other Colorado River Water (C-1) and (C-2)
Phase V: Construction initiation is estimated to be needed by about 2027 and project should be operational by about 2029.

4. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
   a. Continue channel loss studies (if not yet conclusive).

> Decision Milestone: At year 2030, update water demand projections and assess financial markets to plan implementation date for CCR/LCC pipeline if determined to be a viable alternative.

5. Modification of Choke Canyon/Lake Corpus Christi Reservoir Operation Policy (N-1)
   a. Periodically assess need to revise reservoir operating policy considering on-going channel loss studies and updated reservoir sedimentation survey data.

6. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Continue investigations and implement individual alternatives, if appropriate (refer to page 5-5 for list of alternatives).

Year 2031 to 2035

1. Accelerated and Additional Municipal Water Conservation (L-6)
   Phase V items:
   a. Continue Public Information Program
   b. Continue Water Audit Program
   c. Continue Landscape Standards for New Development
   d. Evaluate and Implement New Water Conservation Methods

2. Lake Texana Pipeline (LN-1)
   Phase V: Continue project operation

3. Purchase of Garwood Water Rights and Other Colorado River Water (C-1) and (C-2)
   Phase V: Continue project operation

4. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
   Phase III: Complete any remaining permitting studies or issues.
   Phase IV: Begin final design by about 2035.

5. Modification of Choke Canyon/Lake Corpus Christi Reservoir Operation Policy (N-1)
   a. Periodically assess need to revise reservoir operating policy considering on-going channel loss studies and updated reservoir sedimentation survey data.

6. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Continue investigations and implement individual alternatives, if appropriate (refer to page 5-5 for list of alternatives).

7. Water Treatment Plant Capacity

> Decision Milestone: Water Treatment Plant Capacity: At years 2030 and 2035 update water demand projections and assess need to construct increased plant capacity. Decision will be influenced by projected peak demands and financial markets. A 35 mgd expansion is currently projected to be needed by about 2039.

Year 2036 to 2040

1. Accelerated and Additional Municipal Water Conservation (L-6)
   Phase V items:
   a. Continue Public Information Program
   b. Continue Water Audit Program
   c. Continue Landscape Standards for New Development
   d. Evaluate and Implement New Water Conservation Methods

2. Lake Texana Pipeline (LN-1)
   Phase V: Continue project operation

3. Purchase of Garwood Water Rights and Other Colorado River Water (C-1) and (C-2)
   Phase V: Continue project operation

4. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
   Phase IV: Complete final design by about 2037

Decision Milestone: After assessment of updated water demands and financial markets, schedule construction for CCR/LCC pipeline by about 2037. Begin operation by about 2039.

5. Modification of Choke Canyon/Lake Corpus Christi Reservoir Operation Policy (N-1)
   a. Periodically assess need to revise reservoir operating policy considering on-going channel loss studies and updated reservoir sedimentation survey data.

6. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Continue investigations and implement individual alternatives, if appropriate (refer to page 5-5 for list of alternatives).

7. Water Treatment Plant Capacity:
   Construct 35 mgd water treatment plant expansion by about 2039.

Year 2041 to 2050

1. Accelerated and Additional Municipal Water Conservation (L-6)
   Phase V items:
   a. Continue Public Information Program
   b. Continue Water Audit Program
   c. Continue Landscape Standards for New Development
   d. Evaluate and Implement New Water Conservation Methods

2. Lake Texana Pipeline (LN-1)
   Phase V: Continue project operation

3. Purchase of Garwood Water Rights and Other Colorado River Water (C-1) and (C-2)
   Phase V: Continue project operation

4. Pipeline from Choke Canyon to Lake Corpus Christi (N-5)
   Phase V: Continue project operation (under Plan A)

5. Modification of Choke Canyon/Lake Corpus Christi Reservoir Operation Policy (N-1)
   a. Periodically assess need to revise reservoir operating policy considering on-going channel loss studies and updated reservoir sedimentation survey data.

6. Other Group 2 and Group 3 Alternatives Requiring Further Investigation
   a. Continue investigations and implement individual alternatives, if appropriate (refer to page 5-5 for list of alternatives).