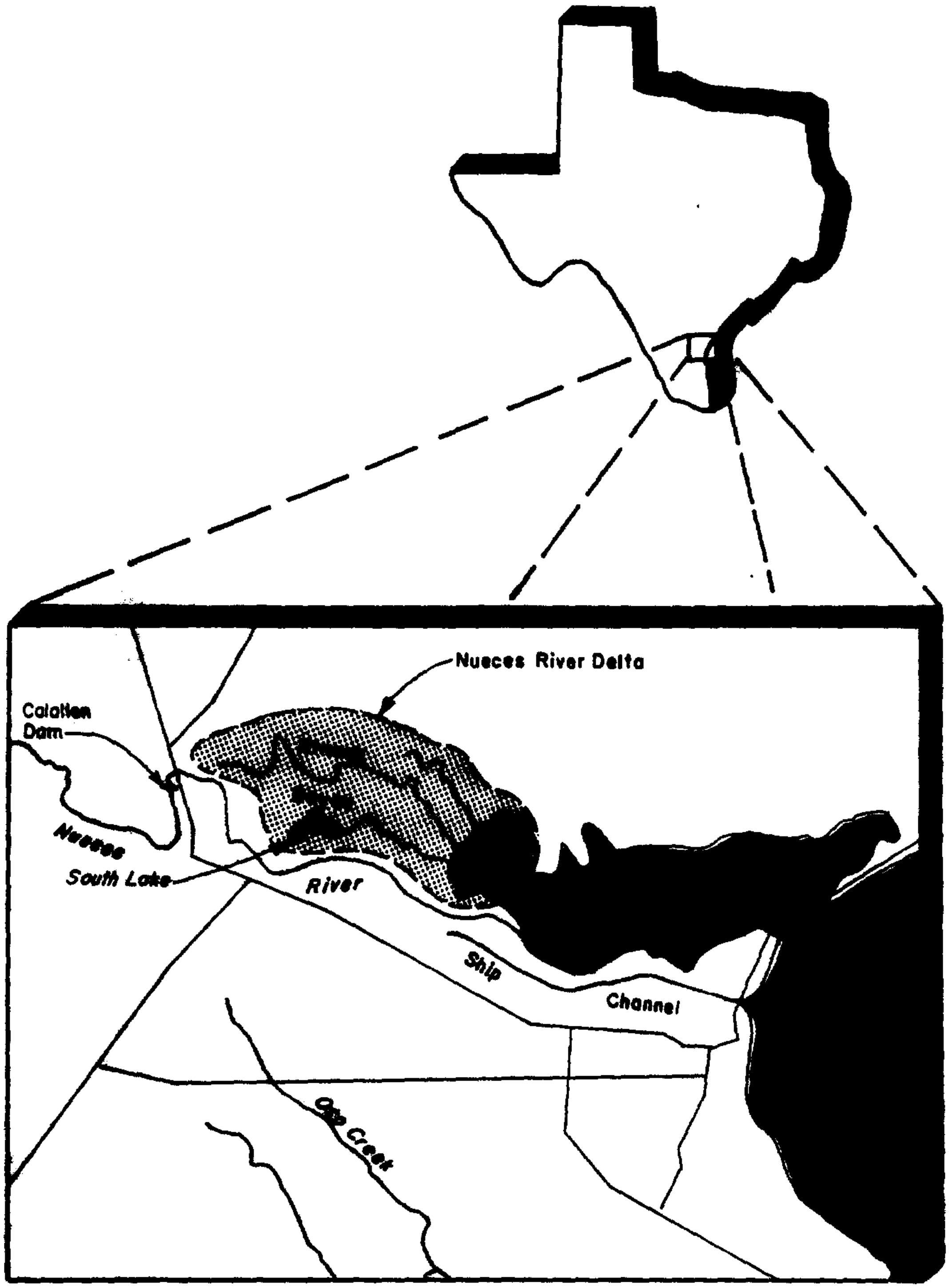
Regional Wastewater Planning Study - Phase II

Nueces Estuary



City of Corpus Christi

Port of Corpus Christi Authority

Corpus Christi Board of Trade

South Texas Water Authority

Texas Water Development Board

March, 1993

HDR

HDR Engineering, Inc.

Naismith Engineering, Inc.

in association with
University of Texas,
Marine Science Institute

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY - PHASE II

Prepared for

City of Corpus Christi
Port of Corpus Christi Authority
Corpus Christi Board of Trade
South Texas Water Authority
Texas Water Development Board

by

HDR Engineering, Inc.
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in association with
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June, 1993

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for
Nueces Estuary
Regional Wastewater Planning Study

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EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY
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1.0 BACKGROUND AND OBJECTIVES

The Choke Canyon/Lake Corpus Christi (CC/LCC) reservoir system of the Nueces River Basin is the principal water supply for the 12-county Coastal Bend region of Texas. In response to concerns about the potential effects of diversion of freshwater from the Nueces River upon the Nueces Estuary, the Texas Water Commission (TWC) placed a condition upon the permit for the development of Choke Canyon Reservoir, requiring the owners to provide not less than 151,000 acre-feet of water per year to the receiving estuaries through a combination of wastewater return flows, and reservoir spills and releases.

In 1990, the TWC established an interim operation plan for the CC/LCC reservoir system which provided for freshwater releases in May and June of 1990, established a Technical Advisory Committee (TAC) to assist in formulating permanent operational procedures, and called for monitoring of the releases to assess their effect upon the estuarine system. In response to the 1990 TWC action, biological monitoring of the effects of the releases was begun, and studies were undertaken in 1991 to assess ways to more efficiently use river diversions and available wastewater effluent to meet estuarine needs. In August, 1991 the TAC made its report to the TWC. On March 9, 1992, the TWC issued an Agreed Order, which established operational procedures, including a monthly schedule of desired inflows to Nueces Bay to be comprised of releases, spills, and diversions. Under the full release schedule, Corpus Christi is required to provide 97,000 acre-feet of water per year to Nueces Bay and/or Rincon Bayou by a combination of releases, spills, and diversions of return flows (wastewater effluent) or stormwater. The remaining 54,000 acre-feet per year of the total 151,000 acre-feet requirement may be delivered to Corpus Christi Bay and other receiving estuaries.

The Texas Water Development Board (TWDB) and local entities funded studies to provide information about how to meet estuarine freshwater needs while minimizing impacts upon reservoir system yields. The methods being evaluated include diversion of river water through Rincon Bayou to Nueces Bay and diversion of wastewater effluent through the Nueces Delta to Nueces Bay instead of releasing river and wastewater flows into the Nueces River, which discharges directly into Nueces Bay. The 1991 Phase I study surveyed quantities and locations of wastewater effluent, made estimates of productivity enhancement due to river and wastewater diversions, and made preliminary estimates of costs of diversion projects. The principal objectives of this Phase II study were to: (1) Continue biological monitoring and productivity evaluations of river and wastewater diversions to the Nueces Delta and Estuary; (2) Prepare the discharge location cost estimates and scheduling information needed to implement the river and wastewater diversion demonstration projects identified and recommended in the Phase I study; (3) Evaluate stormwater and locally available brackish groundwater to meet estuary needs; (4) Update the Lower Nueces River Basin and Estuary Model (NUBAY2), and (5) Evaluate the impact of river, wastewater, and stormwater diversions upon the yield of the CC/LCC System. The results of the study are summarized in the following pages.

2.0 BIOLOGICAL MONITORING OF EFFECTS OF DIVERSION OF FRESHWATER INFLOW AND WASTEWATER RETURN FLOWS IN RINCON BAYOU AND NUECES DELTA

2.1 Primary Production and Biomass Changes of Emergent Marsh Vegetation

Biological monitoring of the effects of diversion of freshwater inflow and wastewater return flows into Rincon Bayou and Nueces Delta, which was begun in 1991 as part of the Phase I study, was continued. Three sites studied in 1991 (Stations 50, 51, and 54) were again studied in 1992. The responses of the vegetation in the Nueces marsh to large freshwater flows in the winter and spring of 1992 were observed and compared to data from 1991, a relatively dry year. The results showed that the above-ground growth for all species was significantly larger at all three sites in 1992 than in 1991. In addition, below-ground growth showed an even larger increase in biomass in 1992, which, in turn, created a very large increase in the overall plant biomass when compared to 1991 levels. The overall percent cover increased in 1992 as well.

2.2 Primary Production of Phytoplankton in Marsh Ponds and Channels

The primary production rates of phytoplankton populations in marsh ponds and connecting channels in the interior of the Nueces Delta were monitored by monthly sampling. The maximum primary productivity rate in the delta increased from 7.22 $gC/m^3/day$ in 1991 to 8.22 $gC/m^3/day$ in 1992 as a result of the increased freshwater inflow.

2.3 Primary Production and Biomass of Microphytobenthos in Marsh Ponds and Channels

The primary production of phytoplankton in the surface sediments (microphytobenthos) was measured at four sites in the marsh ponds. The primary productivity of the microphytobenthos was about 3.8 percent of the water column phytoplankton production rates, which is unusually small compared to rates reported in other publications. In this case, however, it is believed that the absolute production rates in sediment are not low but rather the water column rates are unusually large. Monitoring of the sediment productivity rates should be continued to include higher salinity conditions.

2.4 Primary Production from Freshwater Releases into Nueces Bay

Mean monthly salinity conditions in Nueces Bay showed a variation from 3‰ to 30‰ (mean = 18.8‰) for the period from May 1990 to October, 1992 (‰ means parts per thousand). The highest values occurred during the winter months when precipitation and releases were lowest. In contrast, the lowest salinity values occurred in the late spring and summer when precipitation, spills, and releases are highest. Overall, the rates of primary production measured throughout Nueces Bay and Rincon Delta were not influenced strongly by salinity.

It is notable that Station 4A, located in the lower Nueces River downstream from the Allison Wastewater Treatment Plant, and Station 51, located at the upper end of Rincon Delta where it is largely impacted by freshwater flow increases, both showed the highest mean primary production rates of the six sites sampled. This is evidence that increased freshwater and wastewater return flows have a positive impact on primary productivity in the river and delta.

2.5 Comparison of Primary Production Obtained from Diversions of Freshwater and Wastewater Effluent into Rincon Bayou and Nueces Delta with Primary Production from Freshwater Releases into Nueces Bay

The most direct comparisons of both freshwater and wastewater effects are found in the Nueces River stations where primary productivity rates are nearly always elevated compared to Nueces Bay. The enhanced primary productivity factor of about 5 estimated for the diversion of wastewater return flows to the Nueces Delta in 1991 remained the same after the addition of 1992 data. The introduction of significant quantities of freshwater into Rincon Bayou and Delta in 1992 by direct precipitation and overbanking of the Nueces River elevated the estimated productivity factor from the 1991 estimate of 2 to a value in excess of 3. Data collected in 1992 confirms that wastewater and ambient river water diversions to the Nueces Delta can be expected to increase primary production by factors of about five and three, respectively, when compared to allowing these waters to enter Nueces Bay via the Nueces River.

3.0 DESCRIPTION, ROUTES, SIZES, AND COSTS OF DEMONSTRATION PROJECTS TO DIVERT RIVER WATER AND WASTEWATER EFFLUENT INTO THE NUECES RIVER DELTA

A brief description, together with routes, sizes, and estimated costs of each of three proposed demonstration projects is presented below.

3.1 Project Description and Cost Estimates for Diversion of Nueces River Water at Calallen Dam

This project includes a 12" PVC pipeline from the San Patricio Municipal Water District, W. A. Edwards Pump Station location, northward along the Nueces River, and then eastward beneath U.S. Highway 77 to the proposed discharge area. The pipeline, along with necessary water system appurtenances, and electrical and pump station requirements, would be capable of delivering approximately 2.8 mgd of Nueces River water to the upper delta. Total cost of this project is estimated at $371,000. It is estimated that the time required from the initiation of final design to completion of construction will be approximately 11 to 12 months. The permit applications should be filed concurrent with final design in order to facilitate construction activities at the earliest possible time. Approvals will be required from the property owners within the demonstration area, including the San Patricio Municipal Water District for use of an existing pipeline easement and pump station plant site as well as the McGregor estate and the Thomas E. Finch heirs for pipeline easements.

3.2 Project Description and Cost Estimates for Wastewater Effluent Diversion from Allison Wastewater Treatment Plant

This project includes construction of an 18" PVC pipeline from the Allison Wastewater Treatment Plant northward across the Nueces River and westward to a location in Nueces Bay known as South Lake (TWC Tidal Segment 2482). The project would have the capacity to deliver approximately 2.8 mgd of treated municipal effluent to the demonstration project area. This project would include necessary connections at the Allison Wastewater Treatment Plant, construction of a Nueces River crossing, placement of approximately 7,800 linear feet of effluent pipeline, and construction of a demonstration project area, for a total capital cost of $978,200. It is estimated that from the initiation of final design to completion of construction will require approximately 11 to 12 months.

Permit applications and easement acquisition should be initiated at the start of the final design in order to facilitate construction at the earliest possible date. The City of Corpus Christi should begin at once to seek permission from the TWC to relocate the Allison Wastewater Treatment Plant discharge point from its current location in the Nueces River to the proposed discharge area at South Lake. It is anticipated that this permit modification request will be in the form of a temporary discharge permit to be used for monitoring of the discharge effluent into the demonstration area. Continued use of this location for the Allison Wastewater Treatment Plant outfall will be evaluated after the proposed four-year monitoring period. Easements and right-of-way requirements to construct a pipeline to the demonstration area will be required from approximately six land owners.

3.3 Project Description and Cost Estimates for an Alternative River Diversion Project

In response to Technical Advisory Committee member input, the feasibility of diverting fresh water resources from the Nueces River through the existing O.N. Stevens Water Treatment Plant located at Calallen was addressed in this study. This project would use existing infrastructure to deliver approximately 3.0 mgd of river water to a location in the Nueces Delta that is halfway between the upper portion of Rincon Bayou and South Lake. This potential project would use an existing 36" drain line from the O.N. Stevens Water Treatment Plant to the existing water treatment sludge lagoons located between the Nueces River and IH 37. It would be necessary to construct an 18" pipeline from the sludge lagoons across the Nueces River to the Nueces Delta. It is estimated the total project capital cost would be approximately $551,000. Potential relocation of water treatment sludges from current disposal lagoons to the delta will require further analysis, research, and permitting prior to implementation, and easements will be required from two landowners for pipeline construction and use of the discharge area.

4.0 WASTEWATER QUALITY FOR ESTUARINE DEMONSTRATION PROJECTS

Several meetings with members of the permitting agencies and the environmental community resulted in a consensus that a demonstration project for municipal wastewater effluent from the Allison Wastewater Treatment Plant should be constructed and monitored for a four to five year period prior to implementation of any full-scale transmission facilities. A demonstration project to divert industrial effluent into the Nueces Delta should not be constructed until monitoring of the municipal effluent from the Allison Wastewater Treatment Plant has been completed.

5.0 POTENTIALS FOR INTERNAL REROUTING OF CORPUS CHRISTI WASTEWATER FLOWS

Rerouting potential was considered for four of the City of Corpus Christ's wastewater treatment plants (WWTPs) -- Broadway, Oso, Westside, and Allison. Each plant has a service area and a specific effluent discharge permit and associated discharge point. The Broadway WWTP is located near the mouth of the ship channel and discharges into the Corpus Christi Bay via the ship channel. The Oso WWTP is located on and discharges to Oso Bay. The Westside WWTP is located at the intersection of Saratoga Boulevard (SH 357) and Greenwood Drive and discharges into Oso Bay via Oso Creek. The Allison WWTP is located on McKinzie Road and discharges into the Nueces Bay via the Nueces

River. As the City grows, it is expected that flows and biological loading of the plants will increase. These increases may trigger more stringent Texas Water Commission (TWC) effluent limitations to avoid adverse impacts to the receiving water bodies.

Several alternatives exist for the City of Corpus Christi with regard to collection and treatment options for its wastewater system. If the diversion of Allison Wastewater Treatment Plant effluent (current TWC Permit Conditions are 20-20-4) to the Nueces Delta and Estuary is successful, then the City could consider diverting much or all of its treated wastewater effluent to the Nueces Delta and use available financing to construct necessary transmission facilities in lieu of upgrading plant effluent quality. Internal rerouting of wastewater may provide a cost-effective means of meeting part of the estuarine freshwater needs.

It is estimated that diversion of 6.0 mgd (41 percent) from the Oso WWTP service area to the Westside WWTP would have a capital cost of $22.16 million, with an annual debt service and operation and maintenance cost (O&M) of approximately $2.44 million. However, a diversion of this magnitude would need to be preceded by a decision of the City to expand the Westside WWTP to a "regional" facility.

The largest practical diversion from the Westside service area to the Allison WWTP is approximately 1.0 mgd (33 percent) of untreated wastewater. This diversion is estimated to have a capital cost of $5.31 million, with an annual debt service and O&M cost of $584,000. If this diversion is done, the expansion of the Westside WWTP could be limited to 5.0 mgd instead of the 6.0 mgd mentioned above, which would lower the capital costs of the Oso to Westside WWTP from $22.16 million to $19.16 million, and would lower annual costs from $2.44 million to approximately $2.14 million. However, a 1.0 mgd diversion to the Allison plant will leave very little capacity remaining at this WWTP to satisfy future growth in its service area.

Diversion of the present 6.0 mgd of untreated wastewater from the Broadway WWTP to the Westside WWTP has an estimated capital cost of $26.24 million, with an annual debt service and O&M cost of $2.89 million. However, this diversion would also need to be preceded by a decision of the City to abandon the Broadway WWTP and expand the Westside WWTP to a "regional" facility.

6.0 FEASIBILITY OF STORMWATER DIVERSION FROM OSO AND CHILTIPIN CREEKS TO NUECES DELTA AND BAY

Four projects for potential stormwater diversions to the Nueces Delta were identified and evaluated. The four projects are: (1) Upper Oso Creek; (2) Peters Swale on Upper Chiltipin Creek; (3) Small dam and reservoir on Hondo Creek to store stormwater for later release; and (4) Small dam and reservoir on Hondo Creek to impound stormwater plus groundwater from nearby wells for release in selected months.

6.1 Stormwater Quality

With respect to quality of stormwater from Oso and Hondo Creeks, there are no specific water quality data for evaluation. Hondo Creek presently discharges into the Nueces River downstream of Calallen; thus, the proposed storage reservoir would only change the timing of these flows to the bay. However, any groundwater to be added to these flows would have to be tested and found to be acceptable.

There are no apparent water quality problems which would prohibit diversion of Upper Oso Creek to the Nueces Delta. Drainage from this watershed now enters the Corpus Christi Bay System via Oso Bay.

A recent assessment of nutrient loading of Copano Bay by inflows from Chiltipin Creek does not indicate that there would be a water quality problem with diversions of flows from Peters Swale into Nueces Bay.

6.2 Model Modifications

The Lower Nueces River Basin and Estuary Model (NUBAY2) was modified to incorporate salinity in the monthly determination of releases necessary to comply with the TWC release order, and for use in evaluating the effects upon CC/LCC System yield of transferring stormwater from the adjacent Oso and Chiltipin Creek watersheds into the Nueces Delta and Estuary to meet a portion of the freshwater needs which otherwise would have to be met from reservoir releases.

6.3 Ungaged Inflows

Since information is needed about the quantities of flows into the Nueces Estuary from the presently ungaged areas, two methods of obtaining this information were evaluated: (a) Development of a rainfall-runoff model and a statistical equation for use in estimating monthly ungaged runoff; and (2) Costs of gaging and metering the ungaged areas.

The Texas Water Development Board (TWDB) Rainfall Runoff model (TxRR) was calibrated using gaged streamflow and precipitation records for the Oso and Chiltipin Creek watersheds. The model was used to estimate flows from the drainage areas below Wesley Seale Dam which drain into the Nueces River and/or directly into Nueces Delta and Bay. The estimate of flows is approximately 81,225 acre-feet per year. This is approximately 12 percent of the average annual inflow to Nueces Estuary.

6.4 Gaging and Metering

Measurement of runoff from the presently ungaged watersheds would require installation of a large number of stream gages. A typical gaging and metering station has an installation cost of $7,700. For Hondo Creek and the 13 drainage areas which flow into the Nueces River from the south, downstream of Calallen Dam, the cost of gaging and metering stations would be in excess of $315,700, with an annual estimated operation and maintenance cost of $60,000 to $80,000. No cost estimates could be made for the 67,840-acre Northshore Watershed since data for this area are not adequate for this purpose. However, the costs would clearly be several times that for the area cited above. Thus, the rainfall-runoff model mentioned in Section 6.3 appears to be the least costly method of obtaining estimates of flows into the Nueces Bay and Estuary from the ungaged watersheds.

6.5 Stormwater Diversion Costs

The estimated capital cost for facilities to divert stormwater from a 15,577-acre area of the Upper Oso Creek Watershed to the Nueces River is $19.96 million. The estimated cost for a stormwater diversion channel from Peters Swale at a point east of Odem to

Rincon Bayou of the Nueces Delta is $6.4 million. For a small dam and reservoir on Hondo Creek for storage of Hondo Creek runoff for diversion directly to Rincon Bayou, the capital cost estimate is $2.02 million, with an annual debt service and O&M cost of $223,000. The capital cost of adding a 5.0 mgd well to the Hondo Creek dam and reservoir project would be $945,000, with an annual debt service, O&M, and power cost of $202,000. The costs for a channel dam, intake structure, pump station, pipeline, and discharge structure for the Hondo Creek option ranges from a capital cost of $331,000 for a 2.0 mgd facility to $1.09 million for a 20 mgd capacity facility, with annual debt service, O&M, and power costs ranging from $43,400 to $169,800, respectively.

6.6 Potential Effects of Stormwater Diversion on CC/LCC System Yield

Diversion of stormwater from the 20.3 square mile upper Oso Creek watershed would restore about 227 acre-feet per year of yield to the CC/LCC System at an estimated cost of $2,224 per acre-foot. The Peters Swale diversion from upper Chiltipin Creek is estimated to restore 1,737 acre-feet per year to the CC/LCC System yield at an estimated cost of $405 per acre-foot. The Hondo Creek dam and reservoir storage and diversion project is estimated to increase the CC/LCC System yield by 224 acre-feet per year at an estimated cost of $1,219 per acre-foot.

The stormwater diversion options do not appear to be capable of restoring significant portions of the 30,954 acre-feet of the CC/LCC System yield that the TWC release order effectively assigns to the estuary. In each case, the cost per acre-foot of yield restored is several times higher than the cost of water from the other sources.

6.7 Estuarine Inflow Credits for Ungaged Inflows

The following equation estimates monthly flows from the ungaged watersheds into Nueces Delta and Bay, as a function of the average of monthly precipitation at Weather Service Gage No. 2015 (Corpus Christi WSO AP) and Gage No. 8354 (Sinton). The equation is:

$$R_{ungaged} = -393.27*P_{avg} + 111.66*P_{avg}^2 \qquad \text{(for 3.52 inches} \leq P_{avg} \leq \text{22.96 inches)}$$

Where:

$R_{ungaged}$ = Ungaged inflow to Nueces Bay (acre-feet/month)
P_{avg} = Average precipitation at Corpus Christi WSO AP and Sinton (inches/month)
r^2 = 0.86

(r^2 is a measure of how well the equation explains the variation in ungaged inflows. A perfect explanation would have an r^2 of 1.0)

This equation is a simple method for estimating the ungaged runoff component of inflows to Nueces Delta and Bay.

7.0 EVALUATION OF USE OF SHALLOW BRACKISH GROUNDWATER TO SUPPLEMENT FRESHWATER RELEASES

It was determined through preliminary evaluation of ground water conditions in and around the Nueces Estuary and the area of Edroy, Texas that there is not a sufficient quantity of fresh to slightly saline water (i.e., TDS <3000 ppm) available for use to augment fresh water releases into Nueces Bay. Thus, the use of shallow brackish groundwater to supplement freshwater releases from the CC/LCC System does not appear to be feasible.

8.0 WATER SUPPLY AND RECREATION VALUES OF CHOKE CANYON/LAKE CORPUS CHRISTI SYSTEM

The values of business, employment, and income from use of the CC/LCC system were estimated for 1990, and are summarized below.

8.1 Water Supply

In 1990, reported CC/LCC System Water use was 134,515 acre-feet, of which 43,031 acre-feet was used by the manufacturing sector, 27,445 acre-feet was used by the commercial and services sectors, and 64,039 acre-feet was used by households and for municipal functions. Total value of production by manufacturing and commercial establishments in 1990 was $12.497 billion, employment was 78,915, and 1990 payroll was $1.52 billion. When production, employment, and income multipliers are applied, the gross, economy-wide business effect of the water-using manufacturing industries and commercial establishments was $20.66 billion, with a total employment impact of 109,054 jobs, and a total income effect of $2.45 billion.

8.2 Recreation and Tourism

Average annual visitation to parks at Choke Canyon and Lake Corpus Christi for the period 1988 through 1992 was 1.2 million, with average annual expenditures by visitors of $8.51 million. The gross business associated with recreation and tourism at the CC/LCC system is estimated at $25.15 million annually. The number of jobs associated with this level of business is estimated at 492, with annual incomes of $5.72 million.

8.3 Fishing at Choke Canyon and Lake Corpus Christi

It was estimated that in 1990, 1.1 million people (856,000 Coastal Bend area residents and 258,000 people from other areas) participated in freshwater fishing in the lakes of the area. Expenditures by fishermen were estimated at $44.11 per person in 1990. The economic impacts of this activity in 1990 were estimated at $48.52 million of direct business, $142.29 million of total business, 2,682 full-time jobs, and $32.52 million of income to those who work in the transportation, food, lodging, retail trade, and services industries that supply goods and services to freshwater fisherman.

8.4 Summary of Business, Recreation, Tourism, and Fishing Business, Employment, and Income Associated with the CC/LCC System

The business, employment, and income effects of the industries, commercial establishments, tourism, and freshwater sport fishing in 1990 was estimated at $21.05 billion, 112,228 jobs, and $2.49 billion of income. Of the total business, employment and income effects, 98 percent was from manufacturing and commercial establishments that use water from the CC/LCC System, with recreation related activities accounting for about two percent of the totals.

9.0 POSSIBLE EFFECTS OF OYSTER REEFS, SILL STRUCTURES, AND ELECTRIC POWER STATION DISCHARGES, ON FRESHWATER IN NUECES BAY AND UPON MIXING WITH SALINE WATER OF CORPUS CHRISTI BAY

Preliminary investigations were made into the possible effects of dredging of oyster reefs, channelization of sill structures, and electric power station discharges upon freshwater mixing and salinity of Nueces Bay.

9.1 Past and Present Locations of Oyster Reefs

Between the 1930's and the early 1950's, reefs of oysters were located on the southeast side of Nueces Bay and extended west of the Nueces Bay Causeway. Oysters did not exist in great abundance east of the causeway, and most of the oysters in Nueces Bay were depleted in the early 1950's. Dredging of oyster reefs occurred from the 1930's until 1974. During this period of time, it is estimated that 13 million cubic yards of oyster shell were removed.

An analysis of aerial photographs taken in 1963 and 1987 of Nueces Bay does not show that there has been a change in location of oyster reefs that would have affected circulation, mixing, and salinity concentrations in Nueces Bay during the past 24 years.

9.2 Location of Sill Structures

A large natural sill structure extending from Indian Point on the north to North Beach Peninsula separates Nueces and Corpus Christi Bays. Oyster reefs are attached to this sill. The structure has been a pathway of wagon travel during early settlement of the area, a railroad in the late 1800's, and the Nueces Bay Causeway since 1911. This structure, with the transportation modifications, obviously affects the exchange of water between Nueces and Corpus Christi Bays. However, it is not possible to calculate the effects from data available to this study effort.

9.3 Potential Hydraulic and Salinity Effects from Power Station Discharge and Sill Structure Channelization

Reports from studies of Nueces Bay Power Station discharge concluded that the effects upon Nueces Bay are localized to the immediate area of the discharge plume, and do not appear to have a significant effect upon the entire bay.

In addition to oyster shell dredging, channels have been dredged for petroleum production and maritime activities. Although dredging has been done, data are not available with which to make estimates of its effects upon mixing of fresh and saline water, and thus, it cannot be concluded from the analyses of this study the degree, if any, that dredging and channelization of Nueces Bay has affected its salinity.

9.4 Costs for Sill Structures

Within the scope of this study, the methods and costs of artificial reefs to replace the effects of naturally occurring oyster reefs and sill structures could not be estimated, except to say that the immense size of Nueces Bay (nine miles by three miles) would indicate that such an endeavor would require significant effort and involve considerable (millions of dollars) costs, including those for the necessary federal and state permits.

10.0 CONCEPTS FOR REGIONAL WASTEWATER ENTITY

The City of Corpus Christi's municipal wastewater treatment plants and the ship channel industries currently hold NPDES and State Permits to discharge into the ship channel, and the City also holds permits to discharge into Oso Bay. The creation of a special conservation and reclamation district to receive treated effluent from the City and the ship channel industries, transport the effluent, and discharge it into the Nueces Delta was considered.

10.1 Powers and Authority Needed

A proposed special district that could carry out the river and treated wastewater diversion projects would need to have the following powers:

1. The power to have NPDES and state permits to receive the wastewater from each industry, to transport it by pipeline past the City's Allison Wastewater Treatment Plant, to take wastewater from the City, and to transport the water to the designated delta areas;

2. The power to finance, construct, operate, and maintain pumps and pipelines to convey the wastewater;

3. The power to assess, levy, and collect taxes, to charge rates, or to receive payments from the City or other sources to finance its operations;

4. The power to obtain, by eminent domain or otherwise, sufficient land to receive the discharge in the delta, and all necessary easements, rights-of-way, and leases for conveyance of the effluent; and, perhaps,

5. The power to acquire title to and to operate between 8,000 and 11,000 acres within the delta as a wildlife preserve.

It may be necessary to obtain property rights in order to allow discharge of wastewater effluent. The TWC takes the position that this is not within its jurisdiction; i.e., if effluent is not discharged into a watercourse, the discharge could be a trespass that can be enjoined by the landowner.

10.2 Organizational Structure

It will be necessary to decide whether to create a single purpose district for the management of this project, to contract with an existing district, or to have the City perform the necessary functions (see Section 10.5). If it is decided to create a special district, the district boundaries should encompass the Nueces Delta and such other areas that would benefit from the diversion projects. The creating legislation will provide the number of directors, terms of office, and whether or not the directors are to be elected or appointed, including designation or who is to appoint the directors.

With regard to diverting wastewater to the Nueces Delta, industries are concerned about changing their established discharges for two reasons:

1. Their discharge parameters into the ship channel have been established for existing permits. Changing the point of discharge to the delta may make the discharge parameters more stringent, more difficult to maintain, and more expensive.

2. If significant damage to the bay or delta occurs, the industries are concerned that they will be sued. They are willing to accept responsibility for their own effluent, but they do not want to be responsible for problems caused by others. The concept of joint and several liability for multiple defendants whose acts contribute to the damage is a significant problem.

The possibility of a special district has been suggested, with the hope that the district can insulate the industries from liability for any damage to the delta or bay. However, the rationale of the opinions in the Landers and Atlas Chemical Industries cases indicates that this concept would not be successful; i.e., all of the wrongdoers would be held jointly and severally liable for the entire damages. Therefore, we must assume that the existence of a district will not insulate the industries from liability, and that the only way to protect the industries will be for the district to agree to indemnify them in the event of damage.

10.3 Operational Methods and Procedures

Staff members of the TWC and EPA indicated that the City and the industries will need to maintain their current permits to discharge into the ship channel, and will need to obtain amendments allowing discharge into the proposed new district's conveyance system.

The new district will then need to obtain the proper State and NPDES permits to discharge into the delta.

10.4 Financial Requirements

The purpose of this section is to provide illustrative financial information that could be used in planning future bond sales to finance this new wastewater district's operations. Assuming that funding for this project will be provided by revenue bonds amortized over 20 years at an interest rate of six percent, a bonded indebtedness of $12 million, and an annual debt service of $1,050,000, a rate increase on all City water users of $0.025 per 1,000 gallons per month would be needed to meet the annual debt service. If 120 mgd of water were sold, this user rate increase would result in a $0.33 per month increase in an average household water bill.

10.5 Method(s) of Creation

There are three types of organizations or institutions that could plan, organize, finance, implement, and operate projects to divert river and wastewater to the Nueces Delta and Estuary. The three are: (1) A special district created by the legislature especially for this purpose; (2) One of the existing entities of the area (San Patricio Municipal Water District, San Patricio County Drainage District, or Nueces River Authority); and (3) The City of Corpus Christi, Texas. It appears that all of the entities listed above have the necessary powers and authorities to carry out the river and wastewater diversion projects, but since there may be interest in ownership and operation of an extensive wildlife refuge in association with the river and wastewater diversion projects, it is, therefore, advisable to consider creation of a special purpose district having powers to carry out the diversion projects as well as to own and operate the discharge site lands for a wildlife refuge.

11.0 EFFECTS OF DIVERSIONS OF RIVER, WASTEWATER, AND STORMWATER UPON THE YIELDS OF THE CHOKE CANYON/LAKE CORPUS CHRISTI SYSTEM, INCLUDING ANNUAL COST OF EACH DIVERSION CONSIDERED

The Lower Nueces River Basin and Estuary Model (NUBAY2) was used to calculate the increase in yield resulting from each of the river, wastewater, and stormwater diversions considered in this study. NUBAY2 includes monthly release provisions of the TWC Interim Release Order of March 9, 1992, including provisions within the order for reduced or suspended releases when certain salinity criteria are met in upper Nueces Bay, as well as the latest (1992) productivity factors of river, municipal, and stormwater when diverted to the Nueces Delta. For river and stormwater diversion, the productivity factor used was three, while for wastewater effluent the factor applied was five.

11.1 Evaluation of Nueces River Delta Diversion Projects

The calculations of CC/LCC system yield were based upon the following data and operating conditions. The period of record used was 1934 through 1989, which included significant droughts in the 1950's, 1960's, and 1980's. Both 1990 and year 2040 reservoir sediment conditions were selected, as was Phase IV of the City of Corpus Christi's Operations Plan. Computations performed in this study reflect the channel losses associated with delivery of water from Choke Canyon Reservoir to Lake Corpus Christi and from Lake

Corpus Christi to Calallen diversion dam.

Without dedicated releases to the estuary, the 1990 firm yield of the system is 222,696 acre-feet per year. With the release provisions included in the 1992 TWC Order, the 1990 firm yield of the system is reduced by approximately 30,954 acre-feet per year (13.9 percent) to 191,742 acre-feet per year. The estimate of 191,742 acre-feet is 14,342 acre-feet greater than was estimated in 1991 Phase I report using the release provisions recommended at that time by the TWC Technical Advisory Committee. Thus, under the conditions of the TWC Order of March 9, 1992, the yield effect upon the CC/LCC System is 30,954 acre-feet per year, instead of the previously estimated 42,500 acre-feet per year. The difference is due largely to the provisions in the Order for reduced or suspended releases in response to salinity criteria in the estuary. It should be noted that the 1992 Order is in effect until 1997, at which time a new order could be issued containing different conditions which could result in different yield effects upon the CC/LCC System.

The alternatives are as follows:

Name	Description
NS-1	North Shore Discharges
NS-2	North Shore Discharges
SS-1	Allison WWTP Discharge
SS-2	Allison & Broadway WWTP's Discharges
SS-3	Individual Industrial Discharges
SS-3A	Individual Industrial Discharges
SS-4	Combined Industrial Discharges
SS-4A	Combined Industrial Discharges
SS-5	Combined Municipal and Industrial Discharges
W-1	Westside WWTP Discharge
WO-1	Westside and Oso WWTP's Discharge
R-1	River Diversion
R-2	River Diversion
R-3	River Diversion

SW-1	Upper Oso Storm Water Diversion
SW-2	Peter's Swale Storm Water Diversion
SW-3	Hondo Creek Storm Water Diversion
SW-4	Hondo Creek Storm Water Diversion w/Pumpage

The analyses of the effects of each potential diversion project show that the percentage of the system yield restored varies from a low of 0.7 percent (224 acre-feet per year) for the Hondo Creek Stormwater Diversion (SW-3) to a high of 73.6 percent (22,789 acre-feet per year) for the transfer of the combined South Shore Municipal and Industrial Discharges (SS-5) into the Delta Area. The alternative with the lowest cost per acre-foot of yield restored is the channel from Calallen Dam to Rincon Bayou (R-3). If a channel with the a capacity of 100 mgd were constructed, the system yield could be increased by 19,735 acre-feet per year at a cost of $12.70 per acre-foot assuming a productivity factor of three. The next most economical alternative is the transfer of the Allison WWTP flows to the Delta Area (SS-1). The cost for this alternative is $32.30 per acre-foot with 3,127 acre-feet per year restored to the system yield, assuming a productivity factor of five.

The individual alternative which restores the greatest portion of the firm yield is the transfer of the combined South Shore Municipal and Industrial Discharges (SS-5) to the Delta Area. This alternative restores 22,789 acre-feet per year (73.6 percent) of the firm yield that was lost through implementation of the TWC Order. The corresponding unit cost of this alternative is $59.00 per acre-foot per year. It is important to note that none of the storm water diversion alternatives appear to restore a significant percent of the CC/LCC yield lost to the TWC Release Order, and thus do not appear to be feasible.

A review of the individual alternatives analyzed shows that the most economical alternative is the diversion of river water via a pipeline or canal from Calallen Dam to Rincon Bayou (R-3). However, this alternative on its own can only restore about 63.8 percent of the system firm yield reduction (i.e., 19,735 acre-feet per year). This could be achieved with a maximum channel diversion rate of 100 mgd assuming a productivity factor of three. To obtain additional increases in the 1990 system yield, it would be necessary to combine wastewater diversion alternatives with the river diversion alternative. This was evaluated for eight groups of alternatives and is described below.

11.2 Evaluation of Combined Alternatives

The first five combined groups analyzed (A, B, B′, C, and D) involve the transfer of only municipal wastewater discharges along with the river diversion. The next four groups analyzed (E, F, G, and H) involve the transfer of both municipal and industrial discharges along with the river diversion. The size of the Calallen river diversion in each of the nine combined alternatives was varied until the optimum flow rate was calculated. This optimization resulted in finding the smallest river diversion that would maximize the firm yield restored for each of the combinations of wastewater diversion alternatives.

The combined alternatives are as follows:

Name	Description
A. (SS-1/R)	Allison WWTP Discharge & River Diversion to ND
B. (SS-2/R)	Allison & Broadway WWTP's Discharge and River Diversion to ND
B′. (SS-1 & WO-I/R)	Allison & Westside WWTP's Discharge and River Diversion to ND
C. (SS-2 & W-1/R)	Allison, Broadway & Westside WWTP's Discharge and River Diversion to ND

D. (SS-2 & WO-1/R)	Allison, Broadway, Westside & Oso WWTP's Discharge and River Diversion to ND
E. (SS-5/R)	Combined Municipal (Allison & Broadway WWTP's) and South Shore Industrial Discharges and River Diversion to ND
F. (SS-5 & W-1/R)	Combined Municipal (Allison, Broadway & Westside WWTP's) and South Shore Industrial Discharges and River Diversion to ND
G. (SS-5 & WO-1/R)	Combined Municipal (all four WWTP's) and South Shore Industrial Discharges and River Diversion to ND
H. (SS-5, WO-1, & NS-2/R) ..	Combined Municipal (all four WWTP's) and Industrial Discharges (including South Shore and North Shore) and River Diversion to ND

The results of the analyses for each of the nine combined alternatives shows that the percentage of the yield restored for the first five municipal options varies from a low of 68.4 percent (21,176 acre-feet per year) for Alternative A to a high of 93.3 percent (28,874 acre-feet per year) for Alternative D.

The results of the analyses for the four combined alternatives involving both municipal and industrial discharges (E, F, G, and H) show that the percentage of the system yield restored varies from a low of 93.4 percent (28,915 acre-feet per year) for Alternative E to a high of 98.5 percent (30,484 acre-feet per year) for Alternative H. The alternative with the lowest unit cost is Alternative A (Diversion of Allison WWTP discharges along with an 80 mgd capacity river diversion to the Nueces Delta). This alternative will increase the 1990 system yield by 21,176 acre-feet per year at a unit cost of $14.83 per acre-foot per year. The next most economical alternative is B′ (Diversion of Allison and Westside WWTP discharges along with a 70 mgd capacity river diversion to the Nueces Delta). This alternative would restore 23,033 acre-feet per year of the 1990 yield at a unit cost of $33.47 per acre-foot per year.

The combined alternative which restores the greatest portion of the firm yield is Alternative H (Transfer of all four municipal WWTP discharges, including South Shore and North Shore Industrial discharges as well as a 20 mgd capacity river diversion to the Nueces Delta). This alternative restores 30,484 acre-feet per year of the 1990 firm yield. However, the unit cost of this alternative is $166.31 per acre-foot per year, which is the highest unit cost of all the combined alternatives analyzed. The combined alternative which appears to provide the most water at a comparatively attractive unit cost is Alternative E (Transfer of Allison and Broadway WWTP discharges, plus South Shore Industrial discharges, and a 50 mgd capacity river diversion to the Nueces Delta). This alternative restores 28,915 acre-feet per year of the 1990 firm yield at a unit cost of $51.98 per acre-foot per year. However, due to environmental concerns of regulatory agencies, it is unlikely that permits can be obtained for the discharge of industrial effluent into the delta at this time. For this reason, Alternatives A, B, B′, C, and D (which involve the transfer of only municipal effluent to the delta) may be the only viable options. The combined alternative from this group that appears to be the most attractive under 1990 sediment conditions is Alternative C (Transfer of Allison, Broadway and Westside WWTP discharges as well as 70 mgd capacity river diversion to the Delta Area). This alternative would restore 25,722 acre-feet per year of the 1990 firm yield at a unit cost of $52.99 per acre-foot per year. However, additional analyses were performed on the five municipal options under year 2040 reservoir sediment conditions which suggest that Alternative C may not be the most economical option in the future. These analyses are presented in the following section.

11.3 Evaluation of Combined Alternative - Year 2040 Sedimentation Conditions for Choke Canyon and Lake Corpus Christi

Yield estimates were made for estimated Year 2040 CC/LCC Reservoir sediment conditions. Under these conditions, without releases to the estuary, the Year 2040 yield is estimated at 198,195 acre-feet per year. With estimated Year 2040 sediment, and with the TWC Release Order of March 9, 1992, the Year 2040 yield is estimated at 178,095 acre-feet per year or 20,100 acre-feet per year less. When the effects of the combined municipal wastewater and river diversion projects (Alternatives A, B, B′, C, and D) were taken into account, the analyses showed that each of these alternatives would restore 100 percent of the 20,100 acre-feet of yield lost in 2040 as a result of the TWC Release Order. The costs per acre-foot of yield recovered in 2040, expressed in 1990 prices, would be $15.62 for Alternative A, $45.08 for Alternative B, $38.35 for Alternative B′, $67.80 for Alternative C, and $130.56 for Alternative D. Thus, these analyses for Year 2040 conditions indicate that Alternative A (Allison WWTP Discharge and Calallen River diversion to Nueces Delta) would provide full recovery of the year 2040 yield at a minimal unit cost and could, in the long run, prove to be the most cost-effective alternative to pursue.

12.0 RECOMMENDATIONS

Based upon the results of this Phase II Regional Wastewater Planning Study, the following recommendations are made. (Note: In addition to recommendations one and two recommendations three, four, five, and seven should be considered at a later date in light of results obtained from the Allison WW diversions, and further monitoring of the present CC/LCC releases into the Nueces River.)

1. **Establish a Municipal Wastewater Diversion Demonstration Project from the Allison Wastewater Treatment Plant to the South Lake Area of the Nueces Delta:** The construction of an 18" PVC pipeline from the Allison Wastewater Treatment Plant northward across the Nueces River and westward to a location in Nueces Bay known as South Lake (Tidal Segment 2482) is recommended. This project would have the capacity to deliver approximately 2.8 mgd (average flow) of treated municipal effluent to the demonstration project area. Total capital cost for the construction of this project would include necessary connections at the Allison Wastewater Treatment Plant, construction of a Nueces river crossing, placement of approximately 7,800 lineal feet of effluent pipeline, and construction of a demonstration project area, for a total cost of $978,200. It is estimated that final design to construction completion will require approximately 11 to 12 months. Permitting requirements and easement acquisition should be initiated at the start of the final design in order to facilitate construction at the earliest possible date. The City of Corpus Christi should begin at once to seek permission from the TWC to relocate the Allison Wastewater Treatment Plant discharge location from its current location in the

Nueces River to the proposed discharge area at South Lake. It is anticipated that this permit modification request will be in the form of a temporary discharge permit to be used for monitoring of the discharge effluent into the demonstration area. Continued use of this location for the Allison Wastewater Treatment Plant outfall will be determined after continuous monitoring throughout the four-year monitoring period. Easements and right-of-way requirements to construct the pipeline demonstration area will be required from approximately six individual land owners. This project is described in detail in Section 3.2 of this report.

The diversion of about 2.8 mgd of treated municipal wastewater from the Nueces River to the upper tidal flats of South lake in Rincon Delta is recommended since it would provide a significant source of freshwater and nutrients to enhance emergent plant and phytoplankton growth. Discharged water should be dispersed over a broad area of several acres with provisions for aerial or spraying applications in addition to discharge into shallow receiving ponds. The discharged waters will flow through South Lake and disperse into the brackish marsh ponds and channels and the existing Federal mitigation area before entering Nueces Bay. New emergent vegetation will appear in and around the retention ponds and phytoplankton primary production rates will be enhanced in South Lake and in the lower marsh. The overall productivity (emergent vegetation and phytoplankton) of several hundred acres of Rincon Delta will be increased relative to the current status.

The benefits of increased primary production in the Delta will extend into Nueces Bay and beyond. The upper trophic levels of benthic and water column organisms that consume plankton and detritus will become established and further provide food for predator populations. The interchange of food materials between a bay and marsh will influence many portions of the bay ecosystem, but especially the higher trophic levels including many of the important fish and shellfish species. The increased food availability and lower salinity will also increase the habitat potential of the marsh for larval and immature stages of many marine and estuarine organisms.

2. **Continue Scientific Data Collection and Monitoring of the Nueces Delta and Nueces Bay:** Data collection and monitoring should be carefully designed so as to fully measure and document delta and estuarine responses to freshwater releases and river and wastewater demonstration project diversions to the delta and bay. The monitoring and analyses should be continued in order to fully document the productivity of both river and wastewater diversions to the delta and bay.

3. **Establish a Nueces River Diversion Demonstration Project from the Calallen pool to Upper Rincon Bayou of the Nueces Delta:** It is recommended that a 12" PVC pipeline be constructed from the San Patricio Municipal Water District, W. A. Edwards Pump Station location, northward along the Nueces River, and then eastward across U.S. Highway 77 to the proposed discharge area. This pipeline, along with necessary water system appurtenances, and electrical and pump station requirements, would be capable of delivering approximately 2.8 mgd (average flow) of Nueces River water to the upper delta. Total cost of this project is estimated at $371,000. It is estimated that final design to completion of construction will require approximately 11 to 12 months. The permitting requirements should begin at the same time as the final design in order to facilitate

construction activities at the earliest possible time. Approval will be required from the property owners within the demonstration area. This includes approval from the San Patricio Municipal Water District for use of an existing pipeline easement and pump station plant site, as well as pipeline easements from the McGregor estate and the Thomas E. Finch heirs tract. This project is described in detail in Section 3.1 of this report.

4. **Establish a Nueces River Diversion Demonstration Project through Existing Facilities of the O.N. Stevens Water Treatment Plant at Calallen:** The Phase II Study addressed the feasibility of diverting fresh water from the Nueces River through the existing facilities at the O.N. Stevens Water Treatment Plant located at Calallen. This project would use the existing infrastructure to divert approximately 3 mgd part of the way to a location in Nueces Bay. The recommended project includes utilizing an existing 36" drain line from the O.N. Stevens Treatment Plant to the existing sludge lagoons located between the Nueces River and IH 37. Additionally, it is recommended that an 18" pipeline be constructed across the Nueces River to Nueces Bay halfway between the upper portion of Rincon Bayou and South Lake. It is estimated the total project capital cost will be approximately $551,000. An evaluation of the pipeline placement to tie this alternative demonstration project to Rincon Bayou and to the South Lake area was evaluated. Cost and construction requirements are shown in Section 3.3 of this report. Potential relocation of water treatment sludges from current disposal lagoons to the estuary area was investigated. Further analysis, research, and permitting will be required prior to implementation.

5. **Potentials to Reroute Wastewater Flows Within the Corpus Christi Wastewater Collection System:** It was determined through the Phase II Study effort that several alternatives exist for the City of Corpus Christi with regard to collection and treatment options for its wastewater system. Depending on results from the Allison Wastewater Diversion Demonstration Project, there could be significant opportunities to lower wastewater treatment costs through rerouting of flows within the system, with diversion of larger quantities of effluent to the Nueces Delta in the future. Therefore, it is recommended that Corpus Christi request the TWC to consider holding in abeyance modifications to wastewater discharge permits currently being held by the City of Corpus Christi Westside Treatment Plant until the proposed wastewater demonstration project of recommendation number one has been in operation long enough to provide information about the effects of such effluent upon the estuary. If it is determined through the demonstration project that a higher nutrient loading is preferred, then the City could consider relocating more wastewater to the delta and utilizing financing to construct necessary transmission facilities in lieu of upgrading wastewater treatment plant capabilities. Increased flow along with biological loading on several of the City's wastewater treatment plants will trigger more stringent discharge requirements depending of the allowable loading to the receiving water bodies (i.e., Oso Creek).

6. **Brackish Groundwater, Storm Water, and Estimation of Runoff from Ungaged Basins:** The evaluations of potential sources of brackish groundwater and storm water for diversion to Nueces Delta do not show these to be feasible alternatives, thus no

recommendations are made with respect to implementation of such projects. The costs of gaging and metering the presently ungaged drainage basins which discharge into Nueces and Corpus Christi Bays appears to be too high to recommend at this time. For purposes of making better estimates of the quantities and timing of this source of freshwater, a mathematical equation was estimated using historic data from precipitation stations of the Coastal Bend area. It is recommended that this equation be used in the future for this purpose. The equation is found in Section 6.7 of the report.

7. Establish a Demonstration Project in Tule Lake Area for Industrial Wastewater Diversions: The establishment of a demonstration area for industrial wastewater diversions should be monitored in the Tule Lake area located south of the Nueces River in the Port of Corpus Christi Authority area. Historically, Tule Lake has received a variety of industrial effluent discharges. Recent implementation of environmental regulations, along with changes to treatment processes, have begun to enhance the ecology of Tule Lake. This could serve as a demonstration area which could be monitored prior to the discharge of industrial effluents into the Nueces Delta.

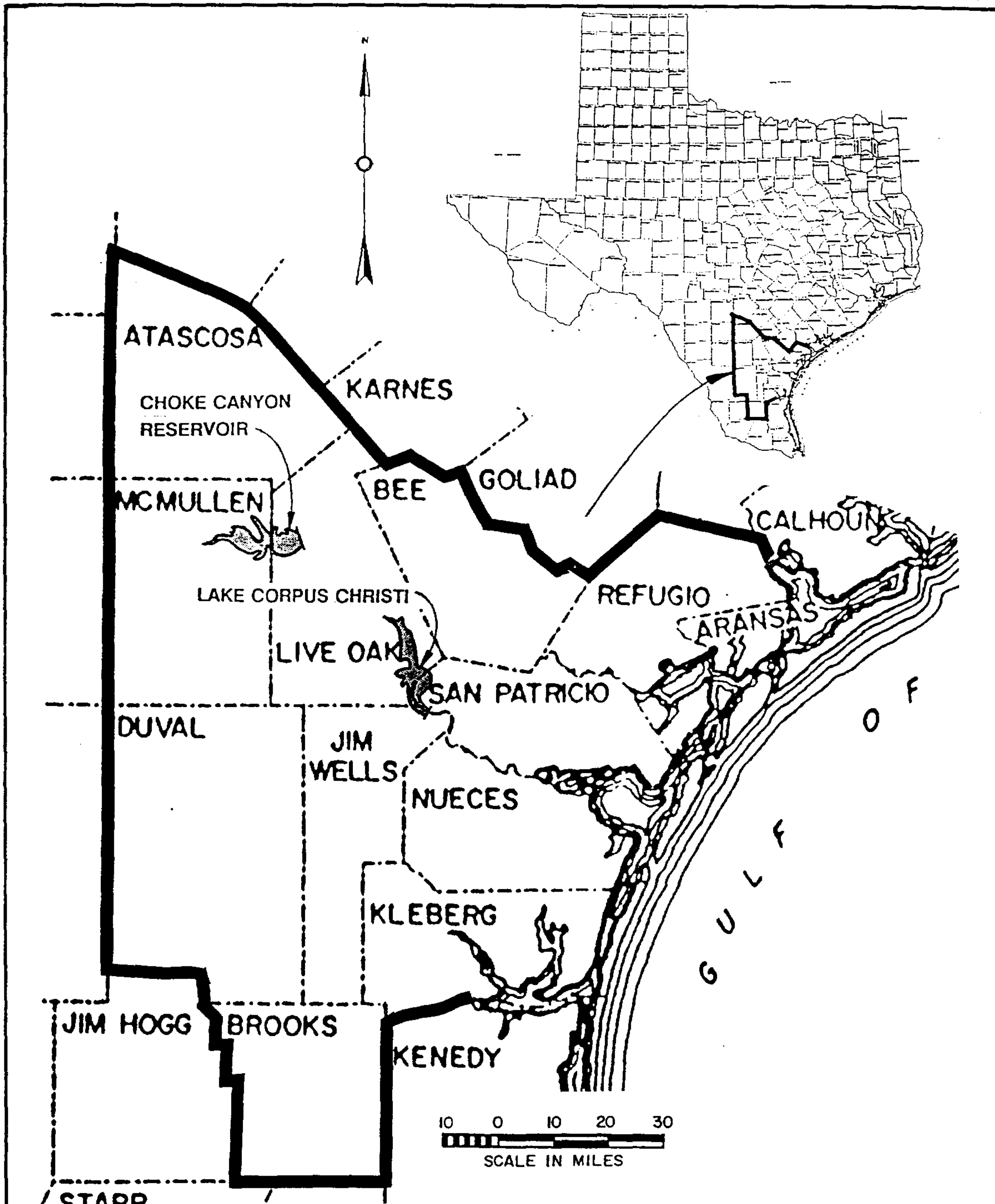
NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY - PHASE II

1.0 INTRODUCTION

1.1 Background

The 12-county Coastal Bend region (Atascosa, McMullen, Live Oak, Bee, Refugio, Aransas, Duval, Jim Wells, San Patricio, Nueces, Kleberg, and Brooks) depends upon the Choke Canyon/Lake Corpus Christi (CC/LCC) Reservoir System of the Nueces River for a large part of its municipal and industrial water supply. These two reservoirs capture and store a portion of the stream flows of the Nueces River Basin. Water from Lake Corpus Christi either spills or is released into the Nueces River, which flows southeasterly from Live Oak and Western San Patricio Counties into Nueces Bay (Figure 1-1). At Calallen, Nueces River flows are diverted and treated for municipal and industrial use and subsequently distributed to water users in the area. These water users include the City of Corpus Christi, the South Texas Water Authority's customers to the south in Nueces, Kleberg, Jim Wells, Duval, and Brooks counties, and the San Patricio Municipal Water District's customers in southern San Patricio County and in Aransas County. The San Patricio Municipal Water District also diverts raw water at Calallen and conveys it to Ingleside, Texas where it is treated and delivered to industries for use there. Over 90 percent of the treated wastewater of the cities and industries is discharged into inlets and arms of Corpus Christi Bay, Oso Bay, the Corpus Christi Ship Channel, and the Nueces River downstream of Calallen. This development, use, and disposal of water affects the quantities, timing, and locations of freshwater flows into the Nueces Estuary.

In response to concerns about the potential effects of diversion of freshwater from



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CORPUS CHRISTI, TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

CHOKE CANYON/LAKE CORPUS CHRISTI SERVICE AREA

FIGURE 1-1

the Nueces River upon the biological community of the Nueces Estuary, the Texas Water Commission placed Special Condition 5.B upon the permit (Certificate of Adjudication No. 21-3214) for the development of Choke Canyon Reservoir. Special Condition 5.B states that the owners of the CC/LCC Reservoir System (the City of Corpus Christi and the Nueces River Authority) should provide not less than 151,000 acre-feet of water per year to the receiving estuaries through a combination of return flows, spills, and releases.

In response to a December 15, 1989 request from the Coalition About Restoration of Estuaries (CARE) that releases be made from Choke Canyon and Lake Corpus Christi in accordance with provisions of the permit, on May 1, 1990, the Texas Water Commission (TWC) issued an order: (1) Establishing an interim operation plan for the Choke Canyon/Lake Corpus Christi reservoir system, (2) Providing for freshwater releases and/or spills for May and June, 1990 (3) Calling for monitoring of the releases to assess their effect upon the estuarine system, and (4) Creating a Technical Advisory Committee to assist the TWC in formulating permanent operational procedures.[1] Following the work of the Technical Advisory Committee, the City of Corpus Christi, the Nueces River Authority, and other local interests, the Texas Water Commission issued an Agreed Order of March 9, 1992, in which:

". . .the Commission finds that it has authority to establish operational procedures under Special Condition 5.B of Certificate of Adjudication No. 21-3214, and that interim operational procedures which have been established should be amended. The Commission also finds that, because of the need to:

> "continue to monitor the ecological environment and health of related living marine resources of the estuaries to assess the effectiveness of freshwater

[1]"Choke Canyon/Lake Corpus Christi Technical Advisory Committee -- Final Report," 1991. Texas Water Commission, Austin, Texas.

inflows provided by interim requirements contained in this Agreed Order relating to releases and spills from Choke Canyon Reservoir and Lake Corpus Christi (collectively referred to as the Reservoir System), as well as return flows;

"develop additional, necessary studies and data relating to such inflow requirements;

"develop a comprehensive, coordinated, regional water management plan for the area served by the Reservoir System;

"establish such operational procedures as necessary within five years of issuance of this Agreed Order which fulfill the purposes of Special Condition 5.B; and

"evaluate potential impacts which may occur to the reservoirs as well as to the availability of water to meet the needs of the Certificate Holders and their customers which may result from those operational procedures,

"an advisory council should be established to consider such additional information and related issues and to formulate recommendations for the Commission's review and action not later than five years from issuance of this Agreed Order."

The TWC order referenced above specifies that at least 97,000 acre-feet of water per year, including return flows, intentional diversions, and spills and releases from reservoirs, as measured at the Calallen gage, is to be provided to Nueces Bay and/or Rincon Bayou according to the following monthly schedule:

January	2,500 acre-feet	July	4,500 acre-feet
February	2,500 acre-feet	August	5,000 acre-feet
March	3,500 acre-feet	September	11,500 acre-feet
April	3,500 acre-feet	October	9,000 acre-feet
May	23,500 acre-feet	November	4,000 acre-feet
June	23,000 acre-feet	December	4,500 acre-feet

The order provided relief from releases when salinity in Upper Nueces Bay reaches specified levels, and during periods of prolonged drought. In the case of salinity, relief from releases begins when salinity in Upper Nueces Bay, for a 10-day period, is 5 ppt below

Salinity Upper Bounds (SUB) except during May, June, August, and October, with a 25 percent reduction in release requirements. When salinity is 10 ppt below SUB, releases can be reduced 50 percent, and when salinity is 15 ppt below SUB, releases can be reduced 75 percent. SUB is established in the order for each month of the year, and ranges from a low of 20 ppt for May, June, and September, to a high of 30 ppt for January, February, March, October, November, and December, with 25 ppt for July and August.

Relief from releases during drought begins at 50 percent reduction when reservoir content is between 40 and 30 percent of capacity and may be suspended when contents fall below 30 percent of capacity, provided water conservation and drought management plans are in operation.

Given the growing demands for water in the water-short Coastal Bend Area, and the fact that the TWC permit conditions and release order of 1990 reduces the CC/LCC System yield by approximately 20 percent, public and private officials organized and funded studies to monitor releases and provide information about ways to meet estuarine freshwater needs with a lessened impact upon reservoir system yields, making this water available to meet both water supply and estuarine needs. The methods being evaluated are: (1) Diversions of river water through Rincon Bayou to Nueces Bay, and (2) Diversions of wastewater effluent through Nueces Delta to Nueces Bay instead of releasing river and wastewater flows into the Nueces River which discharges directly into Nueces Bay.

As a part of the response to the TWC Order of 1990, monthly biological monitoring was begun in May of 1990 in order to observe and measure the biological effects of the freshwater releases upon the Nueces Estuary. The 1990 monitoring program collected samples in Nueces Bay, and in 1991, when the Phase I Regional Wastewater Planning Study was begun, the sampling effort was expanded into the Nueces Delta (Rincon Bayou) in order to collect samples from areas influenced by naturally-occurring events and by freshwater releases from the CC/LCC System. The objective was to obtain information about responses of phytoplankton and emergent marsh vegetation to freshwater. The productivity responses of phytoplankton and marsh vegetation were incorporated into the 1991 Phase I report. During 1992, for this Phase II Planning Study, monitoring of emergent vegetation and phytoplankton productivity was continued, with the results reported in Section 2.0 of this report.

In the 1991 study entitled "Regional Wastewater Planning Study -- Phase I," various ways were addressed by which the freshwater needs of the Nueces Estuary, particularly Nueces and Oso Bays, could be met, The methods evaluated included the diversion of treated wastewater return flows and reservoir releases directly to the Nueces Delta. The potential benefits and impacts associated with such diversions were estimated.[2] The results of the 1991 Phase I study are summarized below:

a. In 1991, wastewater discharges from Corpus Christi wastewater treatment plants were:

- Municipal discharges = 27.3 mgd (30,630 acre-feet per year)
- Industrial discharges = 15.7 mgd (17,615 acre-feet per year)

The study showed that Oso Bay would need about 5.0 mgd to maintain the existing Oso Bay ecosystems.

b. Routes were identified in general and preliminary estimates were made of capital and operating costs for 11 potential wastewater diversion projects and five potential river

[2]"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 Texas Water Development Board, November, 1991, Austin, Texas.

diversions to the head of Rincon Bayou and areas near South Lake in the Nueces Delta.

c. Primary productivity estimates were made for both river diversions and wastewater diversions in relation to releases of freshwater into the Nueces River which then discharges into Nueces Bay. The productivity estimates for river diversions to the Nueces Delta ranged from two to three times that for river flows directly into Nueces Bay; for wastewater diversions to the delta, productivity estimates were three to five times that for river flows to Nueces Bay.

d. The CC/LCC yield effect of the 1990 Texas Water Commission (TWC) freshwater release order was estimated at 42,500 acre-feet annually, or 19.4 percent of the CC/LCC system yield; i.e., the yield was decreased by 42,500 acre-feet per year.

e. Given the productivity factors of river and/or wastewater diversions to Rincon Bayou and the Nueces Delta cited in Section C above, a project involving a combination of river diversion and wastewater diversions appears to have the potential to restore 87 percent of the 42,500 acre-feet of yield that is required to be released under the TWC order, at a capital cost of $12.5 million, an annual operating cost of $1.6 million, or a per acre-foot of water cost of about $42. Costs of water from other sources are estimated in excess of $200 per acre-foot. (Note: 16 individual wastewater and river diversion projects and eight combined river and wastewater diversion projects were evaluated. The project cited here appears to be the most attractive from yield and cost viewpoints.)

f. The recommendations from the Phase I study are:

- Establish a river diversion demonstration project from Calallen to Rincon Bayou;
- Establish a wastewater diversion demonstration project from the Allison Wastewater Treatment Plant to the South Lake Area;
- Continue monitoring and data collection to improve the estimates of enhancement through diversion projects;
- Evaluate the potentials to use locally available brackish groundwater instead of CC/LCC releases to meet a part or all estuarine needs;
- Evaluate the potentials to divert stormwater flows from Oso and Chiltipin Creeks to meet a part of estuarine needs;
- Update the Lower Nueces River Basin and Estuary Model to incorporate TWC release order effects; and
- Conceptualize and describe a regional entity to collect, treat, and divert wastewater to the Nueces Delta.

The results of the Phase I study are the basis for this Phase II study. The Phase II study objectives are stated below.

1.2 Objectives

The purposes of this Phase II study are to: (1) Prepare the information needed to implement the river and wastewater diversion demonstration projects identified and recommended in the Phase I study, and (2) Continue biological monitoring and productivity evaluations of the Nueces Estuary. The specific objectives are to:

1. Measure primary production of emergent marsh vegetation using state-of-the-art techniques to develop a detailed budget estimate of emergent plant growth and productivity.

2. Measure primary production of phytoplankton in intertidal marsh ponds during periodic inundation events.

3. Measure primary production of microphytobenthos in marsh ponds and channels in Rincon Bayou to show the importance of this ecosystem component.

4. Compare the results of objectives 1, 2, and 3 above to those from the biological monitoring of the effects of freshwater releases directly into Nueces Bay.

5. Assess the feasibility of an integrated monitoring plan.

6. Evaluate engineering design, identify discharge locations, make detailed cost estimates, develop implementation schedule, and identify funding sources for river and wastewater diversion projects recommended in Phase I study.

7. Evaluate feasibility of diverting stormwater flows from the Oso and Chiltipin Creeks to Nueces Bay or the Nueces Delta, including effects on CC/LCC System yield.

8. Evaluate the impact of river, wastewater, and stormwater diversions (projects of objectives 6 and 7, above) upon CC/LCC System yield.

9. Analyze relative values of fish harvest, water supply, and recreation afforded by the CC/LCC System and flood control and water supply benefits associated with stormwater diversion.

10. Evaluate the use of shallow, brackish groundwater to supplement freshwater releases.

11. Estimate runoff from subwatersheds downstream of Wesley Seale Dam which flow into the Nueces Estuary.

12. Give consideration to possible effects of oyster reefs, sill structures, and electric power station discharges on retention of freshwater in Nueces Bay and on mixing with saline water of Corpus Christi Bay.

In the following sections of this report, information and analyses are presented for the purpose of meeting the objectives listed above.

2.0 BIOLOGICAL MONITORING OF EFFECTS OF DIVERSION OF FRESHWATER INFLOW AND WASTEWATER RETURN FLOWS IN RINCON BAYOU AND NUECES DELTA

A monthly biological monitoring program was established in May 1990 by the University of Texas Marine Science Institute in an attempt to observe the biological effects of the freshwater releases that were mandated for the Nueces River by the Texas Water Commission. This program sampled in Nueces Bay. The initiation of Phase I of the Regional Wastewater Planning Study of 1991 enlarged the sampling effort into Nueces Delta (Rincon Bayou) in an attempt to collect samples influenced by both natural events and water releases in order to obtain information about resulting biological responses of phytoplankton and emergent marsh vegetation. In this Phase II study the monitoring of emergent vegetation and phytoplankton productivity was continued during 1992 when both a reservoir releases schedule and exceedingly high precipitation occurred. The natural variations of quantity and timing of precipitation events have been used in an attempt to better understand the biological response of plant and microbial communities in Nueces Delta and Nueces Bay as a precursor for a demonstration freshwater and/or wastewater diversion project. The advantages of collecting observations in such a natural experiment are illustrated by the fact that all of the other natural factors and conditions are present in contrast to a mathematical model or a laboratory experiment.

2.1 Primary Production and Biomass Changes of Emergent Marsh Vegetation

This study is a continuation of work begun in 1991 to establish baseline information on the emergent marsh vegetation of the Nueces River marsh in anticipation of proposed alterations in the hydrological regime. The anticipated alterations include the diversion of treated wastewater return flows and freshwater releases. These changes could have a significant impact on the vegetation of the marsh. Freshwater additions to marsh systems are known to have a positive effect on plant growth and productivity, at least for some species (Zedler *et al.*, 1992). Although the objectives of this study did not include direct experiments to test the response of Nueces Delta marsh vegetation to freshwater inflows, nature performed the experiment in 1992 through the provision of record amounts of rainfall in the south Texas region which resulted in large quantities of river flows to the delta. This report provides data on the response of the vegetation in the Nueces marsh to this large freshwater addition in the winter and spring of 1992.

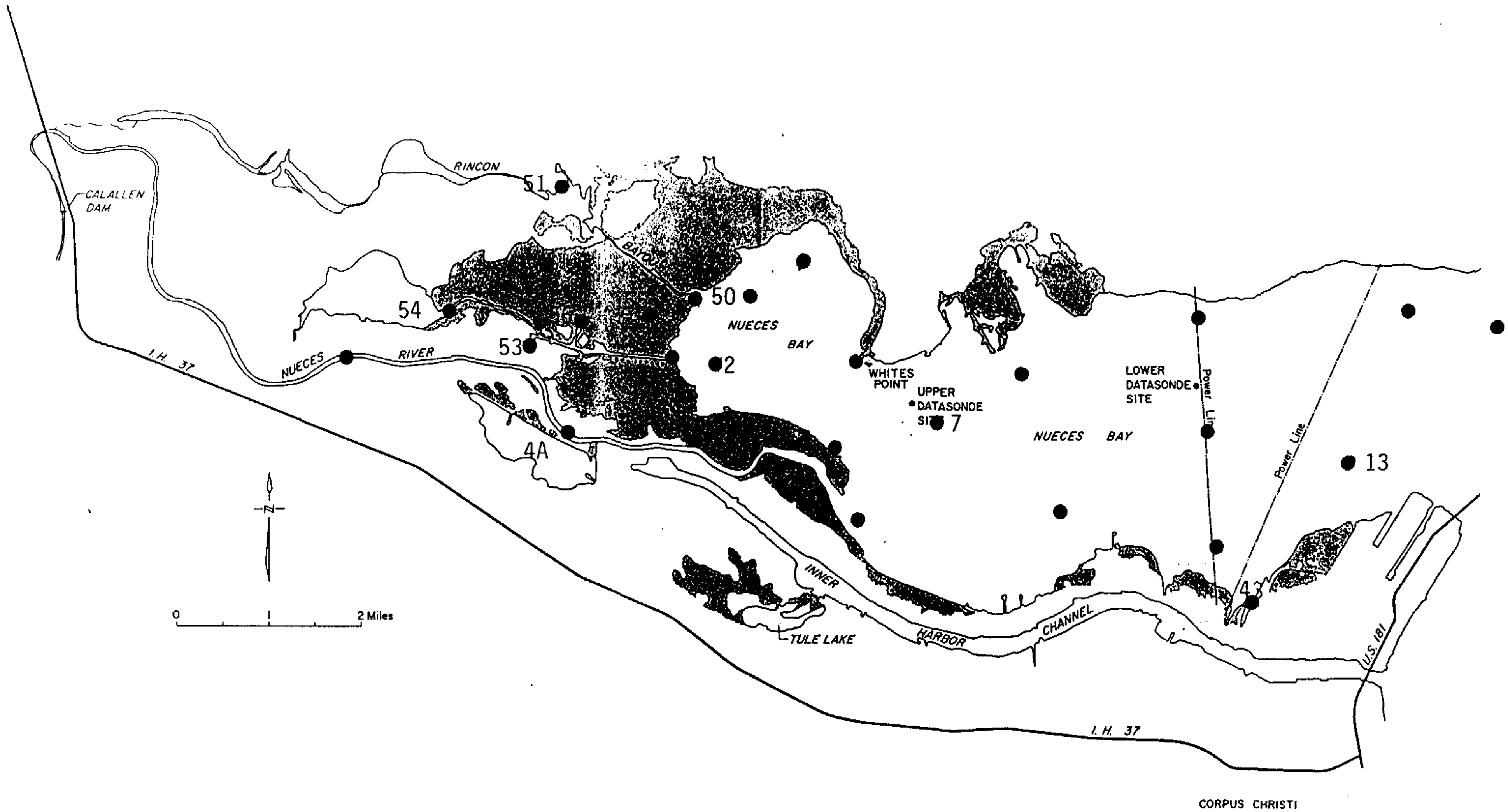
Wetland vegetation is the most obvious and straightforward indicator of habitat condition. Vegetation surveys are useful in documenting the success of plant growth and in evaluating their value for supporting animal populations. Since changes in vascular plant distributions lag behind environmental changes, such as changes in levels of freshwater to an area, vegetation is an indicator of long-term conditions, although individual species may respond rapidly to large seasonal changes in freshwater availability. In this report the results of the summer 1992 field sampling program in the Nueces Delta are presented and the data are compared with data obtained from the same locations in 1991. In general, large changes were noted in the allocation of biomass to above- and below-ground components in various species and in overall percent cover. We believe these responses can be attributed to large additions of freshwater to the marsh in the first six months of 1992.

For the 1992 field work, the same three stations established in the initial 1991 baseline study were used. These sites included: station 50, location at the confluence of Rincon Bayou with Nueces Bay; station 51, situated about three kilometers (km) upstream of station 50 on the Rincon Bayou deep within the marsh; and station 54, on the southern side of the marsh adjacent to a railroad trestle (Figure 2-1). The composition of the vegetation at each of the sites is different, and appears to be related both to elevation, frequency of freshwater inundation, and proximity to Nueces Bay. Of the three stations, site 55 exhibits the lowest plant species diversity and biomass.

The field efforts were focused on the collection of data to estimate plant biomass (above- and below-ground), species composition, and percent cover at each site. Major objectives included:

1. Determination of above- and below-ground biomass for the predominant emergent plant species at each site.
2. Determination of the distribution and percent cover of plant species along an 18-m transect at each site.
3. Comparison of the variations in species biomass and percent cover between 1991 and 1992 at the three sites.

Transect sampling was employed to describe the vegetation pattern of the marsh habitat (Bertness and Ellison, 1987). In July and August 1992, at all three stations in the marsh, beginning at the seaward edge of the marsh and at two-meter (m) intervals moving into the marsh a distance of 18 m, the vegetation was sampled at 2-m intervals along a 10-m transect line parallel to the shoreline. A 0.5 x 0.5 m quadrant subdivided into 100 5 x 5 cm cells was censused at each location. Percent cover of each plant species, bare area, and wrack was determined by counting the number of cells of the quadrant containing each of these items. Wrack-cover was defined as dead plant material greater than two centimeters



Hydrography stations are denoted by filled circles. Productivity stations are numbered.

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FIGURE 2-1

(cm) deep, completely covering one cell.

In addition to transect sampling, the above- and below-ground biomass of the predominant species was determined at each site in July and August, 1992 (and at site 54 in October, 1992). Four cores (9.0 cm diameter, 20 cm deep) were collected from pure stands of each species. Samples were transferred to the laboratory and washed through a one millimeter (mm) sieve. Shoots and leaves were separated from below-ground material (roots and rhizomes), material was dried to a constant weight at 60 degrees Celsius (°C), and then weighed on an analytical balance. Weights were rounded to the nearest 0.1 gram (g).

Measurements of salinity, temperature, and dissolved inorganic nitrogen (DIN; nitrate + nitrite) were collected at each site. Levels of sediment ammonium were determined from several soil samples collected routinely throughout the summer. Elevations were determined using a surveyor's transit, with referencing to established water height above mean sea level from tide level data collected at White's Point (by the Blucher Institute).

2.1.1 Water Column and Sediments

A summary of water salinity measurements made at the three stations is shown in Table 2-1 for 1991 and 1992. At all three sites, salinities were considerably lower in 1992 than in 1991. This was especially true in July 1992 when salinities were less than five parts per thousand (5‰), compared to 11 to 19‰ in 1991. The highest salinity recorded in August 1992 was about 12‰, compared to 24‰ in 1991. The lower salinities reflect increased rain and river inflow which resulted in overbanking and flooding of the marsh several times during late winter and spring. National Oceanic and Atmospheric Administration (NOAA)

Table 2-1 Summary of Water Salinities (‰) at the Three Nueces River Delta Stations in Summer 1991 and 1992			
	Station		
Date	50	51	54
July 1991	16.0	19.0	11.0
Aug. 1991	18.0	22.0	24.0
July 1992	3.8	5.0	3.5
Aug. 1992	11.8	12.2	9.9

Meteorological data from the Corpus Christi airport indicated that about 26 inches of rain had fallen within the first six months of 1992, nearly equivalent to average annual precipitation in most years. Water temperatures at these sites however, were similar between the two years (31° to 36°C).

Sediment pore-water ammonium values averaged between 23 and 50 microMohs (μM) at the three stations. No trend throughout the summer was apparent; however, these values were much lower compared to measurements made in summer 1991 at these sites (range 55 to 164 μM), and reflect the dilution of sediment porewaters by increased precipitation and flooding of the marsh. Levels of dissolved inorganic nitrogen in the water column ranged from undetectable to 0.4 μM, similar to that recorded in 1991.

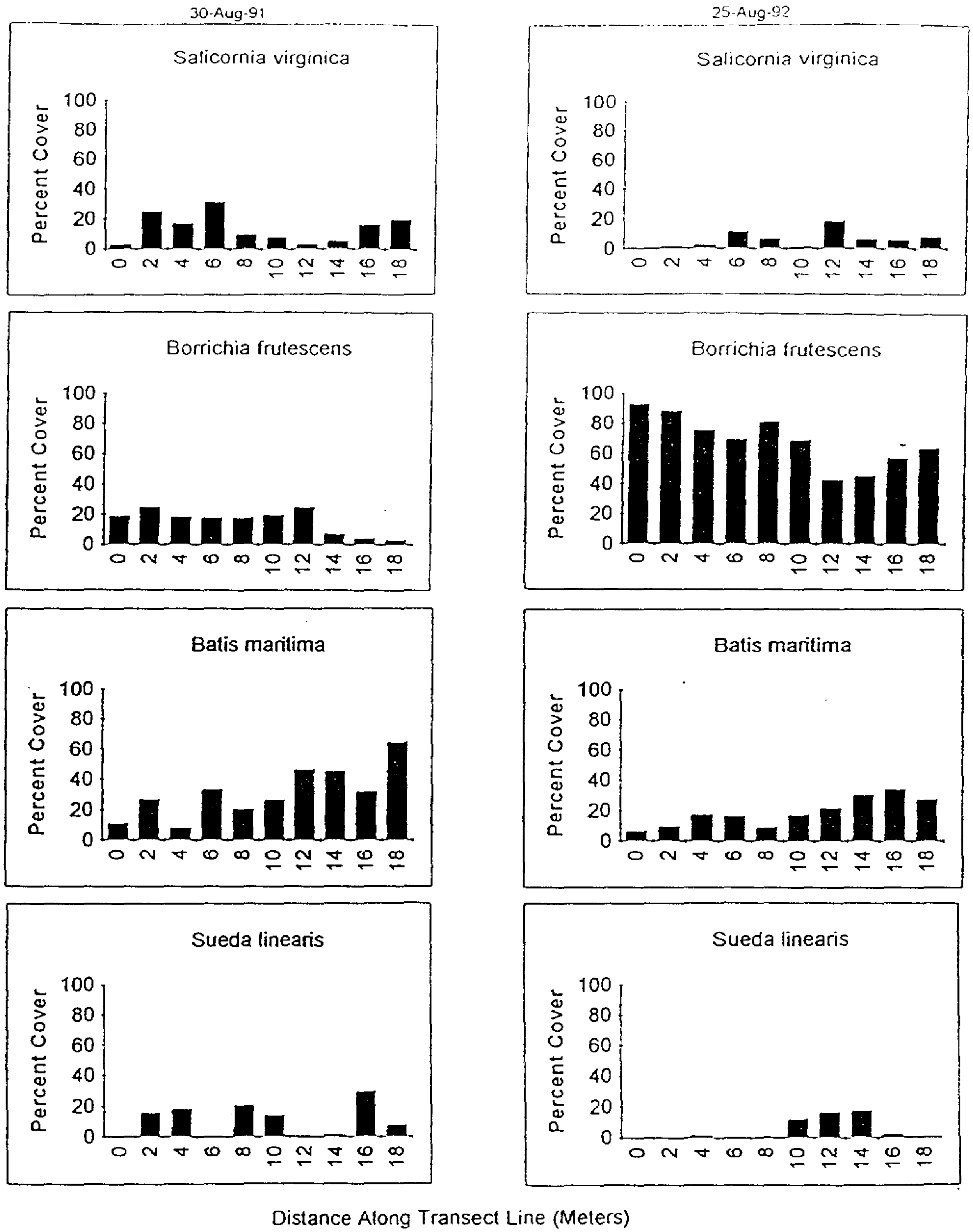
2.1.2 Species Composition and Percent Cover

A comparison of emergent marsh vegetation from transect measurements between

1991 and 1992 is shown in Figures 2-2, 2-3 and 2-4 for each station. With the exception of station 51, no significant differences were found ($P > 0.05$, multivariate analysis of variance, MANOVA) in the distribution of species along each transect between the two summer sampling periods in 1992. However, large differences in percent cover were observed between 1991 and 1992 among several marsh species. Comparison of the overall changes in the percent cover of the vegetation between years was significant ($P < 0.001$, MANOVA) at all three sites.

At station 50, *Borrichia frutescens* (sea ox-eye daisy) dominated the landscape along the entire transect in 1992, with covers ranging from 43 to 93 percent compared to 3 to 31 percent in 1991. Measurable cover of *Salicornia virginica* (glasswort), *Batis maritima* (salt-wort), and *Suaeda linearis* (sea-blite) were also noted in August 1992, but the frequency of these species were much lower in comparison. This contrasts with the vegetative pattern in 1991, in which none of the four species dominated the vegetative cover along the transect. In addition, no wrack or bare space was noted in August 1992, although these two components constituted at least 20 percent of the cover along most of the transect in 1991. The lack of plant litter is attributed to the flooding of the marsh which carried most plant detritus into Nueces Bay. Increased plant growth in 1992 also eliminated bare areas, as *B. frutescens* (sea ox-eye daisy) spread at the expense of the remaining three species.

Borrichia frutescens (sea ox-eye daisy) is not the dominant species at station 51 as noted by the high diversity of plant species at this site (Figure 2-3). These include *Salicornia virginica* (glasswort), *Batis maritima* (salt-wort), *Monathocloe littoralis* (salt-flat grass), *Sporobolus virginicus* (coastal dropseed), *Limonium nashii* (sea lavender), and *Lycium*



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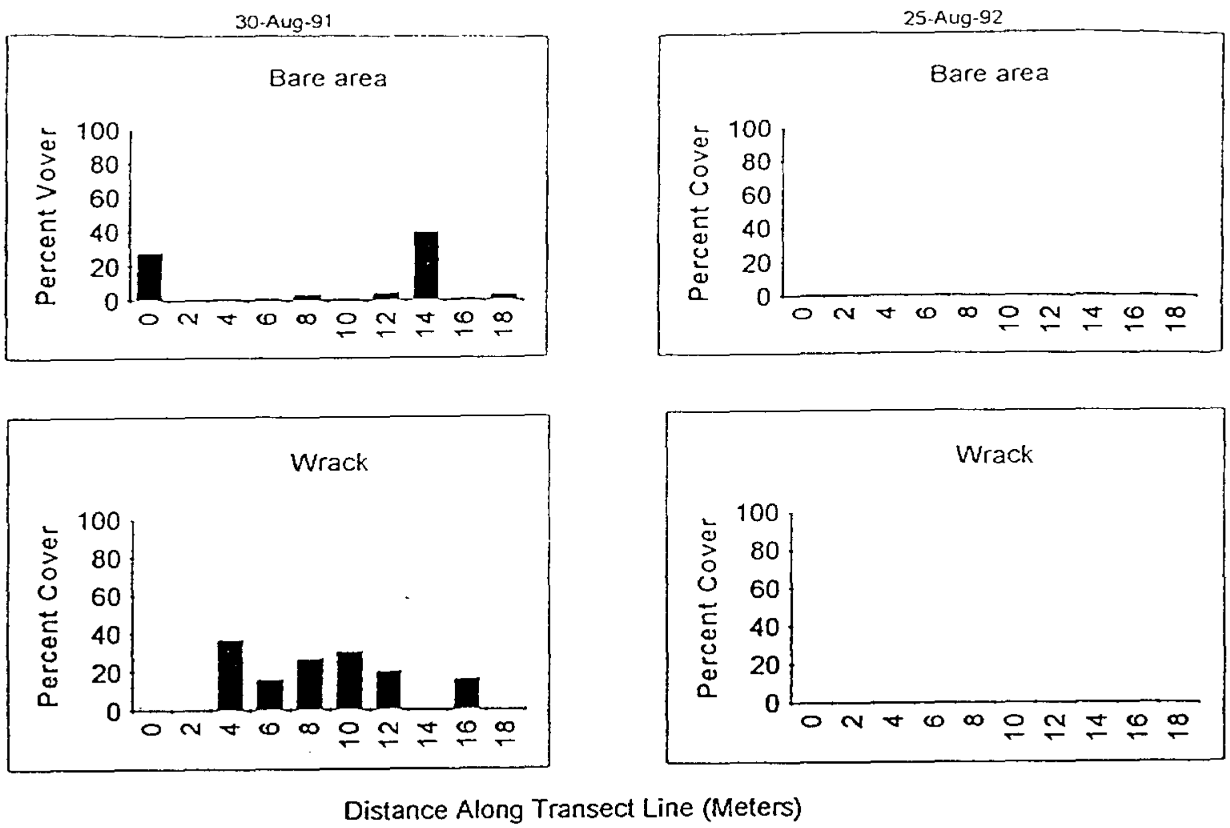
1992 TRANSECT SURVEY DATA
EMERGENT MARSH VEGETATION AT STATION 50
FIGURE 2-2



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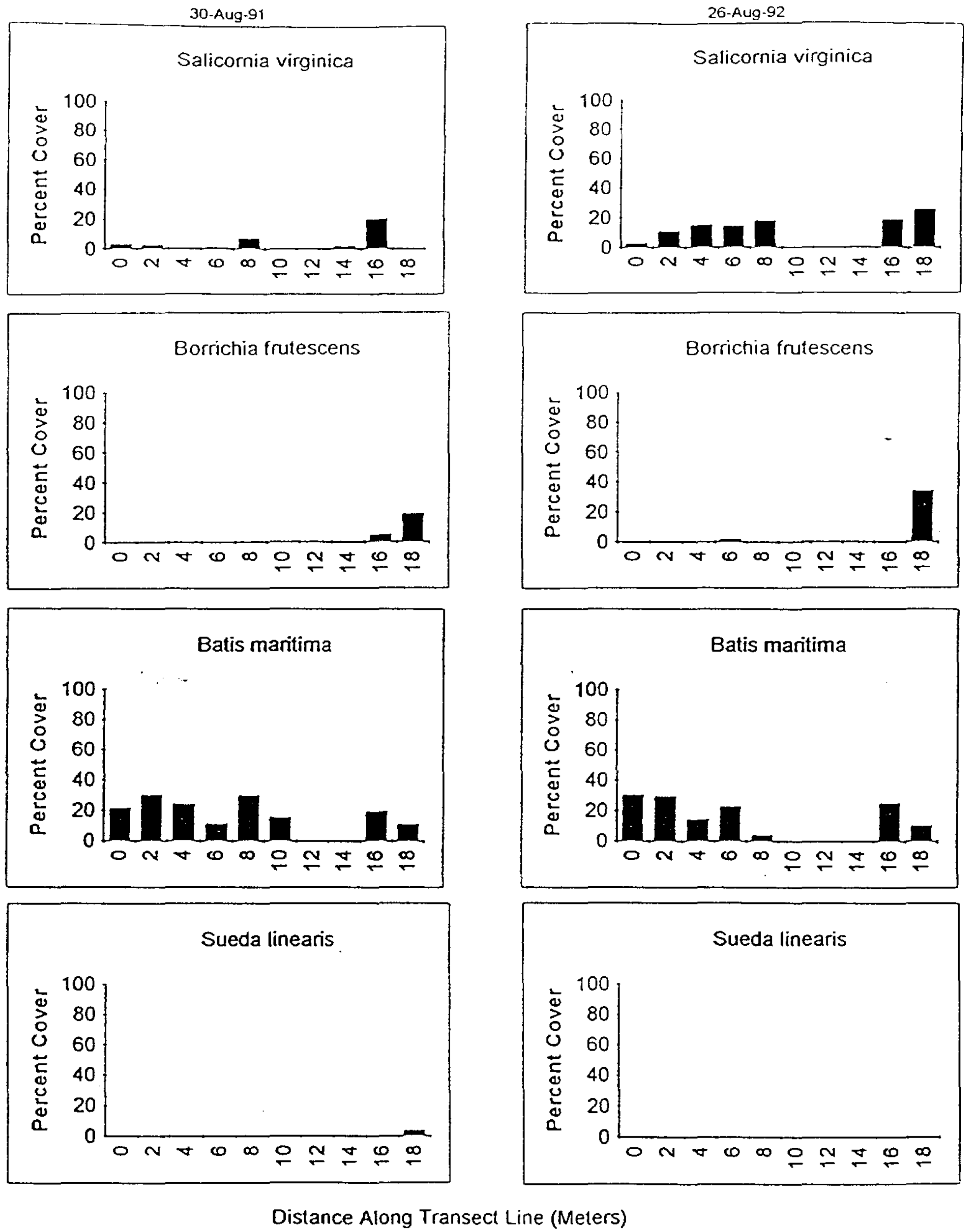
1992 TRANSECT SURVEY DATA
EMERGENT MARSH VEGETATION AT STATION 50
FIGURE 2-2 (CONTINUED)



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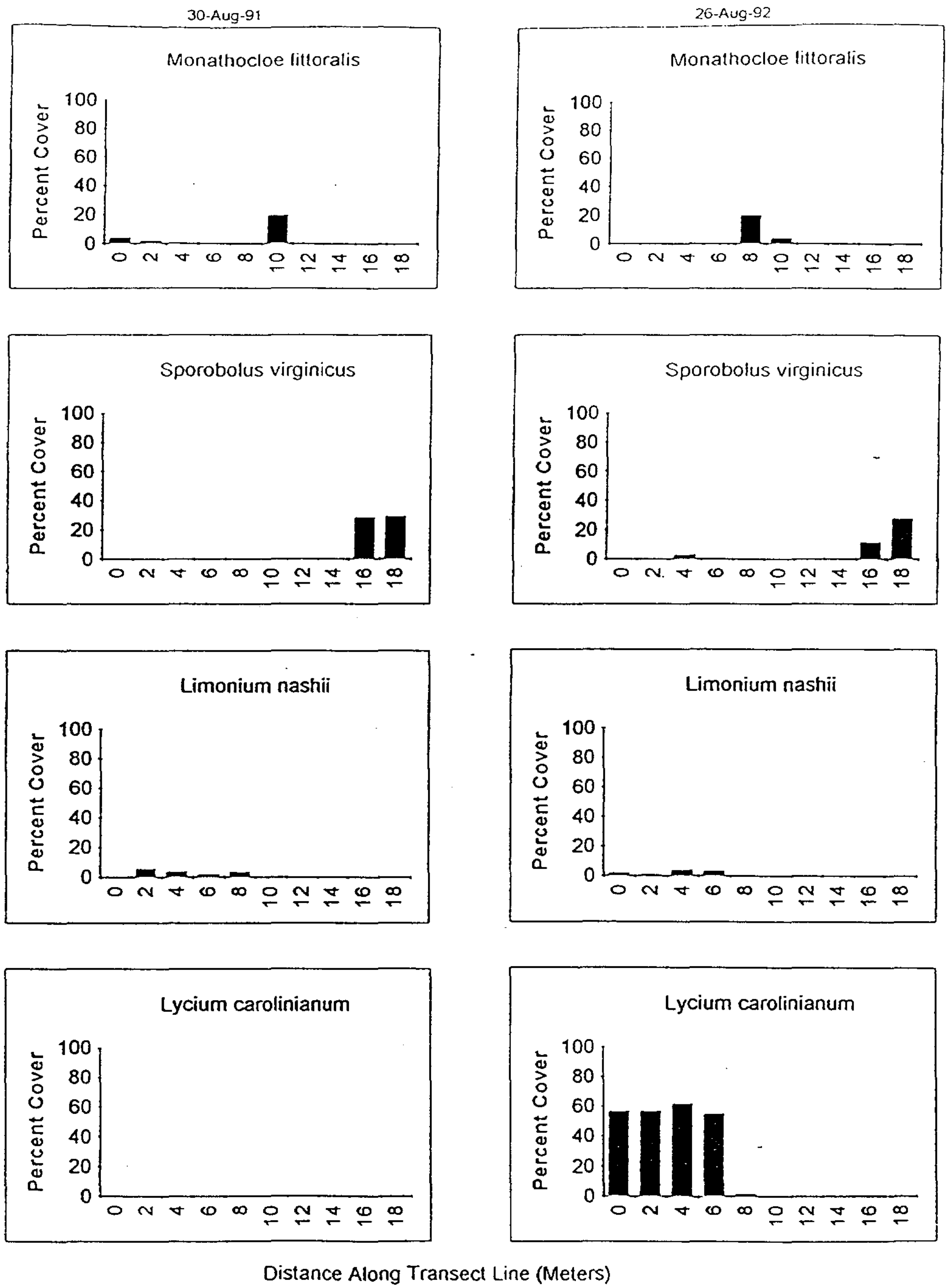
1991-92 TRANSECT SURVEY DATA
EMERGENT MARSH VEGETATION AT STATION 51
FIGURE 2-3



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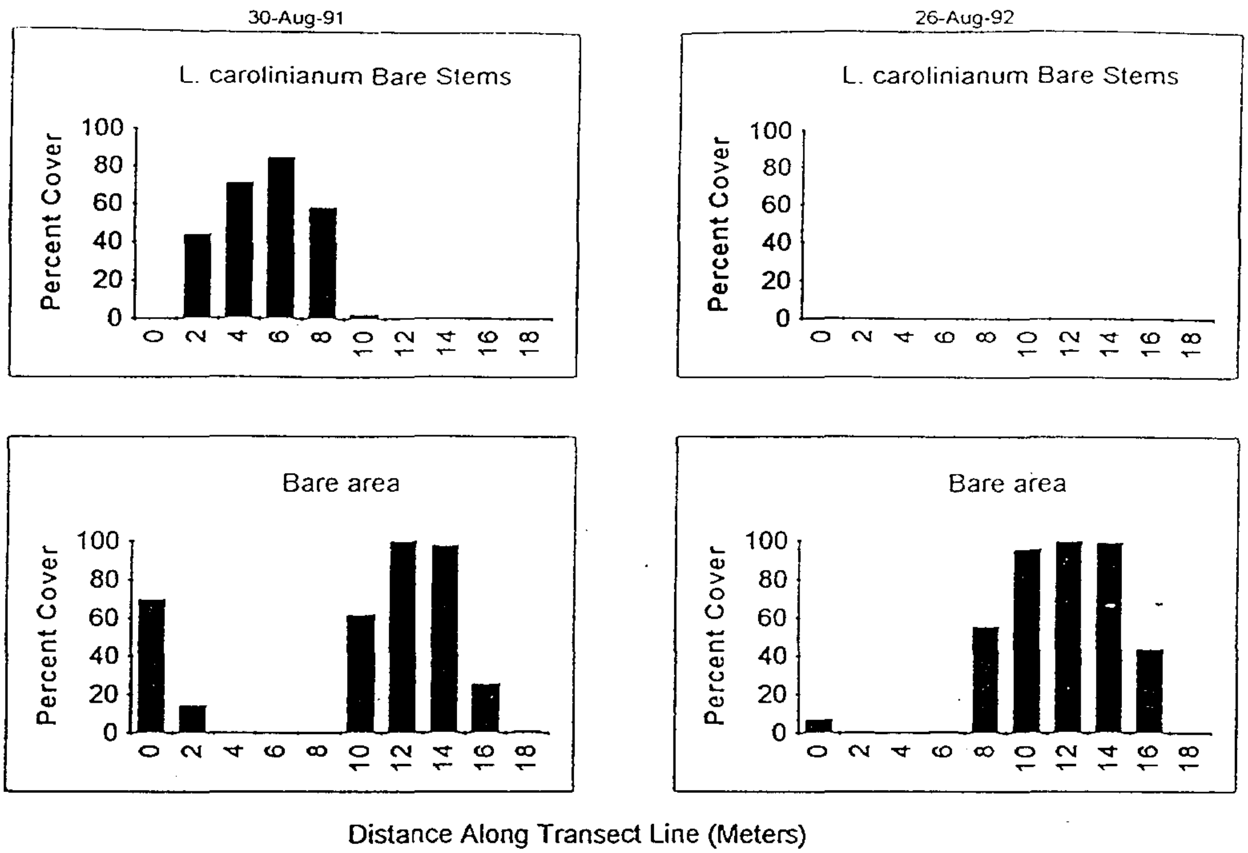
1991-92 TRANSECT SURVEY DATA
EMERGENT MARSH VEGETATION AT STATION 51
FIGURE 2-3 (CONTINUED)



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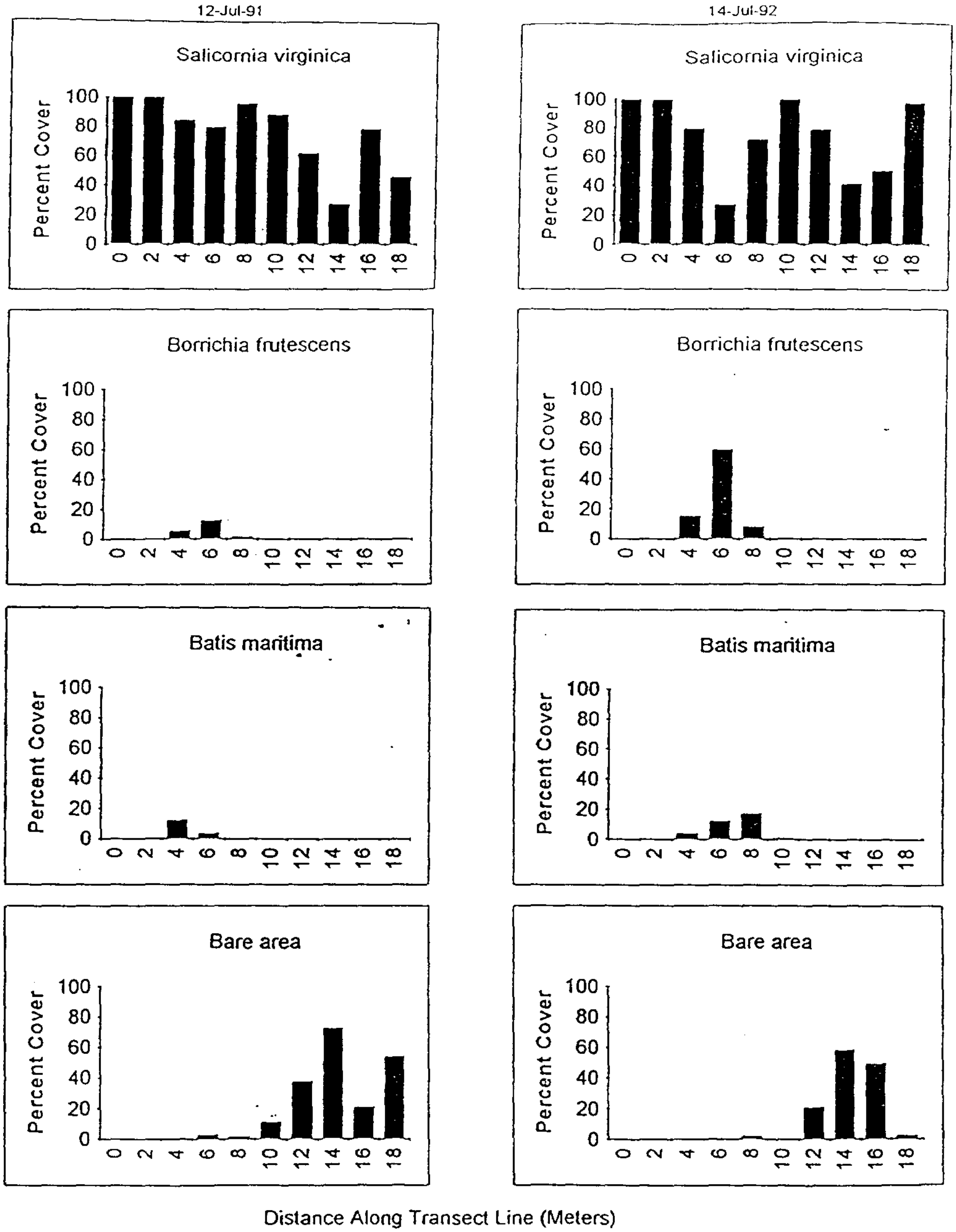
1991-92 TRANSECT SURVEY DATA
EMERGENT MARSH VEGETATION AT STATION 51
FIGURE 2-3 (CONTINUED)



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1991-92 TRANSECT SURVEY DATA
EMERGENT MARSH VEGETATION AT STATION 54
FIGURE 2-4

carolinianum (Carolina wolfberry). A large bare patch, located along an eight meter segment of the transect, between the eight and 16 m marks was readily visible, as also noted in 1991. At station 51, *S. virginica* (glasswort) and *L. carolinianum* (Carolina wolfberry) showed the greatest increases in percent cover from 1991. The Carolina wolfberry, *L. carolinianum*, in particular maintained a healthy cover of shoots and leaves through August 1992. By August 1991, *L. carolinianum* had shed most of its leaves and was characterized by bare and leafless stems. This plant clearly responded to increased freshwater additions to the marsh in 1992 by maintaining a higher percent cover and above-ground biomass through most of the summer.

Increases in plant percent cover and reduction in bare areas were also evident at station 54 in July 1992 compared to the same month the previous year (Figure 2-4). An increase in the percent cover of *Borrichia frutescens,* and *Salicornia virginica* accounted for the major changes at this site. The saltwort *Batis maritima* also extended its cover along the four to 10 m interval of the transect.

2.1.3 Above- and Below-Ground Biomass

The increase in vegetation cover at the three stations from 1991 to 1992 in the Nueces River marsh corresponded to an overall increase in biomass for most species at these sites. At station 50 (Table 2-2), only *Salicornia virginica* biomass decreased between 1991 and 1992, while the biomass of the remaining three species increased. The percentage of below-ground tissue relative to above-ground tissue also increased for all four species common at this site. A similar pattern was evident at station 51 (Table 2-3). Of the

Table 2-2
Change in Peak Biomass and Root/Shoot Ratios of Predominant Marsh Plants at Station 50 in the Nueces River Marsh Between 1991 and 1992

Species	Peak Biomass (g m^{-2})			Root/shoot Ratio	
	1991	1992	% Change	1991	1992
Borrichia frutescens	4770	5769	+21	0.29	0.41
Salicornia virginica	3269	2894	-11	0.18	0.23
Batis maritima	4867	5422	+11	0.56	0.61
Sueda linearis	5336	7301	+37*	0.10	0.18*

*Significant differences ($P<0.05$) between years based on a two-sample t-test ($n=4$ for each species in 1991 and 1992 in nearly all cases).

Table 2-3
Change in Peak Biomass and Root/Shoot Ratios of Predominant Marsh Plants at Station 51 in the Nueces River Marsh Between 1991 and 1992

Species	Peak Biomass (g m^{-2})			Root/shoot Ratio	
	1991	1992	% Change	1991	1992
Borrichia frutescens	4713	6549	+39	0.20	0.26
Batis maritima	1978	2991	+51	0.33	0.33
Sueda linearis	2654	5600	+111	0.09	0.16*
Monantocloe littoralis	1307	3803	+191*	0.15	0.24
Sporobolus virginica	1764	1798	+2	0.28	0.38
Limonium nashii	4729	3912	-17	0.40	0.53

*Significant differences ($P<0.05$) between years based on a two-sample t-test ($n=4$ for each species in 1991 and 1992 in nearly all cases).

six species examined, only *Limonium nashii* decreased in biomass between 1991 and 1992. In addition, all but *Batis maritima* increased the amount of root and rhizome tissue relative to shoot biomass. At site 54, the positive increase in biomass of *B. frutescens* was significant ($P<0.05$) while the biomass of the remaining two species decreased (Table 2-4). Two of the three species common to site 54 showed significant ($P<0.05$) increases in root/shoot ratios (*Borrichia frutescens* and *B. maritima*. Interestingly, an overall drop in biomass was noted for both *S. virginica* and *B. maritima* at station 54 compared to stations 50 and 51; a significant decrease in root:shoot ratios at station 54 for *S. virginica* also occurred. The negative response of both these species may be related to salinity, which was lowest at station 54 compared to either station 50 or 51 (Table 2-1).

Table 2-4
Change in Peak Biomass and Root/Shoot Ratios of Predominant Marsh Plants at Station 54 in the Nueces River Marsh Between 1991 and 1992

	Peak Biomass (g m^{-2})			Root/shoot Ratio	
Species	1991	1992	% Change	1991	1992
Borrichia frutescens	2342	6293	+169*	0.20	0.42*
Salicornia virginica	4317	3716	-14	0.25	0.10*
Batis maritima	7096	4515	-36	0.47	0.82*

*Significant differences ($P<0.05$) between years based on a two-sample t-test (n=4 for each species in 1991 and 1992 in nearly all cases).

Smooth cordgrass, *Spartina alterniflora*, is not presently located along any of the transects at the three stations. However, *S. alterniflora* was sampled in 1991 at station 50 and again in 1992 at a nearby location. In 1991, peak biomass at station 50 was 6574 grams per square meter (g m^2); in 1992, at a nearby site within the marsh on the Rincon Bayou, a peak biomass of 5700 g m^2 was measured. Root:shoot ratios were 0.27 and 0.40, respectively. In both years, peak biomass occurred in July and declined 33 percent by late August. A shift in the location of the *S. alterniflora* site from station 50 was due to erosion of the marsh along the Nueces Bay shoreline. At station 50, the shoreline receded about two meters since the transect was established in 1991. This recession eliminated *S. alterniflora* from station 50 and undoubtably represents a substantial loss of marsh habitat in this region.

The overall increase in peak vegetation biomass and percent cover, based on data collected at three stations in Rincon Delta, suggest an overall increase in marsh productivity in 1992 compared to the previous year. This increase in primary productivity is attributed to the large additions of freshwater, both as direct rainfall and river overbanking events that occurred in late winter and early spring 1992. The above-ground growth for all species was larger in 1992 than in 1991. However, the below-ground growth was even greater, which produced a very large increase in total plant biomass. This increase in below-ground growth and in overall plant biomass in 1992 resulted in statistically significant increases in root/rhizome:shoot ratios for several species. The change reflects a long-term growth pattern of these plants that maintains large reserves of below-ground tissue. These reserves will be utilized in the initiation of new shoot growth in the following season (Spring 1993) and should contribute to their competitive success in the exploitation of new space. In contrast, some perennial species such as *Salicornia virginica* are defined as opportunistic invaders (Zedler, et al., 1992), and are well adapted to major disturbances (such as flooding) through vegetative expansion or new recruitment from seed (Onuf, 1987).

Estimations of plant productivity may be inferred from minimum and maximum standing crops (see Zedler *et al.*, 1992; Onuf, 1987), but there are far more accurate methods for measuring plant productivity through direct measurement of photosynthesis and overall plant biomass. Traditional methods of measuring net aerial primary production (NAPP) through harvest techniques (Espey Huston and Assoc., 1977; Henley and Rauschuber, 1980) are now recognized as inappropriate for most marsh systems due to their destructive nature and consistent underestimation of plant productivity (Onuf, 1987; Pacific Estuarine Research Laboratory, 1990). Alternative approaches to the monitoring of marsh productivity, through direct measurement of photosynthesis (which requires measurement of seasonal changes in biomass and percent cover, as conducted in this study), are probably most appropriate (Pacific Estuarine Research Laboratory, 1990; Zedler *et al.*, 1992) and are recommended in evaluating the productivity of the Nueces marsh system.

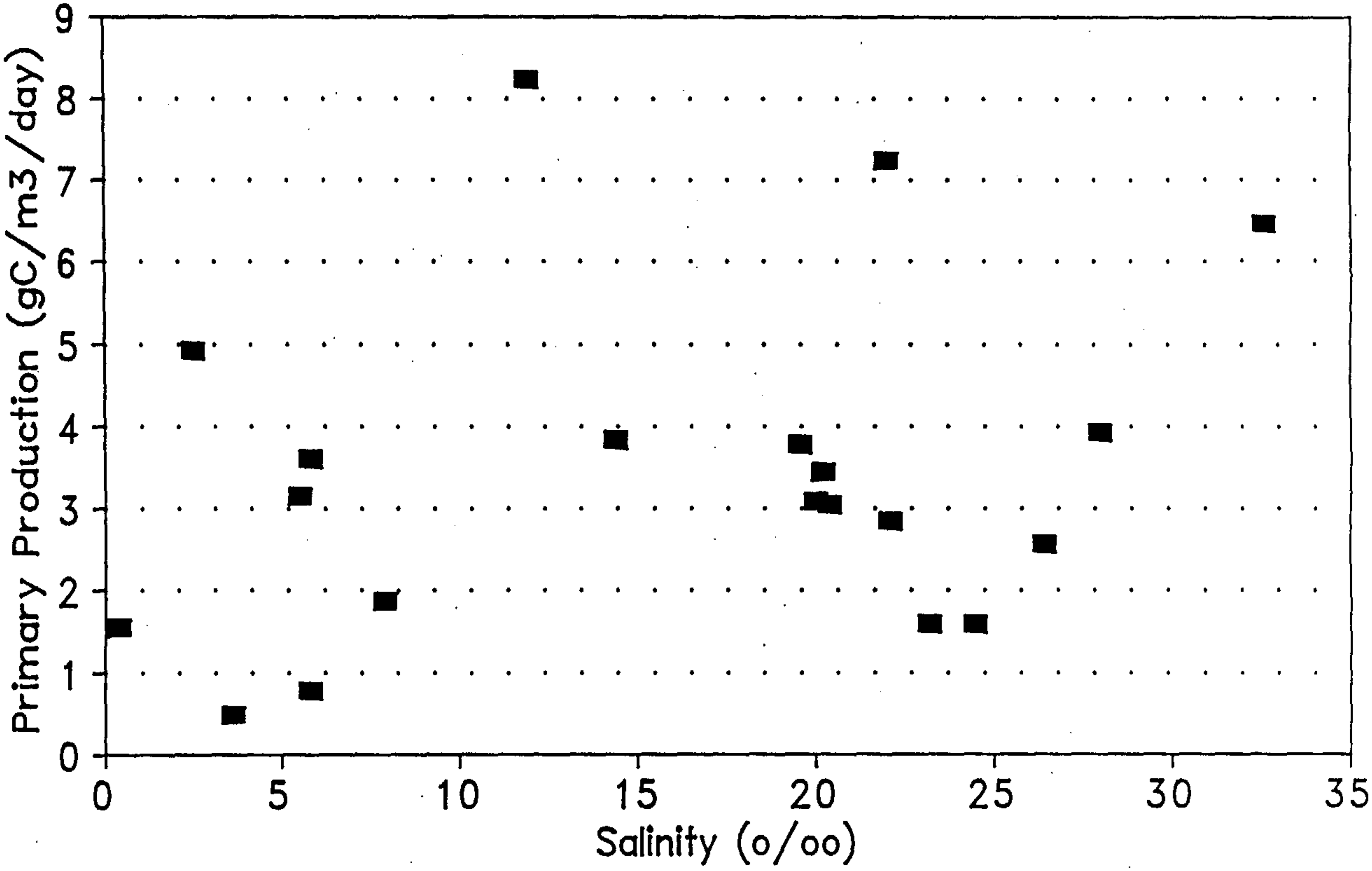
2.2 Primary Production of Phytoplankton in Marsh Ponds and Channels

The primary production rates of phytoplankton populations in marsh ponds and connecting channels in the interior of Rincon Delta (stations 51 and 54) were monitored by monthly sampling of temperature, salinity, nutrients (nitrate, nitrite, ammonium, phosphate and silicate), water transparency, plant pigments, and primary productivity. The large amounts of direct precipitation and the overbanking events of the Nueces River delivered unusually large quantities of freshwater to the Rincon Delta during the first six months of the year. The mean salinity for all samplings at these sites in 1992 was 7.82 ‰ compared to

23.86 ‰ in 1991. The primary production rates in the delta varied from 0.49 to 8.22 with a mean value of 3.40 grams carbon per cubic meter per day ($gC/m^3/day$) (Figure 2-5). This compares to values of 0.10 to 4.78 with a mean of 1.82 $gC/m^3/day$ for the reference station (station 7) in Nueces Bay. The maximum primary production rate in the delta in 1991 was 7.22 but increased to 8.22 $gC/m^3/day$ in 1992 as a result of the increased amounts of freshwater.

2.3 Primary Production and Biomass of Microphytobenthos in Marsh Ponds and Channels

The primary production of phytoplankton in the surface sediments (microphytobenthos) was measured at four sites in marsh ponds in order to include this previously omitted productivity component. The pigment content of sediment ranged from 22.32 to 35.95 milligrams (mg) Chlorophyll per square meter (m^2) which is approximately equivalent to the quantity in the water column (Table 2-5). The primary productivity of the surface sediments ranged from 4.0 to 27.7 with a mean value of 19.1 $mgC/m^2/day$. In comparison, the water column had productivity values of 529 to 1473 with a mean of 806 $mgC/m^2/day$. The primary productivity of the microphytobenthos was about 3.8 percent of the water column phytoplankton production rates. This is unusually small compared to rates in published reports. The absolute rates of production in the sediments are not low but rather the water column rates are large. Monitoring of the sediment productivity rates should be continued to include higher salinity conditions when the water column rates decrease. It is expected that 25 to 50 percent of primary productivity will be contributed by sediment populations in shallow waters where light can penetrate to the bottom.



PHYTOPLANKTON PRIMARY PRODUCTION RATES (g^c/m^3/day) MEASURED IN RINCON DELTA (STA 51 & 54) MARSH PONDS AND CHANNELS FROM NOVEMBER 1990 THROUGH OCTOBER 1992

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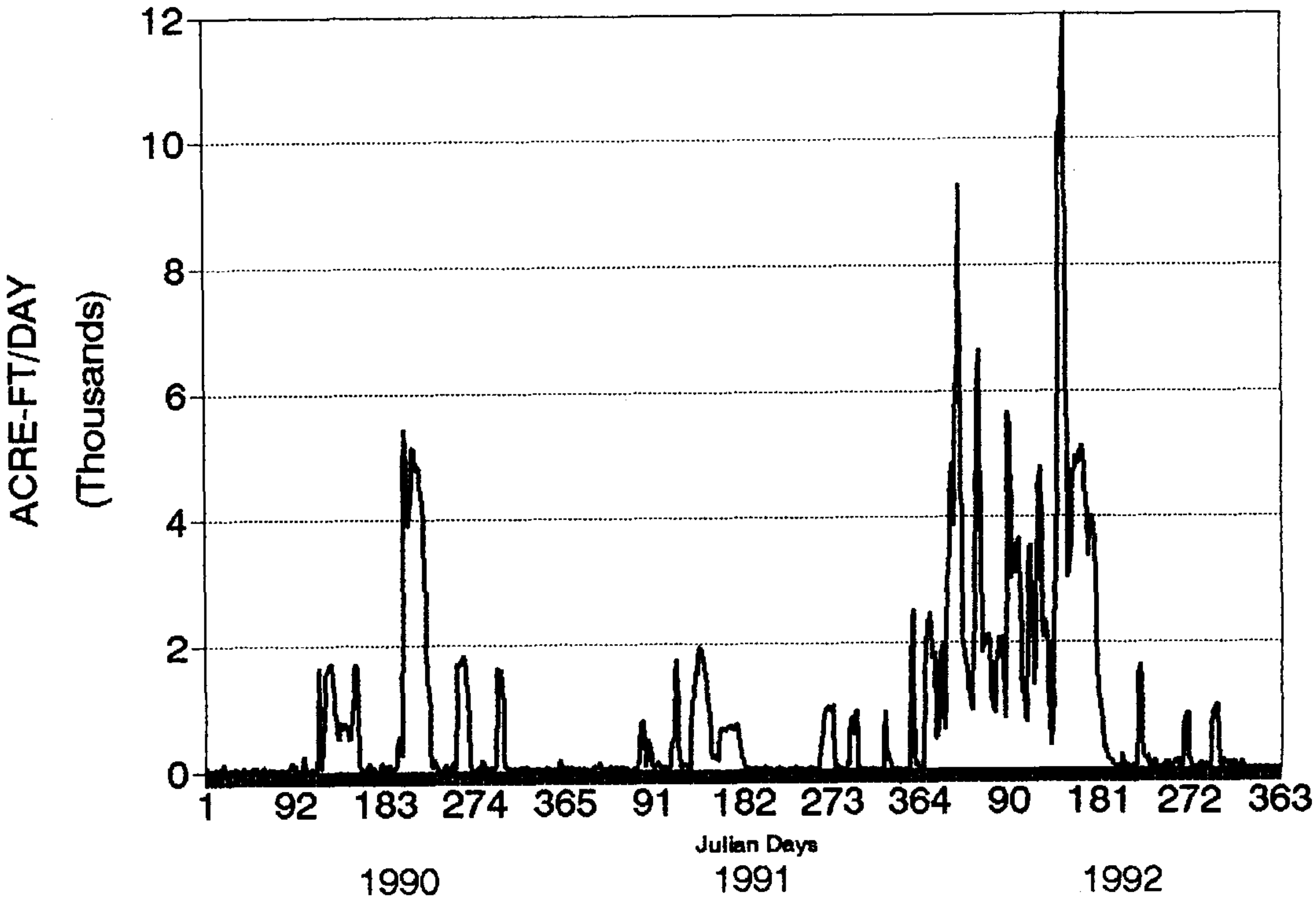
ALLISON WASTEWATER TREATMENT PLANT
TYPICAL WASTEWATER FLOW
FIGURE 2-5

Table 2-5 Primary Productivity Rates and Pigment Biomass in the Water and Sediments in Rincon Delta				
Station	**Sediment Chlorophyll (mg/m^2)**	**Water Productivity ($mgC/m^2/day$)**	**Sediment Productivity ($mgC/m^2/day$)**	**Percent Productivity in Sediments ($mgC/m^2/day$)**
51	22.32	1473	4.02	0.27
53	24.33	601	17.94	2.99
54	26.28	529	26.55	5.02
55	35.95	623	27.72	4.45
Mean	27.22	806	19.06	3.18

2.4 Primary Production From Freshwater Releases Into Nueces Bay

The monitoring of the biological effects of freshwater releases and spills was obtained by the monthly sampling of salinity, temperature, dissolved oxygen, nutrients (nitrate, nitrite, ammonium, phosphate, and silicate), plant pigments, water transparency, and water column primary productivity in Nueces Bay and the lower Nueces River. The samples were collected at 25 sites for hydrography, nutrients, and plankton pigments, while five of the sites included primary production rate measurements (Figure 2-1). The vertical profiles of salinity, temperature, and dissolved oxygen consisted of data collected every five to 10 cm through the water column from surface to bottom. Discrete water bottle samples were taken at the surface and near bottom except in water depths of less than 30 cm where only surface samples were collected. Most station locations were marked by fixed structures (well heads, PVC pipe, etc.) in the bay and geographical positioning systems (GPS) positions were recorded for all samplings. The Nueces River discharge into Nueces Bay and Rincon Delta for the year 1992 was dominated by several inflow events in the winter and spring time periods (Figure 2-6), while the summer and fall had much smaller inflow rates. The total flow past the Calallen gage from January 1 through November 23, 1992 was 600,230 acre-feet, but 95.2 percent of the total occurred before July 1. Flows at or above 5,000 acre-feet/day occurred February 5-11, February 27 to March 1, March 30-31, April 30 to May 1, May 19-27, and June 9-12. Flows of about 2,500 acre-feet/day are capable of overbanking the Nueces River channel and flowing through the Rincon Delta. Releases were not being made during the period of January through June because spills were occurring.

The salinity response to freshwater flow into Nueces Bay was monitored continuously by the Blucher Institute at Corpus Christi State University at hourly intervals at two sites. The upper Nueces Bay site about 1 km off Whites Point is the official salinity monitoring station to determine Choke Canyon/Lake Corpus Christi System (CC/LCC) freshwater release requirements. The other station is located midbay (powerline pole #34) along the upper power line at the established Texas Water Commission (TWC) and Texas Water Development Board (TWDB) monitoring site. The salinity at the upper site was about 18 ‰ at the start of 1992, rapidly dropped 10 to 12 ‰ in mid-January, and dropped precipitously to < 1 ‰ during the very large inflows of early February (Figure 2-7). The salinity remained below 4 ‰ until late June but displayed 2 to 3 ‰ variations with the inflow events from February through June. The salinity increased sharply to about 8 ‰ during late June then increased monotonically with small variations to approximately 26 ‰ through September. At the beginning of October, a small event lowered the salinity below 20 ‰ but salinity



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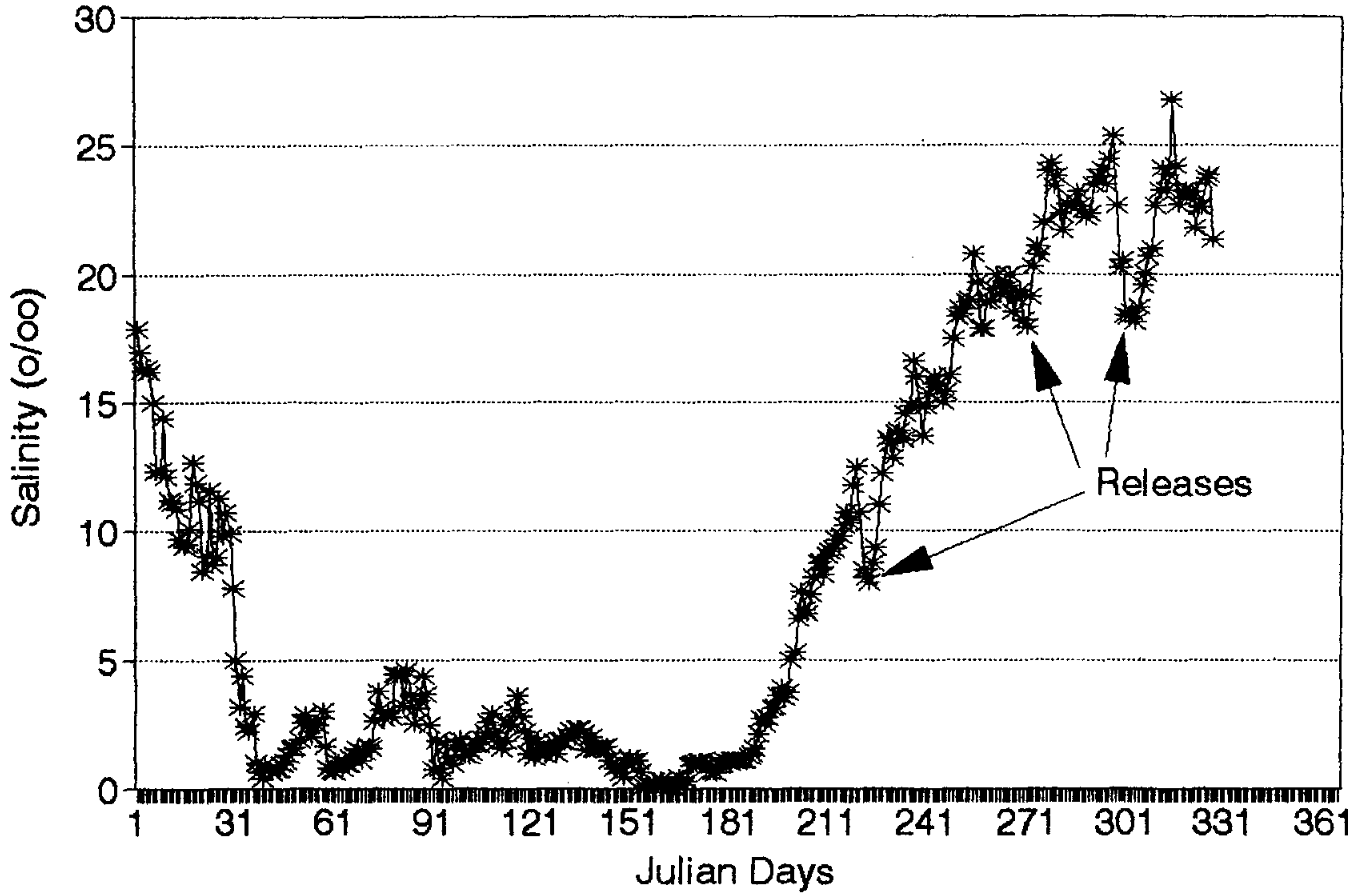
1992 NUECES RIVER DAILY DISCHARGE
CALALLEN GAGE
FIGURE 2-6



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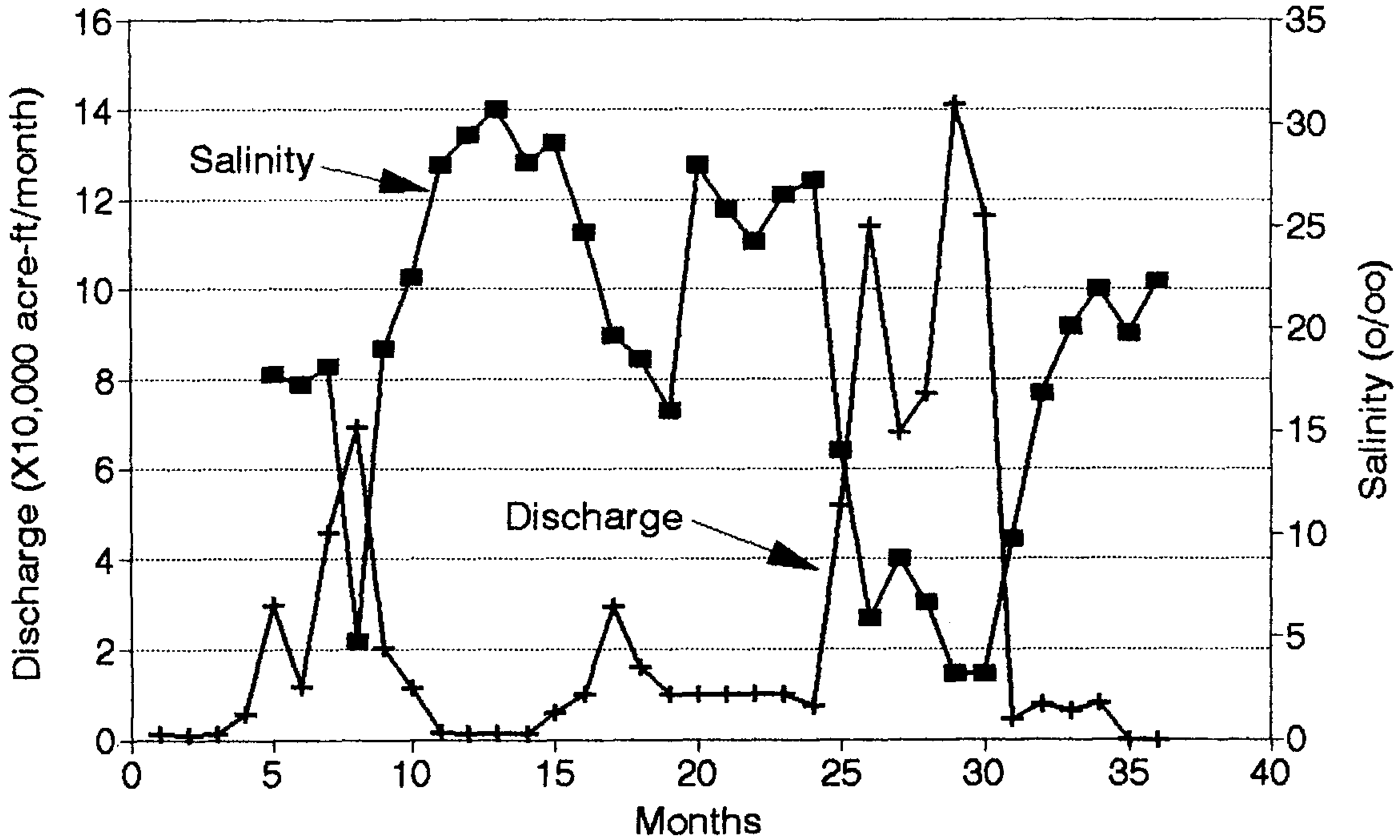
1992 NUECES BAY DAILY MEAN SALINITY
UPPER NUECES BAY DATA SONDE SITE
FIGURE 2-7

rapidly returned to the mid-20's in mid November. The freshwater inflow events completely dominated the salinity responses observed in Nueces Bay. Even the three small inflows of about 1,000 acre-feet/day during the fall lowered the salinity by 2 to 8 ‰. The time lag for both increases and decreases in salinity after changes in inflow ranged from one to three days with a mean of 2.13 days. The range of salinity responses probably reflects differences of circulation within upper Nueces Bay with respect to varying atmospheric and tidal conditions.

The mean monthly salinity conditions in Nueces Bay, as reflected by all of the hydrographic and productivity stations for the freshwater releases, starting in May 1990 and continuing through October 1992, show a variation from 3 to 30 ‰ (mean = 18.81 ‰) with the highest values occurring in the winter when precipitation and releases are lowest (Figure 2-8). The lowest salinity values occurred in late spring and summer during periods of direct precipitation, spills, and releases. The high salinity in the winters of 1990 and 1991 varied by ~4 ‰ while the summer low values ranged from 5 ‰ to 16 ‰ to 3 ‰ for 1990, 1991, and 1992. These summer variations of 13 ‰ reflect the augmentation of releases by natural spills in both 1990 and 1992. When no natural spills occurred in 1991, a mean salinity of about 16 ‰ was the lowest for the year. When only 1992 mean monthly salinities are examined, the correspondence with the daily salinity values observed at the monitoring station is quite apparent (Figure 2-9). This comparison assures that the monitoring station is reflecting conditions representative of the entire Nueces Bay and the monthly monitoring surveys are collecting data on nutrients and productivity for a reasonable timeframe.

The nitrate content and other anions in raw Nueces River water taken into the O.N.



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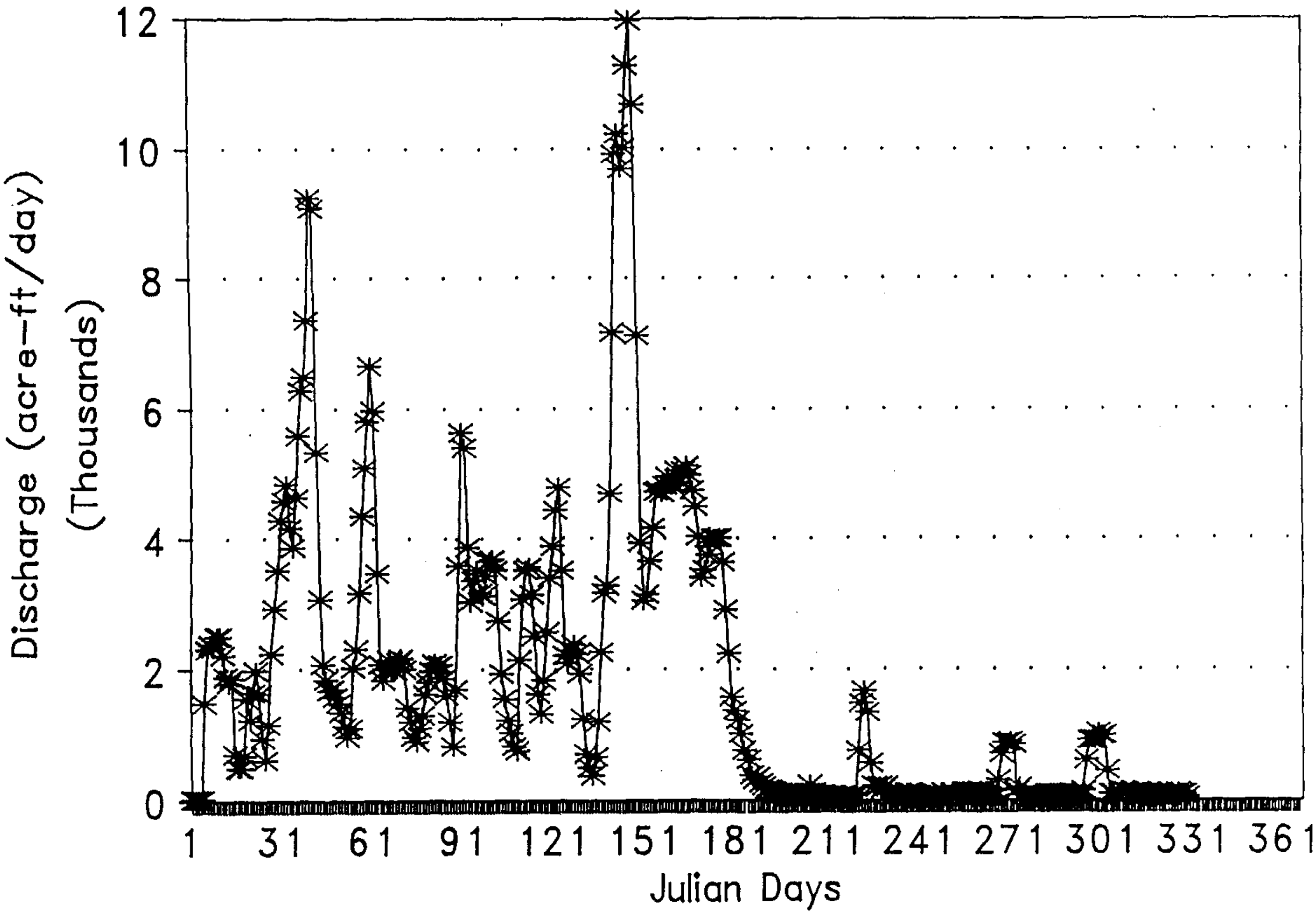
MAY-OCT 1992 NUECES BAY MONTHLY MEAN SALINITY
FROM HYDROGRAPHIC SURVEY
FIGURE 2-8



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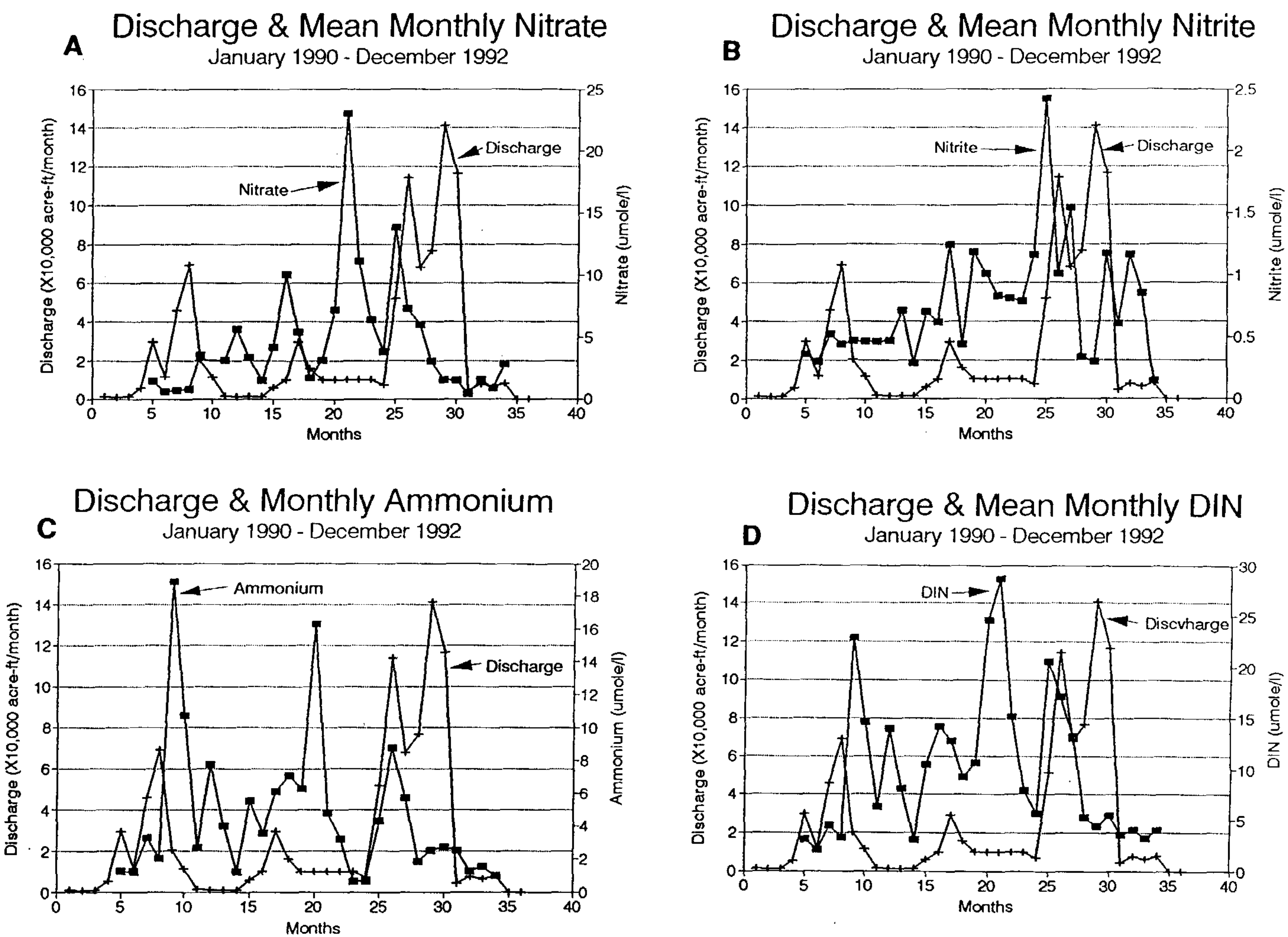
1992 NUECES BAY MONTHLY MEAN SALINITY
FROM HYDROGRAPHIC SURVEYS
FIGURE 2-9

Stevens Water Plant increased by about a factor of 10 during the last two weeks of December 1991 during a period of heavy precipitation (James Dodson, personal communication). The increased level of flow and elevated nitrogen nutrient concentrations of the river water produced a peak for nitrate, nitrite, and ammonium in Nueces Bay at the start of 1992. The mean monthly nitrate concentrations from May 1990 through October 1992 show several peaks that may be related to either freshwater inflow or regeneration/nitrification processes (Figure 2-10a). The range of nitrate was 0.5 to 23 with a mean value of 4.63 micro Mohs per liter (umole/l). The range of nitrite was 0.2 to 2.5 with a mean of 0.76 umole/l. The largest nitrite concentrations occurred during December 1991 and January 1992 when the river waters had elevated concentrations (Figure 2-10b). The other nitrogen nutrient, ammonium, had mean concentrations of 0.5 to 19 with a mean of 4.63 umole/l. The high ammonium concentrations in late summer of 1990 and 1991 were greater than 15umole/l. This conforms with previous observations of large quantities of ammonium observed in the late summer in Corpus Christi and Nueces Bays (Whitledge, 1989) (Figure 2-10c). The higher water temperature at that time of the year promotes the larger in situ ammonium production rates.

The sum of the above nitrogen nutrients is denoted as dissolved inorganic nitrogen (DIN) which represents the inorganic nitrogen available to support plant growth. The range of mean DIN concentrations for May 1990 through November 1992 was two to 28, with a mean of 10.02 umole/l (Figure 2-10d). The lowest DIN concentrations may be small enough to retard phytoplankton growth but values of >5 to 10 umole/l are certainly large enough to promote maximal growth rates if sufficient light is also available. There are few



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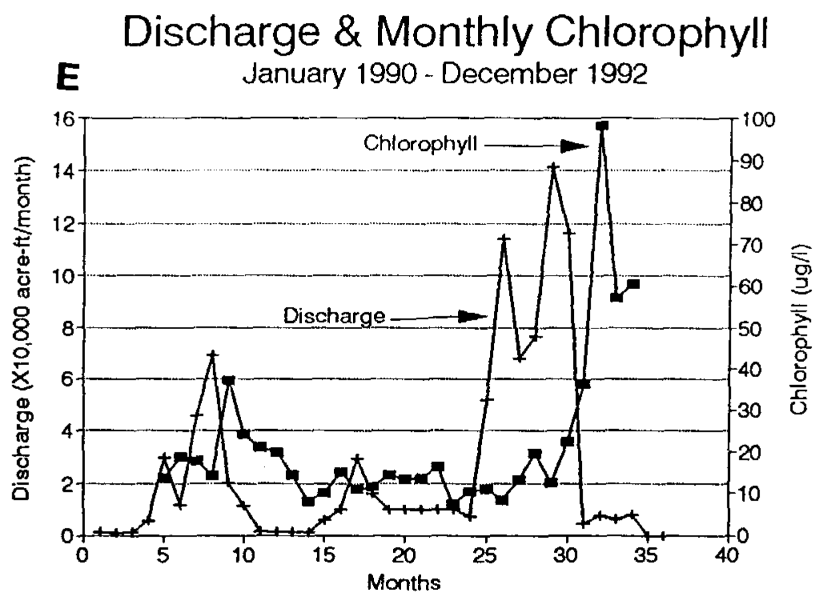
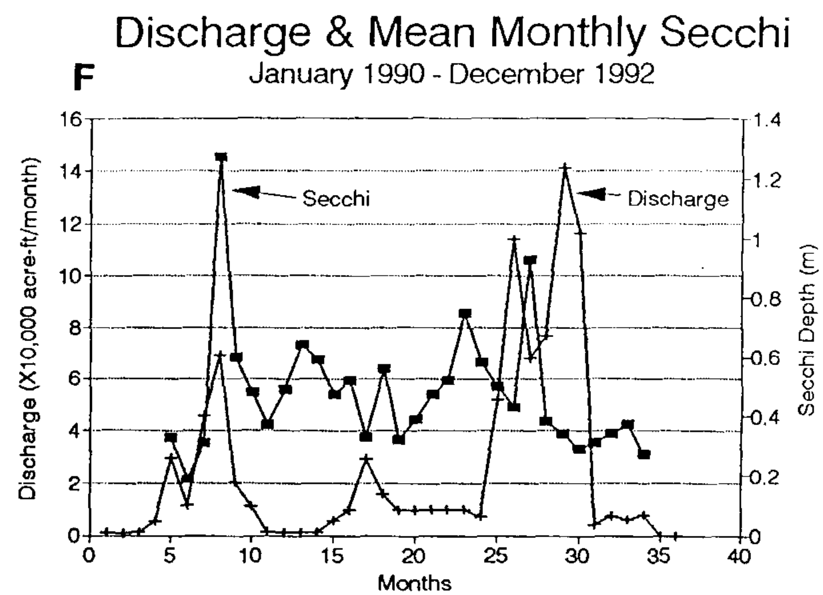
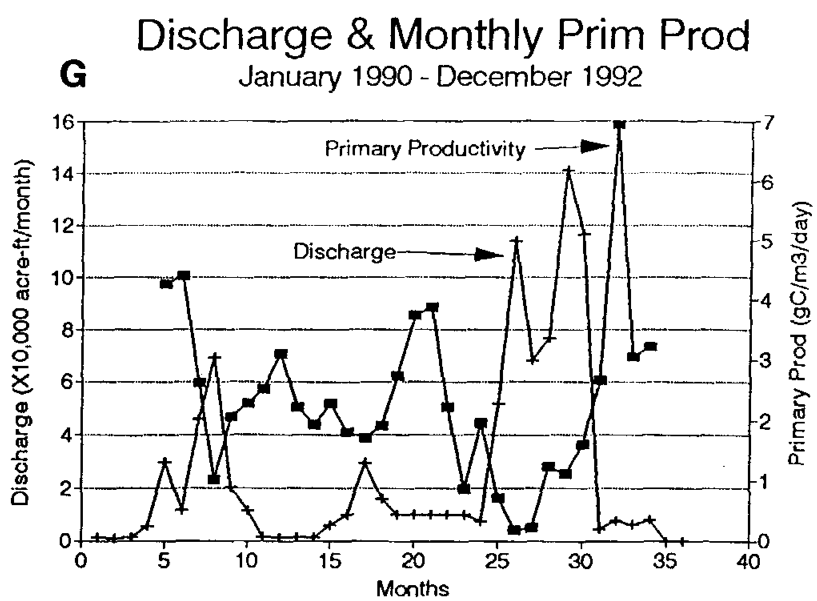
MAY 1990 - OCT 1992 NUECES BAY MONTHLY MEANS
FIGURE 2-10







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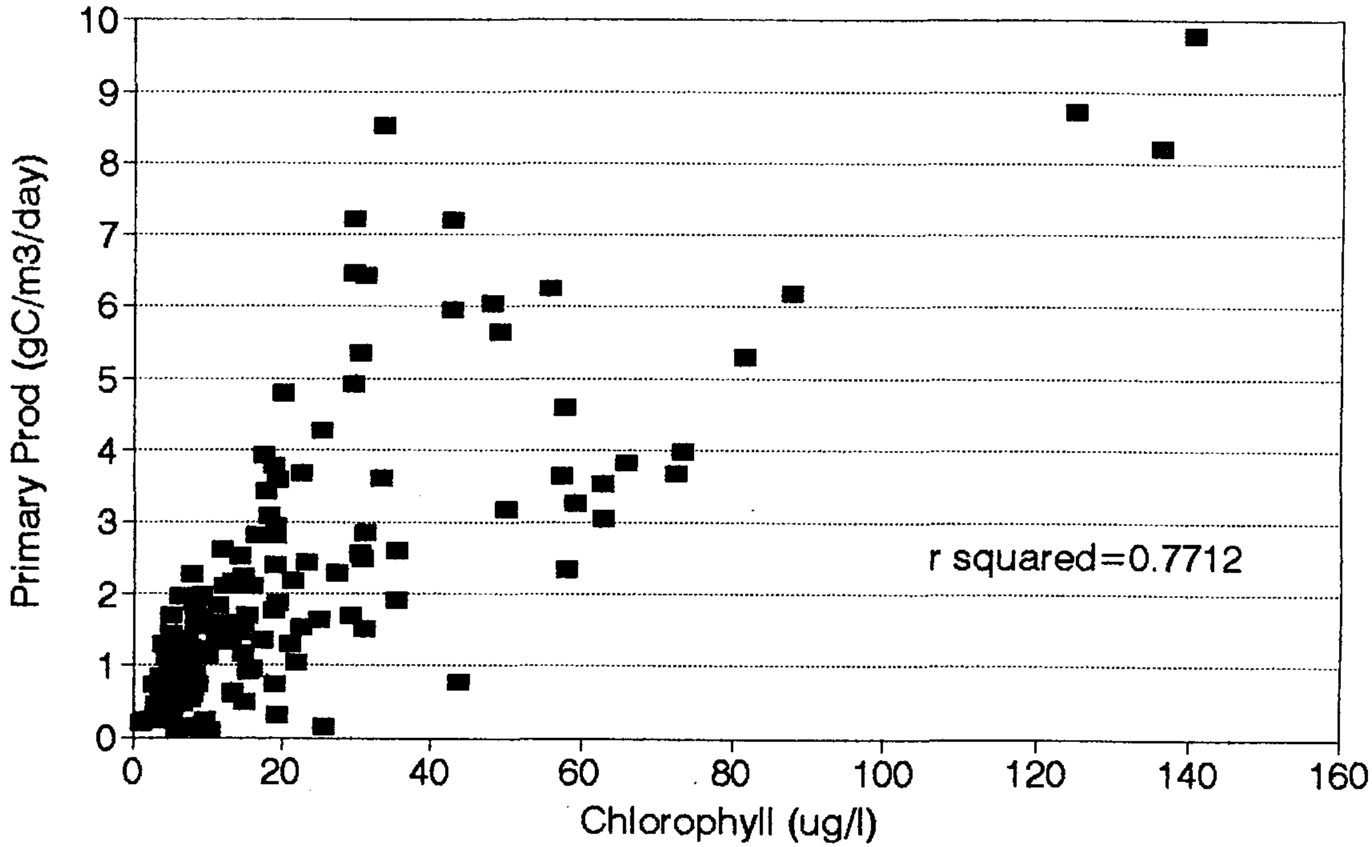
MAY 1990 - OCT 1992 NUECES BAY MONTHLY MEANS
FIGURE 2-10 (CONTINUED)

obvious trends in mean DIN concentrations when compared to the mean salinity values except that the abrupt increases of DIN in August of 1990 and 1991 occur concurrently with abrupt increases in salinity, a possible result of reduced denitrification rates (Whitledge, 1989). The unusually long time period with low DIN concentrations from April through October 1992 resulted from large phytoplankton biomass and high primary productivity rates.

The mean monthly chlorophyll concentration from May 1990 to October 1992 displayed two periods of high values in the fall of 1990 and 1992 (Figure 2-10e) but the remainder of the time chlorophyll concentration ranged between 10 and 20 micro grams per liter (ug/l) with an overall mean of 21.92 ug/l. Both of the enhanced chlorophyll concentrations occurred after large freshwater inflow events. The mean monthly Secchi depth had a poor correspondence with chlorophyll concentrations so the turbidity due to sediment is probably the largest factor in its determination. There are no measurements of suspended particulate such as a transmissometer or nephalometer to confirm this hypothesis (Figure 2-10f).

The mean monthly primary productivity rate measurements for May 1990 through October 1992 varied from 0.2 to 7 with a mean of 2.18 gC/m3/day (Figure 2-10g). The lowest primary production rates were observed during the winter when the day length was short and overcast skies were common. The highest primary production rates were measured during each of the three summers shortly after freshwater inflows from releases and spills. A comparison of chlorophyll concentrations with primary production rate measurements indicates a good relationship (Figure 2-11) which shows that the high rates



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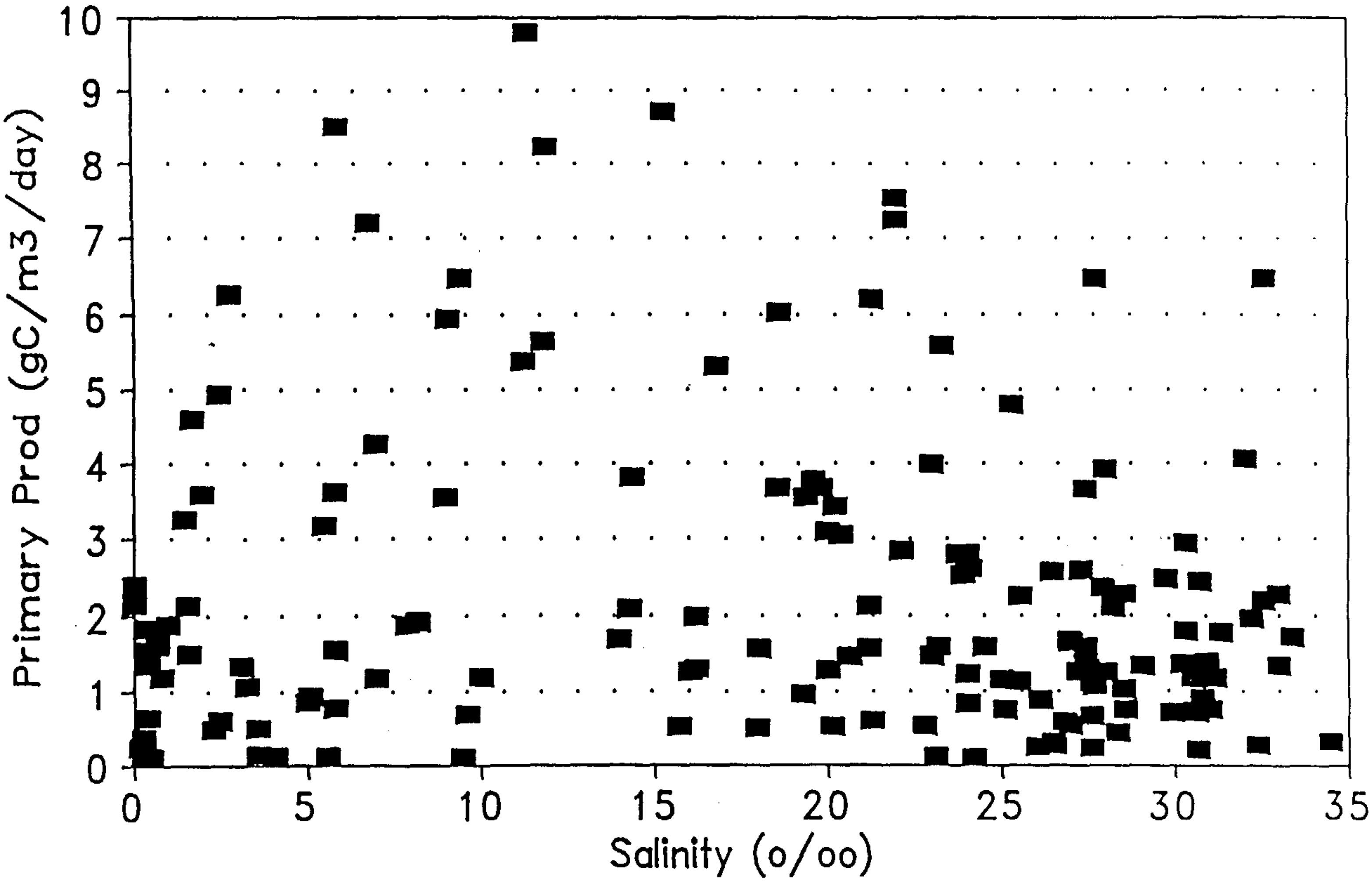
NOV 1990 - OCT 1992 NUECES BAY
PRIMARY PRODUCTIVITY VS. CHLOROPHYLL
CONCENTRATION
FIGURE 2-11

of primary production are responsible for the large concentrations of chlorophyll. Since the chlorophyll-productivity relationship is good, then loss rates by grazing and sinking must not be very important.

Overall, the rates of primary production measured throughout Nueces Bay and Rincon Delta were not influenced strongly by salinity (Figure 2-12). The rates of primary production are lowest at very low (<3 ‰) or very high salinities (>35 ‰) and the maximal rates occur at salinities between 5 ‰ and 35 ‰. The salinity does not directly influence plant growth rates but co-occurs with nutrient elements which do have direct effects. This is shown by the statistically different salinities between 1991 and 1992 using the Mann-Whitney Rank Sun Test, but there was not a significant difference in the primary production rates. Even though 95 percent of the freshwater flowed into Nueces Bay before July 1, 83 percent of the primary production occurred after July 1.

The primary production rates measured at the six locations in Nueces Bay and Rincon Delta are subject to variations with respect to the environmental conditions conducive to plant growth. The mean primary production rates show the highest values in the lower portion of the Nueces River and in the interior of Rincon Delta (Table 2-6). The order from highest to lowest of primary production by station was 4A, 51, 2, 7, 13, and 43 (see Figure 2-1 for station location). Another significant aspect of the primary productivity measurements are the maxima in rates at all stations during August 1992. Station 13 was the only station which had higher rates in a previous sampling in 1990 (Figure 2-13). Station 4A, located in the lower Nueces River downstream from the Allison Wastewater Treatment



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MAY 1990 - OCT 1992 NUECES BAY
PRIMARY PRODUCTIVITY VS. SALTINITY
FIGURE 2-12

Table 2-6 Mean primary production rates and number of samples at stations in Nueces Bay and Rincon Delta						
	St. 2	St. 4A	St. 7	St. 13	St. 43	St. 51
Mean	244.1	410.1	196.1	178.6	125.9	389.5
No. of Samples	24	24	29	29	18	18

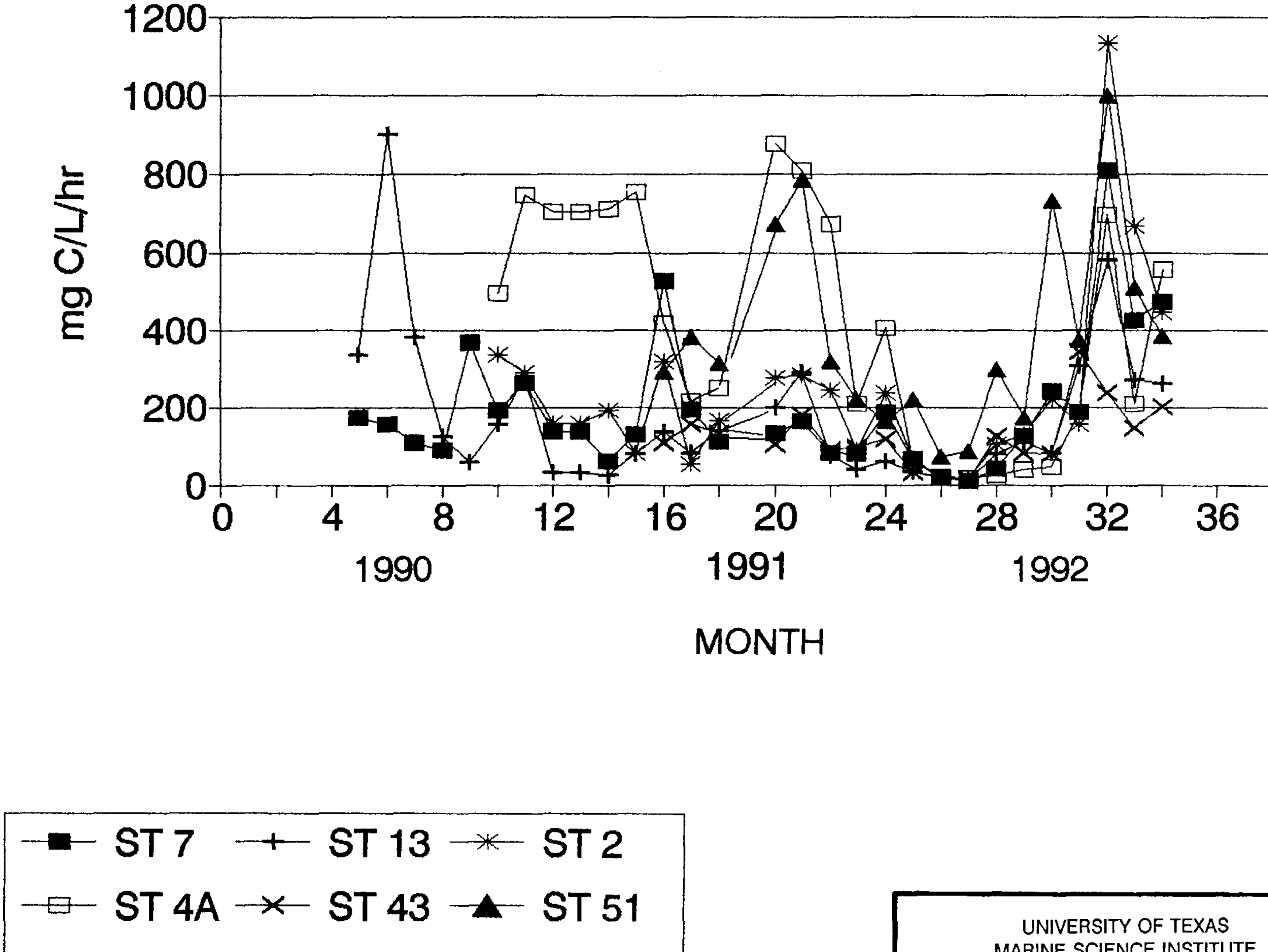
(See Figure 2-1 for the station locations)
Units are mgC/liter/hour.

Plant, enjoys an obvious nutrient enrichment, while station 51 located about five km up in the Rincon Delta responded to freshwater inflows, spill, and overbanking events.

2.5 Comparison of Primary Production Obtained From Diversions of Freshwater and Wastewater Effluent Into Rincon Bayou and Nueces Delta With Primary Production From Freshwater Releases Into Nueces Bay

The results of the Phase I study showed that increased primary production of phytoplankton and emergent vegetation could be expected to occur if Nueces River or Allison Wastewater Treatment Plant waters were diverted into the Rincon Delta rather than flowing down the river and bypassing the brackish marsh area as it currently exists. Phase II continued measuring primary productivity of phytoplankton in the open Nueces Bay and Rincon Delta channels but also gathered additional primary production data for microphytobenthos (phytoplankton growing on the surface of the sediments) and phytoplankton in shallow brackish marsh ponds. The additional measurements were collected under a wider range of salinity, nutrient, and incident radiation conditions.

The overall primary production occurring in the Rincon Delta is comprised of productivity in several plant communities, including the emergent vegetation, water, and



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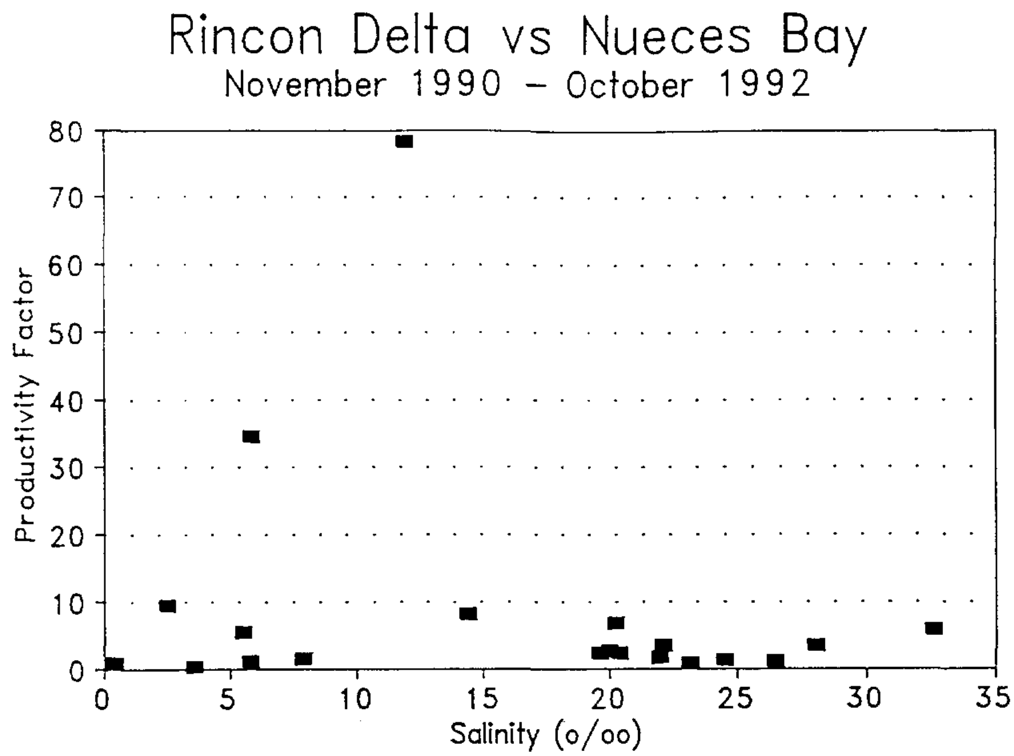
MAY 1990 - OCT 1992 NUECES BAY
PRIMARY PRODUCTIVITY BY STATION
FIGURE 2-13

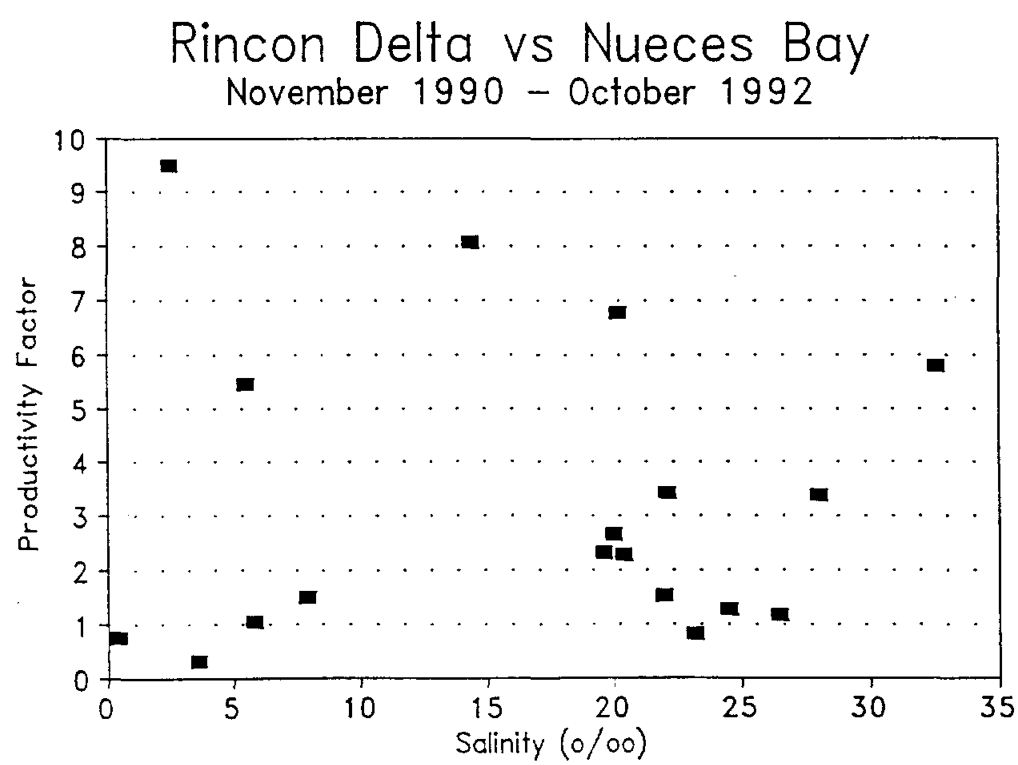
sediment in marsh ponds, and the connecting channels. The emergent vegetation productivity in 1992 ranged from 106 percent to 144 percent of the 1991 estimated value of 1.80 $gC/m^2/day$. These data indicate that the marsh plant growth rate in 1992 was 1.9 to 2.6 $gC/m^2/day$.

The quantities of primary production of the water column in the channels and marsh ponds in Rincon Delta and open Nueces Bay waters were combined for the years 1991 and 1992 to produce an estimate of productivity enhancement in the delta (Figure 2-14). The productivity was 8.54 times higher in Rincon Delta than in upper Nueces Bay but the value declines to 3.21 when two data values are omitted during an unusual "brown tide" bloom that occurred in August and September 1992.

The quantities of primary production of phytoplankton in the Nueces River downstream of the Allison Wastewater Treatment Plant and upper Nueces Bay were compared to estimate the effect of wastewater (Figure 2-15). The overall mean productivity factor for all data collected in 1991 and 1992 for the Nueces River was 2.63 times larger than that of the open Nueces Bay. However, several data points collected at low salinities when the flow rates of the river were large are probably not representative because the transit time was so short and the phytoplankton are washed out of the river before they can grow. When the data below a salinity of 4 ‰ are omitted, the productivity factor ranges from 1.7 to 10.6 with a mean value of 4.97.

The most direct comparison of both freshwater and wastewater effects are found in the Nueces River stations where primary productivity rates are nearly always elevated compared to Nueces Bay. The productivity factor of ~5 estimated for the Nueces River in





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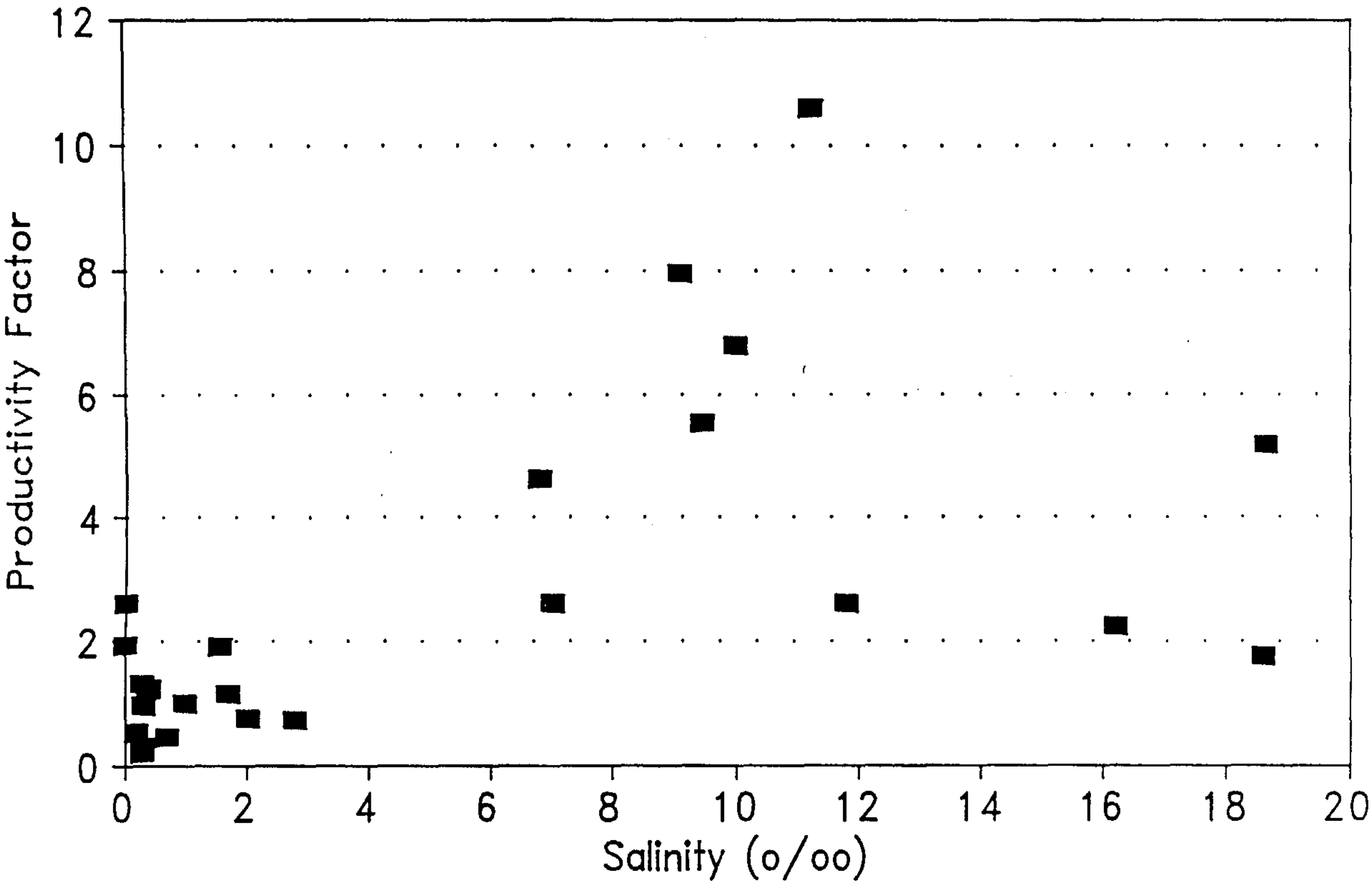
NOV 1990 - OCT 1992 ENHANCED PRIMARY PRODUCTIVITY FACTOR
NUECES BAY VS. RINCON DELTA
FIGURE 2-14



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NOV 1990 - OCT 1992 ENHANCED PRIMARY
PRODUCTIVITY FACTOR
LOWER NUECES RIVER VS. NUECES BAY
FIGURE 2-15

1991 remained the same after the addition of 1992 data. The introduction of additional quantities of freshwater into Rincon Delta in 1992 by direct precipitation and overbanking of the Nueces River elevated the estimated 1991 productivity factor from ~2 to a value of 3.2. This supports the contention that ambient river water diversions to Rincon Delta can be expected to increase primary production by a factor of about three, while wastewater diversions would be expected to produce five times more production. (Note: The distributions of habitat categories in Rincon Delta are needed to estimate more completely the total areal productivity effect of water diversions.)

3.0 DESCRIPTION, ROUTES, SIZES, AND COSTS OF DEMONSTRATION PROJECTS TO DIVERT RIVER WATER AND WASTEWATER EFFLUENT INTO THE NUECES RIVER DELTA

3.1 Diversion of Nueces River Water at Calallen Dam

The Phase 1 Study recommended implementation of a demonstration project to deliver approximately 2.8 million gallons per day (mgd) of freshwater from the Nueces River, upstream of Calallen Dam, to Rincon Bayou. Preliminary discussions were held with representatives from the San Patricio Municipal Water District (SPMWD), and it was proposed that the river diversion pump station would be located on SPMWD property adjacent to the existing W. A. Edwards Raw Water Pump Station. With respect to the demonstration project, the objectives of this section of the Phase II Study are to:

1. Prepare preliminary sizing and layouts of facilities required for the demonstration project;
2. Prepare detailed cost estimates of facilities;
3. Develop a schedule of implementation;
4. Determine the required permitting and approval process;
5. Identify project constraints; and
6. Identify sources of funding.

In addition to the recommended project for diversion at Calallen Dam, a possible alternative river diversion project was evaluated to determine its feasibility. This alternative included utilizing the City of Corpus Christi's existing O. N. Stevens Water Plant raw water pumping and transmission facilities, along with required improvements, to deliver river water to the estuary area northwest of South Lake. The concept of diverting river water through the O. N. Stevens facilities was initiated at a June, 1992 Phase II Technical Advisory

Committee Meeting regarding the project scope. A discussion of this alternative diversion project is included in Section 3.3 of this report.

In order to further define the facilities required by the Calallen Dam demonstration project, additional discussions were held with SPMWD representatives. In addition, record drawings of existing SPMWD pumping and raw water transmission facilities were reviewed and field visits were made to proposed pump station, pipeline, and discharge area sites. It was originally anticipated that current topographic information would be available from surveys performed by the United States Bureau of Reclamation. However, project schedules did not allow completion of surveys prior to publication of this report. Therefore, assumptions were made based on record drawings and United States Geologic Survey (USGS) quadrangle maps. The proposed demonstration project for diversion of river water includes the following:

1. Construction of intake structure and raw water pump station at the existing W. A. Edwards Raw Water Pump Station site;

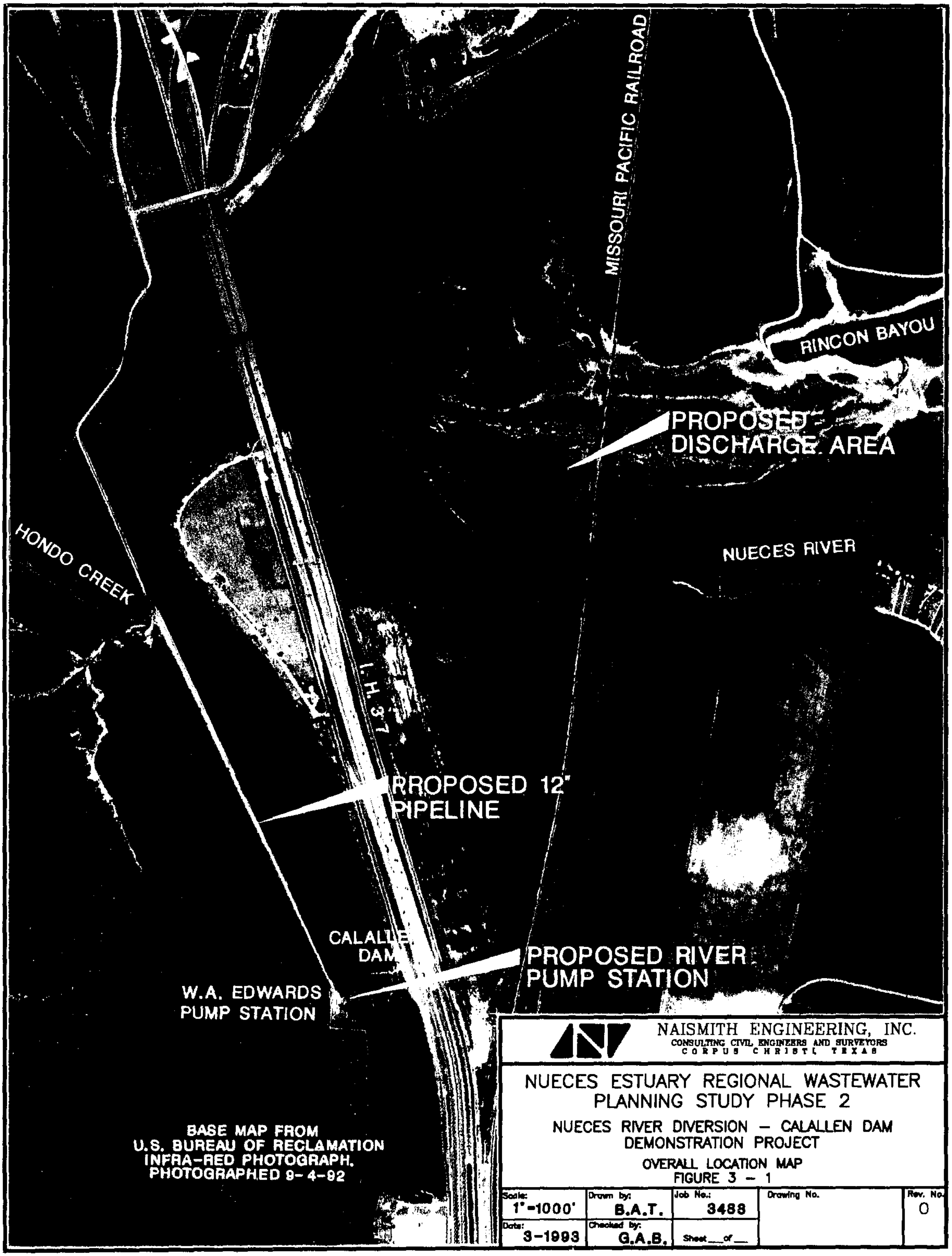
2. Construction of approximately 9,000 linear feet (LF) of 12-inch raw water pipeline; and

3. Construction of discharge area in the upper reaches of Rincon Bayou west of the Missouri-Pacific Railroad.

An overall location map of the pump station site, pipeline routing and Rincon Bayou discharge area is shown in Figure 3-1.

3.1.1 Proposed Intake Structure and Pump Station

A site plan of the W. A. Edwards Raw Water Pump Station is shown in Figure 3-2. Based on preliminary discussions with the SPMWD representatives and site visits, it is


MISSOURI PACIFIC RAILROAD
RINCON BAYOU
PROPOSED DISCHARGE AREA
HONDO CREEK
NUECES RIVER
I.H. 37
PROPOSED 12" PIPELINE
CALALLEN DAM
PROPOSED RIVER PUMP STATION
W.A. EDWARDS PUMP STATION
BASE MAP FROM
U.S. BUREAU OF RECLAMATION
INFRA-RED PHOTOGRAPH.
PHOTOGRAPHED 9-4-92
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CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI, TEXAS
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
NUECES RIVER DIVERSION – CALALLEN DAM DEMONSTRATION PROJECT
OVERALL LOCATION MAP
FIGURE 3 – 1
Scale: 1"=1000'
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Drawing No.
Rev. No. 0
Date: 3-1993
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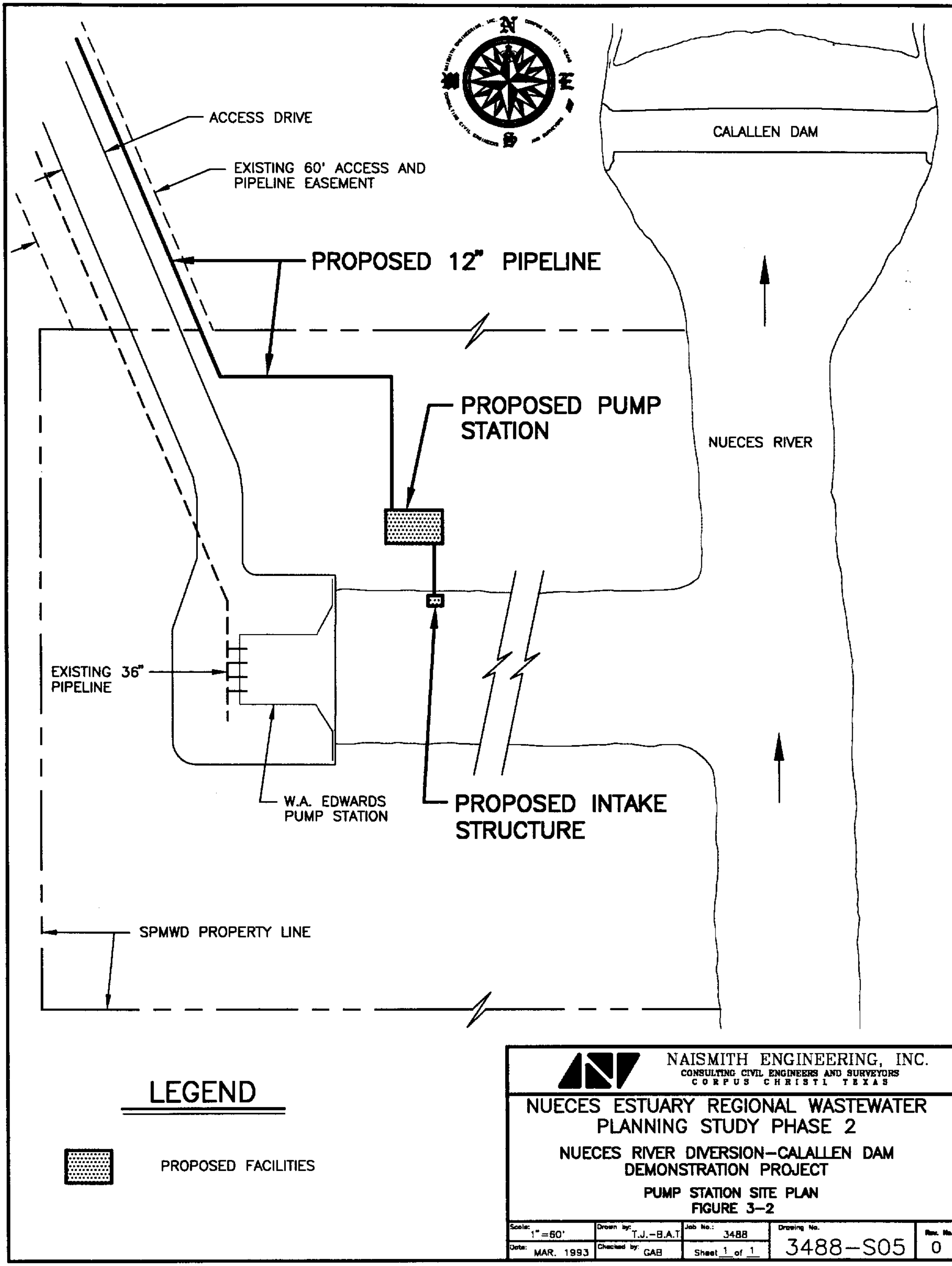
ACCESS DRIVE
EXISTING 60' ACCESS AND PIPELINE EASEMENT
PROPOSED 12" PIPELINE
CALALLEN DAM
PROPOSED PUMP STATION
NUECES RIVER
EXISTING 36" PIPELINE
W.A. EDWARDS PUMP STATION
PROPOSED INTAKE STRUCTURE
SPMWD PROPERTY LINE
LEGEND
PROPOSED FACILITIES
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NUECES RIVER DIVERSION—CALALLEN DAM DEMONSTRATION PROJECT
PUMP STATION SITE PLAN
FIGURE 3–2
Scale: 1"=60'
Drawn by: T.J.–B.A.T
Job No.: 3488
Drawing No. 3488–S05
Rev. No. 0
Date: MAR. 1993
Checked by: GAB
Sheet 1 of 1

proposed that the demonstration pump station be located just northeast of the existing pump station on the north side of the river inlet. The total area required for intake structure and pump station is approximately 60 feet by 60 feet.

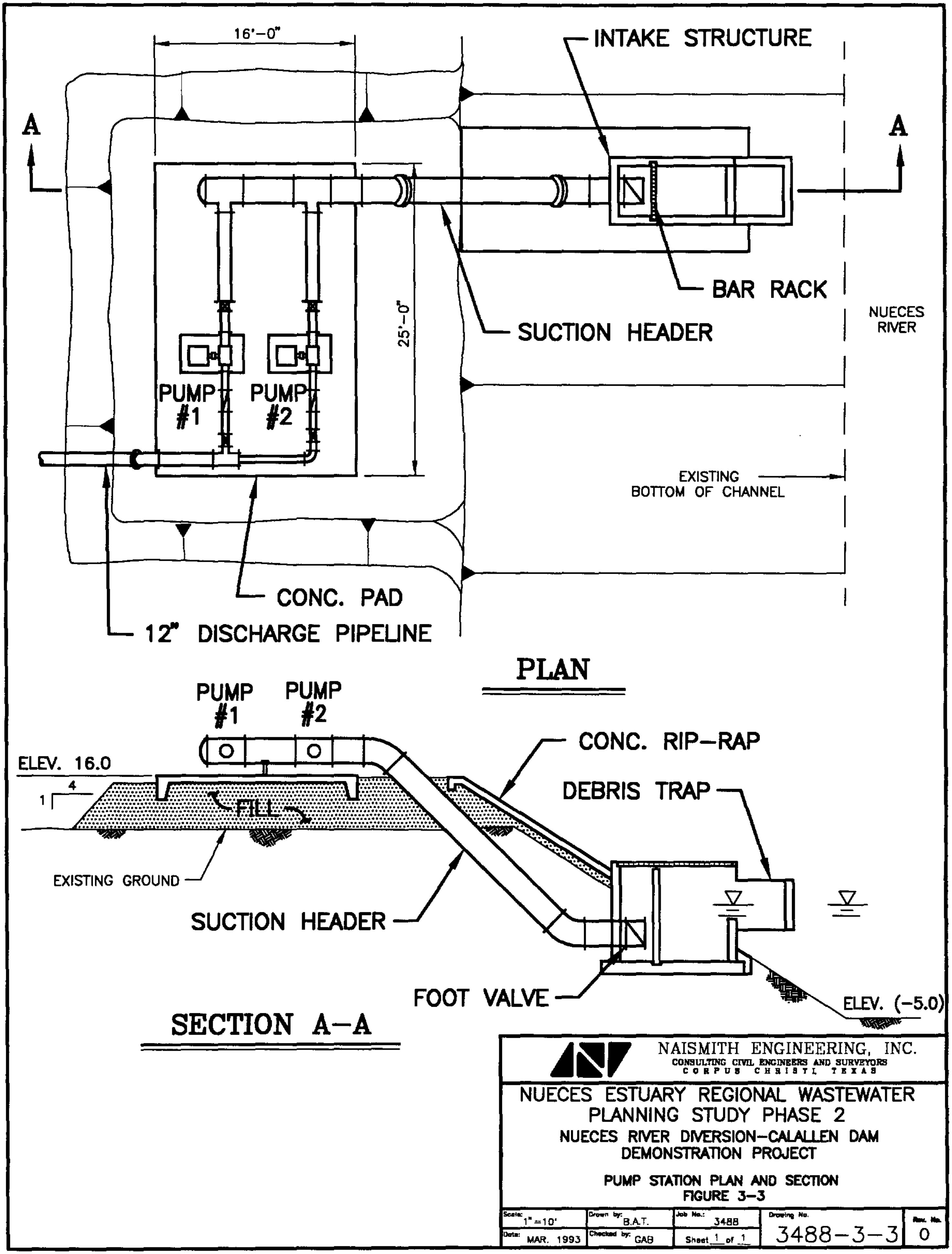
The intake structure will consist of a pre-cast concrete box with an open top and solid walls on three sides. The top will be covered by grating, and the fourth side will include an overflow weir at approximately elevation four feet above mean sea level (MSL) for water intake. A debris trap will be incorporated into the design of the box to prevent floating debris from entering the intake structure. In addition, a removable bar rack will be installed inside the structure to further protect the suction pipe. Final design of the intake structure will include a geotechnical investigation to determine if special foundation structures, such as pilings, will be required.

Preliminary layouts and cost estimates were prepared for alternative pump stations utilizing vertical turbine pumps or horizontal split-case pumps. The horizontal split-case pump layout was determined to be the most economical because the use of vertical pumps required a more expensive concrete sump structure for pump suction. The selected horizontal pumps will be mounted on an above-ground concrete pad. Approximately six feet of fill will be required to raise the pump pad to elevation 16 feet MSL, which is approximately two feet above the 100-year flood elevation. Due to the suction lift requirement, there will be a foot valve on the suction line and a check valve on the discharge line to prevent loss of prime. Final design should also incorporate a device to shut down the pump in the event of a loss of prime due to malfunction of the foot valve. The pump station will discharge into the 12-inch pipeline which will be routed northward to the north property line, then west to the existing 60-foot wide pipeline and access road easement. Preliminary pump station plan and typical sections are shown in Figure 3-3.

Figure 3-4 presents system head and pump curves for a 12-inch pipeline and pump with a design capacity of 2,000 gallons per minute (gpm), which is approximately 3 mgd, at 92 feet of Total Dynamic Head (TDH). The pumps will be operated in an alternating duplex arrangement and flow measurement will be provided by individual meters installed on each pump discharge line. A request will need to be made to Central Power and Light Company for a separate meter and 480 volt power. In addition, a formal request will need to be made to SPMWD's Board of Directors for permission to construct the facilities on its site. Discussions should also be held to determine the feasibility of having SPMWD personnel handle operation and maintenance of the station.

3.1.2 Proposed Raw Water Pipeline

In order to provide the most economical pipeline, various types of pipe and construction techniques were evaluated, including aluminum irrigation pipe, polyvinyl chloride (PVC) irrigation pipe, American Water Works Association (AWWA) C-900 PVC pipe, and above-ground and buried installations. It is recommended that PVC irrigation pipe, which has a pressure rating of 100 pounds per square inch (psi), be used for the majority of the pipeline length. The 12-inch pipeline will be located approximately five feet east of the existing SPMWD access road and will follow its alignment northward for approximately 5,600 feet. In order to minimize installation costs, pipe will be laid with a relatively shallow depth of cover (approximately 18 inches). Approximately 3,600 feet north


16'-0"
INTAKE STRUCTURE
A
A
25'-0"
BAR RACK
SUCTION HEADER
NUECES RIVER
PUMP #1
PUMP #2
EXISTING BOTTOM OF CHANNEL
CONC. PAD
12" DISCHARGE PIPELINE
PLAN
PUMP #1
PUMP #2
CONC. RIP-RAP
ELEV. 16.0
4
1
FILL
DEBRIS TRAP
EXISTING GROUND
SUCTION HEADER
FOOT VALVE
ELEV. (-5.0)
SECTION A-A
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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
NUECES RIVER DIVERSION-CALALLEN DAM DEMONSTRATION PROJECT
PUMP STATION PLAN AND SECTION
FIGURE 3-3
Scale: 1"=10'
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Drawing No. 3488-3-3
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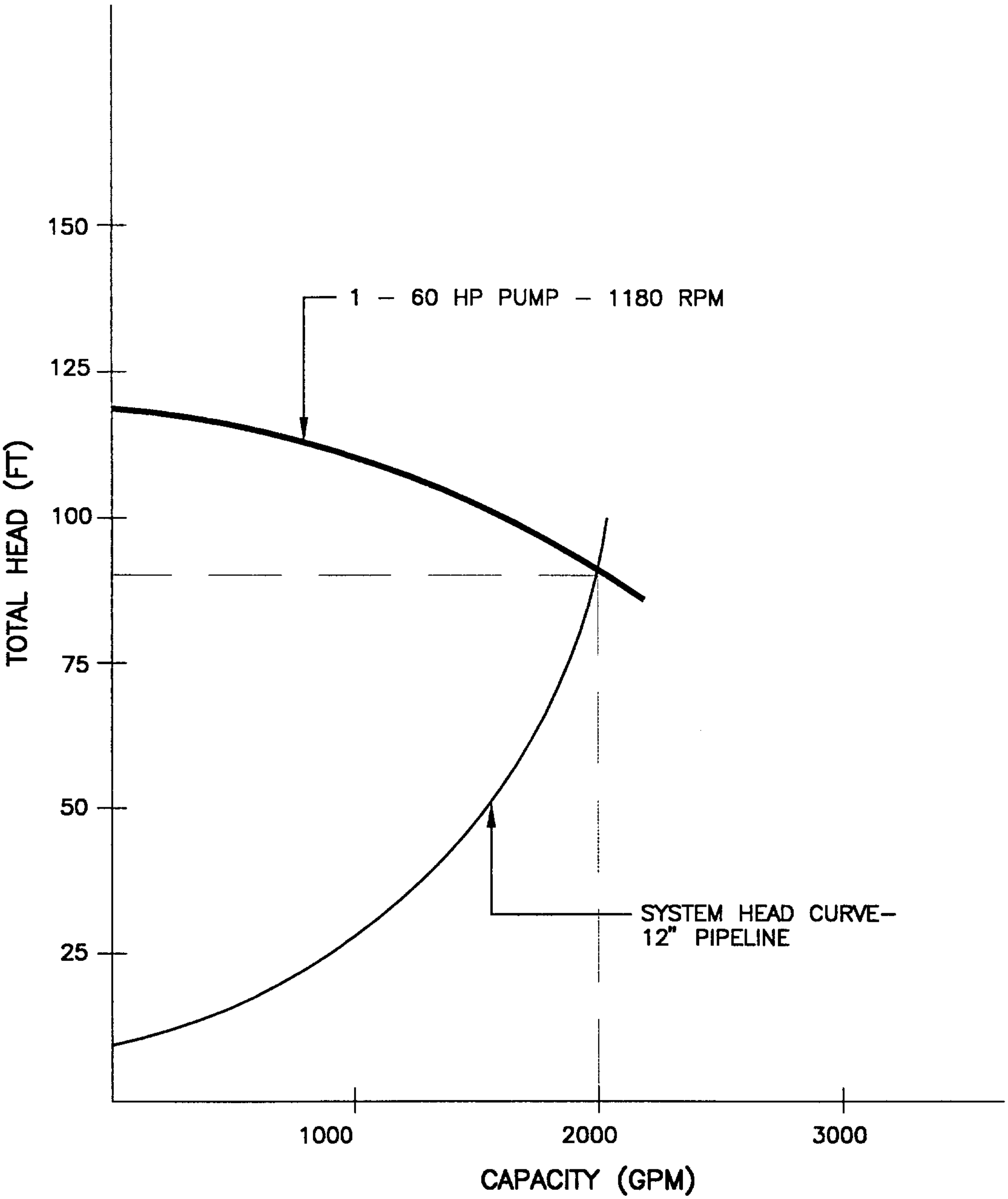

HDR Engineering, Inc.

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CORPUS CHRISTI TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
NUECES RIVER DIVERSION - CALALLEN DAM DEMONSTRATION PROJECT
SYSTEM HEAD AND PUMP CURVES
FIGURE 3-4

of the pump station, the alignment crosses Hondo Creek. Because the existing SPMWD timber bridge over Hondo Creek was not designed to support an additional pipeline, alternatives were evaluated for installation of additional support pilings for an aerial crossing and for installation under Hondo Creek by open cut trenching in the creek bottom. It is recommended that an aerial crossing, utilizing a section of coated steel pipe, be installed at Hondo Creek in order to minimize disturbance of the creek during construction, minimize permitting requirements, and provide for easy pipeline maintenance.

In order to minimize the number of additional easements to be obtained, it is proposed that the alignment follow the existing SPMWD easement to a location approximately 2,200 feet north of Hondo Creek. This portion of the easement is within a single tract of land. At the tract's east property line, the existing easement extends northerly across an adjacent landowner's property to the Interstate Highway 37 (IH 37) right-of-way (ROW). Alignment of the new pipeline will require a new easement from this landowner and will then cross under the elevated portion of IH 37. This crossing will require submittal for a ROW permit from the Texas Department of Transportation. East of the IH 37 corridor, the pipeline alignment will extend in a southeasterly direction across an additional landowner's tract prior to terminating in the discharge area. An easement will also be required from this landowner (see Section 3.1.9).

East of IH 37, the pipeline will cross a proposed Bureau of Reclamation project which will involve excavating a river diversion to allow more frequent overbanking of the river into Rincon Bayou during natural flooding events. The Bureau's exact schedule of construction and project status is unknown at this time. Coordination will need to occur during final design to determine the portion of demonstration discharge pipeline which will need to be placed lower than the Bureau's excavated area.

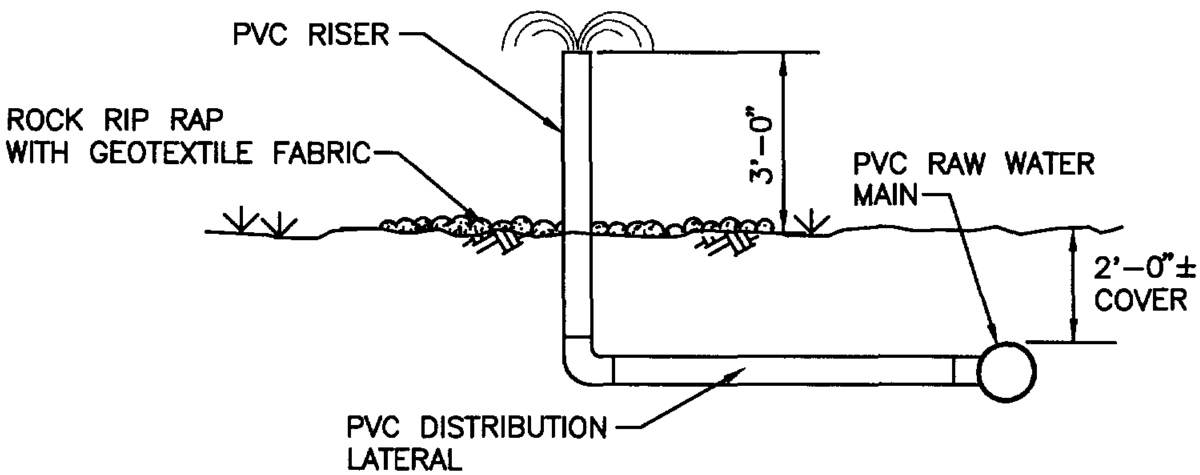
3.1.3 Proposed Rincon Bayou Discharge Area

Areas north of the river and south of Rincon Bayou were visited to determine the most desirable areas for discharge of water to Rincon Bayou. The scope of this study did not include obtaining current topography in the Rincon Bayou area. Therefore, assumptions were made based on topography shown on USGS quadrangle maps and observations during field reconnaissance visits. As previously mentioned, field surveys are currently being conducted by the Bureau and detailed topographic information should be available prior to start of final design. The evaluation of alternative discharge areas did not result in selection of one site as being clearly superior. It was concluded that a number of areas could provide similar benefits in allowing the freshwater to flow overland and disperse into Rincon Bayou. However, in order to minimize the length of the pipeline and resulting project costs, it was decided that the demonstration project pipeline should probably terminate on a tract of land in the upper portion of Rincon Bayou approximately 500 feet west of the Missouri-Pacific Railroad. Existing elevations generally range from approximately 7 feet MSL along the north side of the river bank to approximately 3.5 feet MSL in the vicinity of upper Rincon Bayou. The ground surface is uneven and vegetated, with trees along the river bank and open grassland northward to Rincon Bayou.

The primary criteria for river discharges in this area include providing a low-maintenance system that minimizes pumping costs and maximizes the spreading of water over as much area as possible. In order to accomplish this, the main discharge line will include laterals at approximately five different locations in the discharge area. Each lateral will include approximately six riser pipes which discharge three feet above existing ground. Rock rip-rap with geotextile fabric will be placed around each discharge riser to prevent erosion of the surrounding area. Final construction drawings will include approximate lengths of main and lateral pipes and approximate locations of risers. Exact routings and locations will be determined in the field to minimize disturbance of existing vegetation and natural topography. Laterals and risers will be located within an area equivalent in size to the wastewater diversion project discharge area (approximately 800 feet x 900 feet). Typical details for discharge risers are shown in Figure 3-5.

3.1.4 Costs

A cost estimate summary for this demonstration project is presented in Table 3-1. Intake structure and pump station construction and equipment installation costs were obtained from local contractors with experience in construction of similar facilities. Equipment and materials costs were estimated by performing preliminary quantity takeoffs and obtaining budget estimates from equipment suppliers and manufacturers. Similarly, local underground utility contractors and pipe suppliers were consulted in order to estimate costs for the pipeline, Hondo Creek crossing, and discharge area. Since pre-design estimates were obtained, a 15 percent estimating contingency was added to the construction costs. In order to obtain total project costs, basic engineering services were based on the percentage of construction cost obtained from standard engineering fee curves. Special services,



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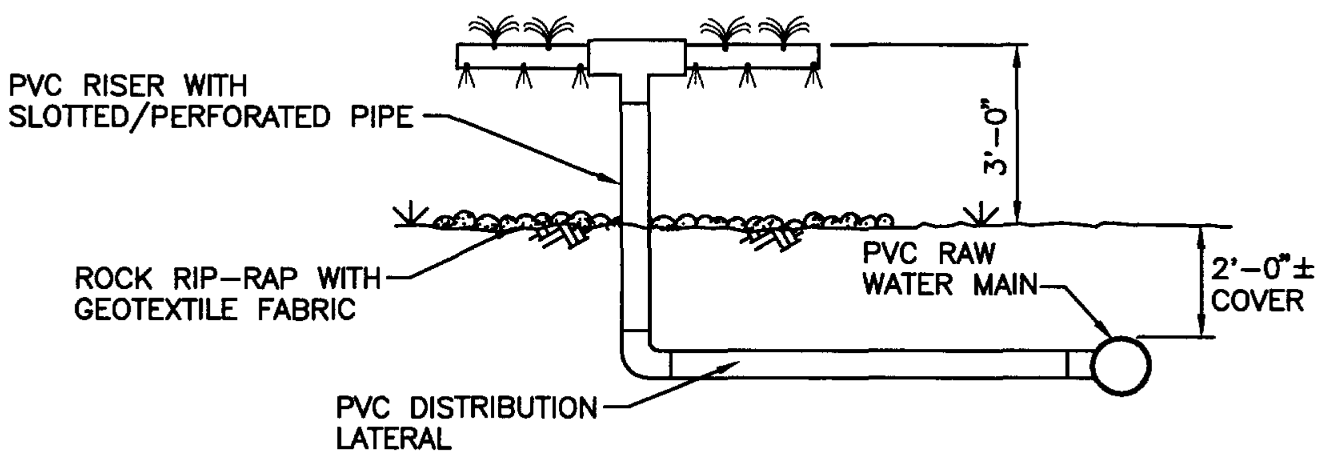

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CORPUS CHRISTI, TEXAS

NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY PHASE 2

NUECES RIVER DIVERSION–CALALLEN DAM
DEMONSTRATION PROJECT

RINCON BAYOU DISCHARGE AREA DETAILS
FIGURE 3 – 5

Scale: NTS	Drawn by: T.J.–B.A.T.	Job No.: 3488	Drawing No. 3488–C04	Rev. No. 0
Date: MAR. 1993	Checked by: GAB	Sheet 1 of 1		

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Intake Structure/Suction Header	LS	1	$35,000.00	$ 35,000
2.	Pump Station	LS	1	55,000.00	$ 55,000
3.	12" Pipeline	LF	9,000	18.00	$162,000
4.	Hondo Creek Crossing	LS	1	10,000.00	$ 10,000
5.	Discharge Area	LS	1	5,000.00	$ 5,000
	Sub-total				$267,000
	Contingency (15 percent)				$ 40,000
	TOTAL ESTIMATED CONSTRUCTION COST				$307,000
	ENGINEERING				
	Basic Services (Approx. 9.5 percent)				$ 29,000
	Special Services (includes geotechnical, permitting, surveying and project start-up)				$ 35,000
	TOTAL ESTIMATED ENGINEERING SERVICES				$ 64,000
	TOTAL PROJECT CAPITAL COSTS				**$371,000**
	AMORTIZED COSTS (Per Year)				
	Debt Service				$ 37,100
	Operations and Maintenance				$ 3,700
	Power Costs				$ 20,000
	TOTAL YEARLY COSTS*				**$ 60,800**

Table 3-1
Cost Estimate
Nueces River Diversion Demonstration Project
Calallen Dam to Rincon Bayou

*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

including geotechnical explorations required for design, permitting, surveying services, and project start-up, were estimated based on experience with similar past projects. Actual costs may vary from those shown, as required by the permitting and easement acquisition process.

Total yearly expenditures are presented in the same format as the Phase I Study by extending total project capital costs over a 10-year period and assuming 10 percent of the annual debt service as operations and maintenance costs. Power costs were calculated by assuming a continuous 365-day per year, 24-hour per day pumping cost of $0.05 per kilowatt hour.

3.1.5 Implementation Schedule

Figure 3-6 shows a time schedule for implementation of this river water diversion demonstration project. The schedule assumes that easement and/or property acquisition will start at the beginning of final design and be completed at the end of the bidding/construction contract award process (a period of approximately 4.5 months). The permitting process will also start at the beginning of final design. The schedule allows a total of four months, including one month after completion of final design for obtaining all required permits prior to construction. Similarly, a four-month time frame is also allowed for securing project funding. Construction and start-up is estimated to encompass a six-month period. Based on these assumptions, total project duration is 11 months from start of final design to facility start-up.

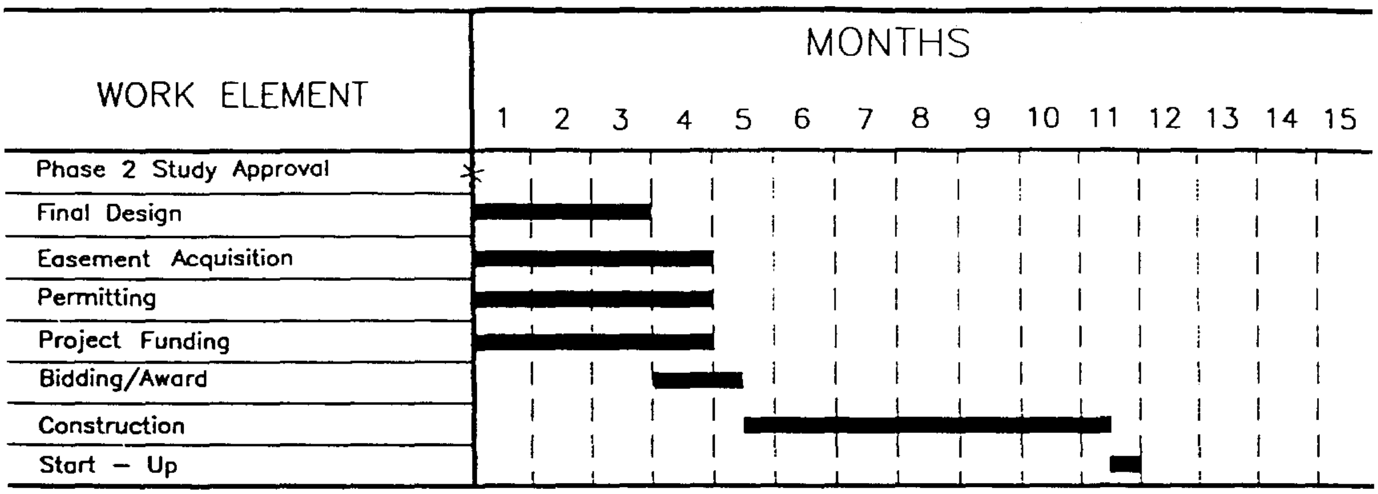
3.1.6 Institutional Arrangements

A listing of local, state and federal approvals and permits which will be required is as follows:

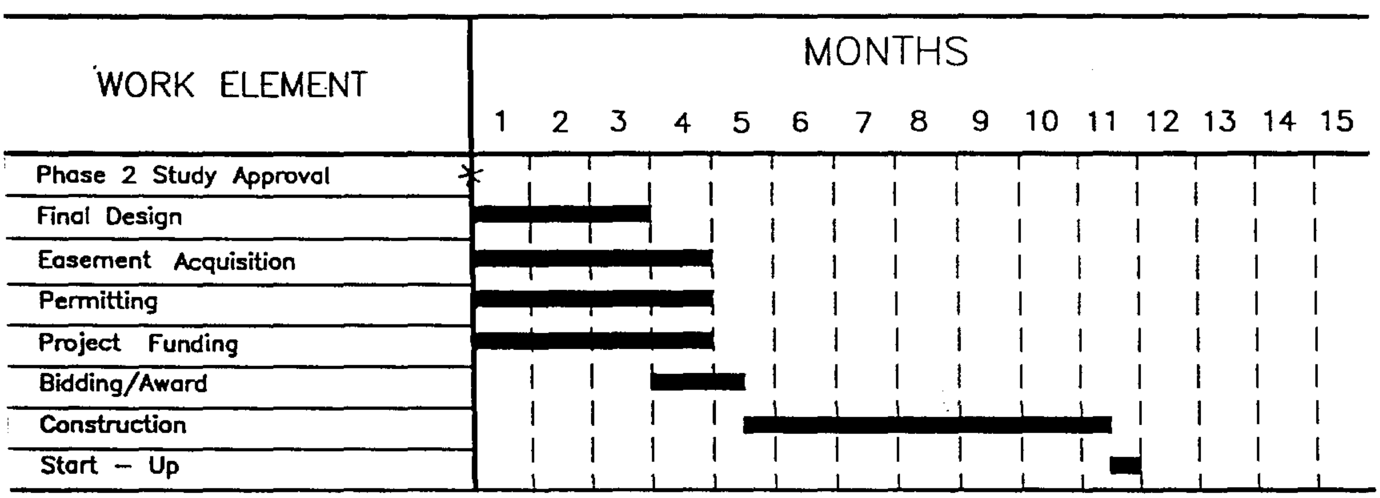
San Patricio Municipal Water District

- Approval to construct intake/pump station at W. A. Edwards Pump Station site.
- Approval to construct pipeline within existing 60-foot access/pipeline

NUECES RIVER DIVERSION



ALLISON WWTP EFFLUENT DIVERSION



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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
NUECES RIVER AND EFFLUENT DIVERSION DEMONSTRATION PROJECTS
IMPLEMENTATION SCHEDULES
FIGURE 3-6

easement.

- Approval of operations and maintenance agreement.

Texas Water Commission (TWC)

- Construction plans and specifications approval.

- Water rights approvals - Based on discussions with TWC Staff, the existing W. A. Edwards river diversion point is permitted to the City of Corpus Christi. Therefore, no additional water rights permits will be required for the river diversion project. This river diversion of 3.0 mgd will be taken into account to determine if a reduction of fresh water releases from the Choke Canyon/Lake Corpus Christi System is in order.

United States Army Corps of Engineers (COE)

- Section 404 individual permit for intake and pump station and Hondo Creek crossing.

- Section 10 individual permit for pipeline and discharge area construction in Rincon Bayou.

U.S. Coast Guard Bridge Division

- Advanced approval category for Hondo Creek crossing. Therefore, no formal permit required.

3.1.7 Constraints

This section identifies certain project constraints and recommends a plan of action for each. This identification process will be on-going throughout subsequent design and construction phases. The demonstration project constraints are generally categorized as being related to: (1) Time schedule, (2) Permitting/approvals, (3) Easement/ROW acquisition, and (4) Construction considerations. Some constraints may be related to more than one of the above considerations.

The constraint which appears to offer the highest potential for schedule delays is the process of acquiring easements and/or ROW from individual landowners. In order to prevent excessive delays, early contact with all landowners will be a high priority. It is also recommended that a meeting be held as early as possible with representatives from all appropriate entities to discuss a formalized landowners negotiation process.

Another constraint which has the potential for affecting the project's schedule is the permitting/approval process. It is recommended that submittals for the COE Section 404 and Section 10 individual permits be made as soon as possible, due to the relatively lengthy public notice process which is required.

As mentioned in Section 3.1.1 of this report, final location of the demonstration pump station at the existing W. A. Edwards Pump Station site is contingent upon formal approval from the SPMWD Board of Directors. It is recommended that a request for this approval be made as soon as possible.

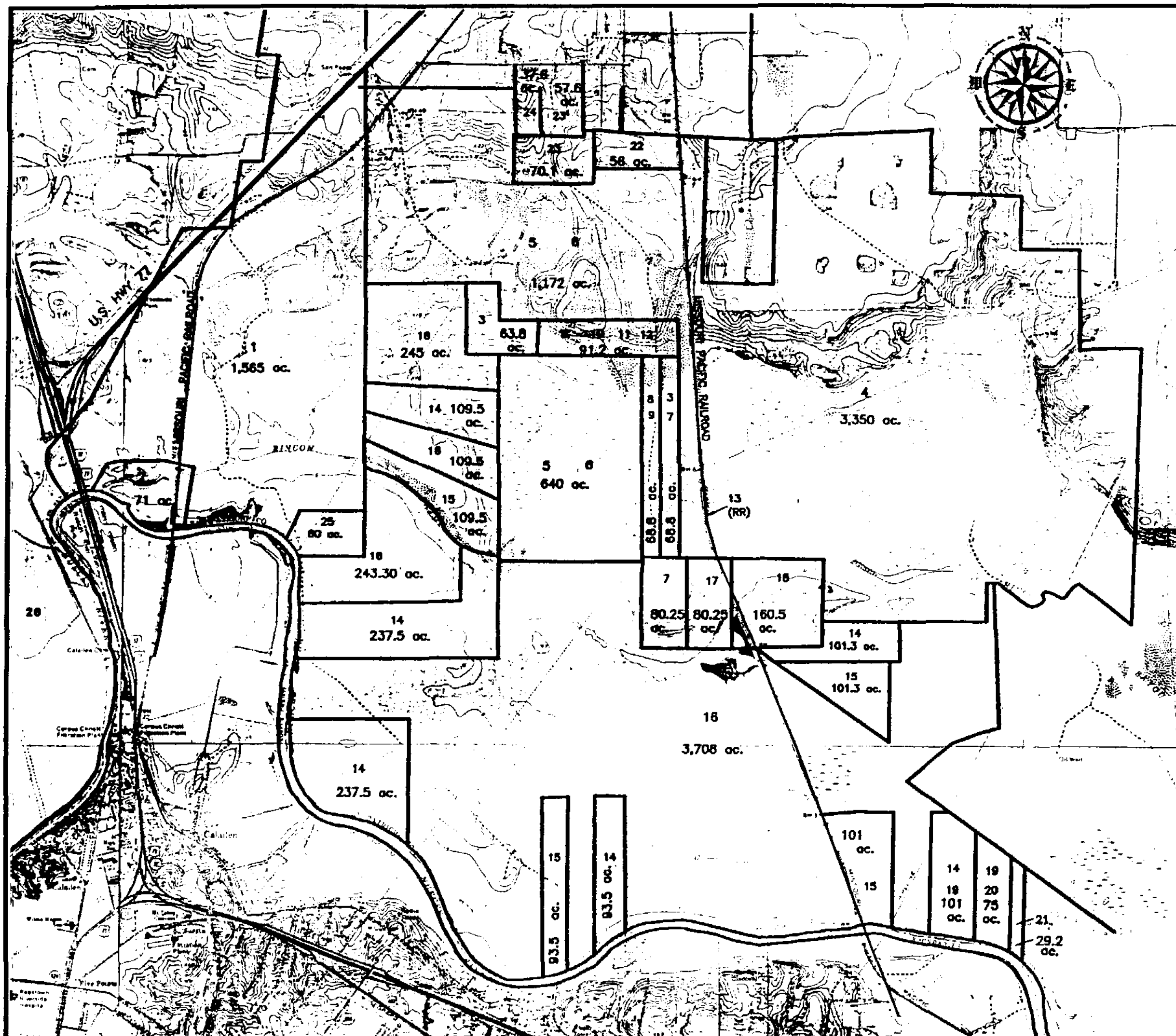
One construction-related constraint which can potentially affect the overall project schedule is the delivery of pump and motor equipment. It is recommended that the construction contract documents require the contractor to submit schedules for procuring all equipment and that a procedure be implemented to track and report the progress throughout the construction phase.

3.1.8 Sources of Funding

Potential sources of funding for the demonstration project include: (1) State funded loans, (2) Federal or state grants, and (3) Capital funds from local sponsors. Preliminary discussions regarding project funding were held with representatives from the TWC, Texas Water Development Board (TWDB), and State Comptrollers Office and are summarized in this section.

The State Revolving Fund (SRF) is a low interest loan program administered by the TWDB. Any political subdivision with the authority to own and operate a sewage system is eligible to receive assistance from the SRF. Loans can be used for the planning, design, and construction of sewage treatment facilities, wastewater recycling and re-use facilities, collection systems, stormwater pollution control projects, and non-point source pollution control projects. The application process has been streamlined since previous federal construction grant requirements are no longer applicable. A letter request to the TWDB Development Fund Manager should be made as soon as possible in order to determine eligibility of the river diversion project. Based on discussions with TWDB staff, such a determination will require a consensus of opinion among the legal, engineering, and fiscal departments, as well as the Board itself. In addition, an inquiry should be made regarding the Water Supply Account Fund, which is normally used to fund hardship cases, but is another source of state funds for similar projects.

A potential source of federal grant funds is currently under consideration by the new administration. Based on available information, a grant program may be administered by the United States Environmental Protection Agency (USEPA) under the Federal Clean Water Act, Section 319, which would involve the issuance of 100 percent federally funded grants for projects which: (1) provide environmental benefit, (2) create new jobs, and (3) can be implemented within a relatively short period of time. It is anticipated that as



PROPERTY OWNER

1. McGregor Estate Heirs
2. Thomas E. Finch, Heirs
3. J. C. Dougherty
4. Griffith and Associates, Inc.
5. Mrs. George Sorenson
6. Roy F. Morris
7. James R. Dougherty Properties
8. Frank L. Boggus et al
9. Carrie B. Fuqua
10. Theda Welch
11. Roy F. Morris and B. La Rue
12. George Sorenson
13. Missouri Pacific Tax Department
14. Casbeel Snell Jr. et al
15. Margaret Snell et al
16. O. S. Wyatt Jr.
17. Elida L. Pena
18. Ethel T. Drought Est.
19. U. S. Army Corps. of Engineers
20. Nina Wells
21. Josephine Lacina Fisher
22. City of Odem
23. W. R. Knight
24. Royce C. Reed
25. Lowell Michael Archer
26. Welder Ranch

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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

NUECES BAY ESTUARY

PROPERTY OWNERSHIP MAP
FIGURE 3 - 7

Scale: 1"=3000'	Drawn by: T.L.	Job No.: 3488	Drawing No.	Rev. No. 0
Date: 3-1993	Checked by: G.A.B.	Sheet __ of __		

located within the Finch tract. In addition, blanket access agreements will be required across the McGregor and Finch tracts to obtain access to the pipeline and discharge areas for maintenance and monitoring purposes.

The minimum recommended width of permanent easement for a single pipeline is 15 feet. An additional 20-foot temporary construction easement or agreement will also be required for this project. Parallel pipelines will require a minimum of 20 feet, with temporary construction easements similar to single pipeline installations. Size of discharge area easement is estimated to be approximately 800 feet x 900 feet. Easements required and approximate sizes are tabulated below.

Easement Purpose	Approximate Dimensions (feet x feet)	Easement Areas (acres)	Owner of Parent Tract	Total Area of Parent Tract (acres)
Pipeline west of IH-37 ROW	900 x 20	0.4	McGregor Estate	1565
Pipeline east of IH-37 ROW	700 x 20	0.3	McGregor Estate	1565
Pipeline	800 x 20	0.4	Thomas E. Finch	71
Discharge Area	800 x 900	16.5	Thomas E. Finch	71
Access	Blanket Agreement	N/A	McGregor Estate	1565
Access	Blanket Agreement	N/A	Thomas E. Finch	71

3.2 Wastewater Effluent Diversion from Allison Wastewater Treatment Plant (WWTP)

The Phase 1 Study recommended implementation of a wastewater effluent diversion demonstration project at the City of Corpus Christi's Allison WWTP. The Allison Plant was selected for the demonstration project because of its proximity to the Nueces Delta and the availability of land for new facilities at its site. The objectives of this section of the Phase II Study are to:

1. Prepare preliminary sizing and layouts of facilities required for the demonstration project;
2. Prepare detailed cost estimates of facilities;
3. Develop a schedule of implementation;
4. Determine the required permitting and approval process;
5. Identify project constraints; and
6. Identify sources of funding.

Currently, effluent from the existing Allison WWTP chlorine contact chamber flows by gravity through a 36-inch ductile iron pipe to a junction box near the northeast corner of the sludge drying beds, then through approximately 300 feet of twin 24-inch pipes to an outfall at Nueces River segment No. 2101 of the Nueces River Tidal Segment. The proposed demonstration project for diversion of the effluent is shown in various levels of detail in Figures 3-8, 3-9, and 3-10 and includes the following:

1. Construction of new junction box between the chlorine contact chamber and existing junction box;
2. Extension of a new 36" gravity line westward along the north side of the chlorine contact chamber to an effluent pump station;
3. Construction of the effluent pump station, consisting of vertical turbine pumps;
4. Construction of approximately 7,800 feet of effluent pipeline northward under the Nueces River, then westward to the discharge area; and
5. Construction of discharge area in a relatively barren salt flat in the southwestern portion of South Lake.


PROPOSED EFFLUENT PUMP STATION
ALLISON WWTP
SOUTH LAKE
PROPOSED 18" EFFLUENT PIPELINE
NUECES RIVER
PROPOSED DISCHARGE AREA
BASE MAP FROM U.S. BUREAU OF RECLAMATION INFRA-RED PHOTOGRAPH. PHOTOGRAPHED 9-4-92
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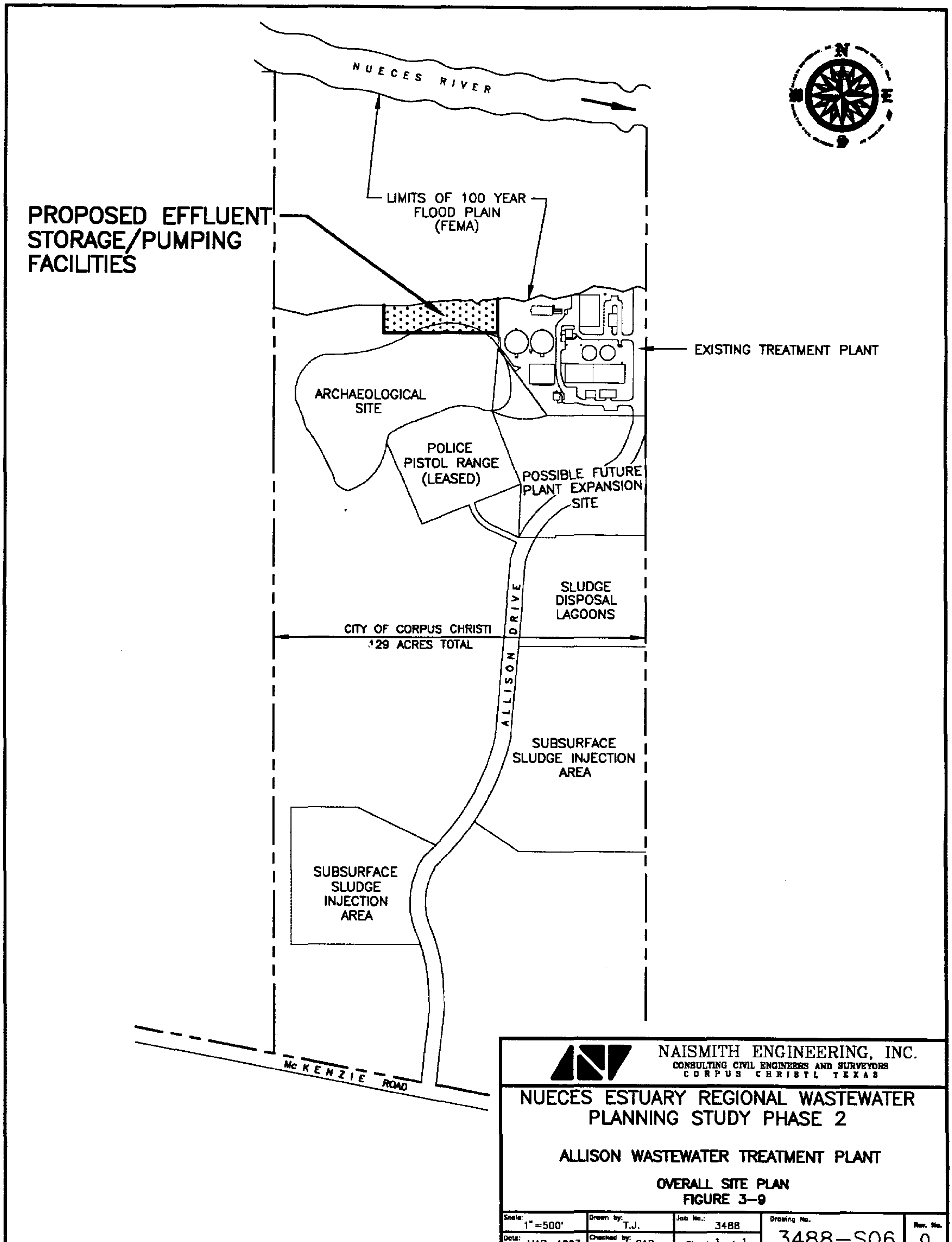
CORPUS CHRISTI TEXAS
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
ALLISON WWTP EFFLUENT DIVERSION DEMONSTRATION PROJECT
OVERALL LOCATION MAP
FIGURE 3 – 8
Scale: 1"=1000'
Drawn by: B.A.T.
Job No.: 3488
Drawing No.
Rev. No. 0
Date: 3-1993
Checked by: G.A.B.
Sheet ___ of ___


NUECES RIVER
LIMITS OF 100 YEAR FLOOD PLAIN (FEMA)
PROPOSED EFFLUENT STORAGE/PUMPING FACILITIES
EXISTING TREATMENT PLANT
ARCHAEOLOGICAL SITE
POLICE PISTOL RANGE (LEASED)
POSSIBLE FUTURE PLANT EXPANSION SITE
SLUDGE DISPOSAL LAGOONS
CITY OF CORPUS CHRISTI
129 ACRES TOTAL
ALLISON DRIVE
SUBSURFACE SLUDGE INJECTION AREA
SUBSURFACE SLUDGE INJECTION AREA
McKENZIE ROAD
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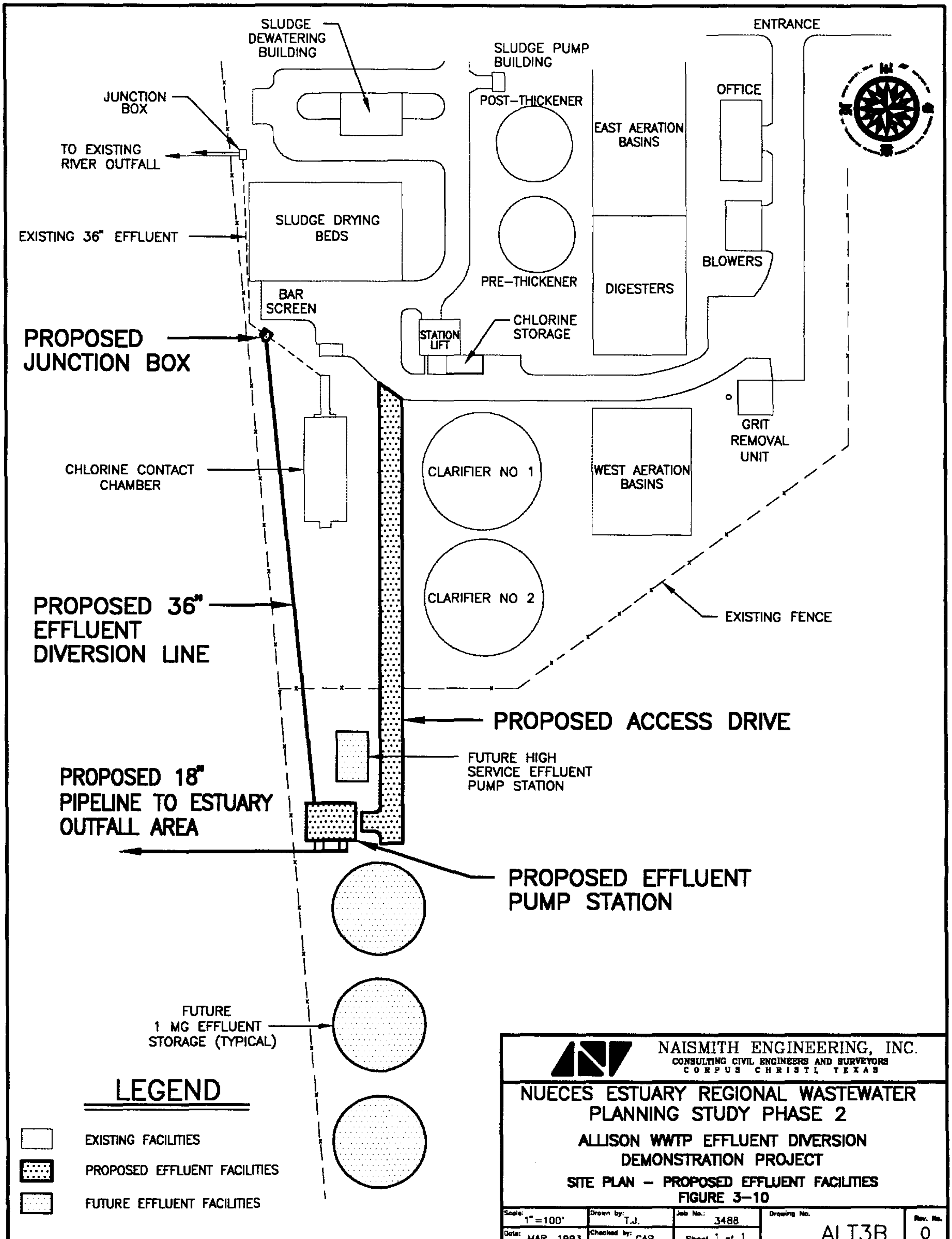
CORPUS CHRISTI, TEXAS
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
ALLISON WASTEWATER TREATMENT PLANT
OVERALL SITE PLAN
FIGURE 3-9
Scale: 1"=500'
Drawn by: T.J.
Job No.: 3488
Drawing No. 3488-S06
Rev. No. 0
Date: MAR. 1993
Checked by: GAB
Sheet 1 of 1


SLUDGE DEWATERING BUILDING
ENTRANCE
SLUDGE PUMP BUILDING
JUNCTION BOX
POST-THICKENER
OFFICE
EAST AERATION BASINS
TO EXISTING RIVER OUTFALL
SLUDGE DRYING BEDS
EXISTING 36" EFFLUENT
BLOWERS
PRE-THICKENER
DIGESTERS
BAR SCREEN
CHLORINE STORAGE
STATION LIFT
PROPOSED JUNCTION BOX
GRIT REMOVAL UNIT
CHLORINE CONTACT CHAMBER
CLARIFIER NO 1
WEST AERATION BASINS
CLARIFIER NO 2
EXISTING FENCE
PROPOSED 36" EFFLUENT DIVERSION LINE
PROPOSED ACCESS DRIVE
FUTURE HIGH SERVICE EFFLUENT PUMP STATION
PROPOSED 18" PIPELINE TO ESTUARY OUTFALL AREA
PROPOSED EFFLUENT PUMP STATION
FUTURE 1 MG EFFLUENT STORAGE (TYPICAL)
LEGEND
EXISTING FACILITIES
PROPOSED EFFLUENT FACILITIES
FUTURE EFFLUENT FACILITIES
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ALLISON WWTP EFFLUENT DIVERSION DEMONSTRATION PROJECT
SITE PLAN – PROPOSED EFFLUENT FACILITIES
FIGURE 3–10
Scale: 1"=100'
Drawn by: T.J.
Job No.: 3488
Drawing No. ALT3B
Rev. No. 0
Date: MAR. 1993
Checked by: GAB
Sheet 1 of 1

3.2.1 Proposed Effluent Facilities at the Allison WWTP Site

Figure 3-9 shows an overall site plan for the Allison WWTP site. Total area of the site is approximately 129 acres. The northern 26 acres is within the Nueces River flood plain and varies in elevation from approximately +2 feet MSL to approximately +10 feet MSL. Existing treatment facilities are located on approximately seven acres at the northeast corner of the upland area at the site, immediately south of the river flood plain.

Portions of the remaining upland area are used for sludge plowing or are leased to various organizations for recreational purposes. A bluff area located immediately west of the existing treatment facility has previously been designated as an archaeological site and limits the location of proposed facilities in this area.

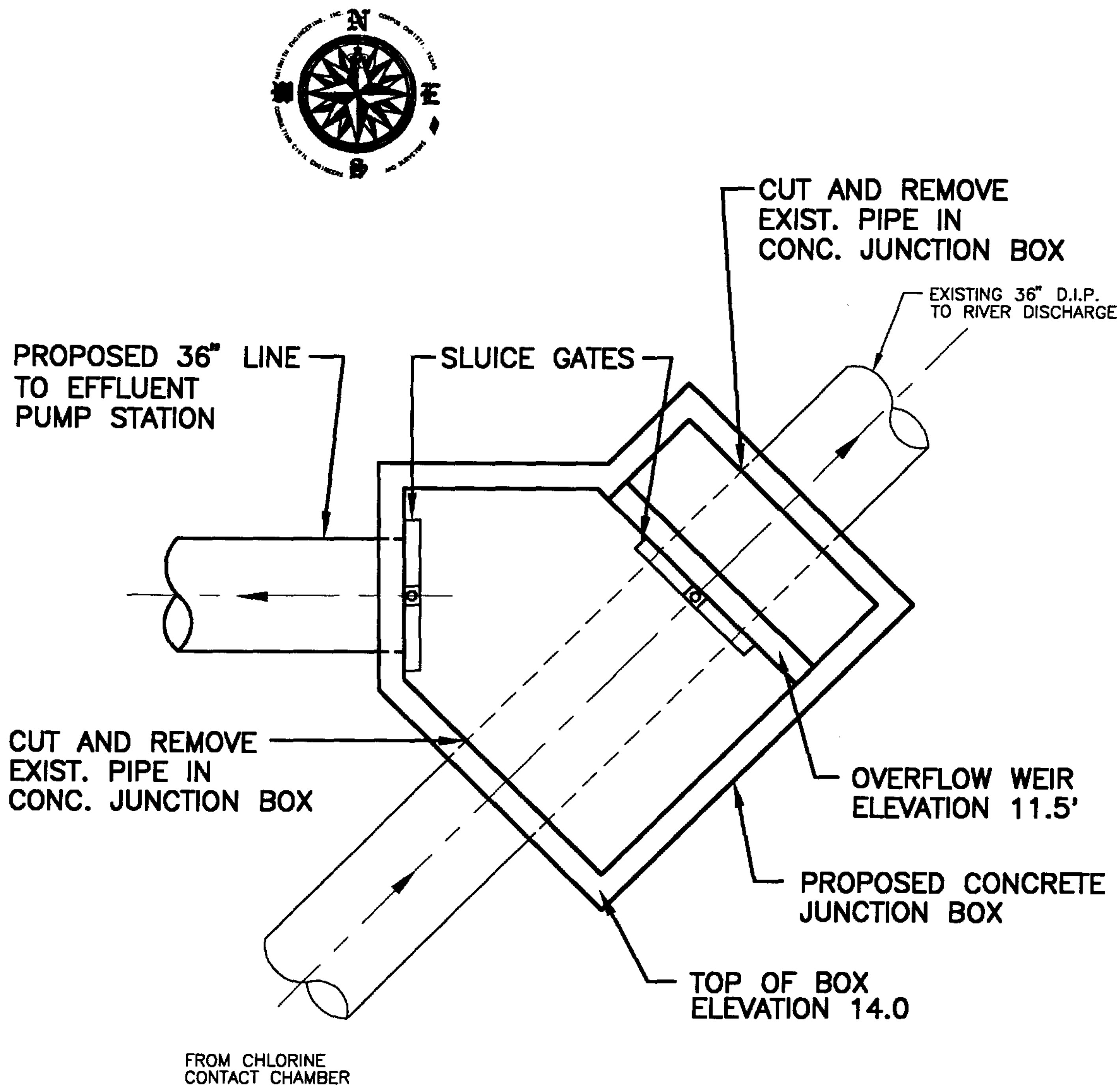
During an EPA-funded expansion of the plant in the early 1980's, the archaeological area was investigated by test excavations and was preliminarily determined to be eligible for inclusion in the National Register of Historic Places. Based on available information, it appears that the proposed location of effluent pumping and storage facilities may encroach on the archaeological site. A request for amendment to Allison's discharge permit will trigger notification to the Texas Historical Commission of the proposed construction. An investigation will then be made to determine: (1) if an encroachment into the archaeological site will occur, (2) if facilities must be relocated, or (3) if mitigation procedures may allow construction of facilities even if an encroachment occurs. This determination may have a major impact on the project schedule and is further discussed in the institutional arrangements section of this report. For purposes of this section, it is assumed that permits may be obtained for locations of effluent pumping and storage facilities as shown in Figure 3-10.

Based on discussions with City Wastewater staff and field visits to the site, it is proposed that effluent facilities be located west of the chlorine contact chamber just upland from the river flood plain. At this time, no formal master planning has been completed by the City for future improvements or expansions to the existing treatment plant. However, site limitations have been discussed with City staff and certain conclusions regarding locations of facilities were reached. Due to limitations of the site immediately east, north, and west of the existing facilities, it is anticipated that future expansion of the plant may occur within the area immediately south of the existing plant or within other southern areas of the overall 129-acre site. One possible scenario would include a common headworks near the southwest corner of the existing plant that would split flow into the existing plant and a new parallel plant. Effluent from both plants could still be discharged directly to the river through gravity outfalls but would be diverted to common effluent storage and pumping facilities during normal operations. City staff have indicated the need to locate proposed effluent facilities as far west as possible, in order to reserve space west of the existing chlorine contact chamber for future plant improvements, if required. The existing overhead main power line may require relocation to accommodate these facilities.

The preliminary layout of proposed and future effluent pumping and storage facilities, shown in Figure 3-10, is based on discussions with City Wastewater staff, reconnaissance visits to the site, and record drawings obtained from City files. The scope of this phase of the study did not include field surveys to obtain current topographic information. Therefore, the layout shown is preliminary and final design will include detailed surveys to verify actual conditions.

Figure 3-11 shows the layout of the proposed junction box, which will include sluice gates to allow diversion of effluent or discharge to the existing outfall when necessary. The 36-inch effluent line from the junction box will be located as close to the existing fence as possible in order to maintain open space west of the chlorine contact chamber for future plant improvements. A future junction manhole may be constructed upstream from the pump station to allow connection of a separate effluent line from the possible future parallel facility located south of the existing plant.

The range of pumping conditions which must be met was determined by review of recent plant flow records for January and February, 1993. A typical 24-hour cycle of flow is shown in Figure 3-12. Based on these records, current average daily flow (ADF) is approximately 2.8 mgd, with a low flow of approximately 1.1 mgd occurring in the early morning hours between 4 a.m. - 7 a.m. and a peak flow of approximately 4.1 mgd occurring in the early afternoon hours between 12 noon and 3 p.m. A smaller peak of approximately 3.6 mgd occurs during the evening hours between 9 p.m. and 10 p.m. Due to the wide range of flows which must be met and the fact that the friction head component of TDH varies substantially because of the length of the pipeline, it will be necessary to select a combination of different sized pumps, or utilize multi-speed or variable speed pumps. Figure 3-13 shows system head and pump curves for an 18-inch pipeline and two-speed pump system. Pump curves shown are for the same size pump being operated at 1170 RPM and 1770 RPM. This system will allow a range of flows to be met by two pumping units as follows:



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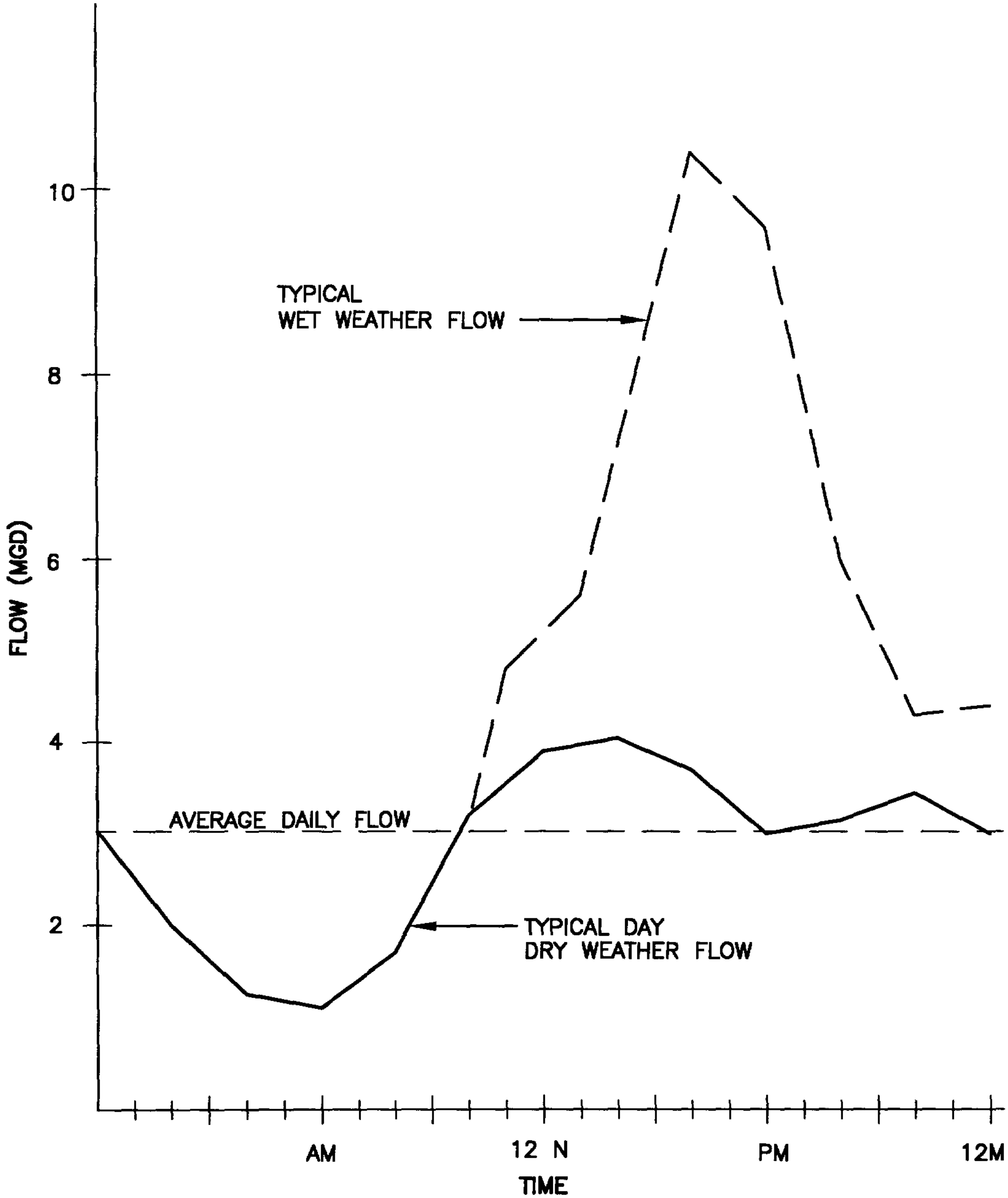
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

ALLISON WWTP EFFLUENT DIVERSION DEMONSTRATION PROJECT

JUNCTION BOX DETAIL

FIGURE 3-11

Scale: 1/4" = 1'-0"	Drawn by: T.J.-B.A.T.	Job No.: 3488	Drawing No.	Rev. No.
Date: DEC. 1992	Checked by: GAB	Sheet 1 of 1	3488-S20	0



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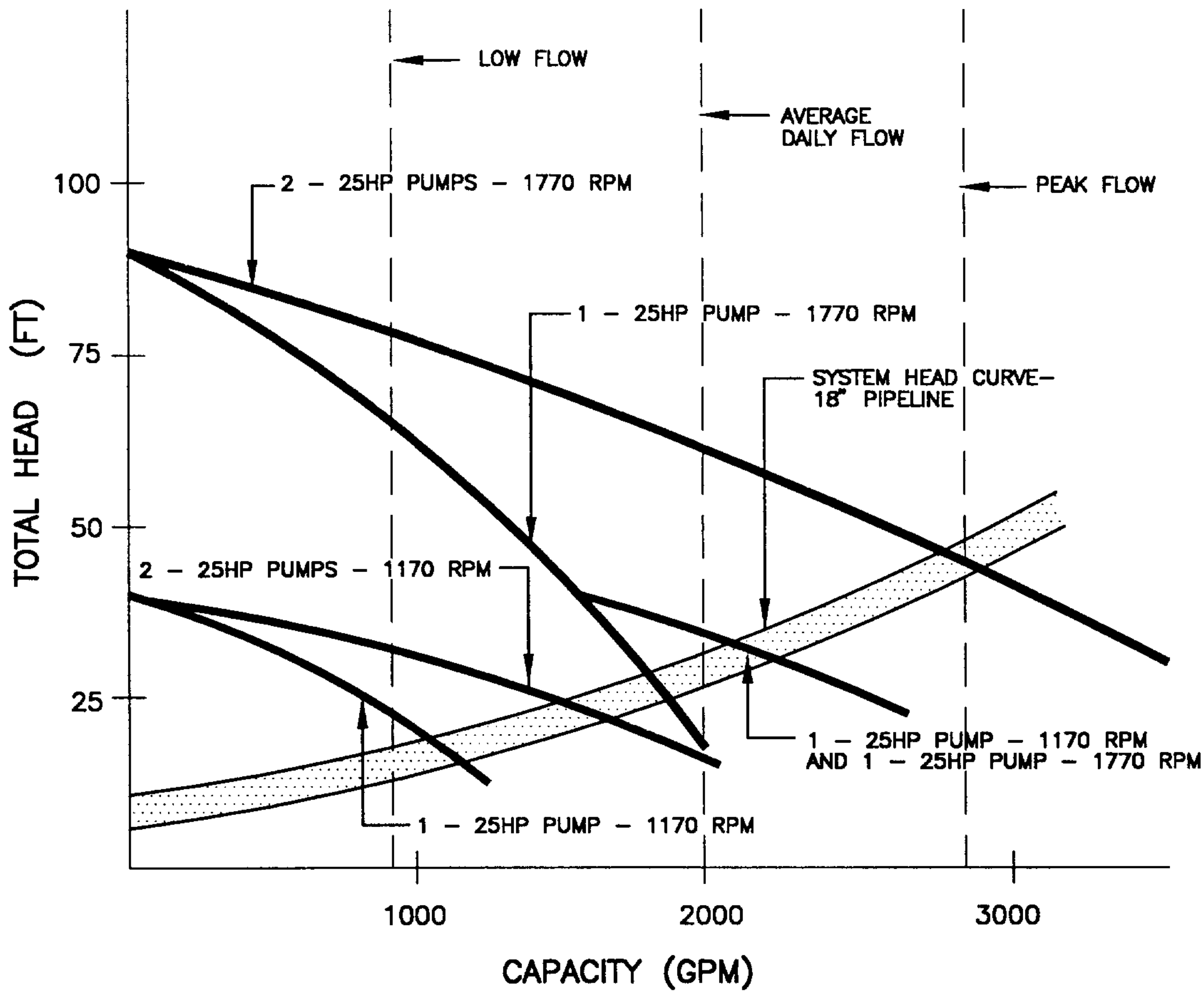
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
ALLISON WASTEWATER TREATMENT PLANT
TYPICAL WASTEWATER FLOW
FIGURE 3-12



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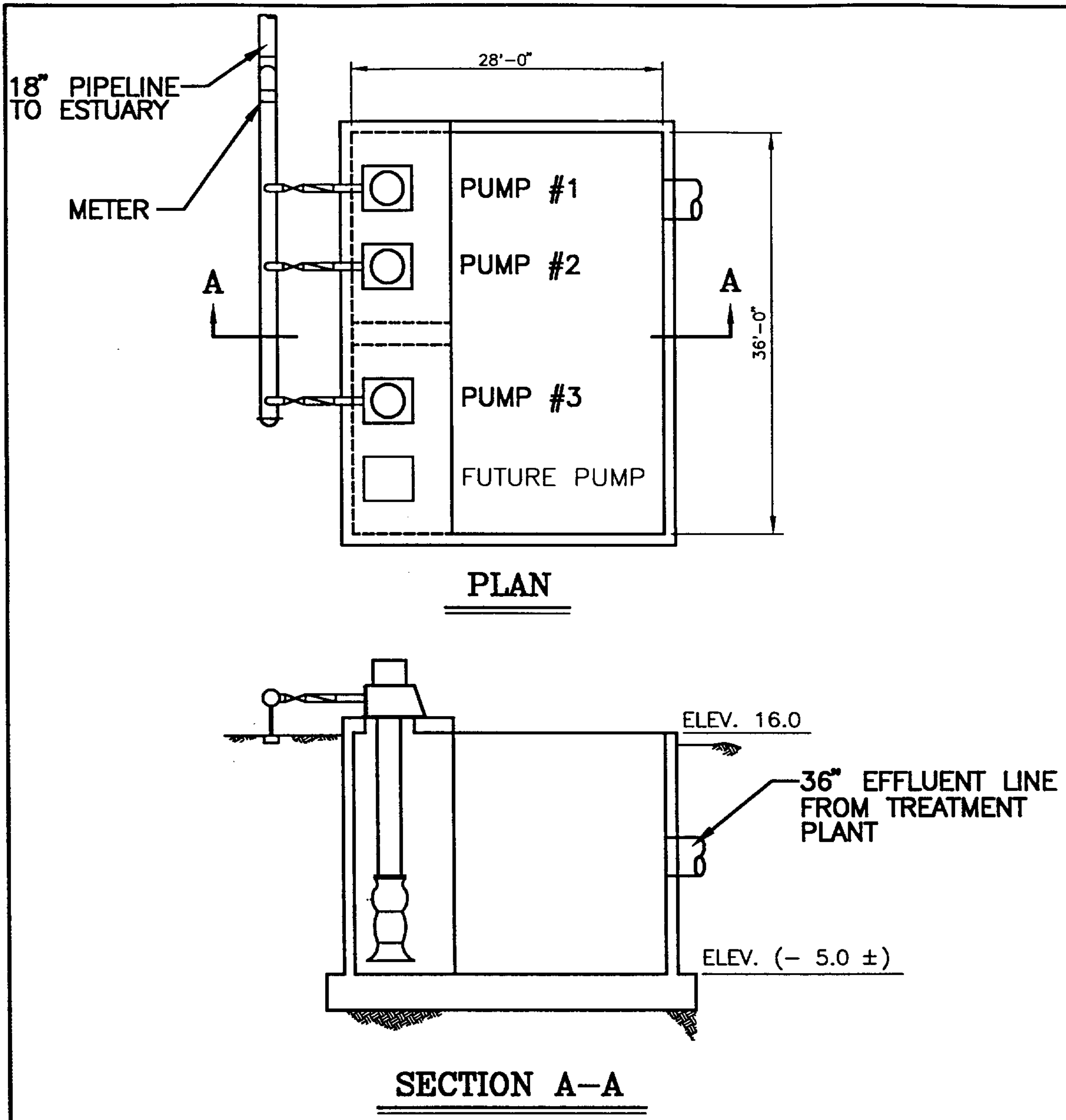
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
ALLISON WWTP EFFLUENT DIVERSION DEMONSTRATION PROJECT
SYSTEM HEAD AND PUMP CURVES
FIGURE 3-13

Flow Condition	Pump Combination
Low flow period	1 pump - 1170 RPM
ADF	2 pumps - 1170 RPM in parallel or 1 pump - 1770 RPM
Small peak period	2 pumps - 1170 RPM and 1770 RPM in parallel
Maximum peak period	2 pumps - 1770 RPM in parallel

A third pumping unit will be provided as standby, so that peak flow can be met with one pump out of service. Preliminary plan and section views of the proposed pump station are shown in Figure 3-14. Additional space is incorporated into the layout to allow for future expansion, if required. This pump selection concept was used for the purpose of preparing preliminary layouts and cost estimates. Final design will include a detailed evaluation of the advantages of systems utilizing constant speed, two-speed, or variable speed pumps.

Different types of pumps, including vertical turbine, wet well-dry well, and submersible pumps were evaluated to determine the most economical pump station layout and most efficient pumping system. A vertical turbine layout was selected because of the relatively lower construction cost involved with a single wet well layout and the higher pump efficiencies in comparison to submersible pumps. Flow to the estuary will be measured by metering pump station discharge with doppler or magnetic type meters. Total plant flow will continue to be measured at the chlorine contact chamber. The difference between the total plant flow and the pump station discharge will determine the amount discharged



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NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY PHASE 2

ALLISON WWTP EFFLUENT DIVERSION
DEMONSTRATION PROJECT

PUMP STATION PLAN AND SECTION
FIGURE 3-14

Scale: N.T.S.	Drawn by: T.J.-B.A.T.	Job No.: 3488	Drawing No. 3488-S29	Rev. No. 0
Date: MAR. 1993	Checked by: GAB	Sheet 1 of 1		

directly to the river.

As previously mentioned, the station must pump a wide range of flows. In order to minimize depth of the wet well within the constraints of pump submergence and the maximum desired water elevation, the wet well is of a relatively large size, with plan dimensions of approximately 28 feet x 36 feet. The review of recent flow records also showed that peak wet weather flows often exceed 10 mgd. Although the large wet well volume could accommodate these flows, sizes of pumps and discharge pipeline would need to be increased substantially. It was not considered economically feasible to size the demonstration project pumps and pipeline for these hydraulic overload conditions. Therefore, provision will be made to allow these wet weather peak flows to surcharge the 36-inch gravity influent line to an overflow weir inside the new junction box. Peak wet weather flows in excess of the effluent pump station capacity will be allowed to overflow directly into the existing river outfall. City staff have projected a slow growth rate within the Allison service area and do not anticipate a required plant expansion within the next 10 to 15 years, unless redirection of the City's internal collection and treatment system occurs. However, the pump station will be designed to allow proposed pumps to be replaced by larger units, as required by future expansion.

Three one-million gallon ground storage tanks are also shown in Figure 3-10 for illustration purposes and future planning. The storage facilities will allow effluent from Allison WWTP and other municipal or industrial wastewater plants to be stored at and pumped from the Allison site to the Nueces Delta. The storage tanks will be located west of the effluent pump station and may be either pre-stressed concrete or welded steel tanks.

Along with construction of the storage tanks, the effluent pump station will be converted into a low-lift station to transfer effluent from the Allison WWTP to the tanks. A high-service pump station will then pump from the storage tanks to the South Lake discharge area or other future designated locations within the Nueces Estuary. Exact piping layout in the tank farm area will depend upon future decisions concerning mixing or segregation of municipal and industrial effluents.

Access to the effluent pumping and storage facilities will be provided by an extension of the plant service drive near the existing lift station westward between the chlorine contact chamber and clarifiers. The demonstration project service drive will be constructed of stabilized limestone or crushed shell, which will be paved with concrete for the permanent installation to match the plant's existing drives.

Electrical service to effluent facilities may be provided from the existing treatment plant power supply line by means of a separate meter or by setting a sub-meter on the existing service.

3.2.2 Proposed Effluent Pipeline to South Lake

Effluent pipeline size for the demonstration project was determined by comparing the initial capital cost and pumping costs over a five-year period for 12-inch and 18-inch sizes. Due to the length of pipeline, the lower pumping costs associated with the 18-inch pipe offset the initial higher capital cost. Therefore, 18-inch pipe is recommended for the initial installation. Due to the low pressure of the system, SDR 41 (100 psi) PVC pipe is recommended as the most cost-effective pipe material. The pipeline alignment will extend north from the pump station to a crossing of the Nueces River, then west along the alignment of an existing caliche road and pipeline to the South Lake discharge area.

Alternatives for the river crossing construction were evaluated, including conventional wet installation methods and boring by directional drilling. It is estimated that conventional wet installation is approximately 10 to 15 percent less expensive than directional drilling. However, conventional construction methods are more susceptible to delays caused by weather factors and result in more environmental disruption and permitting requirements. Directional drilling methods are allowed by the COE's General Permit requirements, which do not require public notice, as does an Individual Permit required by conventional wet construction techniques. Therefore, it is recommended that the crossing be made by directional drilling.

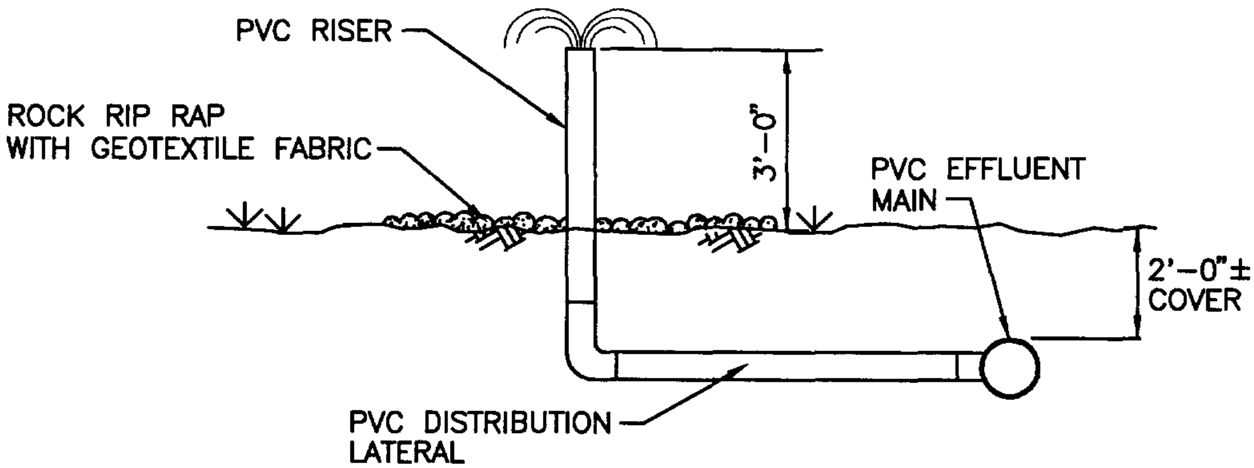
3.2.3 Proposed South Lake Discharge Area

In order to evaluate alternative demonstration project discharge areas, numerous field reconnaissance visits were made to the estuary area between South Lake and Rincon Bayou. Alternative areas were evaluated based on ease of access, topography, vegetation, property ownership, and their relationships to natural flow patterns. A relatively barren salt flat area in the southwestern portion of South Lake, approximately 7,000 feet west to northwest of the Allison WWTP, was selected as the site which would produce maximum benefits. The flat topography and non-vegetated area will allow minimum disturbance of the environment during construction of discharge structures and provide an ideal location for monitoring the impact of wastewater return flows to the area. An existing caliche road will provide relatively easy access to the site. In addition, discharges will flow freely northeast toward South Lake and other portions of the estuary. The discharge area will consist of approximately 15 acres, with discharge facilities arranged in a semi-circular configuration as shown in Figure 3-15. Typical details and cross sections are shown in Figures 3-16 and 3-17.

The main objectives in the discharge of the effluent will be to provide an even distribution over the entire discharge area and allow for isolation of certain areas for experimental research (monitoring). In order to evenly distribute the effluent over as large an area as possible, an impoundment will be created in a portion of the area by constructing an approximately 18-inch high perimeter berm. Internal berms will divide the impoundment into three individual cells to allow isolation and experimentation with various flow rates, water depths, etc. Berms will be constructed from native on-site material, if possible, or imported fill material, if required, and geotextile fabrics will be used for erosion control.

Various inlet pipe configurations were evaluated in order to provide a low maintenance piping system and reduce pumping costs due to pressure requirements. In order to meet these criteria, inlets into each cell will consist of slotted or perforated pipe laterals laid on top of the ground. Crushed rock will be placed around the inlet pipes to prevent erosion and each cell's inlet will be gated to allow isolation or varying of flow. Cells will be constructed generally in a long rectangular shape, with flow entering one end and discharging through the opposite end. Experimentation with various water depths will be accomplished by constructing outlets at different elevations in the perimeter berm. Two different types of outlets, earthen overflow weirs and culvert pipes, will be constructed to


PERIMETER BERM
TYPE 3
INLET (TYP)
EFFLUENT PIPELINE
FUTURE 36" EFFLUENT PIPELINE
EXISTING CALICHE ROAD
CULVERT
NAISMITH ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI TEXAS
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
SOUTH LAKE DISCHARGE AREA
SITE PLAN
FIGURE 3 – 15
Scale: 1"=100'
Drawn by: BAT
Job No.: 3488
Drawing No.
Rev. No. 0
Date: 8-1998
Checked by: G.A.B.
Sheet __ of __



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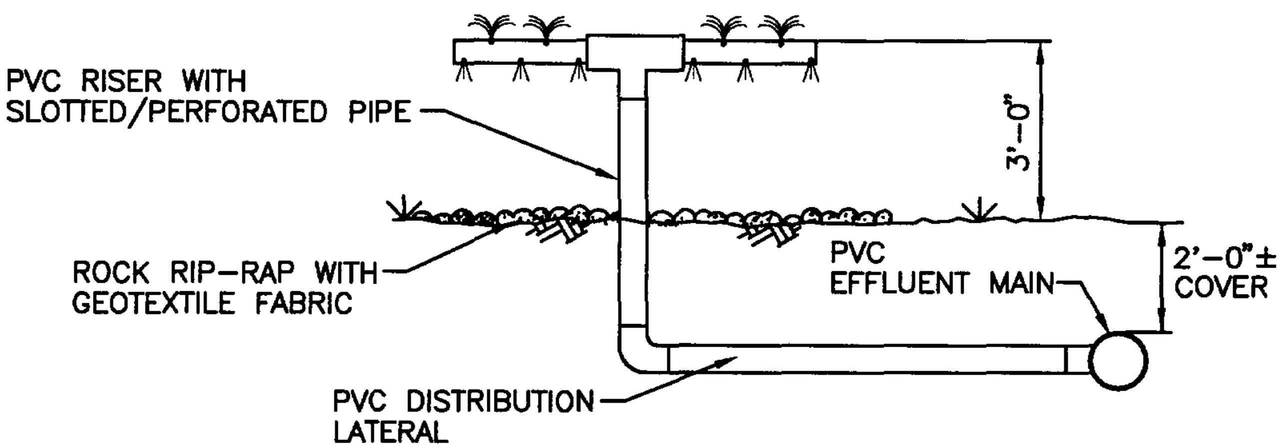
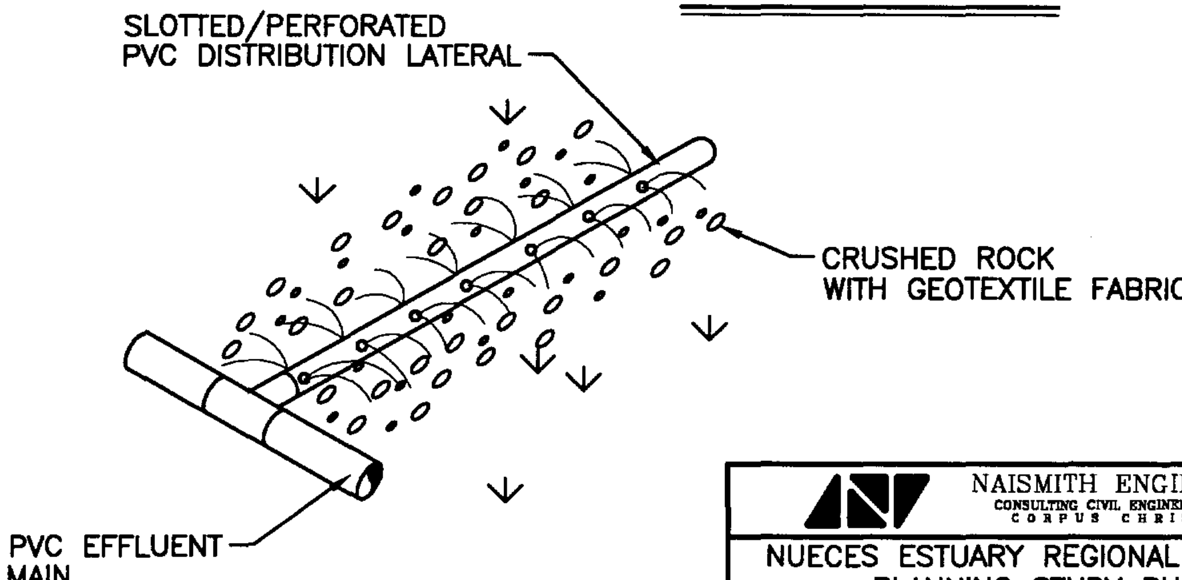


TYPE 2 INLET



TYPE 3 INLET

NAISMITH ENGINEERING, INC.
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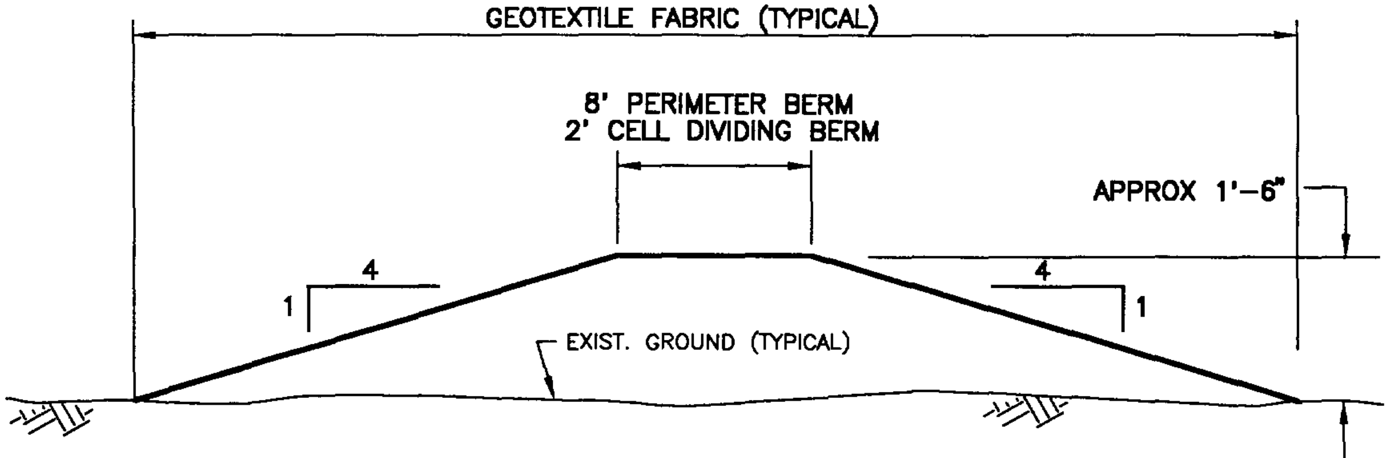
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

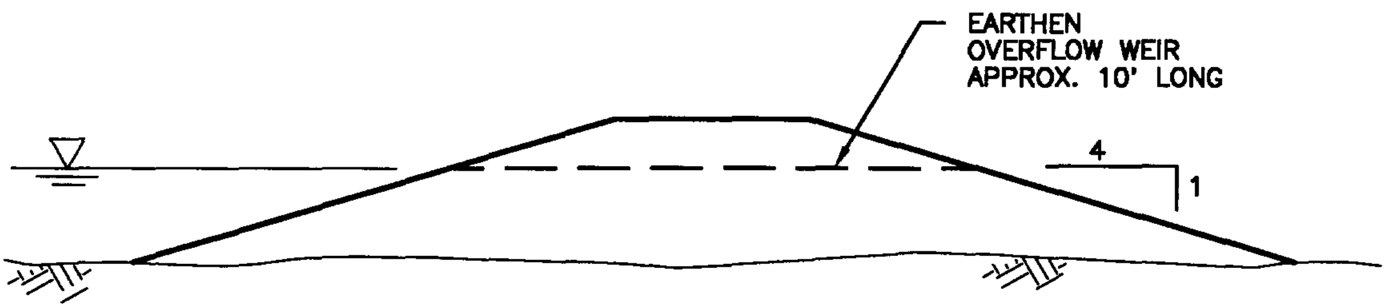
ALLISON WWTP EFFLUENT DIVERSION DEMONSTRATION PROJECT

SOUTH LAKE DISCHARGE AREA DETAILS
FIGURE 3 – 16

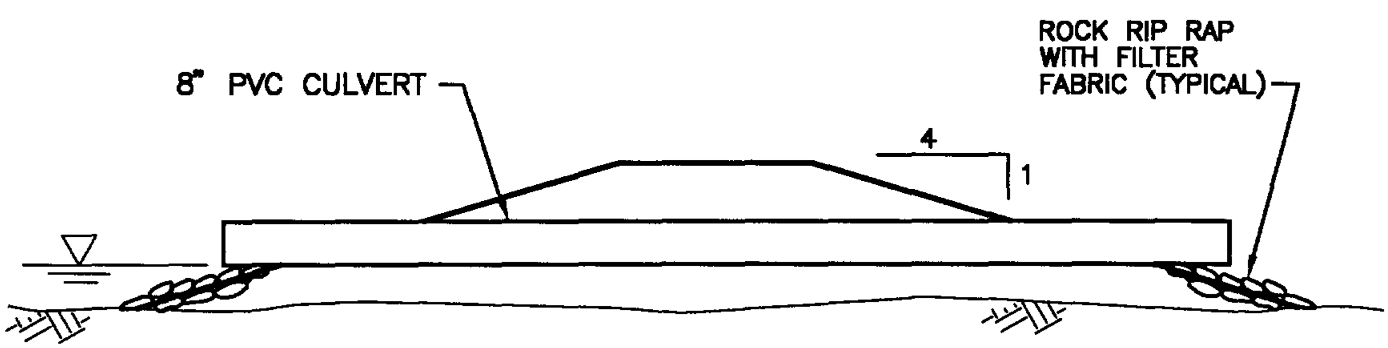
Scale: NTS	Drawn by: T.J.–B.A.T.	Job No.: 3488	Drawing No.	Rev. No.
Date: MAR. 1993	Checked by: GAB	Sheet 1 of 1	3488–C03	0



TYPICAL BERM SECTION



TYPE 1 OUTLET



TYPE 2 OUTLET

NAISMITH ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI, TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

ALLISON WWTP EFFLUENT DIVERSION DEMONSTRATION PROJECT

SOUTH LAKE DISCHARGE AREA SECTIONS
FIGURE 3 - 17

Scale: N.T.S.	Drawn by: T.J.-B.A.T.	Job No.: 3488	Drawing No. 3488-007	Rev. No. 0
Date: MAR. 1993	Checked by: GAB	Sheet 1 of 1		

determine the best method of outlet control for the future permanent installation. It is anticipated that the weirs and culverts will be set to allow water depths in individual cells to vary between six inches and 12 inches.

An additional type of inlet pipe configuration will be located in an open non-bermed area west of the bermed cells. Various types of application techniques were evaluated, including high- and low-pressure mechanical spray heads. However, maintenance and pumping cost considerations dictated that the simplest arrangement with lowest head requirements be used. The inlet system will consist of a main line with approximately eight laterals with risers three feet above the ground surface for areal distribution. This type of multiple areal application will provide a relatively even distribution of discharge which will be allowed to flow freely into the surrounding area. In order to maximize aeration that occurs in the discharge, design of the risers will incorporate features such as perforated pipe to spray water evenly in the surrounding area. This will allow some degree of "spraying," while providing a relatively maintenance-free and low-cost system. Rock rip-rap will be used to prevent erosion in the immediate area of the riser pipes.

3.2.4 Costs

A cost estimate summary for this demonstration project is presented in Table 3-2. Preliminary construction costs for facilities on the Allison WWTP site, such as the junction box and effluent pump station, were obtained from local contractors with experience in construction of similar facilities. Equipment and materials costs were estimated from budget estimates from equipment suppliers and manufacturers. Similarly, local underground utility

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Junction Box	LS	1	$ 12,000.00	$ 12,000
2.	36" Gravity Effluent Line	LF	330	48.00	$ 15,800
3.	Effluent Pump Station	LS	1	276,000.00	$276,000
4.	18" Effluent Pipeline	LF	7,000	35.00	$245,000
5.	Nueces River Crossing	LF	800	220.00	$176,000
6.	Discharge Area	LS	1	31,000.00	$ 31,000
	Sub-total				$775,800
	Contingency (15 percent)				$113,400
	TOTAL ESTIMATED CONSTRUCTION COST				$869,200
	ENGINEERING				
	Basic Services (Approx. 7.7 percent)				$ 67,000
	Special Services (includes geotechnical, permitting, surveying and project start-up)				$ 42,000
	TOTAL ESTIMATED ENGINEERING SERVICES				$109,000
	TOTAL PROJECT CAPITAL COSTS				**$978,200**
	AMORTIZED COSTS (Per Year)				
	Debt Service				$ 97,800
	Operations and Maintenance				$ 9,800
	Power Costs				$ 8,200
	TOTAL YEARLY COSTS*				**$115,800**

Table 3-2
Cost Estimate
Allison WWTP Effluent Diversion Demonstration Project

*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

contractors and pipe suppliers were consulted in order to estimate costs for pipeline, directional drilled river crossing, and discharge area. Since pre-design estimates are used, a 15 percent estimating contingency was added to construction costs. In order to obtain total project costs, basic engineering services were added along with special services, including geotechnical explorations required for design, permitting, surveying services, and project start-up costs. Actual costs may vary from those shown, as required by the permitting and easement acquisition process.

Total yearly expenditures are also presented in Table 3-2 and an annual cost of $115,800 is projected.

3.2.5 Implementation Schedule

Figure 3-6 shows a time schedule for implementation of the Allison WWTP demonstration pump station project. The schedule assumes that easement and/or property acquisition will start at the beginning of final design and be completed at the end of the bidding/construction contract award process (a period of approximately six months). The permitting process will also start at the beginning of final design. The schedule allows a total of 4.5 months, including one month after completion of final design for obtaining all required permits prior to construction. Similarly, a four-month time frame is also allowed for securing project funding. Construction and start-up is estimated to encompass a six-month period. Based on these assumptions, total project duration is 11 months, from start of final design to facility start-up.

3.2.6 Institutional Arrangements

A listing of local, state, and federal approvals and permits which will be required is as follows:

City of Corpus Christi Department of Public Utilities

- Construction plans and specifications approvals.

Texas Water Commission (TWC)

- Amendment to existing wastewater discharge permit to allow dual discharges (existing river and proposed estuary discharges). Based on preliminary discussions with TWC staff, multiple outfalls in the same general area, such as those proposed in the South Lake discharge area, will be permitted as one discharge point. A request will be made to the TWC for approval of multiple outfalls throughout the estuary area, thus allowing the flexibility to distribute effluent to areas where maximum benefit will be obtained.

  Approval of additional future discharge areas will require major permit amendments (which include the public notice process) in order to provide proper notification to all landowners who may be affected by the discharges.

- Construction plans and specifications approval.

State of Texas General Land Office

- Easement required for Nueces River crossing. The General Land Office is the state agency that regulates dredging, filling, and placement of structures on state-owned and submerged lands. An application will be submitted for a right-of-way over public lands, pursuant to Section 51.291 of the Texas Natural Resources Code. Total approval processing time is estimated to be four to six weeks.

United States Army Corps of Engineers (COE)

- Section 10 General Permit for directional drilling of Nueces River crossing (NOTE: Section 10 Individual permit required if conventional wet construction techniques are used).

- Section 404 individual permit for construction of bermed discharge area.

- Section 10 individual permit for construction of pipeline.

United States Environmental Protection Agency

- NPDES Storm Water Erosion Control Plan.

- Archaeological site determination through Texas Historical Commission as part of NPDES permit amendment

3.2.7 Constraints

This section identifies certain project constraints and recommends a plan of action for each. The identification process will be on-going throughout subsequent design and construction phases. The demonstration project constraints are generally categorized as being related to: (1) Time schedule, (2) Permitting/approvals, (3) Easement/ROW acquisition, and (4) Construction considerations. Some constraints may be related to more than one of the above considerations.

The constraints which appear to have the highest potential for schedule delays are the process of acquiring easements and/or ROW from individual landowners and discharge permit modifications. In order to prevent excessive delays, early contact with all landowners should be a high priority. It is also recommended that a meeting be held as early as possible with representatives from all appropriate entities to discuss a formalized negotiation process with the landowners.

Another constraint which has the potential for affecting the project's critical path schedule is the permitting/approval process. It is recommended that submittals for the COE Section 404 and Section 10 individual permits be made, if required, as soon as possible, due to the relatively lengthy public notice process which is required. In addition, as discussed in Section 3.2.1, the proposed location of effluent storage and pumping facilities may encroach into the archaeological site immediately west of the existing treatment plant. Due to the fact that the permitting process may require lengthy site investigations and mitigation procedures, it is recommended that discussions begin with the appropriate agencies as soon as possible. An early determination regarding the location of proposed effluent facilities is essential in order to meet the project schedule.

One construction-related constraint which can potentially affect the overall project schedule is the delivery of pump and motor equipment. It is recommended that the construction contract documents require the contractor to submit schedules for procuring all equipment and that a procedure be implemented to track and report the progress throughout the construction phase.

3.2.8 Sources of Funding

Potential sources of funding for the demonstration project include: (1) State funded loans, (2) Federal or state grants, and (3) Capital funds from local sponsors. Preliminary discussions regarding project funding were held with representatives from the TWC, Texas Water Development Board (TWDB), and State Comptrollers Office and are summarized in this section.

The State Revolving Fund (SRF) is a low interest loan program which is administered by the TWDB. Any political subdivision with the authority to own and operate a sewage system is eligible to receive assistance from the SRF. Loans can be used for the planning, design and construction of sewage treatment facilities, wastewater recycling and re-use facilities, collection systems, stormwater pollution control projects, and non-point source pollution control projects. The application process has been streamlined since previous federal construction grant requirements are no longer applicable. Preliminary discussions with TWDB staff indicate that the effluent diversion project is eligible for funding under the SRF. A letter request to the TWDB Development Fund Manager should be made as soon as possible to confirm this understanding. Based on discussions with TWDB staff, such a determination will require a consensus of opinion among the legal, engineering, and fiscal departments, as well as the Board itself.

A potential source of federal grant funds is currently under consideration by the new administration. Based on available information, a grant program may be administered by the USEPA (under the Federal Clean Water Act, Section 319), which would involve the issuance of 100 percent federally funded grants for projects which: (1) Provide environmental benefit, (2) Create new jobs, and (3) Can be implemented within a relatively short period of time. It is anticipated that as soon as guidance is obtained by the USEPA, proposals will be solicited from eligible entities. Additional inquiries should be made regarding this and other state or federal grant programs which might be available.

Finally, although potential sources of state and federal funds should be investigated, it is possible that major portions of capital funds will be required from local sponsors. Sources include the City of Corpus Christi's Capital Improvement Program, financed through revenue bonds or other means. Local sponsors should begin the process of identifying the method of local funding as soon as possible.

3.2.9 Easements and Rights-of-Way

It is assumed that the Allison WWTP effluent diversion will utilize the acquisition of surface easements or ROW for construction and long-term implementation of these projects. In this case, easements or ROW will be required from the State of Texas for the Nueces River crossing and from three different tracts of land north of the river for the effluent pipeline and discharge area. In addition, a blanket access agreement will be required to cross several tracts in order to obtain access to the discharge area and pipeline routing from public right-of-way. The minimum recommended width of permanent easement for a single pipeline is 15 feet. An additional 20 feet of temporary construction easement or temporary construction agreement should also be obtained. In addition, temporary easements or working area agreements in excess of 20 feet will be required for setup of directional drilling equipment on the north side of the Nueces River. Parallel pipelines will require a minimum easement width of 20 feet, with temporary construction easements similar to single pipeline installations. Size of the discharge area easement is estimated to be approximately 800 feet x 900 feet. Based on property ownership information shown on Figure 3-7, easements required and approximate sizes are tabulated as follows:

Easement Purpose	Approximate Dimensions (feet x feet)	Easement Area (acres)	Owner of Parent Tract	Total Area of Parent Tract (acres)
Nueces River Crossing	250 x 20	0.1	State of Texas	N/A
Effluent Pipeline	5500 x 20	2.5	O.S. Wyatt, Jr.	3708
Effluent Pipeline	900 x 20	0.4	Casbeel Snell, Jr., et al	93.5
Discharge Area	800 x 900	16.5	Margaret Snell, et al	93.5
Access	Blanket Agreement	N/A	McGregor Estate	1565
Access	Blanket Agreement	N/A	Casbell Snell, Jr., et al	237.5 (tract 1) 237.5 (tract 2)

Access	Blanket Agreement	N/A	O.S. Wyatt, Jr.	243 (tract 1) 3708 (tract 2)
Access	Blanket Agreement	N/A	Lowell Michael Archer	60

As an alternative to obtaining easements or ROW discussed above, the Phase II Study included discussions with TWC staff and members of the environmental community regarding outright purchase of property in the delta in order to obtain more long-term flexibility in operating and maintaining these projects. Beneficial reasons for obtaining the estuary in outright purchase, whether by the City of Corpus Christi or by a state or federal agency, include:

1. Allowing better overall management of the entire Nueces Estuary;
2. Assisting with discharge permit limits and flexibility in dealing with TWC/USEPA;
3. Eliminating landowner concerns with flooding, cattle grazing, and other surface land use patterns;
4. Securing upland areas surrounding the wetland areas can be used to encourage USEPA and other Federal Agency participation. Upland areas could be used to enhance migratory game habitat and to filter agricultural runoff;
5. Providing for development of a wildlife refuge which would both provide protection of an environmentally sensitive area as well as enhance tourism related to wild animal viewing; and
6. Providing maximum flexibility with land ownership may assist in full implementation of wastewater return flow diversions and freshwater river diversions to the estuary in the future. This could be the driving force for master wastewater collection and treatment system planning, depending on environmental community acceptance and effluent permit conditions.

Prerequisites to purchase of delta property will include items such as an environmental audit and an extensive title search, to investigate surface and subsurface rights, existing pipeline easements, and other potential conditions.

3.3 Alternative River Diversion Project

As mentioned in Section 3.1, an alternative diversion project was discussed during Phase II Technical Advisory Committee meetings. The primary advantage of this alternative is the fact that it would eliminate the requirement for a new river diversion pump station and its remote operational considerations. This section of the report presents conceptual planning and budget estimates for the alternative project, which will include the following:

1. Utilization of existing City of Corpus Christi O. N. Stevens Water Treatment Plant facilities to deliver approximately 3 mgd of raw water to the vicinity of existing sludge lagoons located approximately 2,000 feet east of the treatment plant;

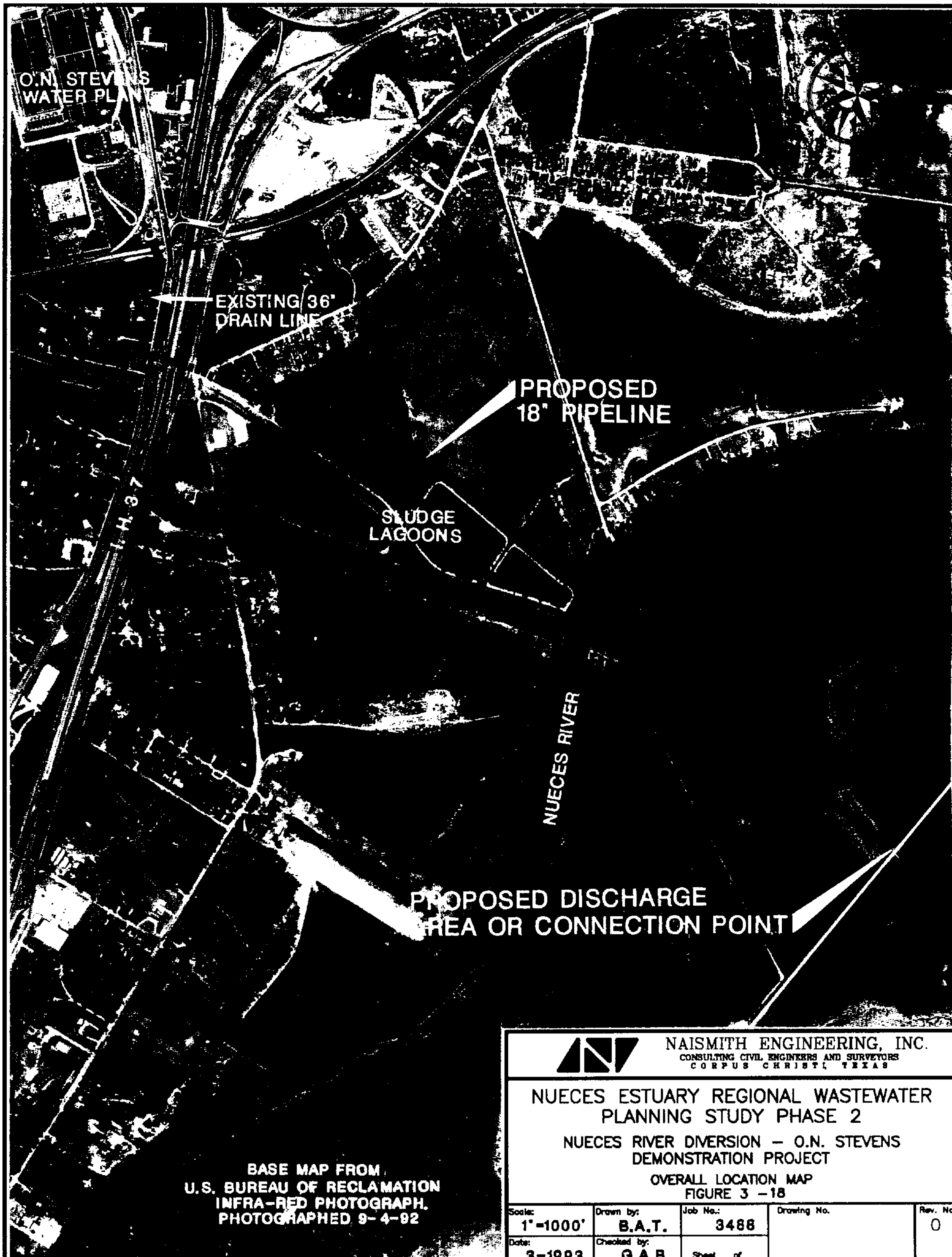
2. Extension of a bypass pipeline around the sludge lagoons northward across the river to the delta; and

3. Construction of a discharge area in the delta area between South Lake and Rincon Bayou and/or discharge by pipeline to Rincon Bayou and/or South Lake.

An overall location map of the existing and proposed facilities is shown in Figure 3-18.

3.3.1 Existing Facilities and Operation

Presently, raw water is delivered from two river pump stations to a raw water receiving structure on the treatment plant site via dual 54-inch raw water lines. Water then flows to the raw water reservoir and through the treatment process. The water surface elevation in the sedimentation basins and filters is approximately 77.5 feet MSL. Sludge from the sedimentation basins and filter backwash may be discharged through a 36-inch


O.N. STEVENS
WATER PLANT
EXISTING 36"
DRAIN LINE
PROPOSED
18" PIPELINE
I.H. 37
SLUDGE
LAGOONS
NUECES RIVER
PROPOSED DISCHARGE
AREA OR CONNECTION POINT
BASE MAP FROM
U.S. BUREAU OF RECLAMATION
INFRA-RED PHOTOGRAPH.
PHOTOGRAPHED 9-4-92
NAISMITH ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI, TEXAS
NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY PHASE 2
NUECES RIVER DIVERSION – O.N. STEVENS
DEMONSTRATION PROJECT
OVERALL LOCATION MAP
FIGURE 3 -18
Scale: 1"=1000'
Drawn by: B.A.T.
Job No.: 3486
Drawing No.
Rev. No. 0
Date: 3-1993
Checked by: G.A.B.
Sheet ___ of ___

gravity pipeline to sludge lagoons located adjacent to the river, approximately 2,000 feet east of the treatment plant, or may be diverted into a washwater holding tank for return to the raw water reservoir. Water surface elevation in the river sludge lagoons is approximately 65 feet lower than the treatment plant basins or about elevation 12 feet MSL.

The sludge lagoons are currently not permitted for discharge and therefore must depend on evaporation, transpiration, and percolation for dewatering. Past operation has included periodic dredging of sludge for remote disposal in accordance with regulations. Due to the fact that the lagoons dewater slowly, particularly during periods of wet weather, they are currently not being utilized for sludge disposal. Basin sludge and filter backwash are currently being returned to the raw water reservoir for reuse. However, based on discussions with City Water Division staff, this mode of operation has certain disadvantages that would be eliminated if discharge of sludge through the 36-inch drain line was possible. In order to improve operations and take advantage of the existing pipeline facilities and available head conditions, it is proposed to construct a new pipeline which would connect to the 36-inch drain line and then bypass the sludge lagoons and divert flow across the river to a discharge area in the Nueces delta.

Hydraulic calculations and cost estimates were prepared for a 3.0 mgd diversion rate in order to compare to the Calallen Dam demonstration project. Based on discussions with City Water Utilities staff, the average flow rate from filter backwash is approximately 1.5 mgd. Therefore, the filter backwash flow would need to be supplemented with an additional 1.5 mgd from the sedimentation basins to provide the total 3.0 mgd.

3.3.2 Proposed Diversion Facilities

In order to meter the amount diverted, a flow measuring device will be installed on the 36-inch drain line at the treatment plant site. Connection will be made to the 36-inch drain line at the sludge lagoons and an 18-inch bypass will extend north of the sludge lagoons to a river crossing (Figure 3-19). Directional drilling techniques, as described in the Allison WWTP effluent diversion section, will be utilized for the river crossing. The 18-inch bypass will then extend across two tracts of land north of the river to a discharge area. Conceptually, it is assumed that the discharge area will be similar in design and cost to the Rincon Bayou discharge area discussed in Section 3.1.3. Ultimately, the 18-inch bypass could be connected to an overall combined effluent/river water diversion system between South Lake and Rincon Bayou (Figure 3-19). A combined system would provide maximum flexibility to distribute river water and wastewater effluent to various areas of the estuary. Preliminary cost estimates for the O. N. Stevens demonstration project diversion and the combined diversion system are shown in Tables 3-3 and 3-4, respectively.

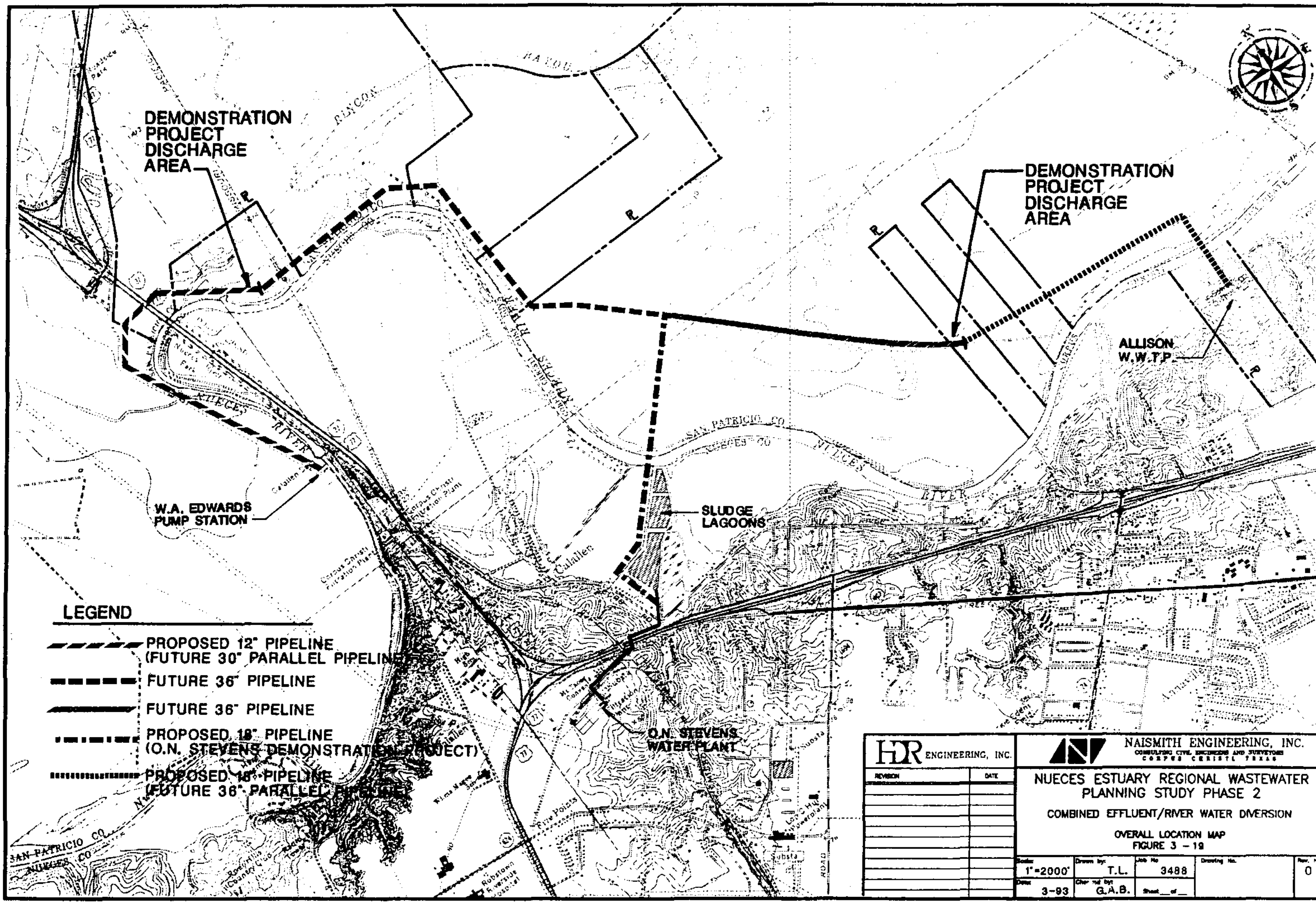

DEMONSTRATION PROJECT DISCHARGE AREA
DEMONSTRATION PROJECT DISCHARGE AREA
ALLISON W.W.T.P.
SAN PATRICIO CO
NUECES CO
NUECES RIVER
W.A. EDWARDS PUMP STATION
SLUDGE LAGOONS
O.N. STEVENS WATER PLANT
LEGEND
PROPOSED 12" PIPELINE (FUTURE 30" PARALLEL PIPELINE)
FUTURE 36" PIPELINE
FUTURE 36" PIPELINE
PROPOSED 18" PIPELINE (O.N. STEVENS DEMONSTRATION PROJECT)
PROPOSED 18" PIPELINE (FUTURE 36" PARALLEL PIPELINE)
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC.
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
COMBINED EFFLUENT/RIVER WATER DIVERSION
OVERALL LOCATION MAP
FIGURE 3 - 19
1"=2000'
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Table 3-3
Cost Estimate
Alternative Nueces River Diversion Demonstration Project
O. N. Stevens Water Plant System

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	18" Pipeline	LF	6,200	$ 35.00	$217,000
2.	Nueces River Crossing	LF	800	220.00	$176,000
3.	Discharge Area	LS	1	5,000.00	$ 5,000
	Sub-total				$398,000
	Contingency (20 percent)				$ 79,600
	TOTAL ESTIMATED CONSTRUCTION COST				$478,000
	ENGINEERING				
	Basic Services (Approx. 8.7 percent)				$ 42,000
	Special Services (includes geotechnical, permitting, surveying and project start-up)				$ 31,000
	TOTAL ESTIMATED ENGINEERING SERVICES				$ 73,000
	TOTAL PROJECT CAPITAL COSTS				**$551,000**
	AMORTIZED COSTS (Per Year)				
	Debt Service				$ 55,100
	Operations and Maintenance				$ 5,500
	Power Costs*				$ 23,000
	TOTAL YEARLY COSTS**				**$ 83,600**

Note: Construction contingency increased to 20 percent due to conceptual nature of estimate.
*Estimated cost to pump 3.0 mgd from the river diversion station to the O.N. Stevens WTP.
**Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

Table 3-4
Cost Estimate
COMBINED EFFLUENT/RIVER WATER DIVERSION SYSTEM

Items to be Completed at W.A. Edwards Pump Station Site to Rincon Bayou

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Permanent Intake Structure & Pump Station (20 mgd)	LS	1	$620,000.00	$620,000
2.	30" Pipeline	LF	9,000	50.00	$450,000
3.	Hondo Creek Crossing	LS	1	30,000.00	$ 30,000
	Sub-total				$1,100,000
	Contingency (35 percent - See note 1)				$ 385,000
	TOTAL ESTIMATED PROJECT COST				1,485,000

Items to be Completed from Rincon Bayou to Connection Point for Possible O.N. Stevens River Diversion

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	36" Pipeline	LF	12,500	$55.00	$ 687,500
	Sub-Total				$687,500
	Contingency (35 percent - See note 1)				$ 240,500
	TOTAL ESTIMATED PROJECT COST				$928,000

Items to be Completed from Connection Point for Possible O.N. Stevens River Diversion to South Lake Demonstration Project Discharge Area

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	36" Pipeline	LF	6,800	$55.00	$374,000
	Sub-Total				$374,000
	Contingency (35 percent - see note 1)				$130,900
	TOTAL ESTIMATED PROJECT COST				$505,000

Items to be Completed at Allison WWTP site to South Lake Demonstration Project Discharge Area

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	1 MG ground storage tank	EA	3	$275,000	$325,000
2.	High Service Pump Station	LS	1	130,000	130,000
3.	36" Effluent Pipeline	LF	6,600	55	363,000
4.	36" Nueces River Crossing	LF	1,200	450	540,000
	Sub-Total				$1,858,000
	Contingency (35 percent - see note 1)				650,000
	TOTAL ESTIMATED PROJECT COST				$2,508,000

Note 1 - Includes construction contingency plus an allowance for engineering, surveying, geotechnical, permitting, and project setup.

4.0 WASTEWATER QUALITY

The Phase I Study entailed determining the number of wastewater discharges in the Corpus Christi Bay Area. The scope of the study included determining the types of discharge sources that existed in the area without an evaluation of the quality of these discharges. It was assumed that all effluents could be treated to a quality suitable for discharge into the estuarine system. This Phase II study includes a further evaluation of the quality of the wastewater effluents (return flows) in an effort to determine the suitability of diverting these discharges into the Nueces Estuary. In order to make an adequate evaluation of these return flows within the realm of this study, it was necessary to limit the scope of the Phase II study to those discharges that presented the most cost-effective solution to the utilization of these wastewater effluents. These dischargers were those facilities, both municipal and industrial, that reside along the inner Corpus Christi Ship Channel, south of the Nueces River, and in various locations around the City.

4.1 Municipal Wastewater

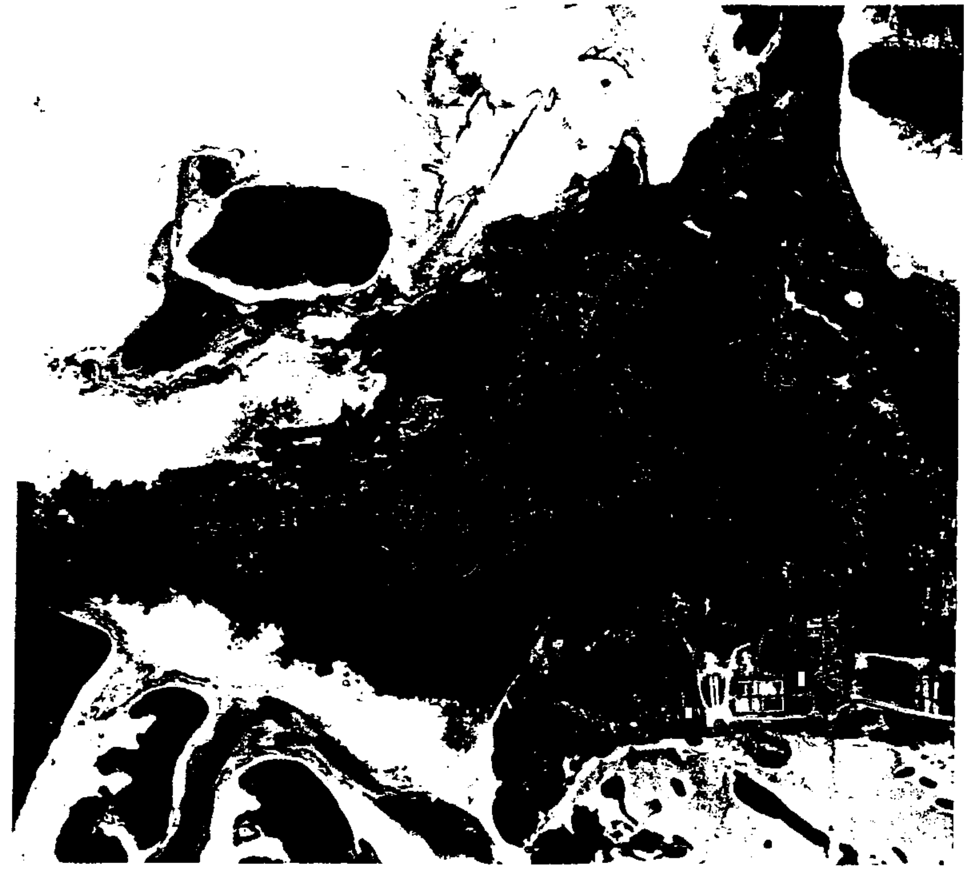
In order to determine the benefits that could result from the discharge of wastewaters in an estuarine system, the Phase I Study concluded that it would be necessary to implement some of the recommended demonstration project alternatives in a subsequent phase. The scope of the Phase II Study includes refinement of two alternative demonstration projects discussed in the Phase I Study, which are as follows: 1) the wastewater effluent diversion from the Allison WWTP into the Nueces Estuary, and 2) diversion of river water from above the Calallen Dam into the Upper Rincon area of the estuary. Following the successful completion of the Allison demonstration project, it is anticipated that the diversion of additional effluent from the Broadway, Oso, and Westside WWTPs may further enhance the productivity of the estuary. The design aspects for these demonstration projects were discussed in Sections 3.1 and 3.2. Prior to completion of the proposed design, it was necessary to evaluate the effect of placing these wastewaters into the estuary.

The primary objective of the wastewater diversion project into the South Lake area of the estuary is to provide greater productivity to the estuarine ecological system than that currently provided by the current discharge location into the Nueces River. A similar situation exists at the Port Aransas WWTP; municipal wastewaters from this facility have been discharged into an environment that closely resembles that of the Nueces Delta, and the effluent limitations at this facility are identical to those of the Allison WWTP. A review of the aerial photographs shown in Figure 4-1 indicates that substantial biological growth has occurred during the time period from 1970 to 1991. It is anticipated that similar biological activity could occur at the South Lake area of the estuary resulting from the wastewater discharge diversion.

4.1.1 Institutional Requirements

A permit to discharge wastewater requires modelling of the receiving water body to determine the contaminant concentrations (effluent limitations) that will not induce an improper balance in the health of that receiving water body. These requirements originated with the Clean Water Act (CWA) of 1972, which was established to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Schnapf, 1990). The

SITE IN 1970



SITE IN 1991

THE ABOVE PHOTOGRAPHS COMPARE THE BIOLOGICAL GROWTH THAT HAS OCCURRED IN A MARSH AREA DURING A TWENTY-ONE (21) YEAR PERIOD FROM 1970 TO 1991. THIS MARSH AREA HAS RECEIVED MUNICIPAL EFFLUENT FROM THE CITY OF PORT ARANSAS WWTP WITH EFFLUENT LIMITATIONS OF 20 mg/l BIOCHEMICAL OXYGEN DEMAND (BOD) AND 20 mg/l TOTAL SUSPENDED SOLIDS (TSS).

HDR ENGINEERING, INC.

NAISMITH ENGINEERING, INC.

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

PORT ARANSAS WWTP DISCHARGE

COMPARISON

FIGURE 4 - 1

3-93	T L	3488		0
	PMP	Sheet 1 of 6		

CWA prohibits the discharge of any pollutants without a permit issued by the National Pollution Discharge Elimination System (NPDES) under Section 402. The USEPA enforces this federal program and has transferred permitting and enforcement responsibility to those states whose approved programs meet federal requirements. The NPDES program has not yet been delegated to Texas; thus, in Texas, wastewater discharges must operate under both the EPA and state programs and therefore must maintain both NPDES and State discharge permits. In Texas, the regulatory body responsible for the state program is the Texas Water Commission (TWC).

The Allison demonstration project will divert effluent from the Nueces River Tidal Segment Number 2101 to the barren salt flat of South Lake in the Nueces Estuary (Segment Number 2482). The facility's current permitted outfall location would still be maintained for effluent monitoring purposes, as well as to provide maximum flexibility to discharge periodically into the Nueces River on a short-term basis during peak wet weather flows. The records received from City of Corpus Christi wastewater personnel indicate the current average daily flow (ADF) rate for the previous 12-month period is 2.5 mgd, a decrease from the flow of 2.8 mgd mentioned in the Phase I Study. Discussions with City Wastewater personnel speculate that water utilization at Sam Kane Beef Processors, Inc. has decreased, resulting in a reduction of wastewater discharging into the City's collection lines that flow to the Allison WWTP.

In Table 4-1, the average monthly discharge for 1992 at the Allison WWTP fluctuates from a low of 2.0 mgd to a high of 3.1 mgd. Although not shown in the table, the lowest recorded ADF rate discharged was 1.2 mgd on October 1, 1992, and the highest recorded

Table 4-1
1992 Allison WWTP Average Monthly Operating Record

Month	Flow (mgd)	BOD (mg/l)	TSS (mg/l)	DO (mg/l)	pH
January	2.630	5	5	7.7	6.7
February	3.081	3	5	7.3	6.7
March	2.825	5	7	6.8	6.6
April	2.499	4	5	6.5	6.4
May	2.802	4	5	6.2	6.5
June	2.793	5	4	5.8	6.5
July	2.425	3	3	5.8	6.4
August	2.470	3	4	5.9	6.7
September	2.447	4	4	6.1	6.9
October	2.276	3	3	6.2	7.2
November	2.073	4	5	5.8	7.3
December	2.001	3	3	6.7	7.1
AVERAGE	**2.53**	**4**	**4**	**6.4**	**6.8**

flow was 6.4 mgd on May 31, 1992. These variations in ADF discharges indicate that water use is not constant; this is attributed to variable water usage at businesses and residences, as well as stormwater infiltration that enters the City wastewater collection system in the Allison WWTP service area.

To determine the potential for diverting effluent into the estuary from the Allison WWTP, it was paramount that the facility's wastewater quality be reviewed. Chemical and biological constituents were determined by reviewing the discharge permit and 1992 operating records obtained from the City wastewater personnel. The discharge permit requires effluent limitations of 20 milligrams per liter (mg/l) biochemical oxygen demand (BOD), 20 mg/l total suspended solids (TSS), minimum 2 mg/l dissolved oxygen (DO), and 6 to 9 standard pH units. Twelve-hour composites for these parameters are analyzed daily.

Table 4-1 displays a 12-month average record for the above parameters and indicates that the Allison WWTP is in compliance with its existing permit. In addition, the facility must conduct priority pollutant analyses on a biannual basis and biomonitoring of the effluent on a monthly basis on test organisms *Cyprinodon variegatus* and *Mysidopsis bahia* according to the 24-hour acute static median lethal concentration (LC 50). These additional testing procedures are required if a facility has a design capacity of at least 5 mgd and/or receives non-residential flows (i.e., refineries, paint shops, automotive garages) that have the potential for generating industrial-type effluents. From discussions with City wastewater personnel, the priority pollutant analyses are in compliance with the maximum allowable concentrations (MACs) for the specified constituents. In addition, the 24-hour LC 50 analyses conducted on effluent samples collected on July 15, 1992, were in compliance; the results of these tests showed that 50 percent or less mortality was demonstrated at every treatment concentration analyses for both test organisms.

The City Wastewater Department submitted an application for renewal of Allison's discharge permit on October 16, 1992. In February of 1993, the TWC issued a draft permit to the City imposing more stringent effluent limitations of 10 mg/l BOD, 15 mg/l TSS, minimum 4 mg/l DO, and 3 mg/l ammonia Nitrogen (NH_3-N) which would be valid for a five-year period.[1] The entire Allison demonstration project's proposed flow will be discharged on a continuous basis into the delta and only periodically into the Nueces River. Therefore, a reduction to these more stringent parameters would result in the following

[1]It is estimated that upgrading the Allison Wastewater Treatment Plant to meet effluent limitations of 10-15-3 will cost approximately $3.6 million, based upon design flow of 5.0 mgd. This estimate is based upon upgrading aeration basins, aeration equipment, and secondary clarifiers to meet Texas Water Commission design criteria.

economical and ecological effects: 1) Removal of many essential nutrients that could be utilized by the estuarine systems; 2) The City being required to allocate additional capital expenditures for a plant upgrade as opposed to utilizing the funds for the infrastructure to divert additional effluents into the delta for maximum benefit for the estuarine system; and 3) Generating more sludge from the upgraded treatment process, resulting in additional disposal costs for the City. This sludge is a product of the wastewater treatment plant's process of removing solids, and these solids have an abundance of organic constituents that could be better utilized in the biological processes to further enhance productivity in the estuary as opposed to enhancing degradation of waste in a landfill environment. If these more stringent effluent limitations are imposed, the City would have three years to ensure that the Allison WWTP is compliant. This short time period restricts the adequate collection of data for the proposed demonstration project. It is anticipated that the monitoring at this demonstration project will be done over a four- to five-year period. Based on the above criteria, it was necessary for the City to request a variance from the draft permitted conditions. Therefore, on February 11, 1993, the City drafted a letter making a request for this variance for reevaluation of the water quality standards. The TWC issued a response to this letter on February 19, 1993 stating that a review of any further data submitted by the City would be conducted in a determination to make any necessary revisions to the draft permit.

The City should also request a time extension from the TWC to allow for long-term monitoring of the current wastewater effluent quality discharged into the estuary. Currently, the data available for the chemical and biological constituents that exist in the wastewater discharges and their effects into estuary environments is limited. Therefore, it is recommended that as many state and federal agencies as possible become involved in the monitoring of the demonstration project to further enhance the acquisition, interpretation, and effective utilization of this vital information.

The diversion of treated municipal effluent into an estuarine environment from its existing outfall location for the purpose of enhancing the productivity of that environment is very unique. A similar project is located in Beaumont, Texas, where post primary and secondary treated effluent from that City's upgraded WWTP is being discharged into Hillebrandt Bayou for additional wetlands tertiary treatment prior to its final discharge (sampling point) and for enhancement of this wetland body. This new treatment process is allowing the City of Beaumont to meet more stringent stream standards for the Bayou without having to meet more stringent direct discharge requirements. The utilization of the Nueces Estuary as a similar wetlands type treatment of the effluent from the Allison WWTP was considered. However, the topography of the area does not allow a discrete wetland area, which would not be subjected to periodic tidal influence or river flooding, to be utilized in the manner required for such treatment. The Allison WWTP diversion effluent will not require further treatment subsequent to plant discharge; the final discharge point is proposed to exist at its current outfall sampling point. Ultimately, additional discharge locations may be permitted to allow maximum management flexibility by the environmental community to discharge the effluent at any chosen location in the estuary, at any time, to provide the maximum productivity enhancement.

In order to identify the permitting process which will be required for the

However, these circumstances should impose modeling of this location as a receiving water body different from a typical wastewater discharge analysis. The DO parameter should not be a significant factor since ample wind over this shallow bay generates adequate DO (dissolved oxygen) levels.

At the conclusion of the demonstration project, sufficient data should be available to establish the BOD and TSS effluent limitations applicable for this discharge location. The EPA and TWC staff members were informed that since the effluent limitations have not been established for the estuary as a receiving water body of wastewater effluents, the current effluent limitations of 20 mg/l BOD, 20 mg/l TSS, and 2 mg/l DO at the Allison WWTP would provide good benchmark parameters for the demonstration project monitoring efforts. It was disclosed by Dr. Terry Whitledge of UTMSI that this estuary would be the best area to support high nutrient loading. In conjunction, a representative of the TWDB stated that the Nueces Estuary has half of the production of other estuaries and in order to increase its productivity to that of other estuarine systems, additional nutrients and fresh water flow would need to be placed in this area. At the conclusion of this meeting, the EPA stated that they would work closely with the TWC in the establishment of the criteria required to implement this project. However, reservations were expressed by these two agencies that will require further study and analysis, particularly with regard to discharging industrial wastewaters into the estuary. Limited data is available on the discharge effects in an estuarine environment of industrial wastewaters, and until further study or implementation of a pilot project to acquire this necessary information, both the EPA and TWC would not permit an industrial effluent diversion of this type into the estuary.

On December 16, 1992, a field trip into the estuary was conducted to give a first-hand view of the proposed Allison demonstration project location. This field trip was attended by some of the same members in attendance at the Austin meeting, in addition to many more interested parties, including the following: City of Corpus Christi, STWA, PCCA, United States Fish and Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD), Audubon Society, Sierra Club, TWC-Austin (standards and permitting section), TWC-District 12 (Corpus Christi), Corpus Christi Bay Area Economic Development Corporation (CCBAEDC), San Patricio County Economic Development Corporation (SPCEDC), Mayor's Water Task Force, Bureau, UTMSI, NEI, and HDR.

As a result of this study and the outcome of the demonstration projects, it is anticipated that further enhancement of the entire estuary system will occur. However, prior to relocating additional wastewater return flows to the estuary and allocating excessive capital expenditures, it must be proven that the demonstration project(s) yield successful results. The success of the demonstration project will be determined by enhanced primary productivity in the estuary, a reduction in the salinity in the estuarine system, and most importantly, improvement in the health of the estuary.

4.1.2 Physical Requirements

Assuming the successful completion of the Allison demonstration project, it is anticipated that additional enhancement of the estuary could be accomplished through the diversion of wastewaters from other WWTPs, as discussed in the Phase I Study. Table 4-2 displays the current discharges and locations, existing permit effluent limitations, and the next renewal date for existing EPA and TWC permits for the respective Corpus Christi municipal WWTPs.

Table 4-2
Current Conditions at City of Corpus Christi Municipal WWTPs

WWTP Facility	Discharge (mgd) Average	Design	Location	Permit Parameters (mg/l) BOD	TSS	Other	Permit Renewal Date EPA	TWC
Allison Plant	2.5	5.0	Nueces River	20	20	2-DO	10-09-95	04-19-93
Broadway	6.5	10.0	Inner Harbor	20	20	2-DO	05-19-96	02-02-97
Oso	14.5	16.2	Corpus Christi	20	20	2-DO	10-25-97	03-01-93
Westside	3.0	6.0	Oso Creek	20	20	2-DO	10-07-96	12-08-92
TOTAL	**26.5**	**37.2**						

As stated previously, the TWC permit for the Allison facility is currently being reviewed to determine the effluent limitations that will be imposed for the next five-year period, beginning on April 19, 1993. The Broadway facility's TWC permit was renewed on May 19, 1992, with the above shown effluent limitations. TWC permit renewal applications for the Oso and Westside facilities have also been submitted; the City has recently received a draft permit for the Westside facility that indicates more stringent effluent limitations may be imposed.

As will be discussed in more detail in Section 5, the City is reviewing rerouting some of the above wastewater service area flows to other collection points as a part of future wastewater collection and treatment planning. It is anticipated that the results of the demonstration projects could have a significant impact on the criteria the City ultimately utilizes in evaluating these future planning needs. If the demonstration projects indicate that diversion of additional return flows into the delta is a benefit to the long-term wastewater planning needs of the area, then rerouting of wastewaters to the delta may be economically feasible. The rerouting options available to the City are summarized in Table 4-3.

Table 4-3
City of Corpus Christi
Internal Wastewater Rerouting Alternatives

WWTP Facility	Treatment Stage	Average Discharge (mgd)		Reroute Location
		Rerouted	Remaining	
Allison	Treated	2.5[1]	0.0	Nueces Estuary
Broadway	Treated or Untreated	6.5	0.0	Allison or Westside
Oso	Treated	7.5	7.0	Westside
Westside	Treated	14.0	3.0[2]	Allison

[1]This was Alternative SS-1 discussed in the Phase I Study.
[2]This quantity is based on receiving the under construction flow of 1.5 mgd rerouted from Horne Road.

The Allison WWTP listed above is the selection chosen for the demonstration project diversion of 2.5 mgd of effluent into the South Lake area (see Figure 3-8). Flow from the Broadway WWTP can be diverted to either the Westside or Allison facilities in either the treated or untreated stage. The Broadway facility was the first WWTP constructed in the City and it will someday have to be refurbished. The plant can either be upgraded to meet new standards that may be imposed, or closed, with its flow rerouted to another service area for treatment. In the latter case, this facility can be converted into a lift station and flow can be diverted by a force main to either the Westside or Allison Plants.

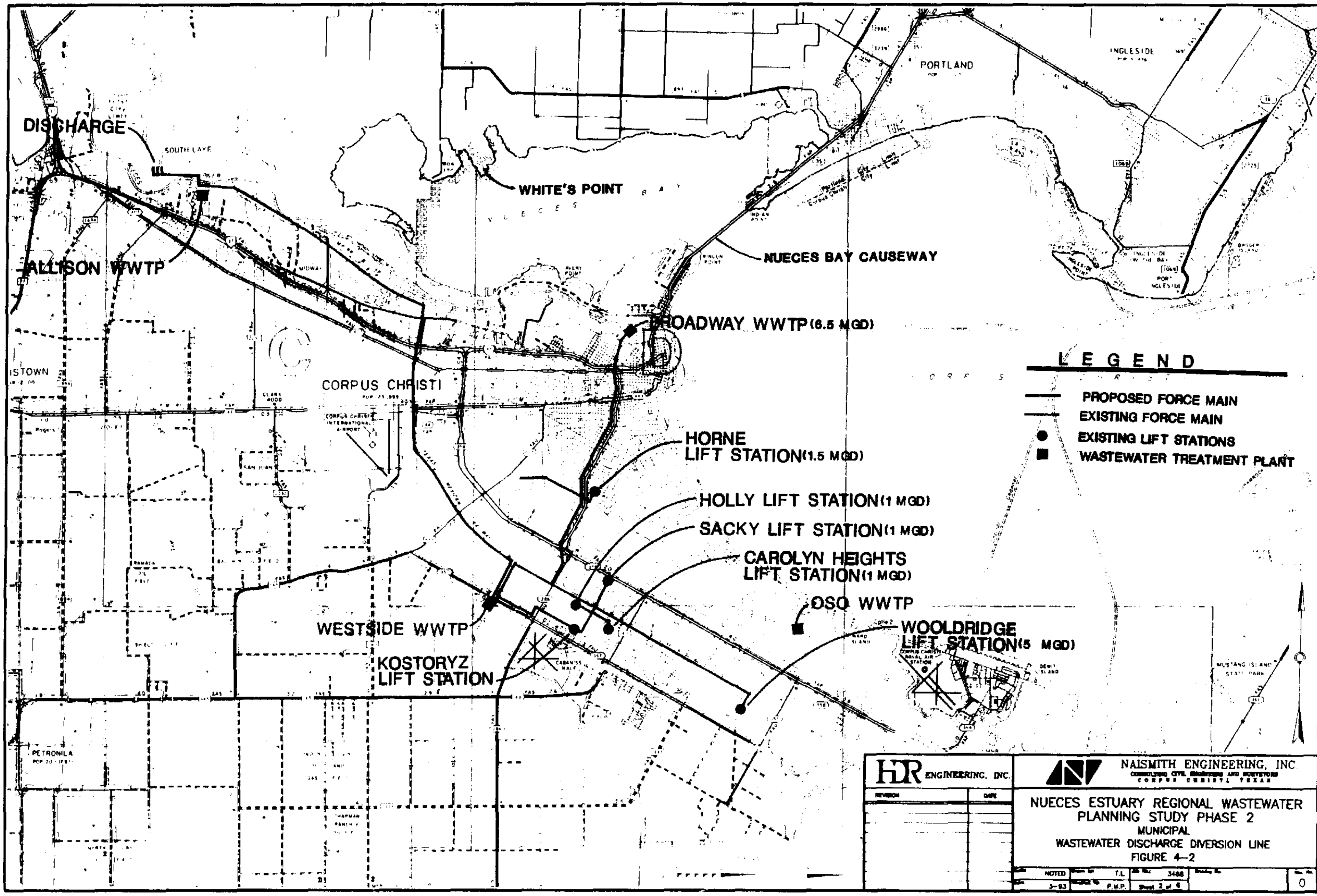
Approximately 7.5 mgd of untreated wastewater from the Oso WWTP service area can be diverted to the Westside WWTP, which consists of 5 mgd from the vicinity of the

Woolridge master lift station, 1 mgd from the Sacky, Holly, and Carolyn Heights lift stations via the Kostoryz lift station, and 1.5 mgd from the Horne Road Lift Station (see Figure 5-1). The remaining 7 mgd will be discharged at this facility's outfall to support the marsh system that has developed as a result of its current discharge.

If the 7.5 mgd from the Oso Service area, in combination with the 6.5 mgd from Broadway, are diverted to the Westside Plant, this facility could serve as a regional municipal WWTP. Thereafter, 14 mgd of treated effluent could be diverted to the Allison plant via a single pipeline for subsequent diversion to the delta (see Figure 4-2). As shown in Table 4-3, the existing 3 mgd discharge would remain at the Westside facility for continued diversion to Oso Creek to maintain the ecological growth that has occurred as a result of this discharge; only those flows in excess of this quantity could be diverted, such as the 1.5 mgd that will soon be rerouted from the Horne Road lift station. One disadvantage of this alternative is that its current plant capacity is essentially unable to handle any additional flow without a plant expansion. However, diversions to the delta could ease the burden of future capital expenditure needs for plant capacity upgrades and structures for more practical diversion of wastewaters into the estuary; this benefit is anticipated to be greater as opposed to applying these same funds to comply with more stringent effluent limitations.

4.2 Industrial Wastewater

In the Phase I study meetings, managers of area industrial facilities expressed reservations about the diversion of industrial effluents to the delta. Current discharge



DISCHARGE
ALLISON WWTP
WHITE'S POINT
NUECES BAY CAUSEWAY
PORTLAND
INGLESIDE
BROADWAY WWTP (6.5 MGD)
CORPUS CHRISTI
HORNE LIFT STATION (1.5 MGD)
HOLLY LIFT STATION (1 MGD)
SACKY LIFT STATION (1 MGD)
CAROLYN HEIGHTS LIFT STATION (1 MGD)
OSO WWTP
WOOLDRIDGE LIFT STATION (5 MGD)
WESTSIDE WWTP
KOSTORYZ LIFT STATION
PETRONILA
LEGEND
PROPOSED FORCE MAIN
EXISTING FORCE MAIN
EXISTING LIFT STATIONS
WASTEWATER TREATMENT PLANT
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
MUNICIPAL
WASTEWATER DISCHARGE DIVERSION LINE
FIGURE 4-2

locations allow for adequate mixing of effluents in the deep receiving waters of either the Nueces River or the Corpus Christi Ship Channel (Inner Harbor). The South Lake area of the estuary is predominantly a barren salt flat area with shallow water bodies that would not allow for the dispersion of contaminants that exist in the effluent. Without this mixing, precipitation of solids and deposition into the soil could occur in this estuarine environment.

Meetings with environmental consultants, TWC and EPA, have also resulted in concern about the concept of diverting industrial effluents into the estuary. Therefore, the Phase II Study includes an analysis of the quality of these industrial effluents to determine if these discharges would be a viable source of wastewater return flows since the volumes that are currently released are abundant. The focus of these diversions is to place effluent in locations that can more likely reap the benefits, but not at the expense of inducing an environmental liability.

4.2.1 Institutional Requirements

As discussed in Section 4.1, utilization of additional wastewater return flows would only be accomplished after the successful completion of the municipal effluent diversion from the Allison WWTP demonstration project. However, based on the assumption that this project will be a success, planning and analysis should be conducted to prepare for the diversion of additional sources of return flows. Industrial facilities in the Corpus Christi area which could provide wastewater return flows were reviewed in the Phase I Study. Based on this review, it was determined that the most viable industrial sources reside south of the Nueces River and the Ship Channel. Therefore, the evaluations mentioned here are based on this criteria. Although the industrial effluents represent large volumes, their source must be more closely examined as compared to that of the municipal effluent. In order to accomplish a comprehensive evaluation, it was necessary to evaluate the types of effluents discharged.

The types of discharges that are released from these facilities can be comprised of any combination of process, cooling water, and sanitary sewerage effluent. The quality of these discharges will determine if discharge is permissible. The industrial facilities were contacted to verify the discharge quantities obtained in the Phase I Study and to obtain the distribution of flow types that comprise these quantities. Table 4-4 displays the information obtained during these conversations.

Table 4-4
Industrial Wastewater Discharge Facilities

Industrial Facility	Discharge Outfall No.	Actual Flow (mgd)	Process (mgd)	Cooling (mgd)	Sewerage (mgd)
American Chrome and Chemical	001	13.2[1]	0.4	12.7[1]	0.1
	201	0.19			
Citgo Refinery (West Plant)	002	0.29	0.29	None[2]	IQ/ST[3]
Citgo Refinery (East Plant)	001	2.40	2.30	0.1	City[4]
Coastal Refinery	001	1.8	1.2	0.6	City[4]
Coastal Javelina	001	0.1	None[2]	0.1	City[4]
Encycle	001	0.46	0.45	None[2]	0.01
Koch Refinery	001	2.6	1.87	0.72	City[4]
Oxy-Corpus Christi	001	1.1	0.33	0.66	IQ/ST[3]
Southwestern Refinery	001	1.44	1.04	0.40	City[4]
Valero	005	2.22	1.11	1.11	0.01[5]

[1]This quantity is recirculated Ship Channel flow.
[2]"None" indicates that this flow type is nonexistent at this facility.
[3]"IQ" represents Insignificant Quantity of flow; "ST" represents On Site Treatment of Flow.
[4]This flow type is discharged into the City collection system.
[5]"ST" (Site Treatment of Flow)

Utilization of process water will require additional review of analytical data and consultations with plant personnel to determine the type and concentrations of constituents in the effluent and to obtain general knowledge about the process systems at each facility. In addition, to effectively measure the effects of this discharge, it would be necessary to implement a pilot project at a location similar to that of the estuary.

The concept of utilizing cooling water was also mentioned to the industrial facilities and the following constraints were identified: 1) cooling water contains additives, including biocides, fungicides, and corrosion inhibitors; 2) this water type may contain dissolved and suspended solid particulates, accumulated from numerous recycling periods, that are in excess of the effluent limitations established for the estuary; and 3) process fluids can be mingled with the cooling water in the event a process unit has a mechanical failure. The industrial facility personnel and chemical additive manufacturers state that additives contained in the cooling water should not prohibit biological growth in a receiving water body since the additives have half lives of five to six hours and full additive degradation typically occurs before the water reaches the facility's treatment plants and discharge outfalls. If the pilot project determines that the solids contained in the cooling water are not beneficial to the enhancement of a receiving water such as the estuary, removal can be accomplished through a settling basin or collecting the effluent prior to excessive recycling. Of the wastewaters at an industrial facility, process fluids have the strongest potential for containing the detrimental chemical constituents. Therefore, prior to discharging these wastewaters, quality testing should be conducted.

The third type of flow is sanitary sewerage effluent. Table 4-4 shows that the majority of the facilities discharge this currently unmeasured flow type to the City's collection lines for subsequent treatment by the Broadway WWTP. If diversion of effluent from the Broadway facility is conducted, the industrial sewerage wastewater will also be acquired. The remaining facilities, whose sewerage is combined with the other types of effluent, discharges approximately 0.12 mgd. The diversion of this small quantity of flow could possibly be utilized through modifications to existing plant operations.

To limit environmental liability associated with the discharge of all industrial wastewater streams from multiple sources into an estuarine environment, it is necessary to determine the quality of each of these effluents prior to the diversion from current facility locations. One-day holding tanks can be connected into existing outfall conveyance mechanisms (i.e., piping, flumes, box culverts, etc.) at each industrial facility contributing a discharge. The effluent discharged can be diverted into the tanks and samples collected and analyzed for the estuary-specific chemical constituents. Following notification that the analyses indicate compliance with the estuary effluent limitations, discharge of the effluent from the holding tanks and diversion to the estuary can commence. On the contrary, if the analyses indicate non-compliance with the effluent limitations, the effluent can be discharged via its current outfall structure. This arrangement would allow the flexibility to maintain dual discharge through existing outfall structures or diversion into the estuary.

4.2.2 Physical Requirements

Prior to diverting any industrial effluents from their current discharge outfall location to the estuary, monitoring of the effects of industrial effluents should be conducted. In order to monitor these effects as they would occur in the estuary, a similar location would have to be chosen. A location with similar characteristics that is currently exposed to industrial effluents is Tule Lake. Tule Lake, owned by the Port of Corpus Christi Authority (PCCA), is a tidally influenced water body located west of the Citgo West Refinery and south of the Ship Channel (see Figure 4-3). In its historical past, this water body has been exposed to a wide array of industrial effluents, including brine water, that have significantly damaged the aquatic inhabitants and vegetative growth. In more recent times, excessive discharges have been limited and sparse emerging plant growth has appeared. The effluents that are currently discharged into this water body consist of a combination of industrial storm and process waters, as well as some non-industrial stormwaters (see Figure 4-3).

Monitoring the discharge effects of the effluent types shown in Figure 4-3 may be accomplished with segregated pilot test sampling plots. In addition, an industrial facility could participate in an additional pilot program by diverting a portion of its effluent to Tule Lake to be sampled along with the other effluents. Prior to initiating the pilot program, samples would need to be collected from the existing soil to establish background concentrations for various organic and inorganic constituents. Thereafter, samples would need to be collected from both the soil and surface water, as well as monitor the biological growth in and around the receiving water. It is recommended that this pilot project would be continued for an extended period, similar to that of the Allison demonstration project, in order for adequate monitoring to be conducted.

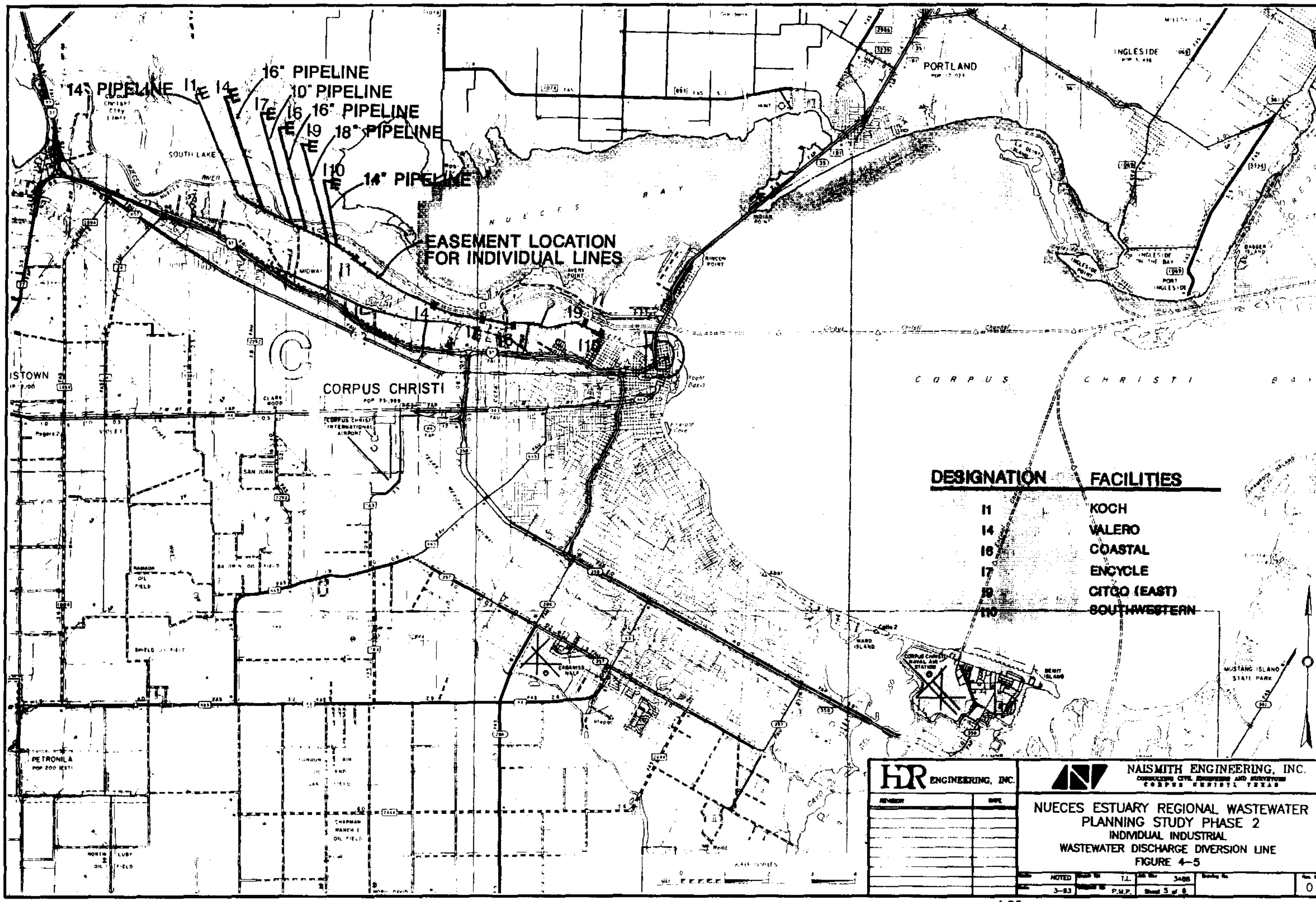
Following the successful completion of the industrial pilot project, it would be recommended to initiate one of the industrial alternatives examined in the Phase I Study.

Following the presentation of the proposed wastewater diversion alternatives to the industrial facility representatives in the Phase I meetings, many preferred to be responsible for their own effluent and not co-mingle it with other industrial facilities. Their concerns were that combining effluents from many different facilities into one common line made all effluent contributors ultimately responsible for any contamination that may occur from a minimum of one contributor. This circumstance is often referred to as joint and severable liability by all contributors for the entire damages sustained and the injured party may pursue recompense against any one separately or against all in one suit.

It is possible to utilize these effluents and satisfy industry concerns at the same time. As mentioned briefly above, prior to any effluent being discharged into the estuary, it would first be diverted into a ground storage holding tank at each industrial facility. Subsequently, samples would be collected from the storage tank and analyzed. If effluent quality is in compliance with the effluent limitations, it can be discharged into a pipeline that flows into the estuary. This intermediate control point is the location for a facility's compliance with its permit. (However, the limitations of environmental liability are still unknown. A recent court ruling stated that even though a permit has been granted to discharge pollutants into a stream, or the most modern control devices available have been installed in the discharger's facility, the discharger is still not relieved from any liability for damages that may occur as a result of his actions.) This compliance point should allow the facility operator to present a record of all effluent discharged and its quality, and to show that the most modern pollution control devices are in place in order to mitigate any environmental damage for which he may be responsible; this process may play an instrumental part in the discovery of the potentially responsible parties (PRPs).

There is a question as to why the industries would want to move their effluents from the satisfactory current discharge outfalls to the estuary where: 1) Enhancement is anticipated to occur; 2) More stringent effluent limitations are likely to be imposed; and 3) The incidence of any contamination is more likely to be noticed since mixing is likely to be less. In order for this diversion alternative to be attractive to the industrial facilities, these concerns must be reduced. This could be accomplished through the establishment of a special district that can indemnify the industries from liability. This special district (see Section 10) would in effect accept the discharge from the holding tank. After the effluent is released from the facility's ground storage tank, either all the participating industries can discharge effluent into a common line, or each participating industrial facility can utilize their own individual line placed at variable locations in the estuary system. The first alternative has an advantage in that the construction of one single line is more economical than the construction of individual lines for each facility. The second alternative has an advantage in that each industry will know exactly where it discharged its own effluent. Regardless of which alternative is chosen, environmental and economic evaluations will determine the best option.

An alternative for the above-mentioned common line diversion discussed in Phase I was alternative SS-4. This alternative utilizes all the industrial facilities south of the Ship Channel and the Nueces River, discharging their effluent into a common line which flows first to the Allison WWTP and subsequently to the delta (see Figure 4-4). The second alternative, also discussed in Phase I, was alternative SS-3 (see Figure 4-5), which was the


14" PIPELINE
I1
I4
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I6
16" PIPELINE
I9
18" PIPELINE
I10
14" PIPELINE
EASEMENT LOCATION
FOR INDIVIDUAL LINES
SOUTH LAKE
NUECES BAY
PORTLAND
INGLESIDE
CORPUS CHRISTI
CORPUS CHRISTI BAY
PETRONILA
DESIGNATION FACILITIES
I1 KOCH
I4 VALERO
I6 COASTAL
I7 ENCYCLE
I9 CITGO (EAST)
I10 SOUTHWESTERN
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC.
NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY PHASE 2
INDIVIDUAL INDUSTRIAL
WASTEWATER DISCHARGE DIVERSION LINE
FIGURE 4-5

diversion of all the same industrial effluents discussed in SS-4, but utilizing only those flows greater than 0.5 mgd. These flows would be transported to the estuary via individual distribution lines; the final discharge points would be different for each facility's line, placed in locations in the estuary that would receive the most benefit. As stated in Phase I, all existing facility discharge outfalls would be maintained to have the flexibility to continue discharging effluent to this location whenever necessary.

4.3 Mixed Municipal and Industrial Wastewater

The utilization of both municipal and industrial effluents will provide the largest amount of flow, thereby increasing the amount of freshwater diverted into the delta. The implementation of a full-scale combination of these two effluent types diverted into the delta is contingent upon the successful completion of the municipal effluent demonstration project and the industrial effluent pilot project. These two projects should allow sufficient time to monitor the effects from the discharge of these effluents. However, the effects of mixing these two waste streams and diverting them into the estuary are not adequately understood at the present time.

4.3.1 Institutional Requirements

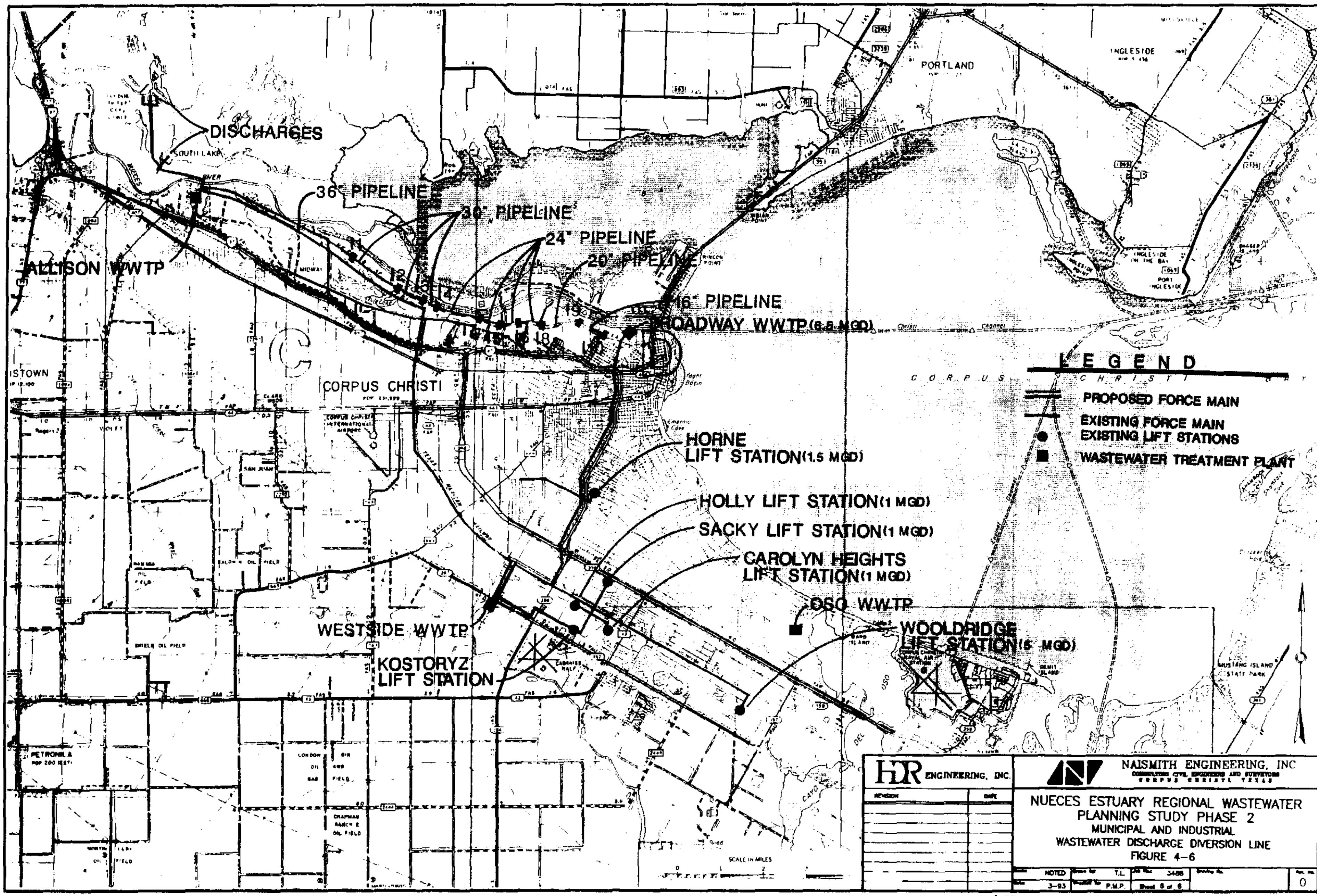
The diversion of both municipal and industrial wastewater to the estuary can be accomplished, but the concept of mixing the various waste streams must be analyzed to determine the accumulative effect of adding a number of industrial effluents together and discharging into the estuary. In addition, as discussed in Sections 4.2 and 10, the creation of a special district for implementation and management of such a project should be considered.

At the conclusion of the municipal demonstration and industrial projects, the effects of these individual discharges on the estuary should be definitive. However, the effects on the estuary of the combination of these two wastewater streams may not be so obvious. As stated briefly in Section 4.1.1., the Allison WWTP, along with the Broadway and Westside WWTPs, may provide a good indication of these effects, since sanitary sewerage collection lines that flow to these facilities are connected to non-residential systems that have the potential for generating industrial effluents. The type of industrial effluents (process, cooling, and sewerage) that will be utilized should also be considered; this should be defined following the completion of the industrial pilot project.

The creation of a special district to buffer the participating wastewater diversion contributors from liability may be essential in order to allow these diversions to occur. This will be discussed in more detail in Section 10.

4.3.2 Physical Requirements

The alternative considered for mixing municipal and industrial effluents for diversion into the estuary was a combination of Figure 4-2 and Figure 4-4 (see Figure 4-6). Figure 4-2 shows the common line diversion of City municipal effluents to the Allison WWTP, while Figure 4-4 shows a common line diversion of all south shore industrial effluents to the Allison WWTP. At the Allison Plant, the industrial and municipal effluents would be stored in separate holding tanks and various combinations of these effluents can be diverted into the estuary.


DISCHARGES
36" PIPELINE
30" PIPELINE
24" PIPELINE
20" PIPELINE
16" PIPELINE
ALLISON WWTP
BROADWAY WWTP (6.5 MGD)
CORPUS CHRISTI
PORTLAND
INGLESIDE
HORNE LIFT STATION (1.5 MGD)
HOLLY LIFT STATION (1 MGD)
SACKY LIFT STATION (1 MGD)
CAROLYN HEIGHTS LIFT STATION (1 MGD)
OSO WWTP
WOOLDRIDGE LIFT STATION (5 MGD)
WESTSIDE WWTP
KOSTORYZ LIFT STATION
LEGEND
PROPOSED FORCE MAIN
EXISTING FORCE MAIN
EXISTING LIFT STATIONS
WASTEWATER TREATMENT PLANT
CORPUS CHRISTI BAY
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
MUNICIPAL AND INDUSTRIAL WASTEWATER DISCHARGE DIVERSION LINE
FIGURE 4-6

5.0 FEASIBILITY OF INTERNAL RE-ROUTING OF WASTEWATER FLOWS

The Phase I Study identified potential sources of wastewater return flows, which included diverting portions of effluent from the City of Corpus Christi's Broadway, Westside and Oso WWTP's, in addition to the proposed diversion of the Allison WWTP effluent.

Previous wastewater master plans performed for the City have also presented various possible raw wastewater diversions from one service area to another. These possible diversions are in connection with master planning of the City's wastewater treatment options for certain WWTP service areas.

Some of the diversions, such as rerouting of flow from the Horne Road lift station, have recently been implemented in connection with the Westside WWTP expansion. The Horne Road project, which was recently awarded, will divert approximately 1.5 mgd from the Oso service area to the expanded Westside WWTP. This diversion will not only provide additional flow for the expanded Westside WWTP, but will also result in an increase in reserve capacity available at the Oso WWTP, thus delaying either its expansion or revisions to its permit conditions. In addition, this diversion will help to relieve overloaded portions of the collection system.

The decision to implement any particular additional diversion(s) will depend on the City's adoption of an overall city-wide wastewater treatment master plan. In this regard, the City Council has recently conducted preliminary meetings with City staff regarding possible wastewater collection and treatment options. As of this date, no final decisions have been made by City Council. However, internal diversions of wastewater may provide the potential of improving operations within the City's collection and treatment systems, while moving toward a cost-effective solution to the estuary's freshwater needs.

5.1 Diversions from Oso WWTP Service Area to Westside WWTP Service Area

The 1986 Oso-Westside Wastewater Master Plan (1986 Master Plan), prepared for the City of Corpus Christi, evaluated a number of possible changes to service areas for the two plants. One wastewater routing alternative (Alternative No. 6) proposed decreasing the Oso service area and expanding the Westside service area by diversion of flows. The 1986 Master Plan rejected this alternative and stated that the cost of reconfiguring pipelines to divert flow away from Oso WWTP was an unwise expense, because the Oso WWTP had available unused capacity.

However, when the estuary's freshwater needs are considered as a factor, some portions of the flow diversions included in this alternative may become feasible. For purposes of this report, diversion of only the southernmost portion of Oso's service area was pursued, due to its proximity to the Westside WWTP. This portion of the Oso service area is served by a master lift station located on Wooldridge Road east of Airline Road, which was designated as Lift Station (LS) #40 in the 1986 Master Plan. Diversion of flow may be accomplished by making pump and discharge piping modifications at LS #40 and constructing a new force main northeast to the Holly Road corridor, then northwest along Holly Road to the Greenwood Drive trunk sewer. Total length of force main is approximately 35,600 LF. Assuming that the total existing flow in LS #40 (5 mgd) is diverted, a 24-inch force main will be required.

Additional flows from the southern portion of the Oso service area downstream of

LS #40 could be diverted by modifications and force main extensions from the Sacky Road lift station (LS #30), the Holly lift station (LS #31) and the Carolyn Heights lift station (LS #32). Total diversion of these flows would add approximately 1 mgd to Westside WWTP via the existing Kostoryz lift station (LS #31A) and force main.

Proposed diversions from the Oso WWTP service area to the Westside WWTP service area are shown in Figure 5-1 and cost estimates are presented in Table 5-1.

5.2 Westside WWTP Capacity

Westside WWTP currently has an average daily flow (ADF) of 3.0 mgd. The 1.5 mgd diversion from Horne Road pump station will bring the flow to 75 percent of its permitted 6.0 mgd capacity and trigger the TWC permit requirement to begin design of a plant expansion. The City has recently submitted a request for renewal of the Westside discharge permit and the draft permit is written for a final phase ADF of 8.0 mgd.

If the additional 6.0 mgd diversion discussed in Section 5.1 is implemented, the discharge permit will need to be renewed for a total ADF of at least 14.0 mgd. Future possible diversions, such as rerouting of the Broadway WWTP flow, would require additional capacity. It is apparent that this diversion will need to be preceded by a decision of the City to expand Westside to a "regional" facility.

The 8.0 mgd draft permit includes effluent limitations of 10 mg/1 BOD_5 (Biochemical Oxygen Demand), 15 mg/1 TSS (Total Suspended Solids), 3 mg/1 NH_3-N (Ammonia Nitrogen) and a minimum of 6 mg/1 of DO (Dissolved Oxygen). Based on preliminary discussions with City and TWC staff, it is possible that an expanded plant would

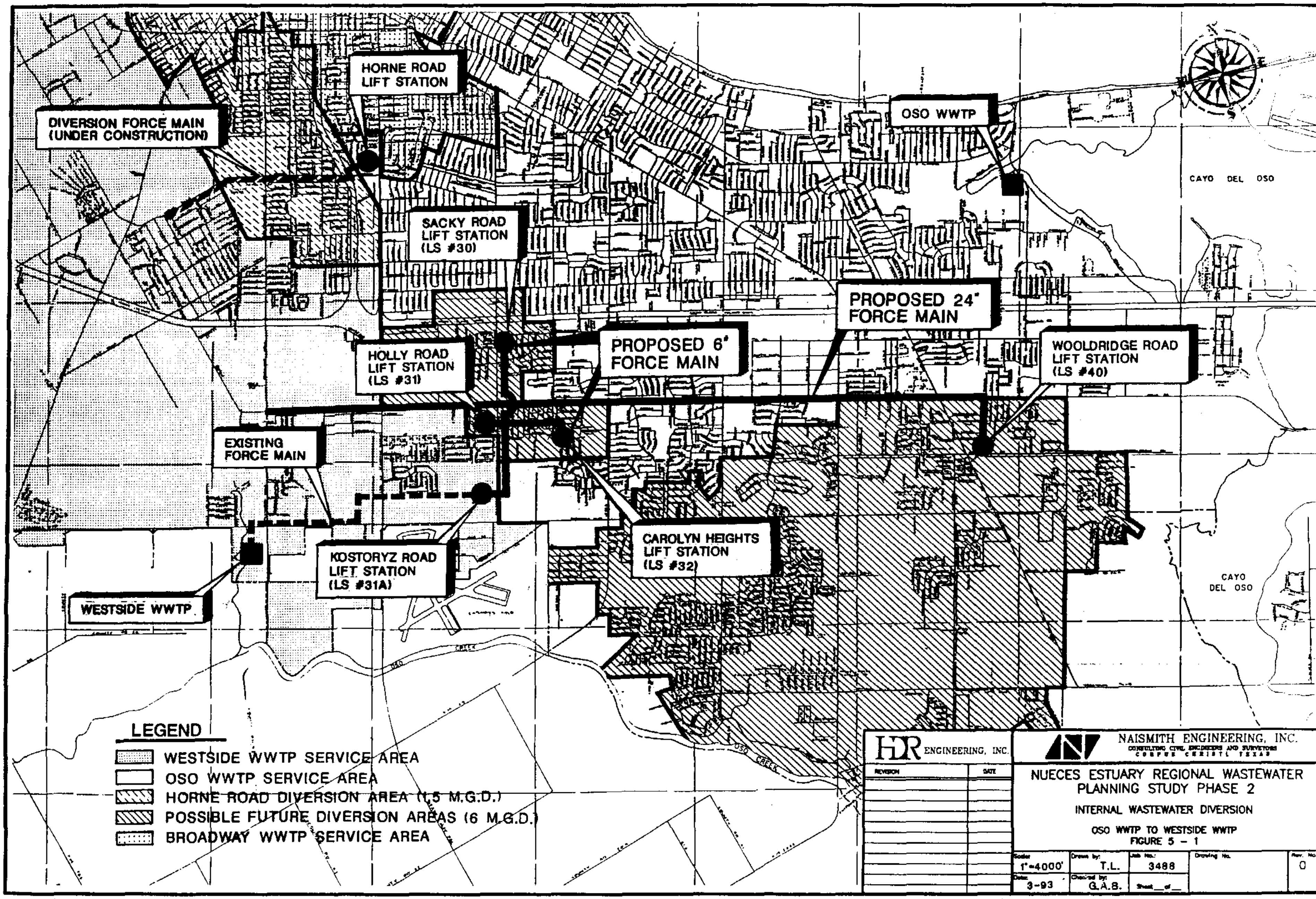

HORNE ROAD
LIFT STATION
DIVERSION FORCE MAIN
(UNDER CONSTRUCTION)
OSO WWTP
CAYO DEL OSO
SACKY ROAD
LIFT STATION
(LS #30)
PROPOSED 24"
FORCE MAIN
PROPOSED 6"
FORCE MAIN
HOLLY ROAD
LIFT STATION
(LS #31)
WOOLDRIDGE ROAD
LIFT STATION
(LS #40)
EXISTING
FORCE MAIN
CAROLYN HEIGHTS
LIFT STATION
(LS #32)
KOSTORYZ ROAD
LIFT STATION
(LS #31A)
WESTSIDE WWTP
CAYO
DEL OSO
OSO CREEK
LEGEND
WESTSIDE WWTP SERVICE AREA
OSO WWTP SERVICE AREA
HORNE ROAD DIVERSION AREA (1.5 M.G.D.)
POSSIBLE FUTURE DIVERSION AREAS (6 M.G.D.)
BROADWAY WWTP SERVICE AREA
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC.
NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY PHASE 2
INTERNAL WASTEWATER DIVERSION
OSO WWTP TO WESTSIDE WWTP
FIGURE 5 – 1
1"=4000'
T.L.
3488
0
3-93
G.A.B.

Table 5-1
Cost Estimate
Internal Wastewater Rerouting
(Diversion of 6.0 mgd from Oso WWTP Service Area to Westside WWTP Service Area)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Wooldridge Road Lift Station Modifications	LS	1	$30,000.00	$ 30,000
2.	24" Force Main, open cut	LF	33,600	70.00	$2,352,000
3.	24" Force Main, jack & bore	LF	2,000	150.00	$ 300,000
4.	Sacky Rd, Holly & Carolyn Heights Lift Station Modif.	LS	1	30,000.00	$ 30,000
5.	6" Force Main, open cut	LF	7,000	25.00	175,000
6.	6" Force Main, jack & bore	LF	600	70.00	42,000
7.	8" Force Main, open cut	LF	3,600	35.00	126,000
8.	8" Force Main, jack & bore	LF	300	80.00	$ 24,000
	Sub-total				$3,079,000
	Contingency (35 percent - see Note 1)				$1,078,000
	SUBTOTAL REROUTING PROJECT COSTS				$4,157,000
	SUBTOTAL WWTP EXPANSION COSTS (6 mgd @ $3/gallon - see Note 1)				$18,000,000
	TOTAL PROJECT COSTS				**$22,157,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$2,215,700
	Operations and Maintenance				$221,600
	TOTAL YEARLY COSTS*				**$2,437,300**

Note 1: Includes construction cost contingency plus an allowance for engineering, surveying, geotechnical, permitting, and project startup.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

be faced with even more stringent effluent limitations (i.e., lower NH_3-N criteria) and the cost of required additional treatment would be a factor in the decision to expand Westside in excess of 8.0 mgd.

5.3 Diversions From Westside WWTP Service Area To Allison WWTP Service Area

It may be feasible to limit the size of Westside WWTP expansion required by diversion of flow from the Oso service area by a further diversion of flows from the Westside to Allison service areas.

For purposes of this report, consideration was given only to diversion of the westernmost portion of Westside's service area, due to its proximity to the Allison WWTP. The only lift station in this area which is large enough to be a candidate for diversion is LS #10A (McBride Lane south of Up River Road), which has a flow of approximately 1.0 mgd.

Diversion of flow from LS #10A may be accomplished by making pump and discharge piping modifications and constructing a new force main along Up River Road to the Turkey Creek trunk sewer, thence to Allison WWTP.

Proposed diversion from the Westside WWTP service area to the Allison WWTP service area is shown in Figure 5-2 and the cost estimate is presented in Table 5-2.

5.4 Allison WWTP Capacity

The Allison WWTP currently has an ADF of 2.5 mgd and is permitted for 5.0 mgd. Diversion in excess of 1.25 mgd into Allison WWTP will trigger the TWC requirement to begin design of a plant expansion (at 75 percent of design capacity). Therefore, diversion

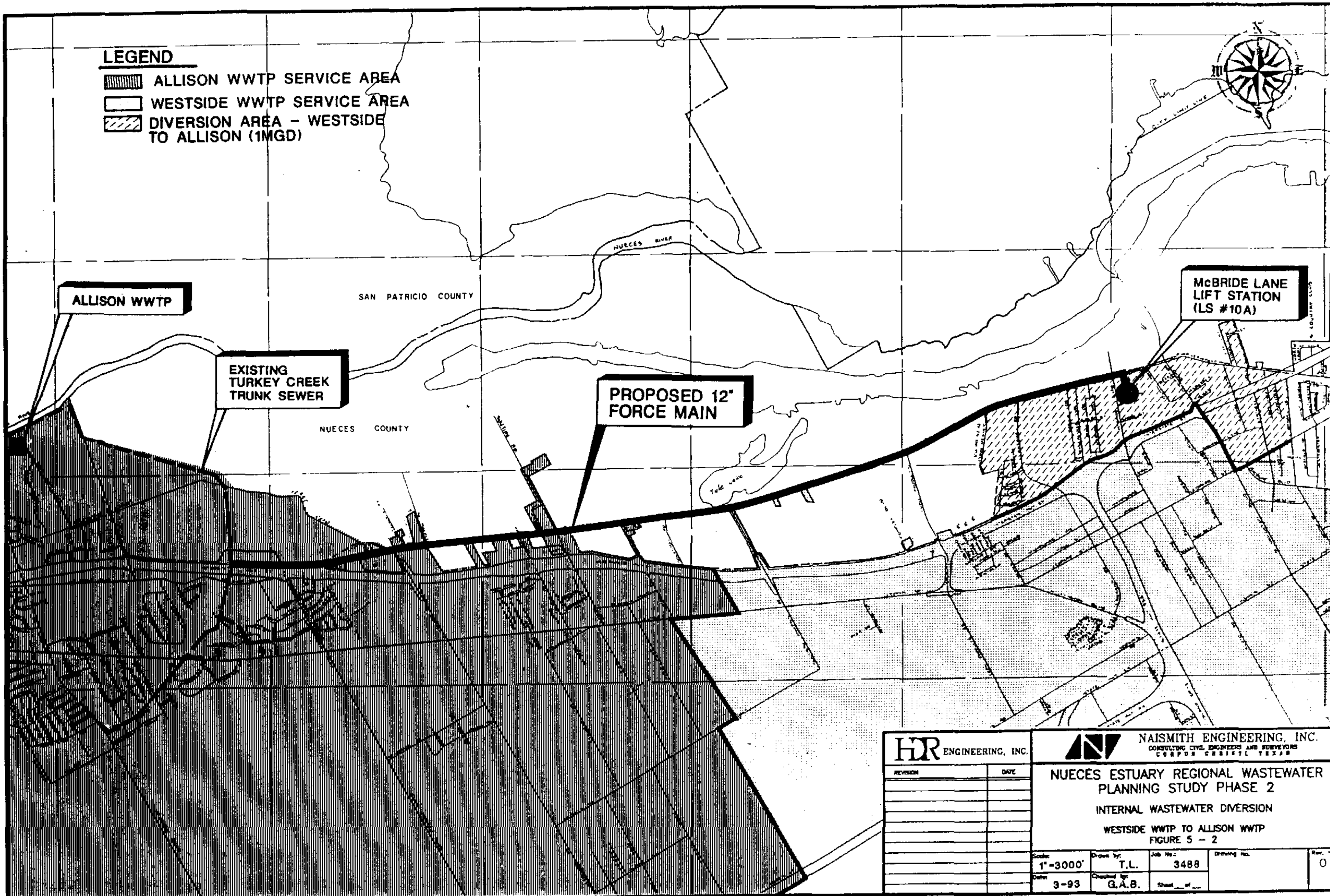

LEGEND
ALLISON WWTP SERVICE AREA
WESTSIDE WWTP SERVICE AREA
DIVERSION AREA – WESTSIDE TO ALLISON (1MGD)
ALLISON WWTP
EXISTING TURKEY CREEK TRUNK SEWER
PROPOSED 12" FORCE MAIN
McBRIDE LANE LIFT STATION (LS #10A)
SAN PATRICIO COUNTY
NUECES COUNTY
NUECES RIVER
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC.
REVISION
DATE
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
INTERNAL WASTEWATER DIVERSION
WESTSIDE WWTP TO ALLISON WWTP
FIGURE 5 – 2
Scale: 1"=3000'
Drawn by: T.L.
Job No.: 3488
Drawing No.
Rev. No. 0
Date: 3-93
Checked by: G.A.B.

Table 5-2
Cost Estimate
Internal Wastewater Rerouting
(Diversion of 1.0 mgd from Westside WWTP Service Area to Allison WWTP Service Area)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	McBride Lift Station Modifications	LS	1	$10,000.00	$ 10,000
2.	12" Force Main, open cut	LF	32,000	50.00	$1,600,000
3.	12" Force Main, jack & bore	LF	1,000	100.00	$ 100,000
	Sub-total				$1,710,000
	Contingency (35 percent - see note 1)				$599,000
	SUBTOTAL REROUTING PROJECT COSTS				$2,309,000
	SUBTOTAL WWTP EXPANSION COSTS (1 mgd @ $3/gallon - see note 1)				$3,000,000
	TOTAL PROJECT COSTS				**$5,309,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$530,900
	Operations and Maintenance				$53,000
	TOTAL YEARLY COSTS*				**$583,900**

Note 1: Includes construction cost contingency plus an allowance for engineering, surveying, geotechnical, permitting, and project startup.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

of LS #10A would leave very little capacity remaining to satisfy future growth in Allison's service area prior to the need for an expansion.

A decision by the City to pursue expansion at the Allison WWTP will require evaluation of several factors, including the cost of treatment required to achieve more stringent effluent limitations (unless the estuary demonstration project monitoring yields results that encourage a higher nutrient loading, i.e., 20 mg/l BOD_5 and 20 mg/l TSS or greater).

5.5 Diversion of Broadway WWTP to Other WWTP's

In addition to diversions of portions of the Oso and Westside WWTP service areas, as described in Sections 5.1 through 5.4, a long-range diversion alternative involving the Broadway WWTP was evaluated on a conceptual basis.

The Broadway plant is the City's oldest wastewater treatment facility, and presently has an average daily flow of 6.0 mgd. Its aging infrastructure, and possible future permit modifications, will eventually require replacement or major upgrades. As an alternative, the treatment facility could be taken out of service. Raw wastewater could be collected at the site and pumped to another facility, such as the Westside or Allison WWTP, for treatment.

Figure 5-3 shows a conceptual routing of force main to divert untreated wastewater from the Broadway Plant site to the Westside WWTP. The routing shown is conceptual in nature and was for the purpose of preparing an approximate cost estimate, as shown in Table 5-3. Due to the conceptual nature of the estimate, further evaluation of this alternative will be required to determine its feasibility.

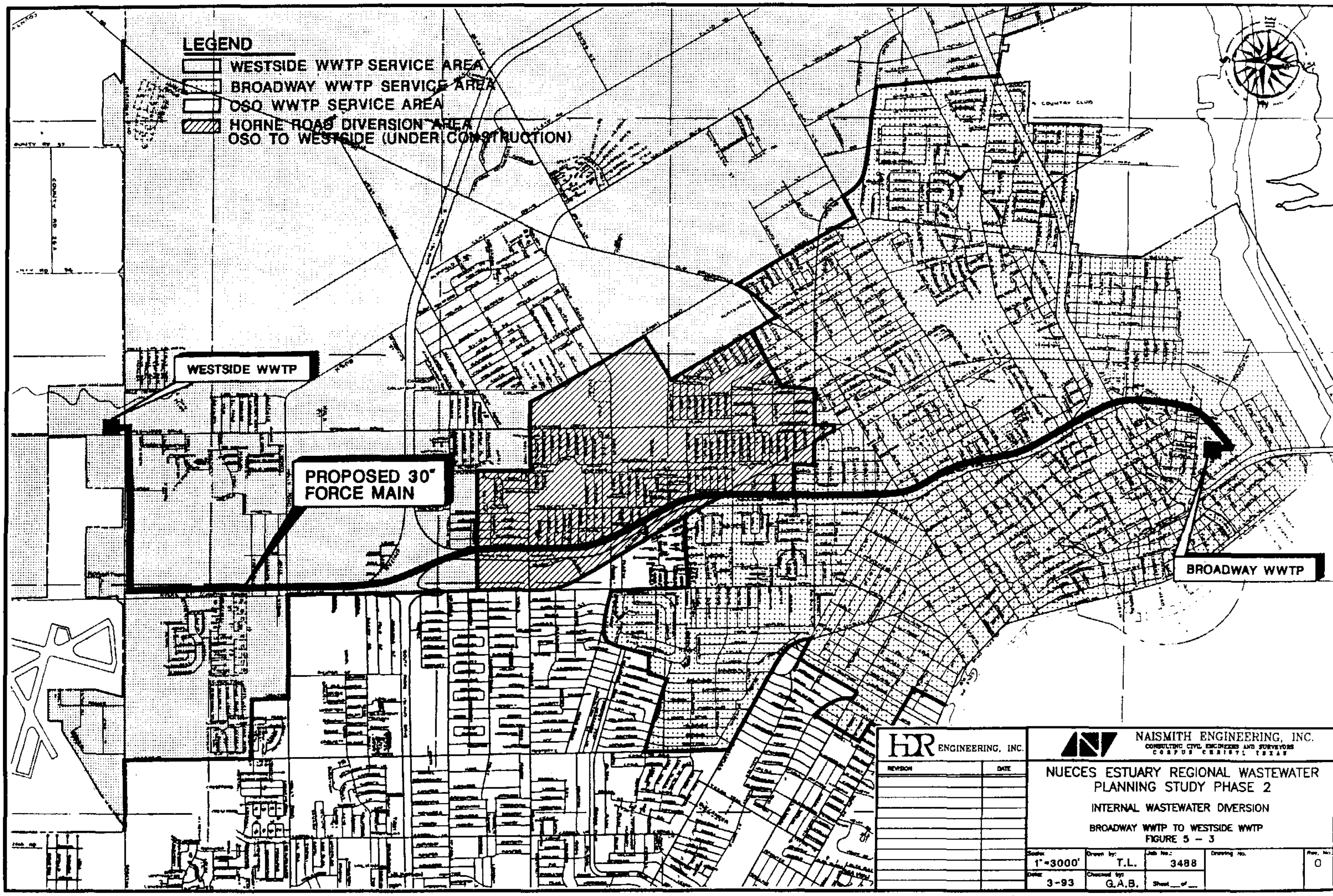

LEGEND
WESTSIDE WWTP SERVICE AREA
BROADWAY WWTP SERVICE AREA
OSO WWTP SERVICE AREA
HORNE ROAD DIVERSION AREA
OSO TO WESTSIDE (UNDER CONSTRUCTION)
WESTSIDE WWTP
PROPOSED 30" FORCE MAIN
BROADWAY WWTP
HDR ENGINEERING, INC.
NAISMITH ENGINEERING, INC.
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
INTERNAL WASTEWATER DIVERSION
BROADWAY WWTP TO WESTSIDE WWTP
FIGURE 5 – 3
1"=3000'
T.L.
3488
0
3-93
G.A.B.

Table 5-3
Cost Estimate
Internal Wastewater Rerouting
(Diversion of 6.5 mgd of Broadway WWTP to Westside WWTP)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Broadway Lift Station	LS	1	$300,000.00	$300,000
2.	30" Force Main, open cut	LF	39,000	80.00	$3,120,000
3.	30" Force Main, jack & bore	LF	9,000	175.00	$1,575,000
	Sub-total				$4,995,000
	Contingency (35 percent - see note 1)				$1,748,000
	SUBTOTAL REROUTING PROJECT COSTS				$6,743,000
	SUBTOTAL WWTP EXPANSION COSTS (6.5 mgd @ $3/gallon - see Note 1)				$19,500,000
	TOTAL PROJECT COSTS				**$26,243,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$2,624,000
	Operations and Maintenance				$262,000
	TOTAL YEARLY COSTS*				**$2,886,000**

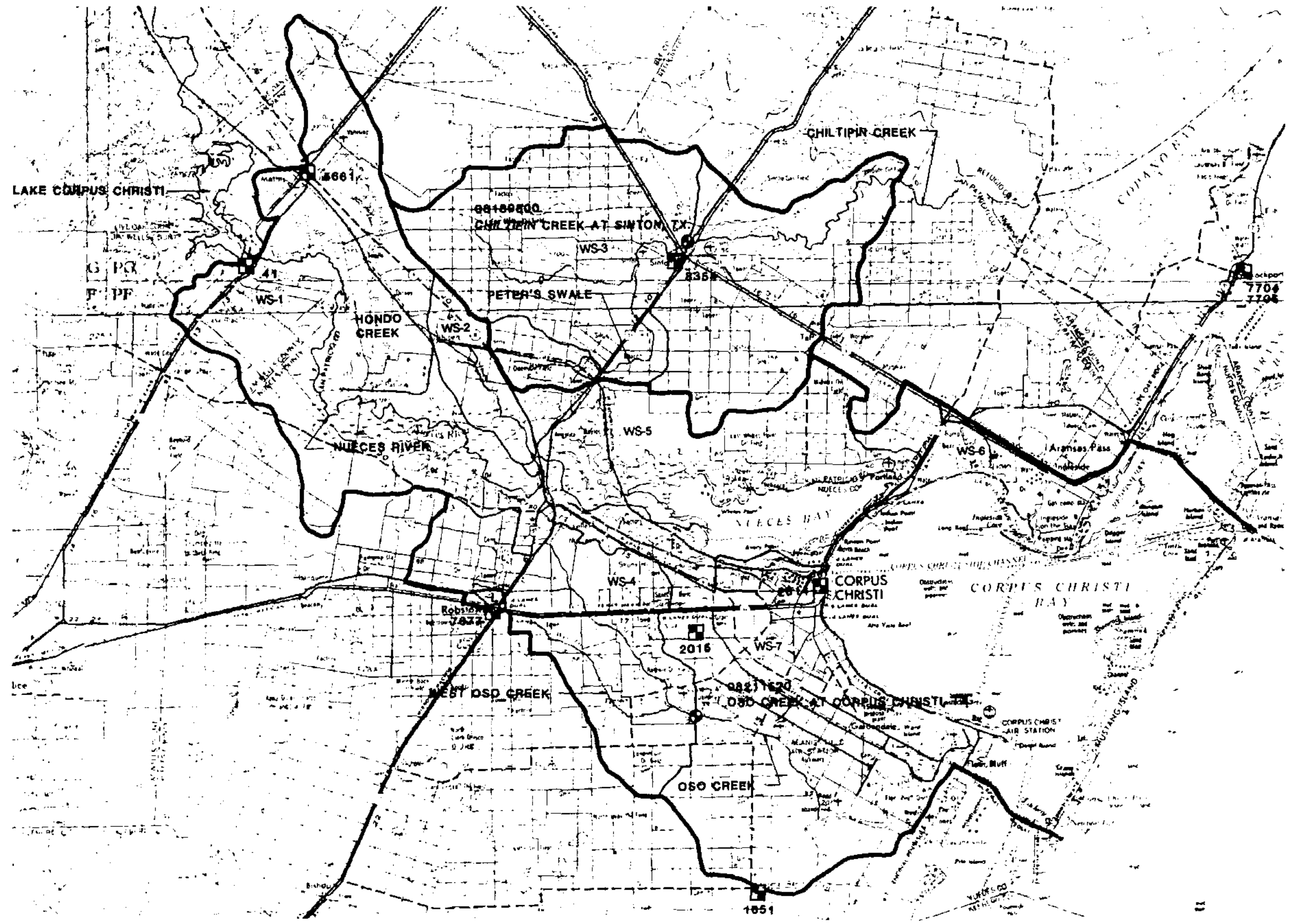
Note 1: Includes construction cost contingency plus an allowance for engineering, surveying, geotechnical, permitting, and project startup.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

6.0 FEASIBILITY OF STORMWATER DIVERSION FROM OSO, HONDO, AND CHILTIPIN CREEKS TO NUECES DELTA AND BAY

Four potential projects were evaluated for diversion of stormwater runoff from the Oso and Chiltipin Creek watersheds to various discharge locations within the Nueces Delta. In addition, the alternatives included a small dam and lake for storage of storm water within the Nueces River Basin from Hondo Creek for release to the delta and estuary when needed. The four potential projects are: (1) Upper Oso Creek diversion of stormwater to the Nueces River; (2) Peters Swale (Upper Chiltipin Creek) diversion near Odem, Texas to the Nueces Delta; (3) Small dam and reservoir on Hondo Creek to impound stormwater for subsequent release to the delta; and (4) Number three above (small dam and reservoir to impound stormwater and groundwater from a nearby well) for release to the delta during May, June, September, and October. The watersheds of the area are shown in Figure 6-1. The analyses which follow address: (a) The quality and suitability of these stormwater diversions; (b) Modifications made to the Lower Nueces Basin and Estuary Model to include stormwater diversion; (c) The development of ungaged runoff estimates above and below Calallen Dam; (d) The stormwater diversion projects studied and their effects on CC/LCC System yield; (e) The cost estimates of the proposed stormwater diversions; and (f) A proposed method for calculating ungaged runoff below Wesley Seale Dam for the purpose of obtaining estuarine inflow credits.

6.1 Quality and Suitability of Stormwater for Diversion to Nueces Delta and Bay

The stormwater of the Upper Oso Creek watershed being considered for diversion to the Nueces River originates from agricultural cropland and a part of the City of



HDR Engineering, Inc.

NAISMITH ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

UNGAGED WATERSHEDS OF CORPUS CHRISTI AREA

FIGURE 6-1

Robstown. At the present time, this water flows into Oso Creek and drains into Oso Bay. Although there are no data with which to evaluate the quality of this water, there are no indications in Oso Creek nor Oso Bay of any water quality problems that would prohibit its diversion to the Nueces River and Delta. However, the storm runoff should be sampled and analyzed before giving further consideration for its use in a diversion project.

The water quality of Chiltipin Creek was recently assessed in a study of nutrient loading of Copano Bay and possible effects of primary production (Shormann, 1992).[1] The dissolved inorganic nitrogen (DIN) concentrations ranged from 1 to 115 μmole,l over an eight-month period with the maximum concentration appearing in January 1992. Overall, the nitrogen and phosphorus influxes were calculated to represent 17.0 and 18.8 percent of the loading of Copano Bay, respectively. This nitrogen loading was judged to result from runoff of agricultural fertilizer which stimulated primary production in Copano Bay (Shormann and Whitledge, manuscript). Since Peters Swale (upper Chiltipin Creek) represents about one percent of the Chiltipin Creek discharge, then less than one percent of the nitrogen and phosphorus would be diverted from Copano Bay to the Nueces watershed. The quality of water from Peters Swale appears to be suitable for diversion to the Nueces Delta and Bay.

In the Hondo Creek cases, the stormwater being considered is from a watershed which presently drains into the Nueces River. The only change would be storage and release at a later date. Thus, there would be no significant water quality changes that would

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[1]Shormann, D.E. 1992. The effects of freshwater inflow and hydrography on the distribution of brown tide in south Texas Bays. M.A. Thesis, Department of Marine Science, The University of Texas at Austin, Port Aransas, Texas, 112 pp. Shormann, D.E., and T.E. Whitledge, Manuscript. Nutrient loading and freshwater inflow effects on the primary production in Copano Bay. To be submitted to Estuaries.

affect the suitability of this water for diversion to the Delta. However, in the case of a dam on Hondo Creek into which ground water would be pumped and stored, the quality of the ground water would need to be assessed. Since no well exists at the proposed site, no groundwater quality samples could be obtained. Thus, as in the case of stormwater diversions from Oso Creek, water quality information is needed before further consideration could be given to implementing this project, should it appear to be feasible from the quantitative standpoint (see Section 6.5).

6.2 Lower Nueces River Basin and Estuary Model Modifications

An updated version of the Lower Nueces River Basin and Estuary Model called NUBAY2 was developed to facilitate assessment of the impacts of the Texas Water Commission (TWC) Interim Order of March 9, 1992 on the firm yield of the CC/LCC System. The Interim Order includes provisions for relief from Nueces Bay inflow requirements based on measurements of salinity near the mouth of Upper Nueces Bay and recognizes inflow credits for effluent and stormwater intentionally diverted to Nueces Bay and/or the Delta. Specific enhancements to the Model incorporated since the completion of Phase I of the Nueces Estuary Regional Wastewater Planning Study are summarized in the following paragraphs.

The most significant difference between NUBAY2 and the previous versions is the capability of incorporating salinity in the monthly determination of releases necessary to satisfy the Nueces Bay inflow requirements. Salinity in Upper Nueces Bay at the beginning of each month is estimated as a function of estuarine inflow in the previous month using the following log-quadratic equation developed by the Texas Water Development Board (TWDB) and included in the Texas Water Commission Technical Advisory Committee Report (TWC, 1991).

$$\ln S = 3.633 - 0.1511 * \ln Q - 0.0894 * (\ln Q)^2$$

where: S = Salinity in parts per thousand
Q = Combined inflow in thousands of acre-feet per month

Logical computer code was included in NUBAY2 to consider the beginning-of-month salinity estimate relative to upper and lower bounds specified in the Interim Order and ascertain any appropriate reductions to Nueces Bay inflow requirements. As the salinity monitoring program continues in Nueces Bay, alternative relationships for the estimation of salinity which include observed salinity from the previous month, direct precipitation, prevailing winds and/or currents, and other factors should be considered.

Since the completion of the Phase I studies, consideration of the water rights of Nueces County WCID #3 within the Model has been modified slightly. The monthly portion of the full annual WCID #3 diversion right was assumed to be released from Lake Corpus Christi and delivered to Calallen Reservoir in previous model versions. In NUBAY2, monthly releases from Lake Corpus Christi to WCID #3 are limited to the natural inflow to Lake Corpus Christi effectively providing WCID #3 with the same opportunity for diversion which they would have had without the CC/LCC System.

Options have been coded into NUBAY2 to facilitate evaluation of the effects of diversion or importation of stormwater runoff to either Nueces Bay or the Nueces Delta. Diversion of stormwater may be either direct (concurrent with the runoff event) or stored for subsequent release. It was generally assumed that release of stored runoff in dry months or months having greater Nueces Bay inflow requirements would provide the greatest benefits in terms of system yield restored. Options for consideration of groundwater pumpage to augment surface runoff to Nueces Bay were also incorporated in NUBAY2.

6.3 Estimation of Runoff Downstream of Wesley Seale Dam

In accordance with the Texas Water Commission Interim Order of March 9, 1992, measured flows passing Calallen Dam as well as other presently ungaged volumes of stormwater runoff may be credited towards the Nueces Bay inflow requirements (see Figure 6-1 for watersheds). Hence, quantification of these ungaged runoff volumes could have an important impact on the firm yield of the CC/LCC System. Three important components of this study were calculation of daily areal precipitation for the 1934-89 period, calibration of a daily model capable of estimating runoff based on precipitation and basin characteristics, and application of this model to estimate ungaged runoff from various subwatersheds downstream of Wesley Seale Dam. The methods of calculation and the resulting estimates are presented below.

6.3.1 Development of Daily Areal Precipitation

Daily and monthly basin runoff were calculated for each of the seven subwatersheds identified in Figure 6-1 and listed in Table 6-1 using daily areal precipitation. Fourteen National Weather Service (NWS) precipitation gages and one TWDB gage in the Nueces Bay area were used to develop the precipitation data for the identified subwatersheds. The precipitation gages used in this study are summarized in Table 6-2. The subwatersheds and

Table 6-1 Subwatershed Identification and Characteristics			
Watershed No.	**Area (sq. mi.)**	**Adjusted SCS Curve No.**	**Description**
WS-1*	190	59	Nueces River Basin from Wesley Seale Dam to Calallen Dam
WS-2*	23	59	Hondo Creek Basin
WS-3	133	72	Chiltipin Creek Basin from its headwaters to the USGS streamflow gage at Sinton, TX
WS-4	97	77	Upper Oso Creek Basin from its headwaters to the USGS streamflow gage at Corpus Christi, TX
WS-5*	106	62	Nueces River and Bay Basin from Calallen Dam to the causeway
WS-6	37	58	North Shore Basin that feeds Corpus Christi Bay
WS-7	158	74	Lower Oso Creek Basin from the USGS streamflow gage at Corpus Christi, TX to Corpus Christi Bay
*These watersheds drain into Nueces Bay.			

selected precipitation stations are shown in Figure 6-1.

In order to estimate missing daily precipitation data, an inverse distance ratio weighting procedure using data from up to four nearby gages was adopted. In applying this procedure, an imaginary vertical and horizontal grid is centered on the gage being filled and concurrent records from each of the closest gages in each of the four surrounding quadrants are then weighted in proportion to relative distance from the gage being filled. The weighted precipitations from the four surrounding gages are then summed to obtain an estimate of the precipitation at the gage being filled. The period of record used in this

Table 6-2
Selected Precipitation Gages

Gage No.	Period of Record	Location	Operator
3508	1/16 to 12/90	George West, TX	NWS
639	11/01 to 12/90	Beeville, TX	NWS
144	4/11 to 12/90	Alice, TX	NWS
7677	10/22 to 12/90	Robstown, TX	NWS
2015	1/00 to 12/90	Corpus Christi (WSO AP), TX	NWS
8354	9/21 to 4/85	Sinton, TX	NWS
2014	1/36 to 8/80	Corpus Christi, TX	NWS
1651	4/59 to 12/90	Chapman Ranch	NWS
5661	7/64 to 12/90	Mathis, TX	NWS
4810	1/00 to 12/90	Kingsville, TX	NWS
7529	1/48 to 9/84	Refugio, TX	NWS
7704/7705	1/01 to 12/90	Rockport, TX	NWS
9892	8/16 to 7/64	Woodsboro, TX	NWS
41	10/62 to 12/90	Wesley Seale Dam	TWDB

study extends from 1934 to 1989. Artificial filling of the precipitation data was minimized by using the selected precipitation gages in each of five sub-periods identified in Table 6-3.

Once the precipitation records were filled and the sub-periods identified, the daily areal precipitation for each subwatershed was developed using the Thiessen polygon method. In this method, regions of influence for each precipitation gage are determined by a grid of the perpendicular bisectors of map lines connecting each gage. The ratio of the area of influence of a rainfall gage within a given subwatershed to the total area of the subwatershed is then used to weight the amount of areal precipitation that a gage contributes to the total areal precipitation for the subwatershed.

Table 6-3
Subperiods for Precipitation Data Estimation

Gage No./ID	Subperiod 1 1/34-5/47	Subperiod 2 6/47-6/50	Subperiod 3 7/50-6/64	Subperiod 4 7/64-12/76	Subperiod 5 1/77-12/89
3508/George West	■	■	■	■	■
639 Beeville	■	■	■	■	■
144/Alice	■		■	■	■
7677/Robstown			■	■	■
2015/CC (WSO AP)		■	■	■	■
8354/Sinton	■		■	■	■
2014/Corpus Christi	■	■	■	■	
1651/Chapman Ranch				■	■
5661/Mathis				■	
4810/Kingsville			■	■	■
7529/Refugio			■	■	
7704/7705/Rockport		■	■	■	■
9892/Woodsboro	■	■	■		
41/Wesley Seale Dam					■

■ Indicates this gage was used to develop areal precipitation in the subperiod.

6.3.2 Selection and Calibration of Rainfall Runoff Model for Subwatersheds

After developing daily areal precipitation data for the seven subwatersheds, a model was selected to convert the rainfall into runoff for the basin. The TWDB Rainfall-Runoff Model (TxRR) (Matsumoto, J., 1992) was selected. This selection was largely influenced by the past use of this model by the TWDB in studies of the bay and estuarine systems along the Texas coast, including the Nueces Estuary. The model was developed for estimating runoff in ungaged watersheds using the Soil Conservation Service (SCS) Curve Number Method (Soil Conservation Service, 1972) to estimate runoff from precipitation.[2] The model was calibrated to gaged streamflow and precipitation records, and then applied to nearby ungaged watersheds with minor adjustments made to the calibrated input parameters.

Of the seven subwatersheds considered, only Chiltipin Creek and Upper Oso Creek had streamflow gage records. The U.S. Geological Survey (USGS) streamflow gages (Chiltipin Creek at Sinton, Gage #08189800 and (Oso Creek at Corpus Christi, Gage #08211520 were used to calibrate the TxRR Model. Since the TxRR Model needs full year records of gage data, the sub-periods of 1971 to 1986 and 1973 to 1988 were used for the

[2]The SCS direct runoff equation is:

$$QD_t = P_{et}^2 / (P_{et} + S_t)$$

where QD_t is the direct runoff, P_{et} is the effective precipitation which is computed by

$$P_{et} = P_t - Ia_t$$

and the initial abstraction is computed by

$$Ia_t = abstl * S_t$$

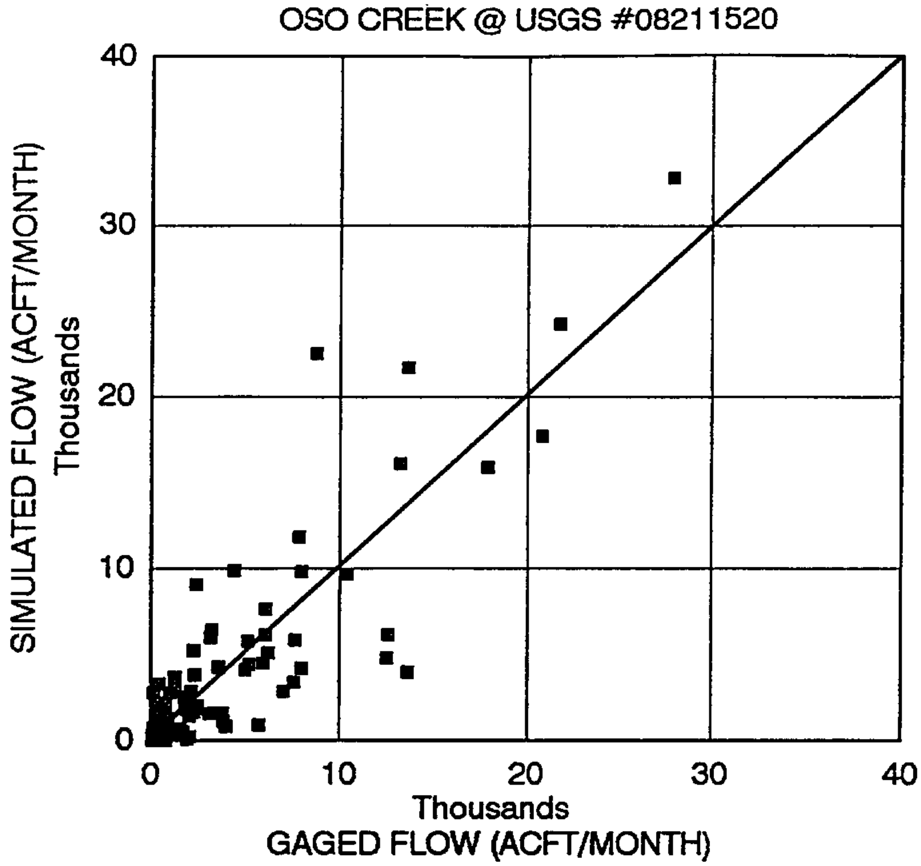
where *abstl* is the initial abstraction coefficient. Note that in the SCS's direct runoff equation, the initial abstraction is constant value of 0.2, but in the above equation the initial abstraction coefficient is treated as an input parameter.

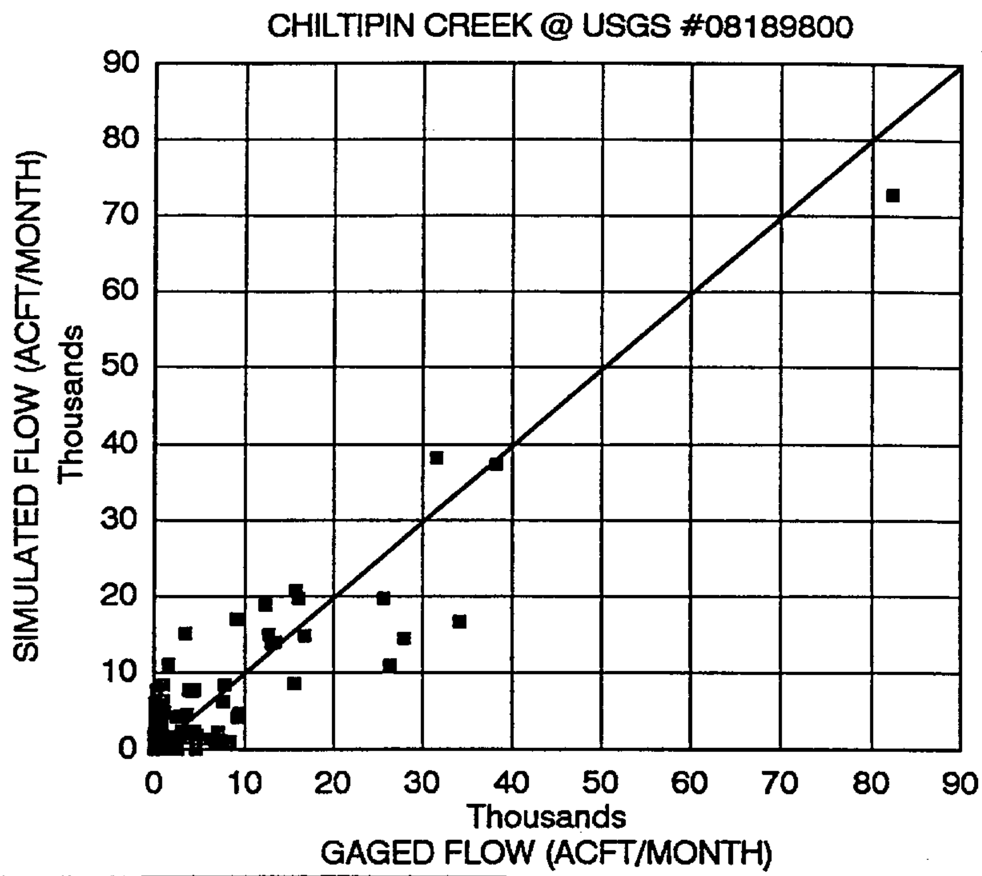
Chiltipin Creek and Oso Creek subwatersheds, respectively, as base calibration periods for the model.

The TxRR Model uses basin characteristics including drainage area, areal precipitation, soil cover complex, and runoff to optimize monthly depletion factors for a given maximum soil moisture. After the best monthly depletion factors were determined for the two calibration subwatersheds, monthly runoff was generated for the two periods of record in which gage data exists. Figure 6-2 presents simulated runoff plotted versus gaged runoff for the two watersheds. These graphs show that the simulated runoff closely matches the gaged runoff. Regressions were performed on the simulated data as a function of the gage data which showed that the slope of the resultant line was not significantly different from one. A slope of exactly one would indicate a perfect one-to-one relationship between gaged and simulated data.

6.3.3 Calculation of Monthly Ungaged Runoff

The calibration runs on Chiltipin and Oso Creeks produced two distinct sets of monthly depletion factors. In the TxRR Model, these depletion factors are optimized based on an assumed maximum soil moisture depth. This maximum soil moisture depth is related to the SCS curve number, and this relationship was used to decide which set of depletion factors should be used in the development of ungaged runoff in the selected subwatershed. Based on similarity of curve numbers, the Chiltipin Creek calibration depletion factors were used to simulate runoff in subwatersheds 1, 2, 3, 5, and 6 (referring to the watershed numbers Figure 6-1 and in Table 6-1), and the Oso Creek calibration depletion factors were





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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
TXRR MODEL SIMULATIONS VS. GAGED FLOW
FIGURE 6-2

used to simulate runoff in subwatersheds 4 and 7. The simulated runoff was then included in the Lower Nueces River Basin and Estuary Model that was modified for this study. Actual gaged flows were substituted into the simulated records for the Oso Creek and Chiltipin Creek subwatersheds, when such flows were available.

The simulation of flows below Wesley Seale Dam performed for this study resulted in an average annual runoff of approximately 81,225 acre-feet, which is approximately 12 percent of the average annual inflow to the Nueces Estuary. This average is approximately 0.04 percent greater than the runoff estimated by the TWDB and used in Phase I of the Nueces Estuary Regional Wastewater Planning Study. However, the estimates in this study differ significantly in the distribution of the runoff above and below Calallen Dam. The estimate of runoff above Calallen Dam calculated for this study was approximately 12,885 acre-feet per year for the 56 years simulated. The TWDB's estimate of this runoff was 18,430 acre-feet per year for the same period. Therefore, the estimates used in this study redistribute approximately 5,500 acre-feet per year, or approximately seven percent of the ungaged runoff annually, from above Calallen Dam to below the dam. This results in a slightly lower firm yield in the CC/LCC System because the system must release more water to satisfy water supply requirements at the Calallen diversion.

6.4 Gaging and Metering Station Considerations and Costs

This section presents considerations and costs for installation of stations to gage and meter:

1. Stormwater inflows into the Nueces River from the Calallen area downstream of the Calallen Dam; and

2. Diverted flows from areas in the Oso Creek Basin.

6.4.1 Typical Stream Gaging and Metering Station

Typical stream gaging and metering stations will include the following equipment:

1. Primary measuring device, which may be either a weir or flume.
2. Secondary measuring device for measuring the liquid level, which may be an ultrasonic sensor or pneumatic bubbler type stage sensing system with pressure transducer.
3. Electronic datalogger, which totalizes and records flows.
4. Power supply, typically consisting of a 12 volt battery with solar panel, due to remote locations of stations.
5. Field enclosure for electronic equipment.
6. Optional equipment might include a rain gage, typically a tipping bucket type which transmits a signal to the datalogger for recording rainfall, and telephone modem for communication with a control computer which could access all station data.

Depending upon the particular stormwater inflow, gauging and metering stations may be installed in open channels, box culverts or circular pipe culverts. The recommended primary measuring device for open channel and box culvert applications is a rectangular or V-notch weir plate. Palmer-Bowlus flumes are recommended for use in circular pipe culverts.

Weir installations will include a removable bulkhead with an opening beneath the notch to allow silt, sand, and other solid material accumulations to be sluiced as required. Weir plates will be constructed with steel or aluminum angle framing utilizing 1/4-inch or 3/8-inch steel or aluminum sheeting.

Palmer-Bowlus flumes will be fabricated with structural aluminum or steel skeletons assembled in place in the pipe, with the final shape made of a stiff mix of concrete poured without forms.

Costs for typical gaging and metering stations are summarized below.

	Equipment Required	Approximate Cost
1.	V-notch or rectangular weir plate (for box culvert or natural drainage channel)	$1000
2.	Pneumatic bubbler type stage sensing system with pressure transducer	$1000
3.	Electronic datalogger, and accessory equipment	$3500
4.	12-Volt batter with solar panel	$300
5.	Field enclosure	$800
6.	Rain gage (optional)	$700
7.	Modem (optional)	$400
	TOTAL COST	$7,700

6.4.2 Drainage Basins for Stormwater Inflows into the Nueces River from the Calallen Area Downstream of the Calallen Dam

The 13 ungaged basins which flow into the Nueces River from the Calallen area downstream of the Calallen Dam are shown on Figure 6-3. Basin boundaries are taken from the Master Plan for Storm Drainage for the Area West of Clarkwood Road and the Flour Bluff Area of the City of Corpus Christi, Texas, prepared by Naismith Engineering, Inc., dated 1970 (hereinafter referred to as the 1970 Master Plan) and are designated by the same letters used in the 1970 Master Plan (i.e., WC, WD, etc.). The 13 basins have a total drainage area of 5,510 acres (see list below). In addition, the 14,720-acre Hondo Creek watershed and the 67,840-acre Northshore watershed (WS-5 of Figure 6-1 and Table 6-1) are ungaged.


WB
WC
WD
WE
WF
WG
WH
WI
WJ
WK
WL
WM
WN
WO
WP
WQ
WR
WS
WT
WU
WV
CORPUS CHRISTI
ROBSTOWN
LEGEND
WY CALALLEN AREA INFLOWS
WZ OSO AREA DIVERSION
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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
STORMWATER INFLOWS CALALLEN AREA AND OSO CREEK DIVERSION
DRAINAGE BASINS
FIGURE 6-3
1"=4000'
T.L.
3488
0
3-93
G.A.B.

Locations of gauging and metering stations for each of the 13 drainage basins are described below:

Nueces River Drainage Basin WC
Area: Approximately 1020 acres
Gaging and metering station location:
Five 6 foot x 6 foot box culverts under IH 37 at its intersection with Sharpsburg Road and Up River Road.

Nueces River Drainage Basin WD
Area: Approximately 260 acres
Gaging and metering station location:
10 foot x 5 foot box culvert under IH 37 just east of Magee Lane

Nueces River Drainage Basin WE
Area: Approximately 180 acres
Gaging and metering station locations:
3 foot x 8 foot box culvert under Up River Road northeast of Crystal Lane.
2 foot x 4 foot box culvert under Up River Road between Rehfield Road and FM 1694

Nueces River Drainage Basin WF
Area: Approximately 130 acres
Gaging and metering station location:
72-inch diameter culvert under IH 37 between FM 1694 and Lum Hart Road, or
6 foot x 8 foot box culvert under Up River Road downstream from 72" diameter culvert

Nueces River Drainage Basin WG
Area: Approximately 540 acres
Gaging and metering station location:
7 foot x 7 foot box culvert under IH 37 just east of Lum Hart Road

Nueces River Drainage Basin WH
Area: Approximately 60 acres
Gaging and metering station location:
Two 4 foot x 6 foot box culverts under Up River Road just east of Lum Hart Road downstream from IH 37

Nueces River Drainage Basin WI
Area: Approximately 190 acres

Gaging and metering station location:

72" diameter culvert under IH 37 west of Violet Road and east of Lum Hart Road, or

6 foot x 9 foot box culvert under Up River Road west of Violet Road.

Nueces River Drainage Basin WJ

Area: Approximately 350 acres

Gaging and metering station locations:

Two 7 foot x 5 foot box culverts under IH 37 between McKenzie Road and Violet Road, or

Two 36-inch diameter culverts under unnamed road downstream from box culverts, or

18-inch diameter culvert under gravel road (Violet Road) north of Up River Road.

Nueces River Drainage Basin WK

Area: Approximately 70 acres

Gaging and metering station location:

Numerous small natural drainage swales downstream from IH 37

Nueces River Drainage Basin WL

Area: Approximately 250 acres

Gaging and metering station location:

Numerous small drainage swales downstream from IH 37

Nueces River Drainage Basin WM

Area: Approximately 410 acres

Gaging and metering station location:

10 foot x 6 foot box culvert under IH 37 west of Carbon Plant Road, or

Five 36-inch CMP culverts at unnamed road downstream from IH 37 between Rand Morgan Road and McKenzie Road

Nueces River Drainage Basin WN

Area: Approximately 150 acres

Gaging and metering station location:

Two 36-inch CMP culverts, 2 - 30-inch CMP culverts and numerous small natural drainage swales downstream from IH 37

Nueces River Drainage Basin WO

Area: Approximately 1900 acres

Gaging and metering station location:

Two 6 foot x 10 foot box culverts under Up River road at Turkey Creek, upstream from IH 37

It is estimated that more than 40 gages would be needed to measure runoff from Hondo Creek and the 13 drainage areas identified in Figure 6-3. At a cost of $7,700 per gage, total cost to install gages would be in excess of $315,700. Staffing and other costs for data retrieved and gage maintenance is estimated to be on the order of $60,000 to $80,000 per year. Since data are not available with which to estimate the number of gages needed for the 67,840-acre Northshore watershed, no cost estimates could be made for gaging this area. However, the number would clearly be several times that for the 13 southern drainage areas.

6.4.3 Drainage Basins for Diverted Flows from Areas in the Oso Creek Basin

Existing slopes in the Nueces River drainage basin are considerably steeper than those in the Oso Creek basin. In some instances, this situation may lend itself to an economical diversion of stormwater from the Oso Creek Basin to the Nueces River Basin. Drainage basins for diverted flows from areas in the Oso Creek Basin are shown on Figure 6-1. Basins are based on information from the 1970 Master Plan and are designated by the same letters used in the 1970 Master Plan.

The 1970 Master Plan references a contractual provision that was made between the City of Corpus Christi and the Texas Department of Transportation prior to construction of IH 37 which allowed for ultimate diversion of storm runoff from the upper portions of the Oso Creek Basin into the Nueces River Basin. The capacities of drainage structures under the alignment of IH 37 were increased to permit such diversions.

Design flows were calculated in the 1970 Master Plan and conveyance infrastructure was sized and laid out as the initial step towards possible implementation of these diversions. Infrastructure included circular conduits ranging in size from 48-inch to 132-inch and natural channel improvements (concrete lining, drop structures, erosion control, etc.).

The construction costs of conveyance infrastructure required for diversions were prepared by performing a quantity takeoff on the layout presented in the 1970 Master Plan and applying 1993 cost estimates. Due to the preliminary nature of these takeoffs and costs, a 35 percent contingency is included in the total project costs. Table 6-4 presents cost summaries for infrastructure required to divert flows from several areas in the Oso Creek Basin to the Nueces River Basin. The total estimated cost for structures to divert storm water from Oso Watersheds WS, WP, WQ, WR, WV, and WT (Figure 6-3) is $19,958,000 (Table 6-4).

If the diversion plan is determined to be feasible and implementation moves forward, a trans-basin permit will be required from the TWC. Estimated permitting time ranges from six months to one year.

6.5 Cost Estimates of Diversion And Detention of Stormwater For Controlled Release To Nueces Delta And/Or Nueces Bay

Cost estimates were prepared for the following alternatives for diversion and for detention of stormwater for controlled release to the Nueces Delta and/or Nueces Bay:

1. Open channel diversion for stormwater in Peters Swale near the City of Odem. In addition, this section presents costs for a closed conduit diversion of wastewater effluent in Peters Swale.

2. Pump station and pipeline facilities for diverting stormwater from Hondo Creek south of the Community of Edroy.

Table 6-4
Cost Estimate
Oso Creek Drainage Basin Diversion

Diversion of Oso Creek Drainage Basin WP (adds approximately 220 acres to Nueces River Basin WC, for a total of approximately 1,240 acres)*

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	90" RCP**	LF	600	$231.00	$ 138,600
2.	84" RCP	LF	1,000	200.00	200,000
3.	72" RCP	LF	2,000	135.00	270,000
4.	96" RCP	LF	2,000	269.00	538,000
5.	84" RCP	LF	4,800	200.00	960,000
	Sub-total				$2,106,600
	Contingency (35 percent - See note 1)				$ 737,300
	TOTAL ESTIMATED PROJECT COST				$2,843,900
	TOTAL YEARLY COSTS******				$ 312,829

Diversion of Oso Creek Drainage Basin WQ (adds approximately 400 acres to Nueces River Drainage Basin WG, for a total of approximately 940 acres)***

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	108" RCP	LF	1,050	$346.00	$ 363,300
2.	96" RCP	LF	5,900	269.00	1,587,100
3.	72" RCP	LF	3,100	135.00	418,500
	Sub-Total				$2,368,900
	Contingency (35 percent - See note 1)				$ 829,100
	TOTAL ESTIMATED PROJECT COST				$3,198,000
	TOTAL YEARLY COSTS******				$ 351,780

*No structures are needed for Nueces River Basin WC area.
**RCP = Reinforced Concrete Pipe
***No structures are needed for Nueces River Drainage Basin WG.
****Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

Table 6-4 (cont)
Cost Estimate
Oso Creek Drainage Basin Diversion

Diversion of Oso Creek Drainage Basin WR (adds approximately 570 acres to Nueces River Drainage Basin WO, for a total of approximately 2,470 acres)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	120" RCP	LF	2,100	$425.00	$892,500
2.	108" RCP	LF	2,600	346.00	899,600
3.	96" RCP	LF	1,700	269.00	457,300
4.	60" RCP	LF	1,700	95.00	161,500
5.	48" RCP	LF	1,800	69.00	124,200
6.	132" RCP	LF	1,600	530.00	848,000
7.	Channel Excavation	CY	90,000	1.60	144,000
8.	Concrete Lining	CY	4,300	200.00	860,000
	Sub-Total				$4,387,100
	Contingency (35 percent - see note 1)				$1,535,500
	TOTAL ESTIMATED PROJECT COST				$5,922,600
	TOTAL YEARLY COSTS*				$ 651,486

Diversion of Oso Creek Drainage Basin WT (adds approximately 910 acres to Nueces River Drainage Basin WU, for a total of approximately 1,050 acres)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	102" RCP	LF	1,200	$400.00	$480,000
2.	96" RCP	LF	1,600	269.00	430,400
3.	78" RCP	LF	900	173.00	155,700
4.	60" RCP	LF	1,000	95.00	95,000
	Sub-Total				$1,161,100
	Contingency (35 percent - see note 1)				406,400
	TOTAL ESTIMATED PROJECT COST				$1,567,500
	TOTAL YEARLY COSTS*				$ 172,425

*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

Table 6-4 (cont)
Cost Estimate
Oso Creek Drainage Basin Diversion

Diversion of Oso Creek Drainage Basin WT (adds approximately 677 acres)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Excavation	CY	150,000	$ 1.60	$ 240,000
2.	Concrete Lining	CY	5,600	200.00	1,120,000
	Sub-Total				$1,360,000
	Contingency (35 percent - see note 1)				476,000
	TOTAL ESTIMATED PROJECT COST				$1,836,000
	TOTAL YEARLY COSTS*				$ 221,960

Diversion of Oso Creek Drainage Basin WS (adds approximately 12,800 acres)

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Excavation	CY	500,000	$1.60	$ 800,000
2.	Concrete Lining	CY	13,000	200.00	2,600,000
	Sub-Total				$3,400,000
	Contingency (35 percent - see notes 1 & 2)				$1,190,000
	TOTAL ESTIMATED PROJECT COST				$4,590,000
	TOTAL YEARLY COSTS				$ 504,907
	TOTAL AREA FOR ALL SUBWATERSHEDS				15,577 ACRES
	TOTAL PROJECT COST				$19,958,000
	TOTAL YEARLY COSTS*				$2,195,380

Note 1 - Includes construction contingency plus an allowance for engineering, surveying, geotechnical, and permitting.
Note 2 - Does not include cost for stormwater detention facility, improvements to existing drainage structures under IH 37 or easement/ROW acquisition.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

6.5.1 Peters Swale Stormwater Diversion

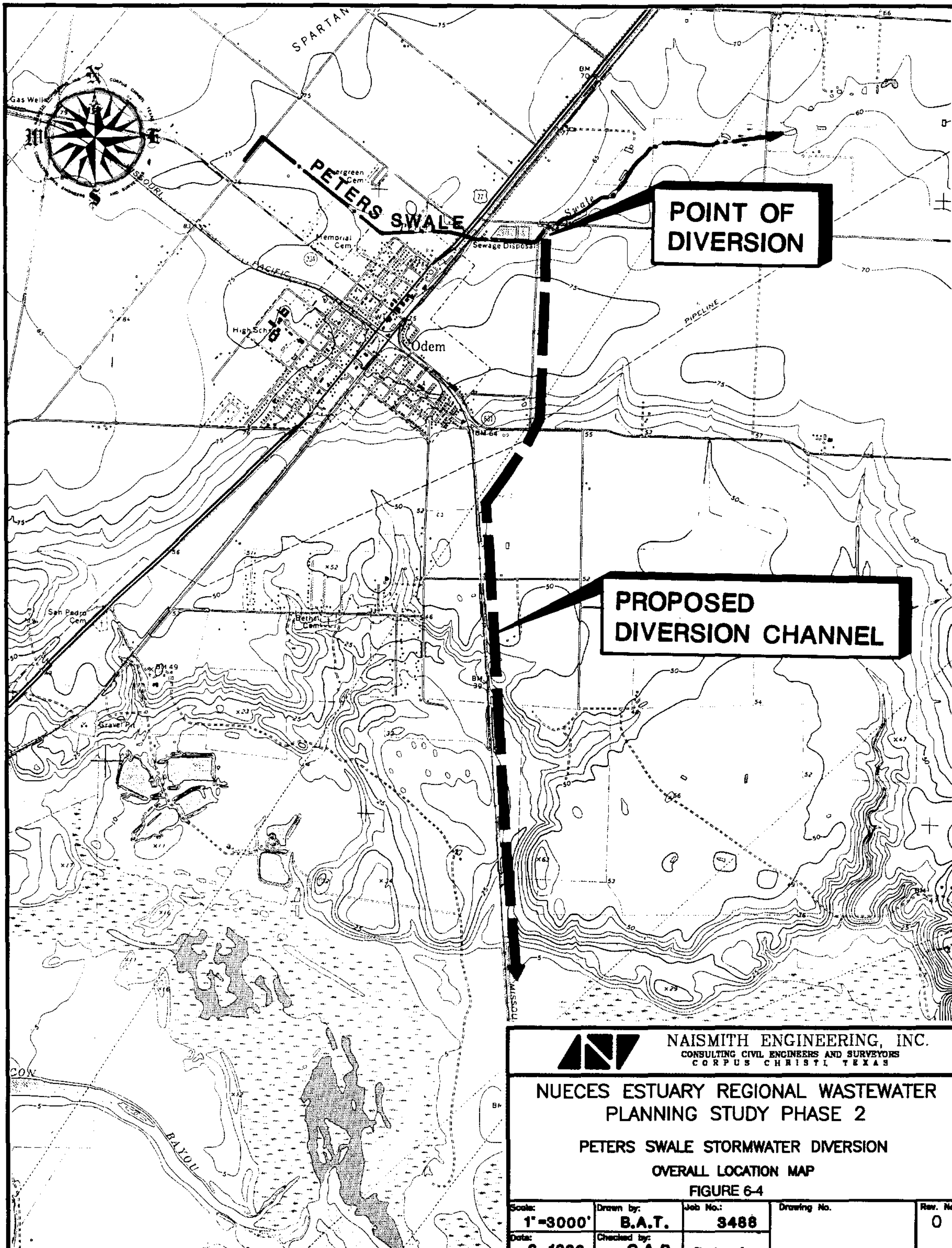
The 1987 San Patricio County Flood Control Study (hereinafter referred to as the 1987 Study) recommended, as one of the flood control alternatives, construction of a flood control diversion channel originating at Peters Swale upstream of County Road (CR) 42 and proceeding southward paralleling the Missouri Pacific Railroad to outfall at Nueces Bay. Routing of the diversion channel is shown in Figure 6-4.

The 1987 Study recommended a channel cross section with 75' bottom width and 3:1 side slopes in a 300' ROW. The channel was sized to convey the 100-year design discharge of 6760 cubic feet per second (cfs). Structural improvements required by channel construction included a bridge structure at Highway 631, two county road bridges (CR 51 and CR 64), a low water crossing, and an outfall structure.

For purposes of this study, it was assumed that the full channel section would be constructed to divert stormwater flows. Diversion channel costs presented in the 1987 Study were updated from 1987 to 1993 by inflating the costs at a rate of five percent per year. Capital costs are estimated at $6.4 million, with annual costs of $703,890 (Table 6-5).

Factors which will need to be evaluated further if this alternative is selected for additional study and design include:

- Right-of-way or easement acquisition;
- Pipeline crossings;
- Environmental constraints, such as endangered or threatened species, sensitive habitat, etc.;
- Potential impact on archaeological resources; and
- Permitting requirements.



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PETERS SWALE STORMWATER DIVERSION

OVERALL LOCATION MAP

FIGURE 6-4

Scale:	Drawn by:	Job No.:	Drawing No.	Rev. No.
1"=3000'	B.A.T.	3488		0
Date: 3-1993	Checked by: G.A.B.	Sheet__of__		

Table 6-5 Cost Estimate Peters Swale Stormwater Diversion					
Item	**Description**	**Unit**	**Approx. Quantity**	**Unit Price**	**Total Amount**
1.	Excavation & Disposal	CY	1,800,000	$ 1.60	$2,800,000
2.	Clear & Grub	Acre	45	450.00	20,000
3.	Vegetation Establishment	Acre	140	2,000.00	280,000
4.	CR 51 Bridge Structure	SF	3,510	52.00	183,000
5.	Hwy 631 Bridge Structure	SF	8,970	65.00	583,000
6.	CR 64 Bridge Structure	SF	5,070	52.00	264,000
7.	Low Water Crossing	LS	1	100,000.00	100,000
8.	Outfall Structure	LS	1	130,000.00	130,000
9.	Right-of-Way	Acre	150	2,000.00	300,000
	Sub-total				$4,740,000
	Contingency (35 percent - See note 1)				$1,659,000
	TOTAL ESTIMATED PROJECT COST				$6,399,000
	TOTAL YEARLY COST				$ 703,890

Presently, the City of Odem, San Patricio Commissioners Court, and San Patricio County Drainage District are pursuing flood control alternatives in Odem which eliminate the need for the Peters Swale project by constructing other channel and structural improvements. The Peters Swale alternative was abandoned for economic reasons. Additionally, such a diversion would require a trans-basin permit from TWC, a process which is estimated to take 12 months to complete.

This Phase II Study also identified an alternative diversion which involves existing wastewater effluent flow in Peters Swale. The City of Odem is currently permitted for discharge of approximately 173,000 GPD (i.e., 193.78 acre-feet/yr) of effluent into Peters Swale in the vicinity of the previously discussed channel diversion. This alternative proposes to extend the treatment plant's discharge line southward along the routing of the channel diversion to an outfall in the estuary. Approximately 18,000 LF of 8-inch PVC sewer outfall is proposed. Cost of this alternative is shown in Table 6-6. An amendment to the City of Odem's waste discharge permit will be required for this diversion.

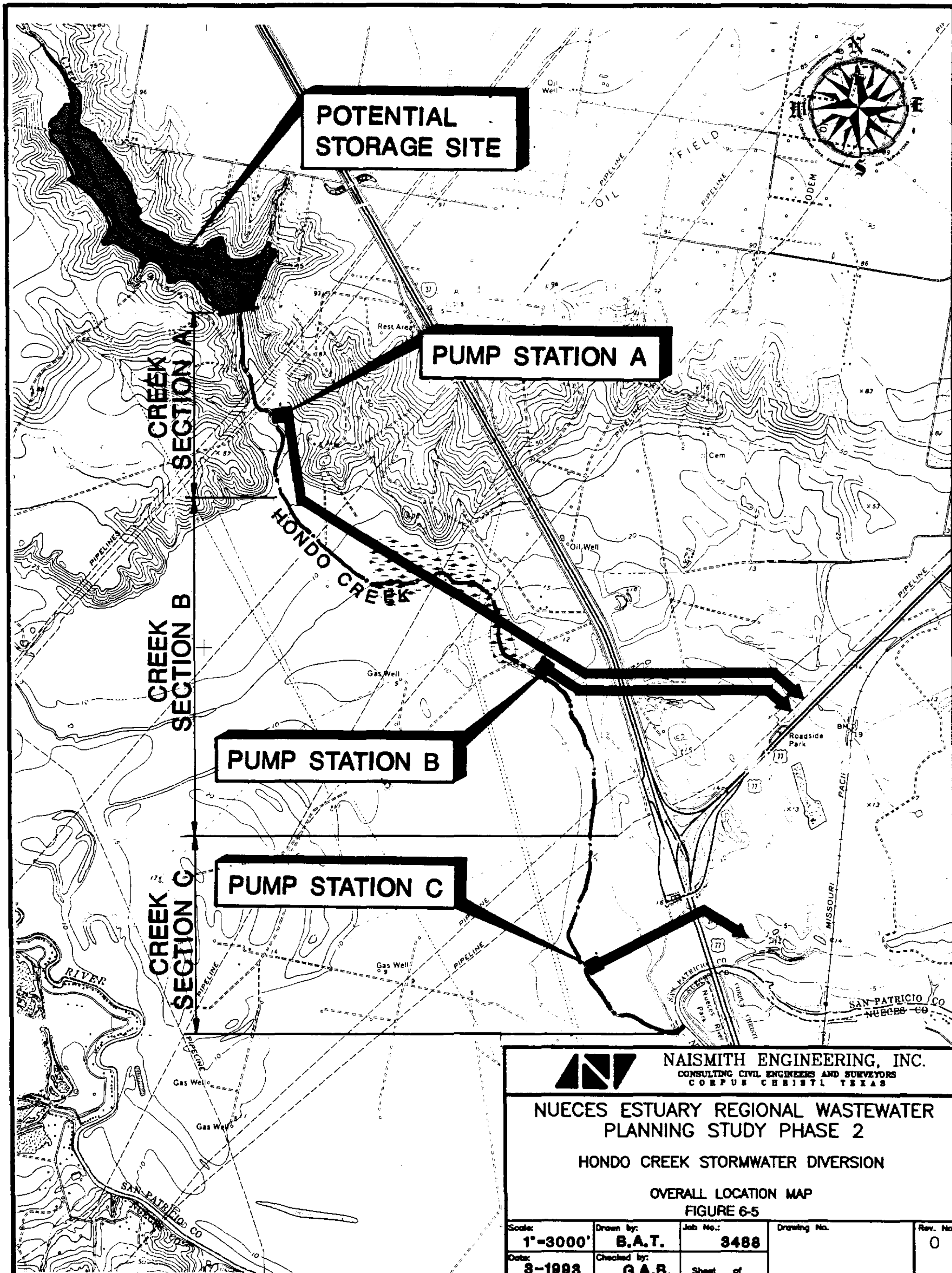
Table 6-6
Cost Estimate
Peters Swale Alternative Effluent Diversion

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	8" PVC Gravity Main	LF	18,000	$ 20.00	$360,000
2.	Manhole	Ea.	26	1,500.00	39,000
	Sub-total				$399,000
	Contingency (35 percent - See note 1)				$140,000
	TOTAL ESTIMATED PROJECT COST				$539,000
	TOTAL YEARLY COSTS*				$ 59,290

Note 1 - Includes construction contingency plus an allowance for engineering, surveying, geotechnical, permitting, and project start-up.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

6.5.2 Hondo Creek Storage and Diversion to Nueces Delta

This section presents a discussion of stormwater pump station and transmission pipeline facilities required for diversion of Hondo Creek stormwater through controlled release to the Nueces Delta. Reservoir facilities associated with diversion of Hondo Creek are described in previous sections of this study. Proposed reservoir, pump station, and pipeline locations are shown in Figure 6-5, and a conceptual plan for a typical creek pump station is shown in Figure 6-6. Alternative pump station locations and pipeline routings


POTENTIAL STORAGE SITE
PUMP STATION A
PUMP STATION B
PUMP STATION C
CREEK SECTION A
CREEK SECTION B
CREEK SECTION C
HONDO CREEK
OIL FIELD
ODEM
RIVER
SAN PATRICIO CO
NUECES CO
Roadside Park
Rest Area
Gas Well
Oil Well
Cem
PIPELINE
MISSOURI PACIFIC
NAISMITH ENGINEERING, INC.
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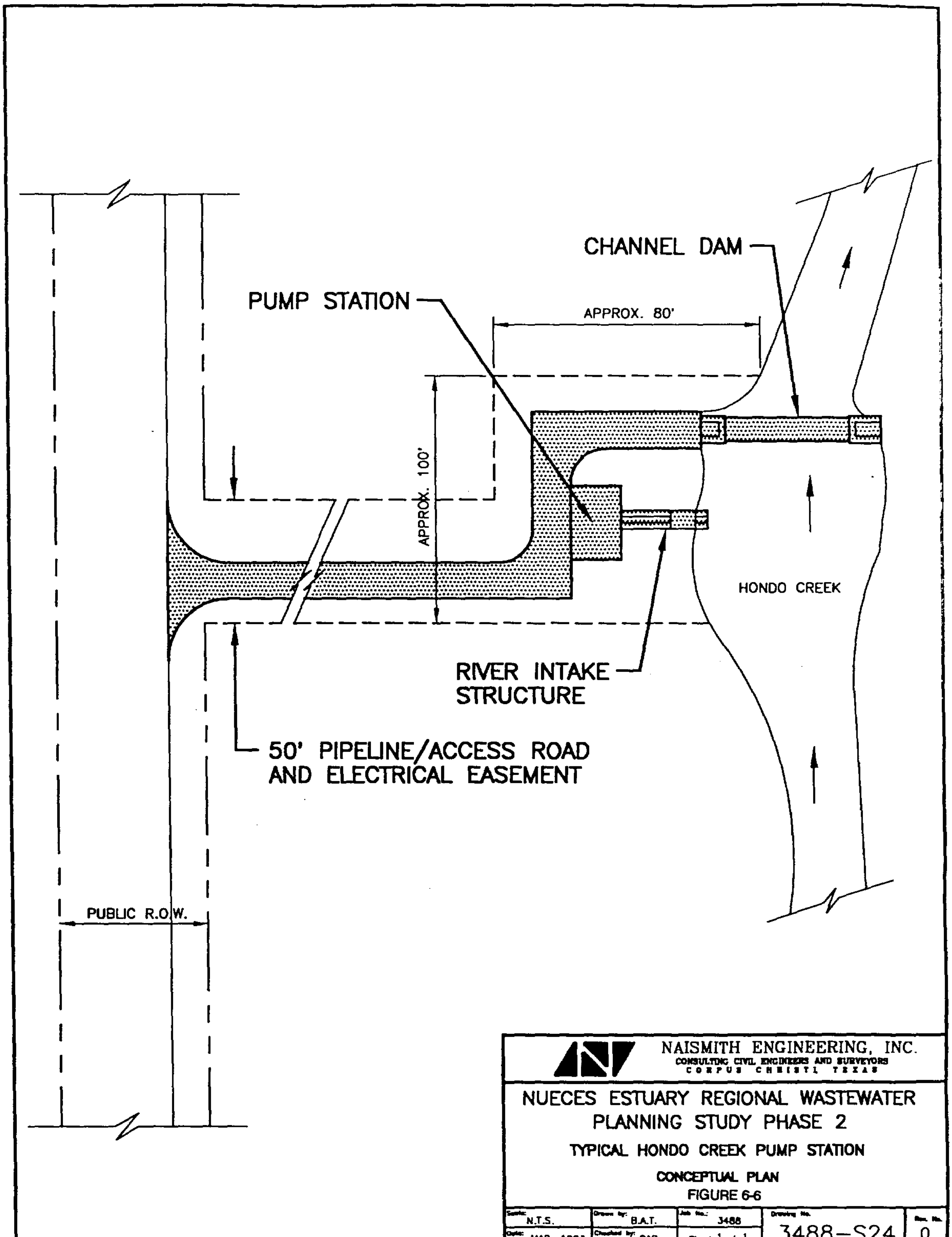
CORPUS CHRISTI TEXAS
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
HONDO CREEK STORMWATER DIVERSION
OVERALL LOCATION MAP
FIGURE 6-5
Scale: 1"=3000'
Drawn by: B.A.T.
Job No.: 3488
Drawing No.
Rev. No. 0
Date: 3-1993
Checked by: G.A.B.
Sheet ___ of ___


CHANNEL DAM
PUMP STATION
APPROX. 80'
APPROX. 100'
HONDO CREEK
RIVER INTAKE STRUCTURE
50' PIPELINE/ACCESS ROAD AND ELECTRICAL EASEMENT
PUBLIC R.O.W.
NAISMITH ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI TEXAS
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
TYPICAL HONDO CREEK PUMP STATION
CONCEPTUAL PLAN
FIGURE 6-6
Scale: N.T.S.
Date: MAR. 1993
Drawn by: B.A.T.
Checked by: CAB
Job No.: 3488
Sheet 1 of 1
Drawing No. 3488-S24
Rev. No. 0

were evaluated to determine the most feasible and cost-effective facilities. Topography shown on USGS quadrangle sheets was utilized for conceptual planning purposes.

The dam would be located across Hondo Creek, south of the community of Edroy. Reservoir water surface would be controlled at approximately elevation 50 feet MSL. Three downstream locations were evaluated for locations of possible creek pump stations and the least expensive is discussed in the following section of this report. Cost estimates of the Hondo Creek Dam and a 5 mgd well to augment the reservoir storage are presented in Table 6-7.

6.5.2.1 Creek Pump Station A

Referring to Figure 6-5, it is observed that the existing Hondo Creek flow is contained within relatively well-defined banks for approximately 4,500 feet downstream from the dam structure (this section is designated as Creek Section A). Alternative Pump Station A is located within this section, approximately 3,000 feet downstream from the dam structure. For purposes of this cost estimate, it is assumed that a creek pump station will include a channel dam on Hondo Creek, intake structure with bar racks, and intake pipeline to the pump station. Pumps will be either horizontal centrifugal or vertical turbine types. From Pump Station A, a discharge pipeline will be routed in a southerly direction, roughly paralleling Hondo Creek to a point approximately 4,000 feet north of the IH 37 - US 77 highway interchange. The routing will turn eastward, with a bore under IH 37 to a discharge structure in the upper reaches of Rincon Bayou just north of US 77. Total pipeline length is approximately 16,000 feet.

Table 6-7
Cost Estimate
Hondo Creek Dam and 5.0 mgd Well

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Embankment Dam	LS	1	$960,000.00	$ 960,000
2.	Relocations (four structures shown on USGS topo map near Edroy)	LS	1	200,000.00	200,000
	Sub-total				$1,160,000
	Contingency (35 percent - See note 1)				$ 406,000
	TOTAL ESTIMATED CONSTRUCTION COST				**$1,566,000**
	Land (see note 2)				$ 458,000
	Power Line Relocation				(Note 3)
	TOTAL PROJECT CAPITAL COSTS				**$2,024,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$202,400
	Operations & Maintenance				$20,200
	TOTAL YEARLY COSTS FOR DAM*				**$222,600+**
1.	5 mgd well	LS	1	$700,000.00	$700,000
	Contingency (35 percent - See note 1)				$245,000
	TOTAL PROJECT CAPITAL COSTS				**$945,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$ 94,500
	Operations & Maintenance				$ 9,500
	Power Costs				$ 98,000
	TOTAL YEARLY COSTS FOR WELL*				**$202,000+**

Note 1 - Includes construction contingency plus an allowance for engineering, surveying, geotechnical, and permitting.
Note 2 - Based on purchasing land to top of dam elevation 70 ft-msl using $750/acre.
Note 3 - Power line relocation cost estimate was not calculated. Approximately 2.2 miles of power line will require relocation. The cost will depend on the type of power line present.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

6.5.2.2 Creek Pump Station B

Hondo Creek Section B is located approximately 14,000 feet downstream from Creek Section A (Figure 6-5). This section flows through a relatively flat, marshy area where the flow is generally not confined to a distinct creek bed but appears to spread over a wide area. However, a small length of creek in this section is contained within a distinct bed for approximately 2,000 feet prior to spreading into a wide flow area. Alternative Pump Station B is located within this section and is similar in concept to Pump Station A. From Pump Station B, a discharge pipeline would be routed eastward, with a bore under IH 37 to a discharge structure in the upper reaches of Rincon Bayou just north of US 77. Total pipeline length is approximately 6,000 feet.

6.5.2.3 Hondo Creek Pump Station C

A distinct creek bed is apparent within the final 6,000 feet of Hondo Creek, which is designated as Creek Section C (Figure 6-5). Pump Station C is similar in concept to Pump Stations A and B and is located approximately 3,000 feet upstream from Hondo Creek's confluence with the Nueces River. The pipeline would be routed eastward, crossing under the elevated portion of IH 37 immediately north of the Nueces River to a discharge structure in Rincon Bayou approximately 1,500 feet east of IH 37. Total length of pipeline is approximately 4500 feet.

Factors which will need to be further evaluated if one of these alternatives is selected for additional study and design include:

- Land requirements for intake and pump station site;

- Operation and control of facilities;
- Maintenance considerations;
- Number and type of pumping units;
- Roadway access to pump station;
- Electrical service to pump station;
- Environmental constraints, such as endangered or threatened species, and sensitive habitat;
- Potential impact on archaeological resources;
- Permitting requirements;
- Other pipeline crossings;
- Roadway crossings;
- Geotechnical factors;
- Hydrology of the creek; and
- Required channel improvements;

Implementation of the project will require a water rights permit for the reservoir, which is estimated to require a minimum one-year time frame.

6.5.2.4 Hondo Creek Pump Station and Pipeline Costs

Initial capital costs and annual power costs were determined for the three alternative pump station locations and pipeline routings for pumping rates of 2 mgd and 20 mgd (Table 6-8). Pipeline sizes for these pumping rates are 12 inches and 30 inches, respectively.

Due to the length of pipeline required, Creek Pump Station C at an annual cost of $43.4 thousand for a 2.0 mgd facility or $169.8 thousand for a 20 mgd capacity facility is the least costly of the three alternatives. If Hondo Creek diversion is determined to be feasible, it is recommended that Creek Pump Station C be further evaluated. However, it is possible that further evaluation would discover constraints which would rule out construction at the location shown. In that case, one of the other two pump station sites (or an additional site not identified in this study) would need to be evaluated.

6.6 Stormwater Diversion Alternatives and Summary of Impacts on CC/LCC System Yield

As previously stated, four alternatives were evaluated for diversion of stormwater runoff from three watersheds to various discharge locations within the Nueces Estuary. These alternatives included diversion of stormwater from the adjacent Oso and Chiltipin Basins and the storage and later release of storm runoff from Hondo Creek. The modified Lower Nueces River Basin and Estuary Model (NUBAY2) was used to study the impacts of these stormwater diversions on the CC/LCC System yield. The four alternatives and their impacts on the system yield are described in the following paragraphs.

6.6.1 Upper Oso Creek Diversion, Alternative SW-1

Alternative SW-1 involves the diversion of stormwater from the Upper Oso Creek drainage basin into the Nueces River and eventually into the bay. The drainage area considered for diversion encompasses approximately 20.3 square miles of the headwaters of Oso Creek near Robstown. This alternative was identified in the recently completed Stormwater Master Plan prepared for the City of Corpus Christi and involves redirection of stormwater runoff via a channel cut from the existing Ditch "A" at State Highway 77 to

Table 6-8
Cost Estimate

Hondo Creek Pump Station A - 2 mgd Capacity

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Dam	LS	1	$25,000.00	$ 25,000
2.	Intake Structure & Pump	LS	1	80,000.00	80,000
3.	Station	LF	16,000	30.00	480,000
4.	12" PVC Pipeline	LS	1	5,000.00	5,000
	Discharge Structure				
	Sub-total				$590,000
	Contingency (35 percent - See note 1)				$206,500
	TOTAL PROJECT CAPITAL COSTS				**$796,500**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$79,700
	Operation and Maintenance				$8,000
	Power Costs				$13,000
	TOTAL YEARLY COSTS*				**$100,700**

Hondo Creek Pump Station A - 20 mgd Capacity

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Dam	LS	1	$25,000.00	$ 25,000
2.	Intake Structure & Pump	LS	1	550,000.00	550,000
3.	Station	LF	16,000	50.00	800,000
4.	30" PVC Pipeline	LS	1	7,000.00	7,000
	Discharge Structure				
	Sub-Total				$1,382,000
	Contingency (35 percent - See note 1)				484,000
	TOTAL PROJECT CAPITAL COSTS				**$1,866,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$ 186,600
	Operation and Maintenance				$ 19,000
	Power Costs				$ 98,000
	TOTAL YEARLY COSTS*				**$303,600**

*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

Table 6-8 (cont)
Cost Estimate

Hondo Creek Pump Station B - 2 mgd Capacity

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Dam	LS	1	$25,000.00	$25,000
2.	Intake Structure & Pump	LS	1	80,000.00	80,000
3.	Station	LF	6,000	30.00	180,000
4.	12" PVC Pipeline	LS	1	5,000.00	$ 5,000
	Discharge Structure				
	Sub-Total				$290,000
	Contingency (35 percent - see note 1)				$ 102,500
	TOTAL PROJECT CAPITAL COSTS				**$ 391,500**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$ 39,000
	Operation and Maintenance				$ 3,900
	Power Costs				$ 7,000
	TOTAL YEARLY COSTS*				**$ 49,900**

Hondo Creek Pump Station B - 20 mgd Capacity

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Dam	LS	1	$25,000.00	$ 25,000
2.	Intake Structure & Pump	LS	1	550,000.00	550,000
3.	Station		6,000	50.00	300,000
4.	30" Pipeline	LF	1	7,000.00	7,000
	Discharge Structure	LS			
	Sub-Total				$ 882,000
	Contingency (35 percent - see note 1)				$ 309,000
	TOTAL PROJECT CAPITAL COSTS				**$ 1,191,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				$ 119,100
	Operation and Maintenance				$ 11,900
	Power Costs				$ 43,000
	TOTAL YEARLY COSTS*				**$ 174,000**

*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

Table 6-8 (cont)
Cost Estimate

Hondo Creek Pump Station C - 2 mgd Capacity

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel Dam	LS	1	$25,000.00	$ 25,000
2.	Intake Structure & Pump	LS	1	80,000.00	80,000
3.	Station				
4.	12" PVC Pipeline	LF	4,500	30.00	135,000
	Discharge Structure	LS	1	5,000.00	5,000
	Sub-Total				$ 245,000
	Contingency (35 percent - see note 1)				86,000
	TOTAL PROJECT CAPITAL COSTS				**$ 331,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				33,100
	Operation and Maintenance				3,300
	Power Costs				7,000
	TOTAL YEARLY COSTS*				**$43,400**

Hondo Creek Pump Station C - 20 mgd Capacity

Item	Description	Unit	Approx. Quantity	Unit Price	Total Amount
1.	Channel dam	LS	1	$25,000	$ 25,000
2.	Intake structure & pump station	LS	1	550,000	550,000
3.	30" pipeline	LF	4,500	50	200,000
4.	Discharge structure	LS	1	7,000	7,000
	Sub-Total				$ 807,000
	Contingency (35 percent - see note 1)				282,000
	TOTAL PROJECT CAPITAL COSTS				**$1,089,000**
	AMORTIZED COSTS (PER YEAR)				
	Debt Service				108,900
	Operation and Maintenance				10,900
	Power Costs				50,000
	TOTAL YEARLY COSTS*				**$169,800**

Note 1 - Includes construction contingency plus an allowance for engineering, surveying, geotechnical, permitting, and project startup. Does not include easement/ROW acquisition.
*Debt service calculated at 10 percent of capital costs; operations and maintenance calculated at one percent of capital costs; and power costs calculated at $0.05 per kilowatt hour.

the Nueces River in the vicinity of the CP&L power plant. This alternative resulted in a 227 acre-feet per year increase in the firm yield of the CC/LCC System operating under the TWC Interim Order and assuming a productivity factor of one. This productivity factor is representative of water discharged directly into Nueces Bay. The capital cost of this project is estimated at $4.59 million, with an annual debt service and O&M cost of $504,900. The cost per acre-foot of yield restored by this project would be $2,224.

6.6.2 Peters Swale Diversion, Alternative SW-2

Alternative SW-2 involves the diversion of stormwater runoff from a tributary of Chiltipin Creek named Peters Swale near Odem, Texas, to the Nueces Delta. The area considered for diversion is approximately 16.4 square miles upstream of San Patricio County Road 42. In this alternative, the Peters Swale runoff would be exported to the Nueces Delta through an excavated earthen channel. In addition to enhancement of inflows to the Nueces Estuary, diversion of Peters Swale could result in reduced flooding in both Odem and Sinton according to a Flood Control Study prepared for the San Patricio County Drainage District (Naismith Engineers, 1987). Diversion of the Peters Swale watershed would reduce the contributing drainage area of Copano Bay by less than one percent with no significant impact on the Copano Bay inflows. This alternative would restore 1,737 acre-feet per year of the system yield that is lost when the system is operated under the Interim Order procedures. A productivity factor of three was assumed for fresh water discharged to the Delta. This option is shown in Figure 6-4. Capital costs for the Peters Swale diversion with a 2.0 mgd pumping facility were estimated at $6.7 million with annual debt service, O&M,

and power costs of $738 thousand. Cost per acre-foot of CC/LCC System yield restored would be $425 to $484, depending upon pump station size (Table 6-5).

6.6.3 Hondo Creek Diversion, Alternative SW-3

Alternative SW-3 involves the construction of a small dam and reservoir on Hondo Creek approximately 4.5 miles upstream of its confluence with the Nueces River. The proposed reservoir would have a conservation capacity of 4,480 acre-feet and impound runoff from approximately 63 percent of the Hondo Creek drainage basin. Impounded stormwater would be diverted to the Nueces Delta at a fixed rate of 5 mgd whenever such water is available. Options of direct and indirect diversion from the Hondo Creek Reservoir to the Nueces Delta via a pipeline and via release down Hondo Creek to a pump station and discharge line located near the Nueces River confluence have been considered in this study. This alternative was simulated using NUBAY2 and resulted in an increase of 224 acre-feet per year on the system yield. A productivity factor of three was used since this diversion involves fresh water to the Nueces Delta. This option is shown in Figure 6-5. Capital costs for the dam, reservoir, and a 2.0 mgd pumping facility are $2.36 million with an annual cost of $266,000. Cost per acre-foot of CC/LCC System yield restored is $1,187 (Tables 6-7 and 6-8).

6.6.4 Hondo Creek Diversion with Pumpage, Alternative SW-4

Alternative SW-4 involves construction of the same dam and reservoir described as Alternative SW-3. However, in this option, reservoir storage would be augmented by groundwater supplied at a fixed rate of 5 mgd from a well that would be drilled near the proposed reservoir. In this alternative, water would be released from storage only in the months of May, June, September, and October. These four months have the highest Nueces Bay inflow requirements under the Interim Order. This alternative resulted in an increase of 6,234 acre-feet per year on the firm yield of the system. As with Alternative SW-3, a productivity factor of three was used, representing fresh water delivered to the Delta. This option is also presented in Figure 6-5. Capital cost of this option is $4.06 million, with an annual cost of $594,400 for the dam, reservoir, and 20 mgd pumping facility. Cost per acre-foot of yield restored is estimated at $96. However, it is not clear that the necessary 5.0 mgd well can be developed (see Section 7.0). Thus, this option may not be possible (Tables 6-7 and 6-8).

6.7 Estimation of Estuarine Inflow Credits for Ungaged Runoff

As mentioned in Section 6.3, the TWC Interim Order of March 9, 1992 allows for flows passing Calallen Dam as well as other presently ungaged volumes of stormwater runoff entering Nueces Bay to be credited towards the inflow requirements. Therefore, quantification of the ungaged flows is important to the accounting of flows for the purpose of meeting the conditions of the TWC order. As illustrated in the following discussion, these ungaged flows can be estimated using a daily simulation model calibrated to nearby gaged watersheds. A mathematical function has been developed which relates ungaged runoff entering Nueces Bay to precipitation at two key stations.

Regression analyses were performed in order to develop an equation relating watershed runoff to selected precipitation gage measurements. The simulated ungaged runoff was obtained from the TWDB TxRR Model for watersheds 2 and 5 (for a description of the watersheds, refer to Table 6-1). The combined monthly runoff for these subwatersheds was used as the dependent variable in the regression. These subwatersheds encompass Hondo Creek and the Nueces River and Bay Basins from Calallen Dam to the causeway. The independent variable in these analyses is the average of the monthly precipitation levels reported at National Weather Service Gage No. 2015 (Corpus Christi WSO AP) and Gage No. 8354 (Sinton). The Sinton precipitation gage has a short period of missing record; therefore, the data used in the regression analyses were monthly rainfall and runoff from July 1950 to April 1985 and May 1989 to December 1990. A few other months throughout the period were omitted from the analyses due to incomplete monthly records at one of the precipitation gages.

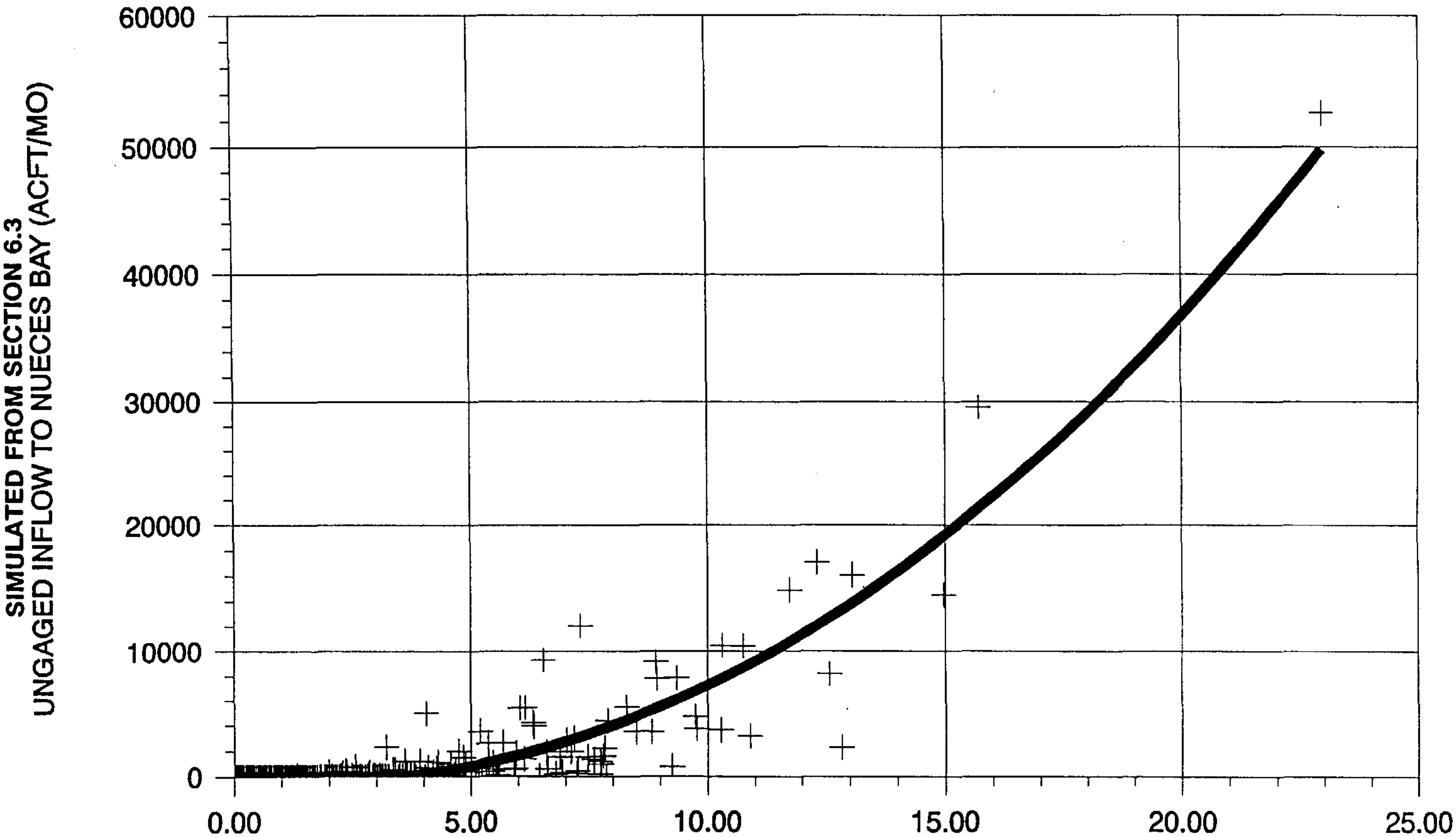
By the visual inspection of the plotted data, it appeared that the rainfall and runoff data could be related in a quadratic form. Regression analyses resulted in the following functional relationship:

$$R_{ungaged} = -393.27 * P_{avg} + 111.66 * P_{avg}^2 \text{ for } 3.52 \text{ inches} \le P_{avg} \le 22.96 \text{ inches}$$

where:

$R_{ungaged}$ = Ungaged inflow to Nueces Bay (acre-feet/month)
P_{avg} = Average precipitation at Corpus Christi WSO AP and Sinton (inches/month)

The coefficient of determination (R^2) for this equation is 0.86, indicating that 86 percent of the variability in the ungaged runoff values is explained by the average and the squared average of the two precipitation gage rainfall levels. The coefficients for P_{avg} and P_{avg}^2 were confirmed significant by the Student's t-test. It is recommended that this function be applied only for monthly precipitation levels in the range noted above. Due to the asymptotic nature of a quadratic function, runoff volumes from rainfall levels greater than 22.96 inches (the maximum observed rainfall level used in this analysis) would likely be overestimated using this equation. Typically, precipitation (P_{avg}) less that 3.52 inches does not result in significant ungaged inflows to Nueces Bay. A graphical presentation of the sample runoff and precipitation data and the relationship presented above is shown in Figure 6-7.



R = -393.27*P + 111.66*P^2 + SAMPLE DATA

R = UNGAGED INFLOW TO NUECES BAY IN ACRE-FEET PER MONTH

P = AVERAGE OF MONTH PRECIPITATION AT CORPUS CHRISTI AND SINTON WEATHER STATIONS IN INCHES PER MONTH

$3.52 \leq P \leq 22.96$

HDR Engineering, Inc.

NAISMITH ENGINEERING, INC.
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CORPUS CHRISTI TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2

RELATIONSHIP OF UNGAGED FLOW TO GAGED PRECIPITATION

FIGURE 6-7

7.0 EVALUATION OF SHALLOW BRACKISH GROUNDWATER TO SUPPLEMENT FRESHWATER RELEASES

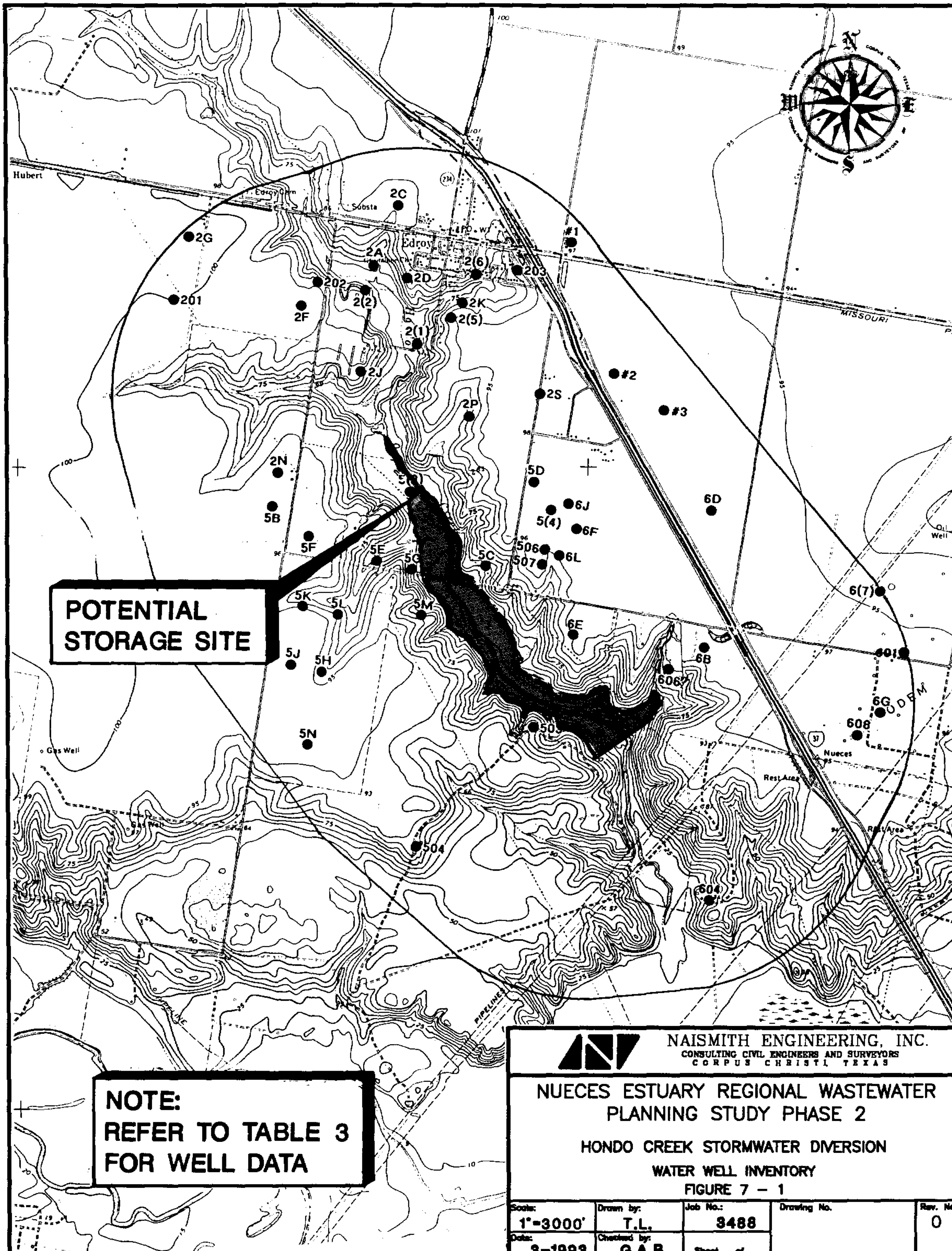
7.1 Preliminary Well Field Identification

This section describes a preliminary evaluation of the ground water conditions in and around the Nueces River estuary and Edroy, Texas areas. The primary objectives were to: (1) evaluate the potential ground water quality in and adjacent to the Nueces River estuary area to determine if fresh to slightly saline water (total dissolved solids [TDS] less than or equal to 3,000 parts per million [ppm]) is available; and (2) determine if enough groundwater resources are available in the Edroy, Texas, area to supplement surface water in the proposed Hondo Creek Stormwater Diversion Project described in Section 6.6.

The scope of work included:

- A study of shallow oil and gas geophysical (electric) logs from holes that were logged to at least 1,500 feet below the current ground surface in and within a half-mile radius of the Nueces River estuary.
- A study of available records for water wells within a half-mile radius of the Nueces River Estuary and a one-mile radius of the proposed Hondo Creek Diversion Project.
- Locate and plot oil/gas wells onto a United States Geological Survey 7.5-minute topographic map for the area of review.
- Acquire water well driller logs and applicable electric logs for evaluation.

Data collection for the evaluation of groundwater to supplement freshwater releases in the Nueces Estuary consisted of research of oil and gas well electric logs that had been logged to at least 1,500 feet below land surface and a water well inventory search. The search area included the Nueces River Estuary and approximately half-mile radius from the estuary boundary (Figure 7-1). Twenty-two electric logs were found that met the above


POTENTIAL STORAGE SITE
NOTE:
REFER TO TABLE 3
FOR WELL DATA
Hubert
Edroy
MISSOURI
2C
2G
2A
2(6)
203
#1
202
2D
2(2)
201
2F
2K
2(5)
2(1)
2J
#2
2S
#3
2P
2N
5D
6D
5B
6J
5(4)
6F
5F
506
507
6L
5E
5C
6(7)
5K
5L
5M
6E
5J
5H
6B
606
601
6G
608
5N
504
604
Gas Well
Rest Area
Nueces
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CORPUS CHRISTI TEXAS
NUECES ESTUARY REGIONAL WASTEWATER
PLANNING STUDY PHASE 2
HONDO CREEK STORMWATER DIVERSION
WATER WELL INVENTORY
FIGURE 7 – 1
Scale: 1"=3000'
Drawn by: T.L.
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Rev. No. 0
Date: 3-1993
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Sheet ___ of ___

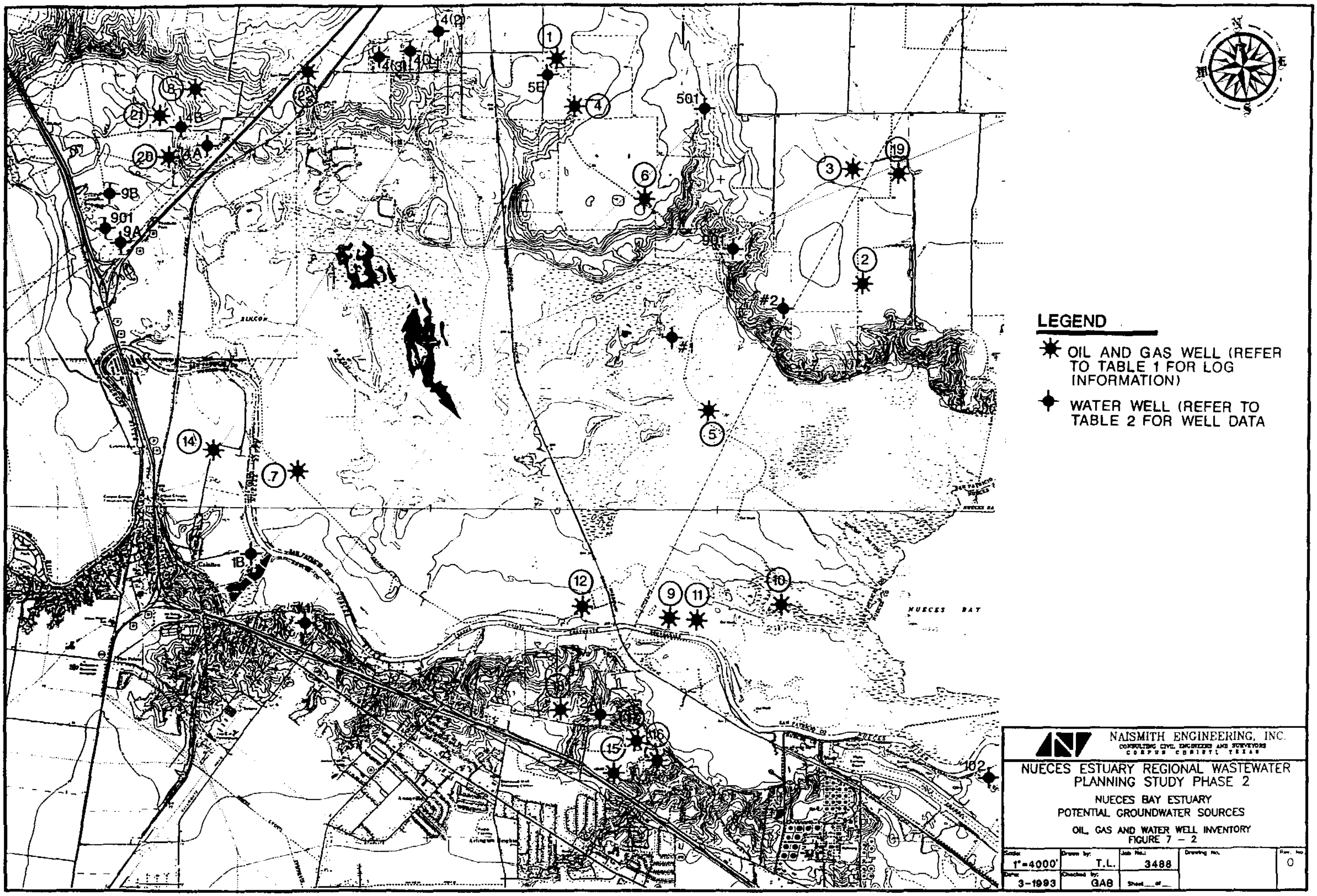
LEGEND
OIL AND GAS WELL (REFER TO TABLE 1 FOR LOG INFORMATION)
WATER WELL (REFER TO TABLE 2 FOR WELL DATA
NAISMITH ENGINEERING, INC.
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
NUECES BAY ESTUARY
POTENTIAL GROUNDWATER SOURCES
OIL, GAS AND WATER WELL INVENTORY
FIGURE 7 – 2
1"=4000'
T.L.
3488
0
3-1993
GAB
NUECES BAY

Table 7-1
Electric Log Information
Nueces River Estuary

Well Location No.	Well Name	Sand Depth (ft BGL)	Calculated NaCl (ppm)
1	A. N. Smith # 1	860-890	8,000
2	Oden Estate # 1	795-820	4,500
3	V. E. Ray # 1	580-600	6,000
4	Turner Brothers # 1	1,080-1,110	8,000
5	Turner Brothers # 2	1,200-1,240	5,500
6	Frank and W. E. Cleveland # 1	1,010-1,050	NA
7	E. O. Ramsey # 1	1010-1050	7,000
8	Kinghorn # 1	520-720	1,500
9	Margaret Sivell # 1	1,000-1,030	5,000
10	"Turk" - State # 1	200-220	10,000
11	Key # 1	200-215	7,000
12	A. A. McGregor # 1	450-480	4,000
13	Fanny D. Wilson # 1	220-240	2,300
13A	Fanny D. Wilson # 2	205-240	1,000
14	Nuakee Estate # 1	1,000-1,030	7,000
15	John Dunn # 5	1,285-1,300	3,500
16	V. B. Grady # B-1	600-630	8,000
17	Kennedy # A-3	1,320-1,365	9,400
18	Charles McKinzie # 1	75-100	2,200
19	L. C. Doney, Jr. # 1	200-250	3,000
20	J. F. Welder Heirs # F-1	580-630	3,800
21	Kinghorn # 1	990-1,1010	7,000
22	A. A. Smith # 1	110-150	3,000

BGL Below ground level; ppm Parts per million
NaCl Sodium chloride; NA Not available

drilled for domestic, irrigation, and livestock supply and are located primarily in the upland areas surrounding the estuary. Because of the relatively shallow depths of these water wells, the potential yields of wells in this area would probably be limited. Data from the water well inventory indicates driller-reported flow rates in the wells near the estuary ranged from 10 to 80 gallons per minute (gpm). Most of these wells are small-diameter domestic or livestock supply wells.

Table 7-2
Record of Wells
Nueces River Estuary

Well State ID (No.)	Owner	Date Complete	Depth of Well (ft BGL)	Diameter of Well (inches)	Use	Flow (gpm)	TDS
83-03-9A	Wallace Lilly	07/19/71	240	4	D	80	NA
83-03-9B	Jim Wilson	06/16/72	257	4	D	65	NA
83-03-901	J. F. Welder	04/23/65	NA	4	S	NA	NA
83-04-4A	Floyd Zahn	09/18/70	192	4	D	40	NA
83-04-4B	Bob Shrote	12/18/72	228	4	D	NA	NA
83-04-4D	L. E. Smith	05/02/77	40	4	IRR	NA	NA
83-04-5E	Edgar Carr	06/05/84	174	4	D	30	NA
83-04-501	A. C. Bickhan	06/15/60	80	4	U	NA	NA
83-04-901	Rusty Griffith	1956	120	8	S	40	2,370
83-12-2A	Ruthie Smith	08/02/83	122	4	D	NA	NA
83-12-1B	Hoyet Gentry	09/20/84	46	4.5	IRR	20	NA
83-13-102	Clara "A" Well # 1	1952	NA	NA	O	NA	NA
83-12-1(1)	William Sheffield	07-23-90	65	4	D	10	NA
83-04-4(2)	Joe Espinosa	06/20/89	60	4	D	50	NA
# 1	Griffith Land & Cattle	08/09/91	85	4	IRR	NA	NA
# 2	Griffith Land & Cattle	08/08/91	103	4	IRR	NA	NA
83-04-4(3)	Carlos Rubio	04/24/91	80	4	D	45	NA

BGL	Below ground level	NA	Not available	U	Unused
TDS	Total dissolved solids	IRR	Irrigation	O	Oil Test
D	Domestic	S	Stock		

7.2 Estimates of Well Field Production Capacities

A target fresh water supplemental volume from ground water of 5 mgd was utilized for the Hondo Creek Dam alternative. However, the overall use of ground water for supplemental supply directly to the estuary or to the Hondo Creek Reservoir appears to be limited. The potential for obtaining 5.0 mgd or larger amounts of ground water containing less than 3,000 ppm TDS within the estuary or in adjacent areas for an extended period of time is limited. Information developed in this study indicates a large variability in ground water quality both laterally and vertically in this area. The uncertainty increases the need to conduct a detailed exploratory program prior to developing well fields. However, a limited amount of fresh to slightly saline ground water from shallow sands on the northern side of the estuary probably could be developed with a series of moderate size wells yielding from about 50 to 200 gpm (0.07 to 0.3 mgd) each. In order to obtain a 5.0 mgd supply from these wells, approximatley 18 to 70 wells would need to be developed.

7.3 Effects on CC/LCC System Yield

The effect of groundwater use to restore system firm yield was analyzed at the Hondo Creek stormwater diversion site. Alternative SW-4, presented previously in Section 6.5, involved using a single 5.0 mgd well near the Hondo Creek proposed dam and reservoir to augment the inflow of stormwater into the structure. It appears that the development of a single well is not practical but that in reality numerous wells would be required. Assuming additional studies might show this to be feasible, which is not likely, the system firm yield that would be restored in this option is 6,234 acre-feet per year (20.1 percent of the recoverable firm yield). The stormwater and pumped groundwater in this analysis were assumed to be of equal quality, and a productivity factor of three was used for the diversions to the Nueces Bay under this option. A similar analysis was performed with the same Hondo Creek system described above without the 5 mgd well. In this option, the firm yield restored to the system would be 857 (2.8 percent of the recoverable firm yield), considerably less than with the well augmentation. Therefore, well augmentation would have a substantial impact in the Hondo Creek stormwater diversion alternative SW-4. However, the well water quality should be assessed before this option is given further consideration.

In general, the effects of groundwater pumpage into the Nueces Bay and/or the Nueces River Delta can be inferred from Figure 11-1 in Section 11. For an assumed well pumpage rate and productivity factor, one can interpolate the effects on system firm yield restored from this family of curves.

7.4 Estimates of Costs

Factors which will affect the unit cost per volume of groundwater delivered include:

1. Preliminary estimates of well field production show a limited potential for large amounts of acceptable groundwater.
2. Areas where wells would be located are relatively remote.
3. Distances required for conveyance and power supply facilities are relatively great.

Remote types of installations, such as wind-driven wells, would not be dependent on costly electric power facilities or high maintenance diesel generators. However, such facilities would provide only minor, localized benefits and would not achieve the overall desired result. Based on the above factors, it is concluded that construction of well field and conveyance facilities for supplementing freshwater releases is not economically feasible.

7.5 Groundwater Supply for Hondo Creek Diversion Project

A water well search was conducted within a one-mile radius of the proposed Hondo Creek reservoir. Fifty-six water wells were located on the site map showing the well locations (Figure 7-1). Most of the wells in the vicinity of the proposed reservoir site are small diameter (four-inch) domestic or livestock supply wells. These wells range in depth from about 100 to 400 feet and most tap sands of the Goliad or Beaumont Formation. The average depth of the wells listed in the area of the potential Hondo Creek reservoir site is approximately 245 feet BGL.

Reported yields from the wells shown on Table 7-3, range from less than 15 to 700 gpm. Limited water quality data indicates most of these wells probably contain ground water with TDS levels ranging from 700 to over 2,000 ppm. Some wells in this area also are reported to contain moderate levels of hydrogen sulfide.

Based on the water well data obtained for the Hondo Creek area near Edroy, Texas, the development of a ground water supply to provide supplemental water to a reservoir should be possible without adversely impacting the existing ground water users. Although the aquifer hydrogeologic properties should be better defined by field testing, the yields of existing wells indicate that approximately four to seven wells yielding from 100 to 200 gpm each could be constructed. These wells, properly located and spaced, could provide a base flow of one million gallons per day (1 mgd) during selected periods when needed to supplement surface water runoff.

Table 7-3
Record of Wells, Hondo Creek Diversion Project

Well (State ID No.)	Owner	Date Complete	Depth of Well (ft BGL)	Diameter of Well (inches)	Use	Flow (gpm)	TDS (ppm)
83-03-2A	E. M. Ortiz	08/10/69	250	4	D	15	NA
83-03-2C	Rosa Dy	07/25/68	260	4	D	20	NA
83-03-2D	Joe Moran	04/08/70	321	4	D	NA	NA
83-03-2-DD	Lonnie Glasscok	08/04/80	205	4	D	100	NA
83-03-2F	Jack Thorton, Jr.	01/25/74	282	4	D	NA	NA
83-03-2G	R. Marburger	09/08/75	139	4	D	15	NA
83-03-2J	H. Perkins	05/21/79	256	4	D	60	NA
83-03-2K	J. Eanes	05/25/79	261	4	D	50	NA
83-03-2N	Lykes Bros., Inc.	05/27/83	328	4	D	100	NA
83-03-2P	G. King	03/28/83	205	4	D	18	NA
83-03-25	S. Livingston	08/16/83	292	4	D	NA	NA
83-03-201	I. Hart	1957	385	12 3/4	IRR	700	NA
83-03-203	W. Herman	1929	275	4	D	NA	465
83-03-6B	J. E. Bucknex	03/24/73	263	4	D	NA	NA
83-03-6D	M.C. Crider	06/26/78	250	4	D	NA	NA
83-03-6E	D. E. Branson	08/08/77	210	4	D	60	NA
83-03-6F	R. D. Foster	06/26/79	221	4	D	25	NA
83-03-6FD	I. G. Casarez, Jr.	08/13/79	252	4	D	50	NA
83-03-6G	J. Westbrook	09/19/78	255	4	D	65	NA
83-03-6J	W. Grainger	03/22/79	279	4	D	NA	NA
83-03-6L	C. Popnoe	06/09/80	255	4	D	75	NA
83-03-601	Moody Institute of Chicago	1959	208	4	D	NA	880
83-03-606	Cox Brothers	1933	260	4	D	NA	NA
83-03-608	J. C. & J. S. Burrows	10/22/45	271	4	D	NA	163
83-03-5B	J. B. Causey	05/13/72	260	4	D	NA	NA
83-03-5BD	James Knight	01/28/76	265	4	D	100	NA
83-03-5C	W. O. Horton	09/04/74	184	4	D	NA	NA
83-03-5E	William Roueche	08/28/78	247	4	D	35	NA
83-03-5F	David Zavala	06/01/79	212	4	D	50	NA
83-03-5G	R. E. Quezada	05/13/80	195	4	D	100	NA
83-03-5H	Ricky Jackson	05/14/81	200	4	D	60	NA
83-03-5J	Robert Tabler	03/13/81	206	4	D	40	NA
83-03-5K	Thomas Schlegel	02/25/81	205	4	D	35	NA
83-03-5L	Gary Pittman	05/11/84	215	4	D	45	NA
83-03-5M	Mark Comiskey	03/09/82	195	4	D	50	NA
83-03-5N	Terry Boening	09/13/84	260	4	D	80	NA
83-03-5O	J. F. Weider Hrs.	04/23/65	160	4	S	NA	703
83-03-506	Gloria Kerr	08/26/78	267	4	D	40	840
83-03-507	Ty Romike	1980	254	4	D	NA	NA
83-03-2(1)	L. D. Watkins	02/01/90	279	4	D	NA	NA
83-03-2(2)	L. D. Watkins	05/16/88	270	4	D	NA	NA
83-03-3(3)	Louis W. Dillon	05/06/87	273	4	D	NA	NA
83-03-5(4)	Vega Homes, Inc.	02/08/90	200	4	D	70	NA
83-03-2(5)	Aurelio Martinez	06/27/86	280	4	D	65	NA
83-03-2(6)	Jim Adams	03/23/89	250	4	D	40	NA
83-03-6(7)	Ignocio Gomez	10/21/86	244	4	D	35	NA
# 1	Robert Stelcusp	08/01/91	281	4	D	NA	NA
# 2	Renaldo Lopez	07/24/91	220	4	D	NA	NA
# 3	Christe Garcia	10/21/91	190	4	D	NA	NA

BGL Below ground level
gpm Gallons per minute
TDS Total dissolved solids
ppm Parts per million
D Domestic
NA Not available
IRR Irrigation

8.0 VALUE OF CHOKE CANYON/LAKE CORPUS CHRISTI RESERVOIR SYSTEM

The Choke Canyon/Lake Corpus Christi System (CC/LCC) stores river flows which are converted into water supplies for the people and the economy of the Corpus Christi area. In addition, the reservoirs are used for recreation and tourism, and the shoreline properties of Lake Corpus Christi are the sites of residential development. In the following sections, estimates of the value of business and employment derived from recreation and water use from the CC/LCC System are presented.

The major annual business that results from water supplied by the CC/LCC System and use of the system for recreation can be expressed by the following equation:

$$B = M + T + SFE$$

where B = Gross annual business, expressed in dollars;
M = Annual value of products produced by manufacturers and other businesses that use water from the CC/LCC System, expressed in dollars, f.o.b. the plants;
T = Annual expenditures by tourists who visit and use the CC/LCC System for recreation; and
SFE = Annual expenditures by sport fishermen who fish the CC/LCC System.

Estimates are presented below for each of the terms of the gross business equation.

8.1 Value of Production and Economic Impact of Industries and Businesses that Obtain Water from the Choke Canyon/Lake Corpus Christi System

The following eight manufacturing sectors depend upon the Choke Canyon/Lake Corpus Christi System (CC/LCC) for their fresh water supplies: (1) food processing, (2) chemicals, (3) petroleum refining, (4) cement and concrete, (5) primary metals, (6) fabricated metals, (7) non-electrical machinery, and (8) electrical machinery. In addition, commercial establishments such as laundries, restaurants, hotels and motels, nurseries, carwashes, and institutions depend upon CC/LCC System Water to operate their businesses.

In 1990, reported CC/LCC System Water use was 134,515 acre-feet, of which 43,031 acre-feet was used by the manufacturing sector, 27,445 acre-feet was used by the commercial and services sectors, and 64,039 acre-feet was used by households and for municipal functions such as fire protection, sanitation, public swimming pools, and watering of public parks and lawns (see Table 8-1).

Total value of production of manufactured goods by CC/LCC water-using industries in 1990 was estimated at $8.5 billion (Table 8-1, column 3), and estimated value of production by the commercial sectors in 1990 was $3.99 billion (Table 8-1, column 3), giving a total value of output of manufacturing and commercial establishments in 1990 of $12.497 billion. Total quantity of CC/LCC System water use of these establishments was 70,476 acre-feet in 1990 (Table 8-1, column 2). These industries and commercial and institutional establishments had 78,915 direct employees in 1990, with an annual direct payroll of $1.522 billion. When production, employment, and income multipliers are applied to the direct production, employment, and wages and salaries payments, the gross, economy-wide business effect of the water-using manufacturing industries and commercial establishments was $20.66 billion in 1990, with a total employment impact of 109,054 jobs, and a total income effect or impact of $2.45 billion (Table 8-1, columns 9, 10, and 11). Without an adequate water supply, as delivered by the CC/LCC System, these industries and commercial establishments could not have functioned at these levels in 1990.

Table 8-1
Economic Impacts of Manufacturing, Commerce, Services, and Institutions That Depend Upon Water from the Choke Canyon/Lake Corpus Christi System -- 1990

Sector	Water Use (ac-ft) 1990	Value of Output ($ million)	Number of Employees	Annual Incomes Paid ($1,000)	Multipliers			Economic Impact		
					Output (T1)	Employment (T1)	Income (T1)	Gross Business ($ billion)	Number Jobs	Income ($ millions)
Col. (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Manufacturing	43,031	8,500.68	$11,544	$359,202	1.73	1.86	2.46	$14.71	$21,472	$883.6
Commercial**	27,445	3,996 .53	67,371	1,163,016	1.49	1.30	1.35	5.95	87,582	1,570 .1
Subtotal	70,476	12,497.21	78,915	1,522,218	--	--	--	20.66	109,054	2,453.7
Municipal	64,039	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	134,515	$12,497.21	$78,915	$1,522,218	--	--	--	$20.66	109,054	$2,453.7

* Source: Texas Input-Output model, Office of Comptroller of Texas (1986 and 1979 models).
** Includes wholesale trade, retail trade, restaurants, finance, insurance, real estate, services, and institutions. Commercial and institutional water use is 30 percent of total, nonmanufacturing water use, as estimated by Texas Water Development Board, 1993, Austin, Texas
Date Sources:
Col (2): Texas Water Development Board Water Use Surveys
Col (3): Estimated from Input-Output Model; "Nueces and Mission-Aransas Estuary, Economic Impact of Recreational Activity and Commercial Fishing," Texas A&M University, College Station, Texas, 1987, adjusted for inflation.
Col (4): County Business Patterns -- Texas, 1990, U.S. Department of Commerce, Economics and Statistics Administration, Bureau of the Census, Washington, D.C.
Col (5): Same as Column 4
Col (6): Texas 1986 Input-Output Model, Office of Texas Comptroller, Austin, Texas, 1989.
Cols(7)&(8): Texas 1979 Input-Output Model, Texas Department of Water Resources, Austin, Texas, 1981.
Col (9): Computed as product of Cols. 3 and 6.
Col (10): Computed as product of Cols. 4 and 7.
Col (11): Computed as product of Cols. 5 and 8.
NA means not applicable.

8.2 Recreation and Tourism Values Associated with Choke Canyon and Lake Corpus Christi

Both public and private recreation facilities have been developed at Choke Canyon and Lake Corpus Christi. The major public recreation facilities are Lake Corpus Christi State Park at Lake Corpus Christi, and Calliham and South Shore Units of Choke Canyon State Park. Private recreation facilities include camping, fishing, resorts, and dining facilities that are available to the public. Estimates of visitation and expenditures associated with recreation and tourism at the public recreation facilities are presented below. Data are not available for private sector facilities.

8.2.1 Visitation at Choke Canyon and Lake Corpus Christi State Parks

According to records of the Texas Parks and Wildlife Department, average annual visitation for the five-year period of 1988 through 1992 was 554,000 at Choke Canyon Parks and 649,000 at Lake Corpus Christi State Park (Table 8-2).[1] Average annual visitation to parks at the two lakes for this five-year period was 1.2 million, 46 percent of which was to Choke Canyon Parks and 54 percent to Lake Corpus Christi State Park. Of total visitation, 10.4 percent were overnight visitors and 89.6 percent were day visitors. These visitation reports are the data used in the following section for making estimates of expenditures and economic impacts of recreation associated with Choke Canyon and Lake Corpus Christi.

[1]1988 is the first year for which visitation data are available for Choke Canyon Parks.

Table 8-2 Annual Visitation to Choke Canyon and Lake Corpus Christi State Parks					
	Years				
	1988	1989	1990	1991	1991
Parks	—— (thousands) ——				
Choke Canyon - Callihan	307	371	334	320	339
Choke Canyon - South Shore	239	246	212	193	208
Choke Canyon - Total	546	617	546	513	547
Lake Corpus Christi	612	593	610	785	648
CC/LCC Total	1,158	1,210	1,156	1,298	1,195

Source: Texas Parks and Wildlife Department

8.2.2 Expenditures and Economic Impacts of Use of Choke Canyon and Lake Corpus Christi Recreation Facilities

According to surveys of visitors to state parks, day visitors spent $6.96 for goods and services and overnight visitors spent $8.00 per night.[2] Thus, for the average annual visitation of 1.2 million, total expenditures by day and overnight visitors is approximately $8.51 million annually (Table 8-3).

According to the recreation surveys, expenditures were distributed among four economic sectors as follows: (1) transportation - 34.8 percent; (2) food - 42.5 percent; (3) lodging - 10.8 percent; and (4) all other - 11.9 percent (Table 8-4).

Given visitation of 1.2 million annually, with expenditures of $8.5 million annually, the gross business associated with recreation at the CC/LCC System is estimated at $25.15

[2] "1990 TORP Assessment and Policy Plan," Parks Division, Texas Parks and Wildlife Department, Austin, Texas. 1991.

Table 8-3 Expenditures by Visitors to Choke Canyon and Lake Corpus Christi State Parks			
Visitor Type	**Average Annual Visitors**	**Average Expenditure per visitor**	**Average Annual Expenditures**
Day	1,078,800	$6.96	$7,508,448
Overnight	124,600	8.00	$ 996,800
Total	1,203,400		$8,505,248

million annually (Table 8-4). The additional number of jobs in the tourism industries that are supported by CC/LCC recreation business is estimated at 492, with incomes received of $5.72 million annually (Table 8-4).

8.3 Expenditures and Economic Impacts of Fishing of Choke Canyon and Lake Corpus Christi

According to a 1986 survey of outdoor recreation activities in the Coastal Bend Region of Texas[3], freshwater fishing is a very popular activity, and Choke Canyon Reservoir is the major place at which freshwater fishing is done. Based upon the survey mentioned above, it is estimated that in 1990, 1.1 million people (856,000 Coastal Bend area residents and 258,000 people from other areas) participated in freshwater fishing in the lakes of the area. Based upon a 1986 survey of Texas households, expenditures by fishermen were estimated at $44.11 per person in 1990, when adjusted for inflation (Table 8-5).[4] Given

[3]Ibid.

[4]"Nueces and Mission-Aransas Estuary: Economic Impact of Recreational Activity and Commercial Fishing," Texas A&M University, College Station, Texas, 1987.

Table 8-4 Economic Impacts of Recreation at Choke Canyon and Lake Corpus Christi State Parks -- 1990									
Sector	Percent	Annual Expenditure (millions)	Multipliers*			Economic Impact			
			Output (T1)	Employment [a] (T1)	Income [b] (T1)	Gross Business ($ billion)	Number Jobs	Income ($ millions)
Transportation**	34.8	$2.960	2.56	43.94	0.51	$7.58	130	$1.51
Food	42.5	3.615	3.22	79.87	0.77	11.64	288	2.78
Lodging	10.8	0.913	3.12	39.55	0.70	2.86	36	0.64
Other***	11.9	1.012	3.04	38.07	0.78	3.07	38	0.79
TOTAL	$100.0	$8.505	--	--	--	$25.15	492	$5.72

* Source: 1986 Texas Input-Output model, Texas Comptroller of Public Accounts, Austin, Texas, December 1989.
** Gasoline Service Stations
*** Retail Trade
[a] No. of full-time jobs per $1.0 million of business.
[b] Wages and salaries per dollar of business (total economy).

Table 8-5
Economic Impacts of Fishing Activity at Choke Canyon and Lake Corpus Christi State Parks -- 1990

Sector	Expenditures per Person* (dollars)	Annual Expenditures by Fishermen** (millions)	Multipliers***			Economic Impacts		
			Output (T1)	Employment [a] (T1)	Income [b] (T1)	Gross Business ($ billion)	Number Jobs	Income ($ millions)
Transportation	$16.34	$17.97	2.56	43.94	0.51	$46.00	790	$9.16
Food	15.74	17.32	3.22	79.87	0.77	55.77	1383	13.34
Lodging	3.44	3.78	3.12	39.55	0.70	11.79	149	2.65
Other	8.59	9.45	3.04	38.07	0.78	28.73	360	7.37
TOTAL	$44.11	$48.52	--	--	--	$142.29	2682	$32.52

* Estimated from Surveys of Sport Fishermen, "Nueces and Mission-Aransas Estuary: Economic Impact of Recreational Activity and Commercial Fishing," Texas A&M University, College Station, Texas, 1987 (adjusted for inflation).
** Number of fishermen is 1.1 million annually (1990 TORP Assessment & Policy Plan, Texas Parks and Wildlife Department, Austin, Texas, 1991).
*** 1986 Texas Input-Output Model, Texas Comptroller of Public Accounts, Austin, Texas, December 1989.
[a] No. of full-time jobs per $1.0 million of business.
[b] Wages and salaries per dollar of business (total economy).
Transportation = Gasoline Service Stations
Food = Restaurants and Grocery Stores
Lodging = Hotels and motels
Other = Retail Trade

the estimated 1.1 million persons who participated in freshwater fishing in 1990, the economic impacts of this activity in 1990 were estimated at $48.52 million of direct business, $142.29 million of total business, 2,682 full-time jobs, and $32.52 million of income to those who work in the transportation, food, lodging, retail trade, and services industries that supply goods and services to freshwater fisherman (Table 8-5). However, there are no data available with which to make estimates of the quantity and value of the freshwater species of fish that are caught by freshwater anglers. Thus, this element of the economic value of the lakes cannot be included in this analysis.

8.4 Summary of Economic Values of Choke Canyon/Lake Corpus Christi System

The economic, employment, and income effects of the industries, commercial establishments, tourism, and freshwater sport fishing calculated in Sections 8.1, 8.2, and 8.3 are summarized below. The total economic impact in 1990 was estimated at $21.05 billion, 112,228 jobs, and $2.49 billion of income (Table 8-6). Of the total business, employment, and income effects, 98 percent is from the manufacturing and commercial establishments that use water from the CC/LCC System, with recreation related activities accounting for about two percent of the totals.

Table 8-6 Summary of Value of Production, Employment, and Incomes Generated by Use of Water and Recreation -- Choke Canyon and Lake Corpus Christi -- 1990			
Sector	**Gross Business ($ billions)**	**Number of Jobs**	**Income ($ millions)**
Manufacturing and Commerce	$20.66	109,054	$2,453.7
Tourism	0.25	492	5.7
Sport Fishing	0.14	2,682	32.5
TOTAL	$21.05	112,228	2,491.9

9.0 POSSIBLE EFFECTS OF OYSTER REEFS, SILL STRUCTURES, AND ELECTRIC POWER STATION DISCHARGES UPON RETENTION OF FRESHWATER IN NUECES BAY AND ON MIXING WITH SALINE WATER OF CORPUS CHRISTI BAY

Technical Advisory Committee members suggested the possibility that dredging of oyster reefs may have altered the hydraulics of bay waters and that these hydraulic changes may influence how freshwater inflows mix with more saline water, thereby affecting overall salinity and the rate of change of salinity within Nueces Bay. This section of the Study includes some preliminary investigations to determine if past dredging, and other man-induced activities, such as electric power station discharges, are affecting the hydraulics of the bay waters and are increasing overall bay salinity. If this scenario is valid, it may be feasible to artificially restore previous conditions and lower bay salinity.[1] Primary objectives of this section are to determine:

1) The past and present distribution of oyster reefs in Nueces Bay;
2) The hydraulic and salinity effects resulting from channelization of sill structures;
3) The salinity effects resulting from the Nueces Bay Power Station discharge; and
4) Costs for mitigation of the effects of the power plant discharge and channelization.

9.1 Past Distribution of Oyster Reefs in Nueces Bay

Information on the past distribution of oyster reefs was obtained through discussions with individuals experienced in local oyster dredging operations and local researchers from

[1] Discussions with local researchers include the view that the occurrence of certain vascular plant species indicate that the Nueces Delta and possibly Nueces Bay may have been more saline in the past than in recent times. However, current water management regulations are directed at keeping bay salinities from increasing.

the regulatory and scientific community. In addition, a review of available literature and aerial photographs was conducted. A summary of the information collected follows.

Mr. August Meinrath, a local resident and former employee of Southern Alkali (currently American Chrome and Chemical) was responsible for locating the oyster reefs in Nueces Bay during the company's dredging operations in the 1930's. He stated that mud shell dredging operations penetrated to depths up to fifteen feet (15) below the bottom of the bay and typically recovered shell material from dead reef structures. Occasionally live reefs were impacted by the dredging, whereupon operations were ceased and the dredging location was changed. Mr. Meinrath stated that large reefs of live oysters were found on the southeast side of Nueces Bay (northwest side of North Beach); the reefs extended west of the Nueces Bay Causeway. However, oysters did not exist in great abundance in the area east of the causeway; most of the live oysters mentioned above were depleted in the early 1950's. This finding supports information from previous studies, which state that oysters thrive in locations where freshwater from rivers and streams mix with more saline waters (Hofstetter, 1965).

In 1959, large scale dredging operations occurred in the bay and by the end of all dredging in 1974, an estimated 13 million cubic yards of oyster shell had been removed (Drumright, 1989).

Past archaeological research provides evidence that salinity in the bay has actually decreased over geologic time. Mr. Kim Cox, a local archaeologist, has conducted research in the Whites Point area which correlates geological data concerning changes in sea level with archaeological data relating to salinity in the bay. The data show that salinity concentrations at Whites Point varied from 10 to 15 parts per thousand (ppt) over a 4,000 year prehistoric period. A transition period of approximately 2,000 years followed and was characterized by a marked decrease in salinity. Thereafter, salinity concentrations up to the present time have ranged from 2 to 5 ppt in the Whites Point area. The correlation between geologic data regarding sea level and the higher salinity concentrations results in the conclusion that rising sea levels inundated the barrier islands, thereby increasing salinity in the bay (Cox, 1993).

An effort was made to obtain photographic documentation prior to the commencement of extensive dredging activities. However, the oldest aerial photographs in this time period that provided clear evidence of the existence of oyster reefs are from 1963. It is significant that an unusually low tide and translucent waters existed at the time this photograph was taken. These conditions permit a relatively clear observation of subsurface structures such as oyster reefs. It is known that oyster reefs were found in abundance near the Whites Point area (Figure 9-1) and just west of the Nueces Bay Causeway (Figure 9-2). (See Figure 4-2 for the location of these two areas in Nueces Bay). Although aerial photographs of other areas of the bay were also reviewed, no additional widespread oyster populations were evident. Oyster reefs observed in the above mentioned figures are visible in crescent shaped configurations, both above and below the water surface. Channels resulting from dredging operations are also observed in both photographs.

9.2 Present Distribution of Oyster Reefs in Nueces Bay

Based on information obtained during this study, comparisons between past and

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NUECES BAY AT WHITES POINT 1963

FIGURE 9 – 1

Scale:	Drawn by:	Job No.:	Drawing No.	Rev. No.
1" =1400'	T.L.	3488		0
Date: 3–93	Checked by: P.M.P.	Sheet 1 of 4		

current aerial photographs and the fact that dredging operations ceased in the early 1970's, it is concluded that the present distribution of oyster reefs has not changed dramatically from the 1960's. The current aerial photographs were taken in 1987 near the Whites Point area (Figure 9-3) and just west of the Nueces Bay Causeway (Figure 9-4). Due to the limitations of the available photographic records, an exact comparison of location and scale to Figures 9-1 and 9-2 is not possible. Therefore, direct comparisons to the 1963 photographs are somewhat limited. For example, higher tide and water opacity conditions existed at the time the 1987 photograph was taken than were evident when the 1963 photographs were taken.

The 1987 photograph (Figure 9-3) shows a larger portion of the Whites Point area in comparison to the 1963 photograph (Figure 9-1), in which the tip of Whites Point is evident at the middle-right side of the photograph. A comparison of photographs shows that portions of reefs at or immediately below the water surface have not changed significantly over the 24-year period. Likewise, the 1987 photograph of Nueces Bay west of the Nueces Bay Causeway (Figure 9-4) shows similar distributions of surface and near surface reefs, in comparison to the 1963 photograph (Figure 9-2) of the same area. A comparison of dredge channels is not easily made because of the different water opacities.

9.3 Location and Description of Sill Structure at Confluence of Nueces and Corpus Christi Bays

A large natural sill structure, or submerged ridge, separates the basins of Nueces Bay and Corpus Christi Bay extending from Indian Point on the north side southward to the North Beach Peninsula. Large oyster reefs are attached to this sill, which was previously

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NUECES BAY AT WHITES POINT **1987**

FIGURE 9 – 3

Scale:	Drawn by:	Job No.:	Drawing No.	Rev. No.
1" = 1600'	T.L.	3488		0
Date: 3–93	Checked by: P.M.P.	Sheet 3 of 4		

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CONFLUENCE OF NUECES AND CORPUS CHRISTI BAYS 1987

FIGURE 9 – 4

Scale:	Drawn by:	Job No.:	Drawing No.	Rev. No.
1" = 1600'	T.L.	3488		0
Date: 3–93	Checked by: P.M.P.	Sheet 4 of 4		

identified as one of the most abundant oyster reef areas of Nueces Bay. Due to its geographic location, the sill was the site of the San Antonio to Aransas Pass Railroad, which was constructed in the late 1800's. Prior to this time, the structure's shallow depth below water surface provided a transportation pathway for early wagon travel across the bays (Drumright, 1989). The Nueces Bay Causeway was completed in 1911 and has since been widened and expanded to its present condition.

It is likely that both the changes to the natural sill and construction of man-made structures at this location result in conditions which affect circulation, mixing of fresh and bay waters, and ultimately affects the salinity in Nueces Bay. The dynamics of this particular location include the mixing of fresh water inflows from Nueces Bay with more saline water of Corpus Christi Bay. However, depending upon the particular combination of environmental factors that are present at any given time, the net effect upon salinity of Nueces Bay cannot be determined from available data.

9.4 Preliminary Investigation into Hydraulic and Salinity Effects Resulting from Power Station Discharge and Channelization of Sill Structure

Based on this investigation, the factors that effect salinity in Nueces Bay can be categorized as (1) natural environmental factors and (2) man-induced factors. Natural environmental factors include wind movement, tidal action, precipitation, evaporation and fresh water inflows. Man-induces factors include such activities as brine discharges, which were discussed in the Phase I Study. It was determined that these highly concentrated brine waters, from oil field activities, had a significant localized influence on increasing the salinity of Nueces Bay. Other man-induced factors include the cooling water discharges into Nueces

Bay from the Central Power and Light (CPL) Company's Nueces Bay Power Station, channelization of sill structures and discharges of treated wastewater, such as the City of Portland WWTP discharges.

Data which correlate salinity in Nueces Bay with natural environmental factors have been documented in previous reports and studies. A review shows that salinity concentrations exhibit considerable variations, depending upon these factors. The effect of wind is important in determining the circulation patterns of the bay. Variable circulation patterns introduce turbulence and mixing, which affect the salinity distribution. Astronomical tides have little influence on the salinity in Nueces Bay due to the restricted entrance, particularly near the confluence of Nueces and Corpus Christi Bays (Orlando, 1991). The evaporational effects that occur in Nueces Bay can be influential in salinity variations, particularly during low freshwater inflow periods. These freshwater inflows can have substantial effects on salinity in the bay. The Nueces River, which enters the bay on its southwestern side, provides the major source of freshwater entering the entire estuarine system, other than periodic local rainfall events. As freshwater enters the bay and mixes with the more saline waters, a reduction in salinity occurs. The larger the volume of this freshwater entering the bay, the greater the reduction in the salinity of the bay waters. It has been concluded that the most significant changes in bay-wide salinity within the Nueces Estuary system is attributed to large, isolated pulses rather than seasonal fluctuations of freshwater inflows (Orlando, 1991).

The investigation into salinity effects from the Nueces Bay Power Station discharge was limited to a review of available reports and operating conditions at the station. The electric power generating station utilizes water pumped from the inner Corpus Christi Ship Channel (connected to Corpus Christi Bay) for heat dissipation. After its once-through system use, the cooling water is discharged into Nueces Bay. During the period of October 1973 through November 1987, the salinity at the entrance to the Ship Channel in Corpus Christi Bay has ranged from 13 ppt to 46 ppt with an average of 31 ppt. During this same time period, the salinity in Nueces Bay at a point located one-half mile from the south shore at the east powerlines has ranged from two ppt to 38 ppt, with an average of 25 ppt. Based on discussions with CPL representatives, the quantity of water averages 450 mgd. It is reasonable to expect that discharge of water from Corpus Christi Bay into the less saline Nueces Bay could result in an increase in the salinity in Nueces Bay. An April 1992 study, conducted for CPL by James Miertschin & Associates, Inc., evaluated historical salinity data in Nueces Bay through statistical and regression analyses to determine whether the data show that this discharge has affected salinity in Nueces Bay. The Study indicated that any effects of the discharge on the salinity of Nueces Bay are localized and appear to be confined to the immediate area of the discharge plume. The study further shows that the difference in salinity associated with the electric power plant discharge is insignificant and should not have an effect on bay-wide salinity (Miertschin, 1992). However, this 1992 analysis was limited to interpretation of previously gathered salinity data. In order to obtain more relevant site specific information, in the vicinity of the outfall, additional field sampling and analysis are required.

Channelization (dredging) in Nueces Bay has occurred as a result of oil field and maritime activities. In addition, oyster reef shells have been dredged for construction materials, lime recovery, and in the manufacturing of products including soda, cements, glass, soaps, and glycols (Drumright, 1989). Dredging activities in Nueces Bay have been concentrated in the area near Whites Point and northwest of Indian Point. An analysis of hydraulic and salinity effects from channelization is based on a simplified application of open-channel flow principles to Nueces Bay. Reports cited in this study have previously defined a salinity gradient, which shows lower concentrations in upper portions of the bay, moving to higher concentrations in lower portions. In addition, some degree of stratification occurs in bay water as a result of higher specific gravity of the more saline water.

Results of sampling have shown that stratification is more pronounced during periods of high freshwater inflows. Therefore, it is deduced that during high freshwater inflows, the velocity of stratified water near the surface allows more freshwater to move into lower portions of the bay before mixing with the heavier, more saline water.

Flow in open channels is affected by the characteristics of the channel bottom. The existence of subsurface features (obstructions), such as oyster reefs, would be expected to affect flow by creating eddys and turbulence, thereby resulting in an increase in mixing of stratified levels. If turbulence is decreased by dredging the bottom and removing the obstructions, it can therefore be argued that recreating the original bottom profile would retain stratified freshwater longer and result in better mixing with saline water. The net result would be a lowering of overall bay salinity. However, the simplified analysis does not take into account the effects of all previously mentioned factors. Therefore, a definitive conclusion stating that an increase in sill structures will lower salinity in the bay under all possible scenarios, cannot be drawn at this time.

9.5 Preliminary Cost Estimates for Freshwater Retention/Mitigation of Effects of Power Plant Discharges and Channelization

Research of the effects on salinity from the power plant discharge was limited to the evaluation of existing reports. The CPL report indicated that localized effects were observed in the discharge plume vicinity. Based on these results, it is concluded that additional field sampling and testing, specific to the discharge plume vicinity, would be necessary to establish more definitive conclusions prior to the implementation of mitigation measures, if necessary.

Mitigation of channelization could include the construction of artificial reefs to simulate the original effects of dredged sill structures. Alternative construction materials were evaluated, including 1) Dredge spoils, 2) Earthen fill material, 3) Concrete rubble, and 4) Concrete structures. The advantages of dredge spoils and earthen fill material include lower construction costs, in comparison to the concrete alternatives. However, concrete rubble or cast concrete structures would provide long-term stability, as compared to materials which would be subject to erosion caused by tidal and wave action. In addition, a mobile pre-cast concrete structure design could be incorporated to allow the reefs to be moved, through an experimentation process, until the most beneficial locations were identified.

It is anticipated that additional sill structures could be constructed in the lower bay area, immediately west of the confluence of Nueces and Corpus Christi Bays, which may affect salinity in all portions of the bay. Sill structures could be added in the middle of the bay to affect the upper bay area. Likewise, structures could be constructed in the upper areas of the bay to affect freshwater inflows early in the bay system.

Within the limits of this study, it was not possible to determine the actual quantity of artificial structures required to impact the overall hydraulic and salinity conditions. However, due to the immense size of the bay (approximately nine (9) miles in length by three (3) miles in width), it is evident that a considerable number would be required.

It is also clear that the artificial reef concept would not lend itself to a pilot-type project similar to the Allison WWTP demonstration project. The Allison demonstration project can be completed in a real-time and real-life situation, at a feasible cost. Determination of the effect of the artificial reef concept would require a substantial commitment of funds, without a reasonable assurance of success.

In addition, the permitting involved with such a project would have a major impact on its feasibility. The Corps of Engineers Section 404 permitting requirement would involve input from numerous local, state and federal agencies, and would be expected to take a considerable amount of time. Due to these economic and permitting constraints, the possibility of constructing sill structures as mitigation for dredging of shell reefs, and the probable lowering of the height of the natural sill at the mouth of Nueces Bay, and past channelization cannot be considered feasible without further study.

10.0 CONCEPTS FOR REGIONAL WASTEWATER ENTITY

The City of Corpus Christi is required to make releases from its reservoir system to maintain the health of the bay and the Nueces River Delta. These releases currently flow into Corpus Christi Bay, where they are distributed in a manner that may be less than optimum in terms of water management for marine life. The same or greater benefit might be obtained by using a lesser amount of water in a more efficient manner. The current project studies gathering wastewater from Corpus Christi's municipal wastewater treatment plants and from industries along the Corpus Christi ship channel, transportation of that water to the delta, and discharging it at locations that may be more efficient and beneficial to marine life in the bay and delta. The City expects that if the benefit of this project is sufficiently demonstrated, it will be permitted to reduce the volume of the required releases from its reservoir system.

The City and the industries involved currently hold NPDES and state permits to discharge into the ship channel, and the City also holds permits to discharge into the Nueces River, Oso Bay, Oso Creek, and Upper Laguna Madre. This section discusses the creation of a special conservation and reclamation district to receive wastewater from the City and the ship channel industries, and to transport the wastewater and discharge it into the delta.

10.1 Powers and Authority Needed

The proposed special district would need to have the following powers:

1. The power to have NPDES and state permits to receive the wastewater from each industry, to transport it by pipeline past the City's Allison Wastewater Treatment Plant, to take wastewater from the City, and to transport the water to the designated delta areas.

2. The power to finance, construct, operate, and maintain pumps and pipelines to convey the wastewater.

3. The power to assess, levy, and collect taxes, to charge rates, or to receive payments from the City or other sources, to finance its operations.

4. The power to obtain, by eminent domain or otherwise, sufficient land to receive the discharge in the delta, and all necessary easements, rights-of-way, and leases for conveyance of the effluent.

5. The power to acquire title to and to operate between 8,000 and 11,000 acres within the delta as a wildlife preserve.

10.1.1 Acquisition of the Right to Discharge in the Delta

Acquisition of the property rights necessary to allow discharge of effluent is important. The TWC takes the position that this is not within its jurisdiction. The language in the TWC permits so states, as follows:

> "The issuance of this permit does not grant to the permittee the right to use private or public property for conveyance of wastewater along the herein described discharge route. This includes property belonging to but not limited to any individual, partnership, corporation, or other entity. Neither does this permit authorize any invasion of personal rights nor any violation of federal, state, or local laws or regulations. It is the responsibility of the permittee to acquire property rights as may be necessary to use the herein described discharge route."

The right to discharge effluent across private property does not appear to have been litigated. The following analysis is a practical solution to the questions raised in that regard.

The most logical way to treat effluent is to consider it to be the same as diffused surface water. The lower landowner has the obligation to receive waters flowing from the upper estate, so long as the water is flowing in its natural state, unhindered by the hands of man. If the water does not reach the lower estate untouched and undirected by the hands of man, the water is no longer surface water, and the lower estate owner has no burden to receive such water. In the case of Mitchell vs. Blomdahl, 730 S.W.2d 791 (Tex.App. Austin 1987), the trial court defined "surface waters" as those which are diffused over ground from falling rain or melting snows and continue to be such until it reaches some bed or channel in which water is accustomed to flow and ceases to be such when it enters a watercourse in which it is accustomed to flow.

Once water gets into a watercourse, it becomes "state water" (Hoefs vs. Short, 273 S.W. 785 (Tex. 1925)). It is generally assumed that a landowner can artificially concentrate surface waters into a natural watercourse on his own land which runs across a neighbor's land and which constitutes a natural outlet for both tracts, provided the total discharge is not beyond the natural capacity of the watercourse. (See for example, Victor Bouldin, "Rights in Diffused Surface Water in Texas," Proceedings of Water Law Conference University of Texas, 1955).

It is reasonable to assume, by analogy, that a landowner can discharge effluent into a watercourse. If the effluent exceeds the "natural capacity" of the watercourse, the permittee is faced with liability for flooding. This question is not dealt with here.

A watercourse is defined by the TWC rules as:

> "A definite channel of a stream in which water flows within a defined bed and banks, originating from indefinite source or sources. (The water may flow continuously or intermittently, and if the latter, with some degree of regularity, depending on the characteristics of the sources)." (TWC Rule 297.1).

This definition is based on opinions in cases such as Hoefs vs. Short, supra and Motl vs. Boyd, 26 S.W. 458 (1926).

If the discharge does not go into a watercourse, but instead flows across a slight swale

In Texas, the line between submerged land owned by the State of Texas and privately owned coastal land depends on whether title to the coastal land originated from a Spanish or Mexican grant, or from a conveyance by the Republic of Texas, before January 20, 1840. If title originated before January 20, 1840, the boundary line is the line of mean higher high tide. If title originated from a post-1840 grant by the Republic of Texas, or from the State of Texas, the boundary is the line of mean high tide. The difference exists because there are two daily high tides and two daily low tides along the Texas coast. In reality, the difference is slight.

Discharge of effluent into state water, above state-owned land, will not prevent lawsuits. In the litigation against Gulf Coast Waste Disposal Authority, discussed in the next section, the commercial fishermen who brought the litigation contend that they have private rights that have been invaded even though the discharge is into state water above state-owned land.

10.1.2 Protection of Industries from Liability Arising out of Discharge of Effluent in the Delta

The industries are concerned about changing their established discharges for two reasons:

1. Their discharge parameters into the ship channel have been established for existing permits. Changing the point of discharge to the delta may make the discharge parameters more stringent, more difficult to maintain, and more expensive.

2. If significant damage to the bay or delta occurs, the industries are concerned that they will be sued. They are willing to accept responsibility for their own effluent, but they do not want to be responsible for problems caused by others. The concept of joint and several liability for multiple defendants

or slope of land, it is presumably not natural drainage untouched by the hand of man, and it can be repelled. For example, in Bishop vs. Harris, 669 S.W.2d 859 (Tex.App.-Tyler), the court held that the owner of the lower estate could build a retaining wall to repel runoff surface waters concentrated and accelerated by construction of parking lots and buildings by the owners of the upper estate on their property.

Effluent that flows into gullies, ravines, swales, draws, or natural depressions, where there is no flow of water except during local rain, is probably not "state water." However, the status of this water may be a fact question. See for example Hoefs vs. Short, supra; International-Great Northern R. Co vs. Reagan, 49 S.W.2d 414 (Tex. 1932); In Re Water Rights of Lower Guadalupe River, 730 S.W.2d 64 (Tex.App.-Corpus Christi 1987, writ of error overruled 749 S.W.2d 771 (Tex. 1988)).

Under this analysis, the determining criteria would be whether or not the water has reverted to state water, or whether it is still privately owned water. If the effluent becomes state water, the only liability will be for flooding or for pollution.

In summary, if effluent is not discharged into a watercourse, the discharge is a trespass that can be enjoined by the landowner. If there is a diffused discharge in the delta, it will be necessary to acquire sufficient interest in the land to authorize the discharge.

To determine what easements will be required to authorize discharge into the delta, it will be necessary to determine whether there is any privately owned land between the proposed 8,000-acre tract and land owned by the State of Texas. If there is privately held land, it may be necessary to obtain an easement to discharge over this land, if the discharge does not become state water before it leaves the 8,000-acre tract.

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whose acts contribute to the damage is a significant problem.

The industries are concerned about a situation where major damage to the delta is alleged from the combined discharge, each of their effluents is alleged to have contributed to that damage, and apportionment of the damage caused by each industry is not possible. Current Texas law is represented by the holding in Landers v. East Texas Saltwater Disposal Co., 248 S.W.2d 731 (Tex. 1952). In that case, two defendants, acting separately and independently, negligently allowed saltwater to flow into the plaintiff's pond and damage it and its fish. The plaintiff sought to have the court hold the defendants jointly and severably liable for his damages.

Prior law held that an action for damages against several defendants jointly, when each acted independently of the others and there was no concert or unity of design between them, could not be maintained. The tort of each defendant was separate when committed, and it did not become joint because afterwards its consequences unite with the consequences of several other torts committed by other persons in producing damages. Each tort-feasor was liable only for the part of the injury or damages caused by his own wrong. The fact that it was difficult to define the damages caused by the wrongful act of each person who independently contributed to the final result did not affect the rule.

The court noted that the rule effectively denied the plaintiff's right to recovery because in such a suit the plaintiff cannot discharge the burden of proving with sufficient certainty the portion of the injury attributable to each defendant. The law effectively relieved the two defendants of the consequences of their wrongs and required the innocent plaintiff to suffer his injuries without recompense.

The court overruled prior law and stated:

> "Where the tortious acts of two or more wrongdoers join to produce an indivisible injury, that is, an injury which from its nature cannot be apportioned with reasonable certainty to the individual wrongdoers, all of the wrongdoers will be held jointly and severably liable for the entire damages and the injured party may proceed to judgment against any one separately or against all in one suit."

The other significant case is Atlas Chemical Industries, Inc. v. Anderson, 514 S.W.2d 309 (Tex. Civ. App.-Texarkana, 1974). In this case, the effluent from the defendant's carbon black plant caused damage to creeks flowing through plaintiff's land, and to plaintiff's land.

The court applied strict liability to those pollution cases in which the defendant has intentionally made the discharge. By intentionally discharging its effluent into the stream, the defendant became liable for all of the foreseeable damages resulting from the harm caused by the effluent. One who intentionally discharges potentially hazardous effluent into a stream does so at his peril and is liable for the foreseeable injuries and damages that may result therefrom.

The court stated:

> "the fact that defendant has been granted a license or permit to discharge pollutants into a stream or the fact that the most modern control devices available have been installed in defendant's plant will not defeat an action for damages sought by the plaintiff. The defendant may introduce evidence of his permit and his compliance with the permit and the fact that he is using the most modern control devices available in an attempt to mitigate his damages."

The case was appealed to the Supreme Court. In Atlas Chemical Industries, Inc. v. Anderson, 524 S.W.2d 681 (Tex. 1975) the Supreme Court said that the principal problem was the application of the two-year statute of limitations. The court said that in resolving this and other questions presented on appeal it did not reach, and expressed no opinion on, other considerations upon which the court of civil appeals wrote at some length.

The possibility of a special district has been suggested, with the hope that the district can insulate the industries from liability for any damage to the delta or bay. The concept is that, if significant damage to the delta or bay occurs, only the district would have liability. The industries, if they are compliant with their permits, would not have responsibility for the damage.

Whether or not a theory can be fashioned to produce this insulation has not been conclusively established. A lawsuit that may answer this question is pending in Harris County. In that lawsuit, numerous shrimpers and fishermen have sued the Gulf Coast Waste Disposal Authority, Champion International Corporation, Simpson Pasadena Paper Company, and others, alleging that their discharge of dioxin (Agent Orange) has prevented oyster harvesting and fishing in the Houston ship channel and Galveston Bay.

The suit alleges that the Gulf Coast Waste Disposal Authority operates a waste treatment plant that receives waste from eight industries and one municipality. The plaintiffs allege that the dioxin comes from the defendant's paper plant and that it is passed through the treatment process and discharged into the Houston ship channel and Galveston Bay.

The issues in the case have not been fully developed. The Gulf Coast Waste Disposal Authority contends that it is shielded from liability by the doctrine of governmental immunity, and that no exceptions to this doctrine exist under the Texas Tort Claims Act. The industries contend that they have not been negligent, that they have been compliant with state and NPDES permits, and that until recently they had no reason to know that dioxin was in their waste discharge, and that the amount of dioxin discharged is far below that which could cause damage. The defendants also contend that the plaintiffs have no property interest in the Houston ship channel or Galveston bay, so that they cannot claim any damage to the channel or bay. The plaintiffs countered by citing cases from other jurisdictions holding that the interest given to a commercial fisherman by the state has long been recognized as a private property right for which he is entitled to compensation when that right is wrongfully damaged by another.

The pleadings currently on file in the lawsuits against the Gulf Coast Waste Disposal Authority do not articulate a defense based on the concept that the industries delivered their waste to a duly authorized public entity, and that the subsequent treatment and discharge of the waste was performed solely by that public entity, pursuant to federal and state permits, so that the industries should not be responsible for any resulting damages. The rationale of the opinions in the Landers and Atlas Chemical Industries cases indicates that this defense would not be successful.

10.1.3 Assumption of Liability by the District

If we assume that the existence of a district will not insulate the industries from liability, the only way to protect them will be for the district to agree to indemnify the industries in the event of damage. In this event, the industries will need to be satisfied that the district can pay any damages. This means that the district will have the power to tax, or that the district will have a contract with the City whereby the City agrees to indemnify the district for any damages. (It is assumed that the industries will not be willing to pay rates to the district to carry their waste to the delta.)

If the district is to have the power to tax, this will have to be confirmed by election. This could be a political problem, particularly with respect to the question as to what taxable property should be included within the district's boundary.

This project is for the benefit of the City's water system. The cost can be borne by the City's customers, both retail and wholesale, either directly through rates, or indirectly through taxes. If the cost is to be raised by taxes, the District's boundary will need to be coterminous with the area served by City Water; i.e., the area encompassing the City's retail customers and the retail customers served by wholesale purchasers from the City. This will achieve rough equity.

Whether or not to proceed in the face of potential liability will require analysis of any potential risk from the use of wastewater generated from cooling operations, and the risk of waste from process water. If the risk analysis concludes that only wastewater from cooling operations should be used, it will be necessary to ascertain the industry's ability to separate its water from cooling operations from its process water, to determine the quantity of wastewater from cooling operations available, and to determine the feasibility of transporting that water to the delta.

10.1.4 Acquisition of Title to 8,000-Acre Tract

Acquisition of 8,000 acres or more of land to create a wildlife preserve and a site for effluent dispersal will require extensive study of the ownership of the surface, the sub-surface rights, and easements. The owners of these rights will be entitled to compensation for any interference with their property rights. It is reasonable to assume that most of these rights can be acquired by negotiation, but typically some rights will have to be condemned. Any abandoned oil wells or disposal pits will have to be identified and dealt with.

The possibility of U.S. Fish and Wildlife contributing to the cost of the wildlife preserve is under study. Provision of a reliable supply of fresh water, through dedication of the City's municipal effluent, may make the site attractive to that agency.

10.2 Organizational Structure

It will be necessary to decide whether to create a single purpose district for this project, to contract with an existing district, or to have the City perform the necessary functions.

If a special district is to be created, it will be necessary to make several decisions, as follows:

1. The District's Boundary. The district's boundary may encompass the delta and ship channel area, all of Nueces County, or a larger area. The boundary is critical if the district's directors are to be elected, and if the district is to have the power of tax.

2. The District Directors. The creating legislation will provide the number of directors, and whether the directors will be elected, or appointed. If the directors are to be appointed, they can be appointed by the governor, the City, the county commissioner's court, or by a combination of various authorities.

3. Financial Ability. If the District is to have the power to tax, this power will have to be confirmed by the voters. If the District will not have the power to tax, it will have to be funded by revenues. It is difficult to imagine what significant revenues might be available to the district other than those that would be available through the City. It is assumed that there is no reason to expect the industries to finance the district, because the industries are receiving no benefit other than their contribution to enhancing the City's

water supply. Therefore, it would be appropriate for the City to fund the district. This would recognize the fact that the district is acting for the benefit of the City's water system. However, the funding mechanism should be broad and flexible enough to allow financial participation by both public and private agencies having an interest in fish, wildlife, and cultural resources; i.e., Nature Conservancy, federal agencies, conservation groups, and similar organizations.

4. Organizational Structure. The district will be governed by a board of directors. The district's functions will be performed by its general manager and staff.

10.3 Operational Methods and Procedures

10.3.1 The Municipal and Industrial Permits

At the conference of October 29, 1992 with staff members of the TWC and EPA, the EPA representative indicated that the City and the industries will need to maintain their current permits to discharge into the ship channel, and to obtain amendments allowing discharge into the district's conveyance system. The district will need State and NPDES permits to discharge into the delta.

10.4 Financial Requirements

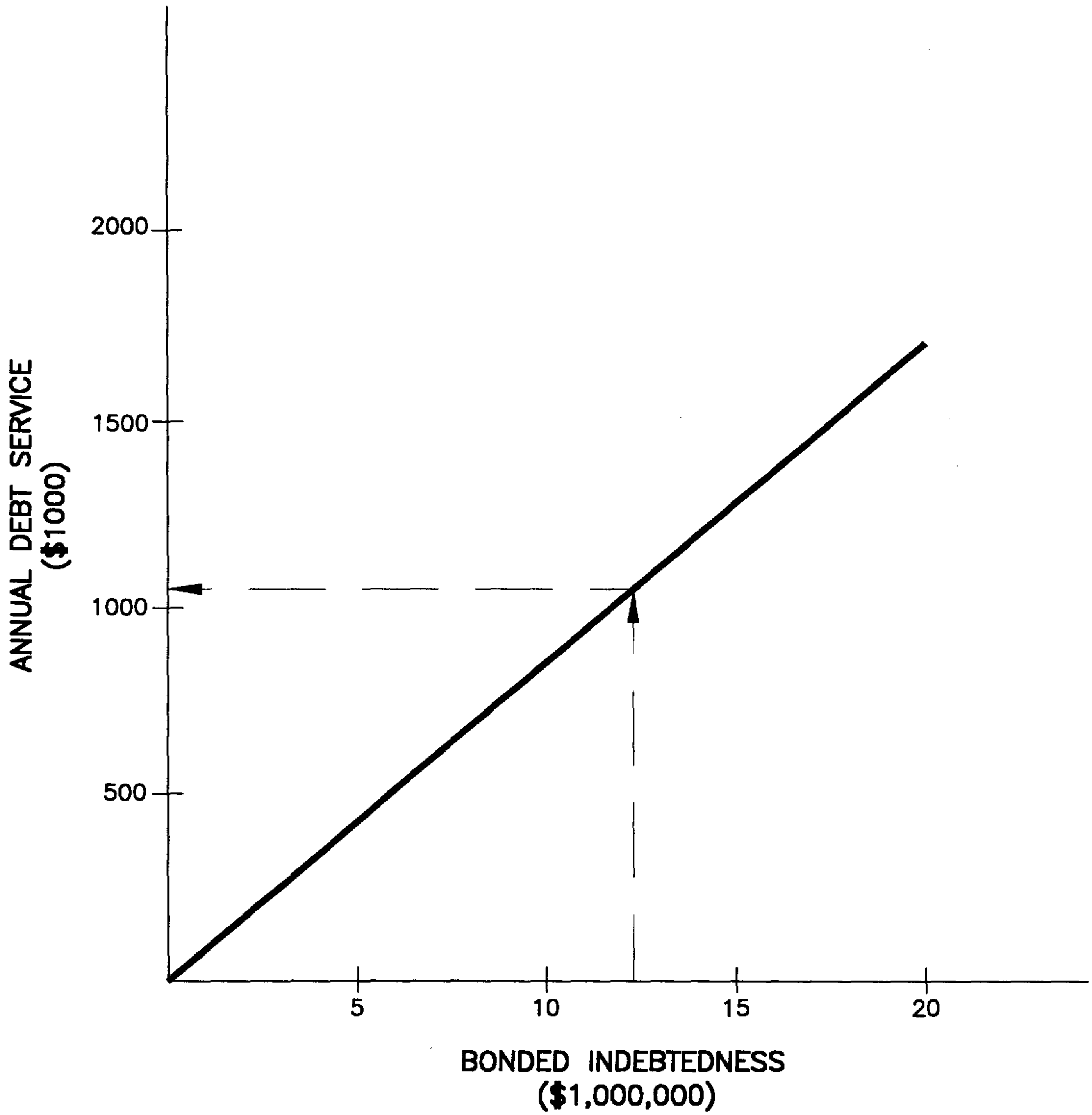
As stated in Section 10.1, a special district would probably have the power to assess taxes, charge rates, or receive payments from the City or other sources to finance its operations. As previously stated, a wastewater diversion project would be for the benefit of the City's water system and therefore, it is likely that the major portion of funding would be provided by or through the City. The purpose of this section is to present illustrative financial information that could be used in planning future bond sales to finance a district's operations. Information presented is based on the following assumptions:

1. Funding will be provided by the sale of revenue bonds;
2. Bonds will be amortized over a period of 20 years; and
3. Interest rate on bonds is 6 percent.

Figure 10-1 shows the relationship between the amount of bonded indebtedness (up to $20 million) and the corresponding annual debt service. An example is shown for a bonded indebtedness of $12 million, which under the assumption stated above would have an annual debt service of $1,050,000.

If the $1,050,000 of debt service mentioned above were to be met through an increase in water rates, a rate increase of $0.025 per 1,000 gallons per month would be needed. For example, the City currently produces and sells approximately 120 mgd of treated water. City water rates are based on a sliding scale, depending upon the amount of water used per month and the type of user (residential or commercial). For purposes of this illustration, it is assumed that a single "across-the-board" rate increase would be implemented, without regard to the type of user or amount of water consumed. Figure 10-2 shows water rate increases which would be required to generate annual revenues (up to $2,500,000), through the sale of 100 mgd, 120 mgd, and 140 mgd of water, respectively. Using the example from Figure 10-1, a rate increase of $0.025 per 1,000 gallons per month would be required to generate an annual revenue of $1,050,000, if 120 mgd of water is sold. At this rate, it is estimated that the average household water bill would increase by $0.33 per month.

Operation and maintenance (O&M) costs were estimated by assuming annual O&M costs of 10 percent of annual debt service. The special district's O&M costs would include



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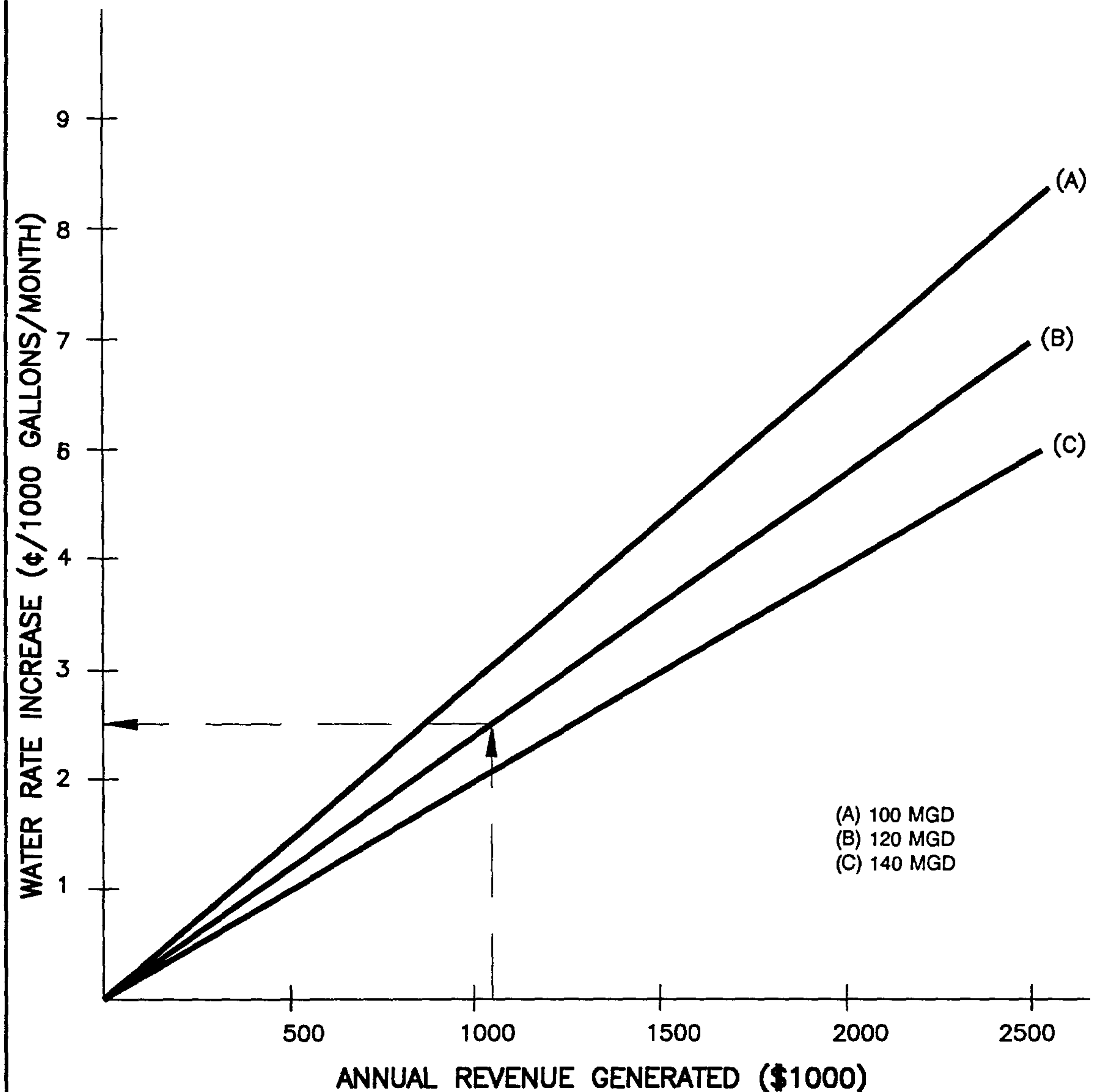
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
BONDING REQUIREMENTS
BONDED INDEBTEDNESS VS. ANNUAL DEBT SERVICE
FIGURE 10-1



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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
BONDING REQUIREMENTS
ANNUAL REVENUE GENERATED VS. WATER RATE INCREASE
FIGURE 10-2

additional personnel requirements or an increase in City of Corpus Christi Department of Public Utilities staff to operate the system. However, based on information available at this time, it is not possible to estimate the costs involved with operation of a district which would develop, implement, and operate wastewater diversion projects.

10.5 Method(s) of Creation

The special district should be created by the legislature so that its powers, functions, and administration can be designed for its purpose.

10.5.1 Contract with an Existing District

Certain existing districts have been suggested as candidates to serve as the special district discussed in this Section 10. These are: (1) San Patricio Municipal Water District; (2) San Patricio County Drainage District; and (3) Nueces River Authority.

Review of the statute creating San Patricio County Drainage District, and later amendatory statutes, indicate that the District has no express authority to handle wastewater, nor to own and operate a wildlife refuge, in its creating statute. However, Sec. 17A of Art. 8280-145 provides that within San Patricio County, the District shall have all of the powers and be governed by the provisions of the General Laws Governing Water Control and Improvement Districts. The General Laws Governing Water Control and Improvement Districts are found in Chapter 51, Texas Water Code. Under certain circumstances, a WCID has the power to treat and dispose of domestic, industrial, or other wastes (Sec. 51.331, Texas Water Code). It is unclear whether San Patricio Municipal Water District would have these powers. However, the application of the Regional Waste Disposal Act, Chapter 30, Texas Water Code, makes this inquiry unnecessary as is stated hereafter.

Review of the statute creating the Nueces River Authority, and later amendatory statutes, indicate that this authority does have express authority to handle wastewater, and to acquire land adjacent to or in the vicinity of the Nueces River for park and recreational facilities.

The Regional Waste Disposal Act (RWDA) is found in Chapter 30, Texas Water Code. It gives certain powers to districts created under Art. XVI, Sec. 59 or Art. III, Sec. 52 of the Texas Constitution. The San Patricio Municipal Water District, San Patricio County Drainage District, and Nueces River Authority all fall within this category of District.

The RWDA authorizes districts to perform the functions previously discussed in this section of the Phase II report. It also authorizes these districts to contract with the City to perform those functions, and the City is authorized to pay for this service from its waterworks system, sewer system, or its combined water and sewer system. The contract can be an obligation against the taxing power of the City if this is authorized by an election. The district may issue bonds secured by a pledge of all or part of the revenue from such a contract.

The 8,000-acre tract may be used as a wildlife refuge. This project would be open to the public through picnic areas and trails for hiking and horseback riding. The definition of "park purposes" is probably broad enough to include this use (see for example State v. Merrill, 334 S.W.2d 432 (Tex. 1960)). Legislation will be required to authorize the San

Patricio Municipal Water District or the San Patricio County Drainage District to own and operate the 8,000-acre tract. The Nueces River Authority has existing power to acquire land adjacent to or in the vicinity of the Nueces River for park and recreational facilities.

The directors of the existing districts–San Patricio Municipal Water District, San Patricio County Drainage District, and Nueces River Authority–are appointed from areas outside of the City. It will therefore be advisable to consider any potential conflict between the interest of the City and the interest of the special districts that may arise in the future.

10.5.2 Private Foundation

It may be possible to identify a private foundation that will contribute its own funds to the project, and that will be eligible to receive contributions from the City, U.S. Fish & Wildlife, and others.

10.5.3 The City

The City has the power to acquire and own property or any interest therein, within and without the City limits, by eminent domain, or otherwise. The City has the power to construct public works and improvements, to own and operate any public utility, and to provide and support parks, recreational, and cultural activities (Article X, City Charter).

It may not be necessary to create a special district if its only purpose is to receive and dispose of wastewater. However, ownership and operation of an extensive wildlife refuge is not within the normal activities of the City, and it is therefore advisable to consider creation of a special district for that purpose.

11.0 CHOKE CANYON/LAKE CORPUS CHRISTI SYSTEM YIELD IMPACTS AND COST COMPARISONS OF DIVERSION ALTERNATIVES

Each of the alternatives involving the transfer of wastewater and stormwater to Nueces Bay and/or the Nueces River Delta, as well as each of the alternatives involving the diversion of river water from Calallen Reservoir into Rincon Bayou, was evaluated to determine the relative impact each would have upon the yield of the CC/LCC Reservoir System. In addition, alternatives including the use of groundwater either through direct pumpage to the Nueces Delta or through storage in the Hondo Creek stormwater impoundment and diversion alternative were considered.

The increase in yield for each alternative was computed, along with the annual cost of each alternative to determine the annual unit cost (i.e. dollars per acre-foot per year) for the corresponding increase in yield. All yield computations were performed utilizing an updated version (NUBAY2) of the Lower Nueces River Basin and Estuary Model which was previously developed by HDR. The original model was modified during the course of this study to include monthly release provisions consistent with the Interim Order of the Texas Water Commission (TWC) dated March 9, 1992 (TWC, 1992). The version of NUBAY2 utilized in this study includes provisions for reduced or suspended releases when certain salinity criteria are met in the estuary. In addition, the model was modified to include the latest productivity factors which reflect the relative productivity enhancement values of municipal effluent, stormwater, and river water diverted to the Nueces Delta (see Section 2 for discussion of productivity factors).

The firm yield of a reservoir system is defined as the quantity of water which can be reliably diverted year after year from the reservoir system even during the worst droughts of record. The firm yield of a reservoir system will vary depending upon sediment accumulation, operating rules, and, in the case of the CC/LCC System, the location where water is actually diverted. The period of record for this study is 1934 through 1989, which included significant droughts in the 1950s, 1960s, and 1980s. For this study, both 1990 and year 2040 reservoir sediment conditions were selected as was Phase IV of the City of Corpus Christi's Operations Plan. Under the Phase IV operation policy, 2,000 acre-feet are released each month from Choke Canyon Reservoir until the level in the Lake Corpus Christi drops to 76 feet-MSL, which is 18 feet below conservation level. At this level, monthly releases from Choke Canyon are increased, based on water supply and estuarine inflow requirements, to the quantity sufficient to maintain an operating level of 76 feet-MSL at Lake Corpus Christi. Estimates of system firm yield reported in this study reflect the losses associated with delivery of water from Choke Canyon Reservoir to Lake Corpus Christi and from Lake Corpus Christi to the Calallen diversion dam, the point at which water from the CC/LCC System is diverted for treatment.

Reservoir operation studies were performed on the CC/LCC System to determine the firm yield of the system without dedicated releases to the estuary. Under these conditions, the 1990 firm yield of the system is 222,696 acre-feet per year. The next studies were performed with the release provisions included in the TWC Interim Order. For these conditions, the 1990 firm yield of the system is reduced by approximately 30,954 acre-feet per year (13.9 percent) to 191,742 acre-feet per year.

Each individual wastewater, river, and stormwater diversion project was evaluated to determine to what extent it would restore the 30,954 acre-feet per year yield lost under 1990 sediment conditions. After the individual diversion projects were evaluated, then combinations of projects were evaluated to determine the more economical options. These combinations of projects were then evaluated under 2040 sediment conditions.

11.1 Evaluation of Nueces River Delta Diversion Projects

Reservoir operation studies were performed for each of the projects that would transfer wastewater, river water, and stormwater to the Nueces Delta utilizing the following productivity factors for flows diverted to various locations within the Nueces Delta and Estuary:

	Type of Diversion	Delivery Location	Productivity Factor
A.	Municipal Wastewater Return Flows	Nueces River Mainstem	1
		Rincon Bayou	5
		South Lake	5
		Nueces Bay	1
B.	Nueces River Water from Calallen	Nueces River Mainstem	1
		Rincon Bayou	3
C.	Stormwater	Nueces Bay	1
		Rincon Bayou	3
D.	Groundwater		

These productivity factors reflect the appropriate values as reported herein by the University of Texas Marine Science Institute (see Section 2.0).

The firm yield restored for each of the individual projects is summarized in Table 11-1, with the exception of groundwater (brackish well water) alternatives involving direct pumpage to the Nueces Delta. Estimates of the firm yield restored through direct

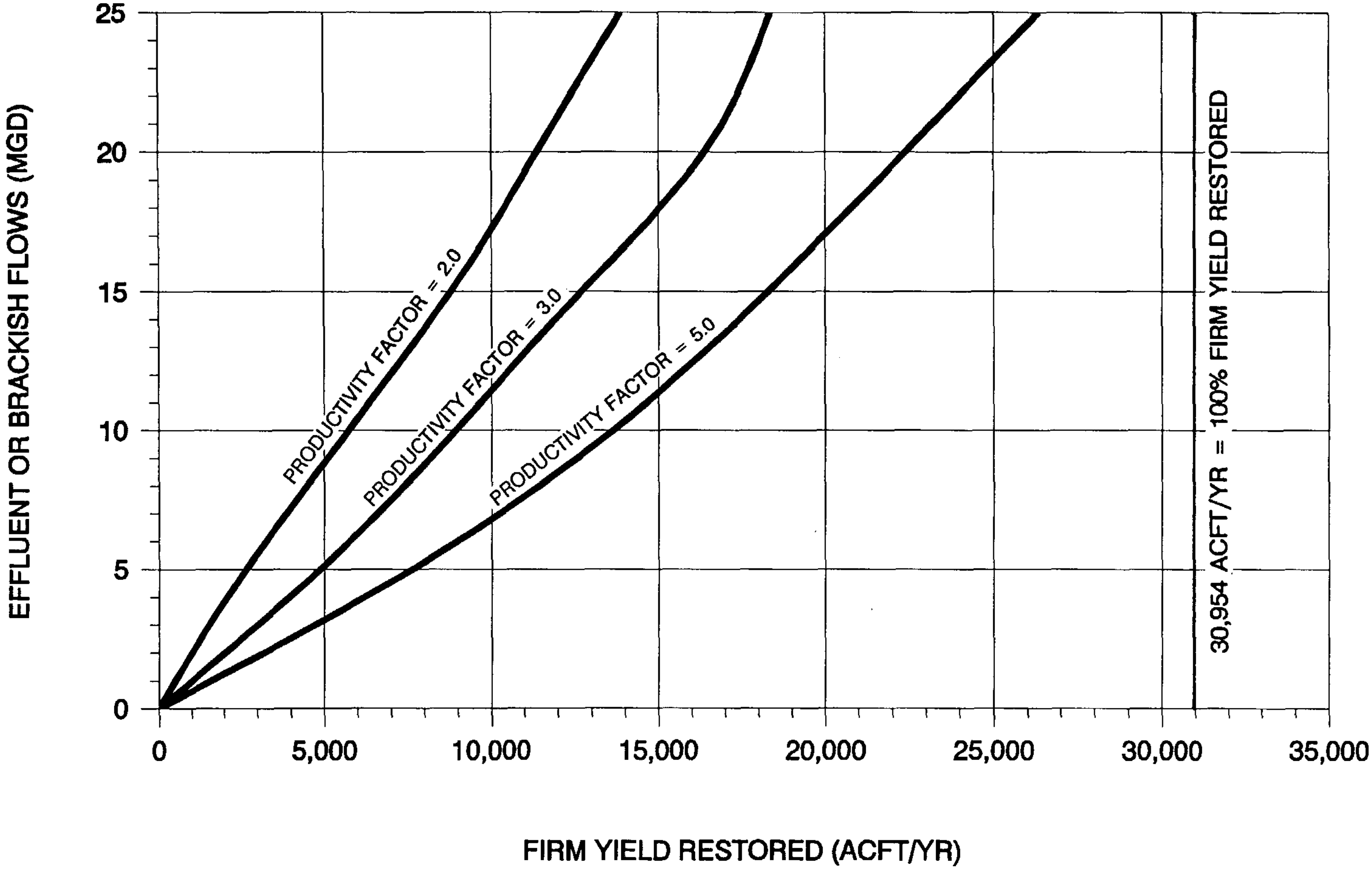
TABLE 11-1
Summary of Flow Volumes and Yield Restoration for Individual Alternatives

Alternative	Description	Return Flow to Bay** (mgd)	Municipal Flow to Delta (mgd)	Industrial Flow to Delta (mgd)	Maximum River Flow to Delta (mgd)	Productivity Factor for Water to Delta	System Yield Restored (ac-ft/year)	Percentage of System Yield Restored*
NS-1	North Shore Discharges	7.84	0	0	0	-	1,686	5.4
NS-2	North Shore Discharges	3.15	1.49	3.20	0	5	10,311	33.3
SS-1	Allison WWTP Discharge	1.46	2.80	0	0	5	3,127	10.1
SS-2	Allison & Broadway WWTP's Discharges	1.46	8.80	0	0	5	11,656	37.7
SS-3	Individual Industrial Discharges	4.26	0	11.68	0	5	16,350	52.8
SS-3A	Individual Industrial Discharges	15.94	0	0	0	-	3,380	10.9
SS-4	Combined Industrial Discharges	4.26	0	12.21	0	5	17,136	55.4
SS-4A	Combined Industrial Discharges	16.47	0	0	0	-	6,804	22.0
SS-5	Combined Municipal and Industrial Discharges	1.46	8.80	12.21	0	5	22,789	73.6
W-1	Westside WWTP Discharge	4.26	3.00	0	0	5	5,070	16.4
WO-1	Westside and Oso WWTP's Discharge	4.26	12.0	0	0	5	16,824	54.4
R-1	River Diversion	4.26	0	0	15	3	6,435	20.8
R-2	River Diversion	4.26	0	0	20	3	8,054	26.0
R-3	River Diversion	4.26	0	0	100	3	19,735	63.8
SW-1	Upper Oso Stormwater Diversion	4.26	0	0	Variable*	1***	227	0.7
SW-2	Peter's Swale Stormwater Diversion	4.26	0	0	Variable	3	1,737	5.6
SW-3	Hondo Creek Stormwater Diversion	4.26	0	0	5	3	224	0.7
SW-4	Hondo Creek Stormwater Diversion w/Pumpage	4.26	0	0	20	3	6,234	20.1

*Percentage of Reduction (30,954 acre-feet/yr) in CC/LCC System firm yield due to Texas Water Commission Interim Order of March 9, 1992 which is restored by diversion of flows to the Nueces Delta.
**4.26 mgd is the quantity of effluent currently returned to Nueces Bay.
***Upper Oso Stormwater diversion is assumed to terminate in Nueces Bay.

groundwater pumpage or effluent diversions may be interpolated based on a specified productivity factor from the curves presented in Figure 11-1. As shown on the last column of Table 11-1, the percentage of the system yield restored (percent of 30,984 acre-feet of yield reduction due to TWC Interim Order of March 9, 1992) varies from a low of 0.7 percent (224 acre-feet per year) for alternative SW-3 (Hondo Creek Stormwater Diversion) to a high of 73.6 percent (22,789 acre-feet per year) for alternative SS-5 (Transfer of Selected South Shore Municipal and Industrial Discharges into the Delta Area).

To determine which of the individual alternatives are more economical relative to both yield and cost, capital and annual unit costs were calculated and are presented in Table 11-2. This table indicates that the alternative with the least unit cost is the channel from Calallen Dam to Rincon Bayou. If a channel with a capacity of 100 mgd were constructed, the system yield could be increased by 19,735 acre-feet per year at a unit cost of $12.70 per acre-foot assuming a productivity factor of three. The next most economical alternative is SS-1 (Transfer of the Allison WWTP flows to the Delta Area). The unit cost for this alternative is $32.30 per acre-foot with 3,127 acre-feet per year restored to the system yield, assuming a productivity factor of five. A graphical presentation of the unit cost and firm yield volume restored for each alternative is shown in Figure 11-2. As is apparent in this figure, the individual alternative which restores the greatest portion of the firm yield is Alternative SS-5 (Transfer of Selected South Shore Municipal and Industrial Discharges to the Delta Area). This alternative restores 22,789 acre-feet per year (73.6 percent) of the firm yield that was lost through implementation of the TWC Interim Order. The corresponding unit cost of this alternative is $59.00 per acre-foot per year.



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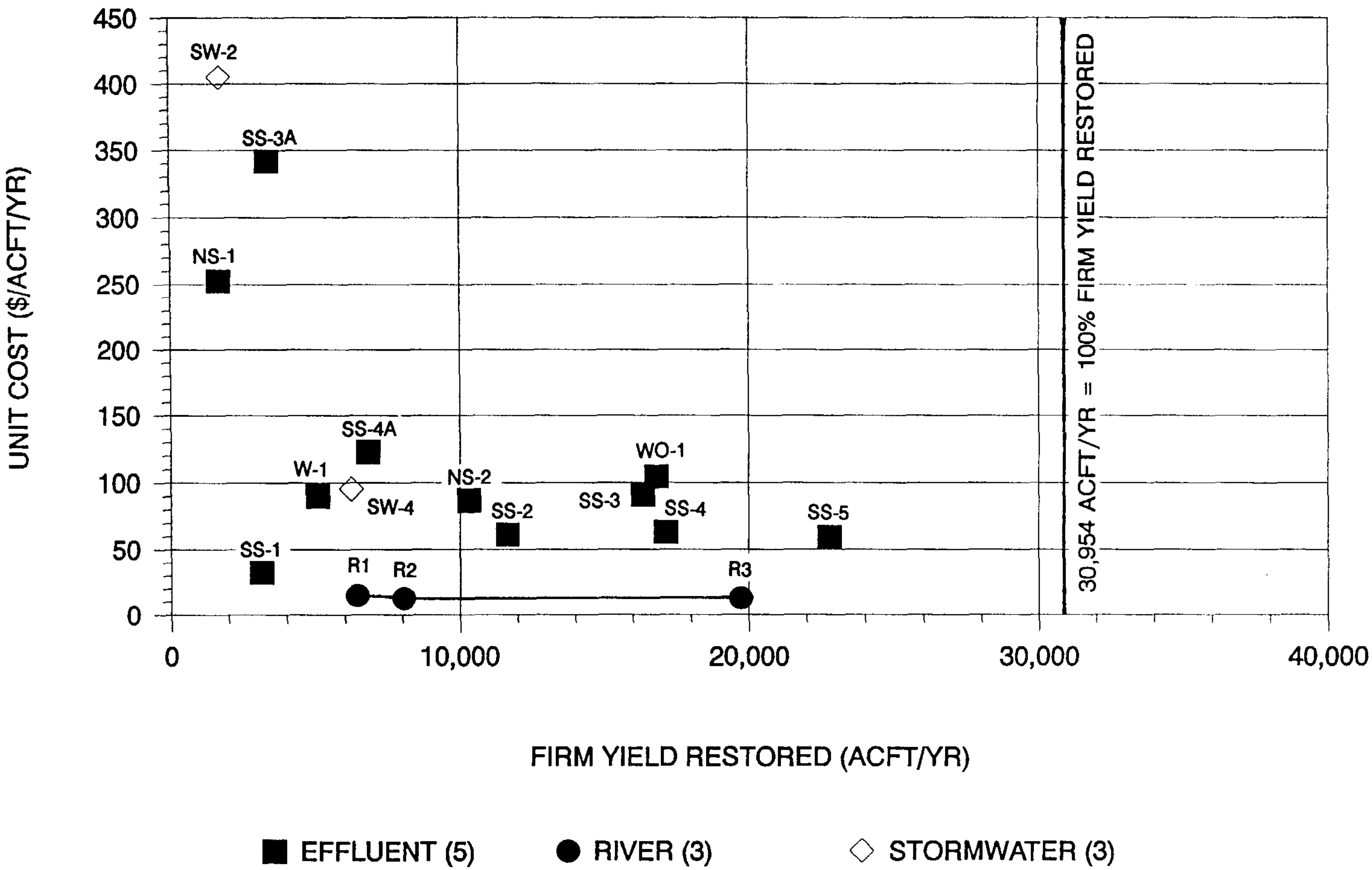
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
YIELD RESTORATION BY EFFLUENT OR BRACKISH WELL DIVERSION
FIGURE 11-1

TABLE 11-2
Nueces Estuary Regional Wastewater Planning Study
Summary of Unit Costs for Individual Alternatives

Alternatives	Description	Quantity		Cost		Productivity Factor for Delta Water	System Yield Restored (ac-ft/yr)	Unit Costs $/ac-ft/yr
		ac-ft/yr	mgd	Capital ($million)	Annual ($thousand)			
NS-1	North Shore Discharges	4,011	3.58	3.737	426.1	-	1,686	252.7
NS-2	North Shore Discharges	5,254	4.69	7.867	895.4	5	10,311	86.8
SS-1	Allison WWTP Discharge	3,137	2.80	0.978	115.8	5	3,127	32.3
SS-2	Allison & Broadway WWTP's Discharges	9,859	8.80	5.961	711.7	5	11,656	61.1
SS-3	Individual Industrial Discharges	13,085	11.68	13.289	1,489.8	5	16,350	91.1
SS-3A	Individual Industrial Discharges	13,085	11.68	10.235	1,155.9	-	3,380	342.0
SS-4	Combined Industrial Discharges	13,679	12.21	8.920	1,077.5	5	17,136	62.9
SS-4A	Combined Industrial Discharges	13,679	12.21	7.296	834.3	-	6,804	122.6
SS-5	Combined Municipal and Industrial Discharges	23,537	21.01	10.455	1,345.6	5	22,789	59.0
W-1	Westside WWTP Discharge	3,361	3.00	4.071	456.8	5	5,070	90.1
WO-1	Westside and Oso WWTP's Discharge	13,440	12.00	15.390	1,755.1	5	16,824	104.3
R-1	River Diversion	N/A	15.0	0.908	95.0	3	6,435	14.8
R-2	River Diversion	N/A	20.0	0.982	102.0	3	8,054	12.7
R-3	River Diversion	N/A	100.0	2.411	250.0	3	19,735	12.7
SW-1	Upper Oso Stormwater Diversion	Variable		4.590	504.9	--	227	2224.2
SW-2	Peter's Swale Stormwater Diversion	Variable		6.399	703.9	3	1,737	405.2
SW-3	Hondo Creek Stormwater Diversion	Variable 5 mgd max		2.481	273.0	3	224	1218.8
SW-4	Hondo Creek Stormwater Diversion w/Pumpage	Variable 20 mgd max May, June, Sept, Oct		4.058	594.4	3	6,234	95.3



NOTE: STORMWATER ALTERNATIVES SW-1 AND SW-3 HAVE UNIT COSTS OF $2224/ACFT/YEAR AND $1219/ACFT/YEAR, RESPECTIVELY.

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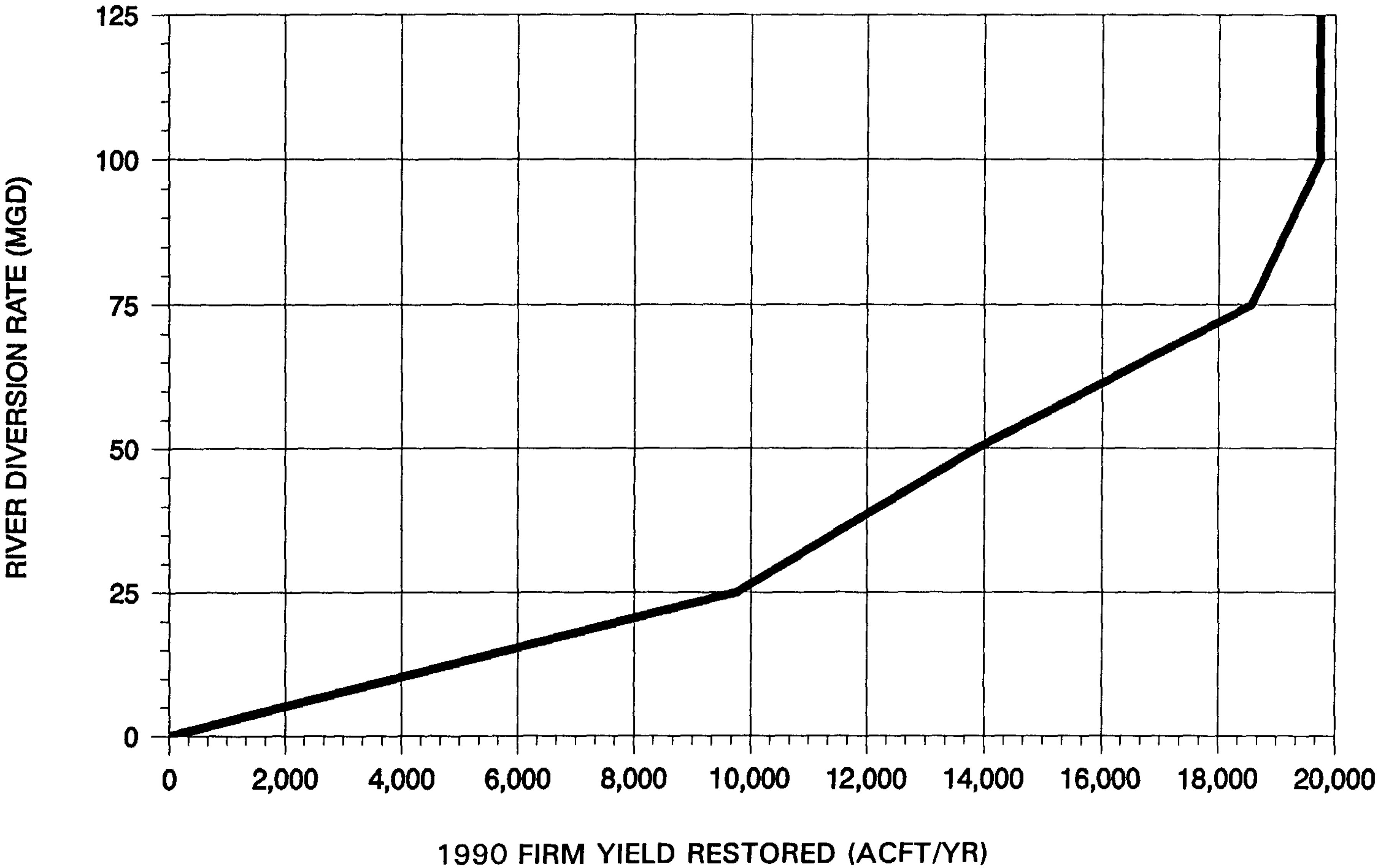
NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
UNIT COST SUMMARY - COMBINED RIVER & WASTEWATER DIVERSION ALTERNATIVES - YEAR 2040
FIGURE 11-2

In the evaluation of the stormwater diversion alternatives, Alternative SW-4 (Hondo Creek Stormwater Diversion with Groundwater Pumpage) restores the greatest portion of the firm yield. This alternative restores 6,234 acre-feet per year (20.1 percent) at a unit cost of $95.30 per acre-foot per year. In the alternatives SW-1 (Upper Oso Stormwater Diversion) and SW-2 (Peters Swale Stormwater Diversion) flood control benefits and firm yield restoration were considered. However, from a flood control standpoint, neither of these two options are of much benefit. In a flood control study done for the San Patricio County Drainage District (HDR/NEI, 1987), an economic benefit/cost analysis was performed on the Peters Swale diversion. This analysis calculated that the benefit/cost ratio for the diversion of Peters Swale flows to protect Odem and/or Sinton, was barely equal to one (indicating that the project benefit equals the expenditures for building the diversion). The City of Corpus Christi's Master Drainage Plan reported that the Oso Creek diversion would only reduce the peak discharge at the lower end of Oso Creek by 184 cfs or approximately 0.5 percent of the total peak. These conclusions, combined with the fact that the Hondo Creek diversions (SW-3 and SW-4) provide little or no flood control benefits suggest that flood control benefits from the stormwater diversion projects presented in this study are minimal at best. Therefore, no attempt to include flood control benefits in the cost analyses of the stormwater alternatives was included in this study.

11.2 Evaluation of Combined Alternatives

A review of the individual alternatives analyzed clearly shows that the most economical alternative is the diversion of river water via a pipeline or canal from Calallen Dam to Rincon Bayou. However, this alternative on it's own can only restore about 63.8



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NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
YIELD RESTORATION BY RIVER DIVERSION
FIGURE 11-3

TABLE 11-3
Summary of Flow Volumes and Yield Restoration for Combined Alternatives

Combined Alternative	Description	Return Flow to Bay (mgd)	Municipal Flow to Delta (mgd)	Industrial Flow to Delta (mgd)	Maximum River Flow to Delta (mgd)	Productivity Factors		System Yield Restored (ac-ft/year)	Percentage of System Yield Restored*
						WW to Delta	River to Delta		
A. (SS-1/R)	Allison WWTP Discharge and River Diversion to ND**	1.46	2.80	0.00	80	5	3	21,176	68.4
B. (SS-2/R)	Allison & Broadway WWTP's Discharge and River Diversion to ND**	1.46	8.80	0.00	70	5	3	24,328	78.6
B'. (SS-1 & WO-I/R	Allison & Westside WWTP's Discharge and River Diversion to ND**	1.46	5.80	0.00	80	5	3	23,033	74.4
C. (SS-2 & W-1/R)	Allison, Broadway & Westside WWTP's Discharge and River Diversion to ND**	1.46	11.80	0.00	70	5	3	25,722	83.1
D. (SS-2 & WO-1/R)	Allison, Broadway, Westside & Oso WWTP's Discharge and River Diversion to ND**	1.46	20.80	0.00	50	5	3	28,874	93.3
E. (SS-5/R)	Combined Municipal (Allison & Broadway WWTP's) and South Shore Industrial Discharges and River Diversion to ND*	1.46	8.80	12.21	50	5	3	28,915	93.4
F. (SS-5 & W-1/R)	Combined Municipal (Allison, Broadway & Westside WWTP's) and South Shore Industrial Discharges and River Diversion to ND**	1.46	11.80	12.21	50	5	3	29,456	95.2
G. (SS-5 & WO-1/R)	Combined Municipal (all four WWTP's) and South Shore Industrial Discharges and River Diversion to ND**	1.46	20.80	12.21	30	5	3	30,295	97.9
H. (SS-5, WO-1, & NS-2/R)	Combined Municipal (all four WWTP's) and Industrial Discharges (including South Shore and North Shore) and River Diversion to ND**	0.35	22.29	15.41	20	5	3	30,484	98.5

*Percentage of reduction (30,954 ac-ft/yr) in CC/LCC System firm yield due to Texas Water Commission - Interim Order, which is restored by diversion of flows to the Nueces Delta.
**ND means Nueces Delta.

from a low of 93.4 percent (28,915 acre-feet per year) for Alternative E to a high of 98.5 percent (30,484 acre-feet per year) for Alternative H.

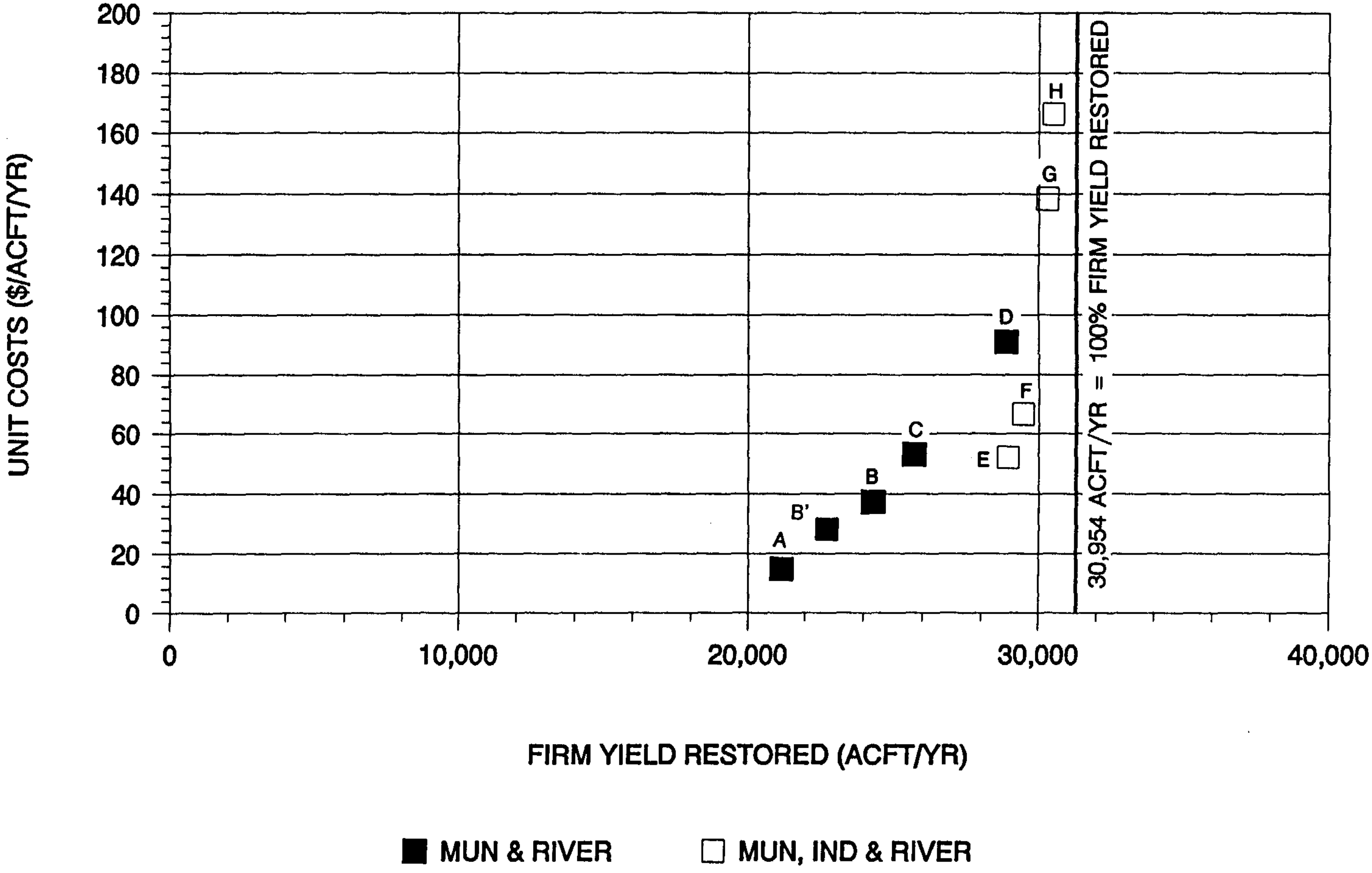
To determine which of the combined groups of alternatives are more economical relative to both yield and cost, capital and annual unit costs were calculated and are presented in Table 11-4. This table shows that the alternative with the lowest unit cost is Alternative A (Diversion of Allison WWTP discharges along with an 80 mgd capacity river diversion to the Delta Area). This alternative will increase the 1990 system yield by 21,176 acre-feet per year at a unit cost of $14.83 per acre-foot per year. The next most economical alternative is B′ (Diversion of Allison and Westside WWTP discharges along with an 80 mgd capacity river diversion to the Delta Area). This alternative would restore 23,033 acre-feet per year of the 1990 yield at a unit cost of $33.47 per acre-foot per year.

A graphical presentation of the unit costs and the firm yield volumes restored for all nine groups of combined alternatives is shown in Figure 11-4. As indicated in this figure, the combined alternative which restores the greatest portion of the firm yield is Alternative H (Transfer of all four municipal WWTP discharges, including South Shore and North Shore Industrial discharges as well as a 20 mgd capacity river diversion to the Delta Area). This alternative restores 30,484 acre-feet per year of the 1990 firm yield. However, the unit cost of this combined alternative is $166.31 per acre-foot per year which is the highest unit cost of all the combined alternatives analyzed. The combined alternative which appears to provide the most water at a comparatively attractive unit cost is Alternative E (Transfer of Allison and Broadway WWTP discharges, plus South Shore Industrial discharges, and a 50 mgd capacity river diversion to the Delta Area). This alternative restores 28,915 acre-feet

TABLE 11-4
Summary of Unit Costs for Combined Alternatives

Combined Alternative	Description	Quantity: WW to Delta (mgd)	Quantity: River to Delta (mgd)	Cost: Capital ($million)	Cost: Annual ($thousand)	Productivity Factors: WW to Delta	Productivity Factors: River to Delta	1990 System Yield Restored (ac-ft/year)	Unit Cost ($/ac-ft/yr)
A. (SS-1/R)	Allison WWTP Discharge and River Diversion to ND*	2.80	80	2.850	314.1	5	3	21,176	$14.83
B. (SS-2/R)	Allison & Broadway WWTP's Discharge and River Diversion to ND*	8.80	70	7.836	906.2	5	3	24,328	$37.25
B'. (SS-1 & WO-I/R)	Allison & Westside WWTP's Discharge and River Diversion to ND*	5.80	80	6.921	720.9	5	3	23,033	$33.47
C. (SS-2 & W-1/R)	Allison, Broadway & Westside WWTP's Discharge and River Diversion to ND*	11.80	70	11.907	1,363.0	5	3	25,722	$52.99
D. (SS-2 & WO-1/R)	Allison, Broadway, Westside & Oso WWTP's Discharge and River Diversion to ND*	20.80	50	22.869	2,624.3	5	3	28,874	$90.89
E. (SS-5/R)	Combined Municipal (Allison & Broadway WWTP's) and South Shore Industrial Discharges and River Diversion to ND*	21.01	50	11.973	1,503.1	5	3	28,915	$51.98
F. (SS-5 & W-1/R)	Combined Municipal (Allison, Broadway & Westside WWTP's) and South Shore Industrial Discharges and River Diversion to ND*	24.01	50	16.044	1,959.9	5	3	29,456	$66.54
G. (SS-5 & WO-1/R)	Combined Municipal (all four WWTP's) and South Shore Industrial Discharges and River Diversion to ND*	33.01	30	28.327	4,192.8	5	3	30,295	$138.40
H. (SS-5, WO-1, & NS-2/R)	Combined Municipal (all four WWTP's) and Industrial Discharges (including South Shore and North Shore) and River Diversion to ND*	37.70	20	36.015	5,069.7	5	3	30,484	$166.31

*ND means Nueces Delta.



DELTA PRODUCTIVITY FACTORS:
EFFLUENT (5) & RIVER (3)

HDR Engineering, Inc.

NAISMITH ENGINEERING, INC.
CONSULTING CIVIL ENGINEERS AND SURVEYORS
CORPUS CHRISTI TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
UNIT COST SUMMARY - COMBINED RIVER & WASTEWATER DIVERSION ALTERNATIVES
FIGURE 11-4

per year of the 1990 firm yield at a unit cost of $51.98 per acre-foot per year. However, due to environmental concerns of regulatory agencies, it is unlikely that permits can be obtained for the discharge of industrial effluent into the delta. For this reason, Alternatives A, B, B′, C, and D (which involve the transfer of only municipal effluent to the delta) may be the only viable options. The combined alternative from this group that appears to be the most attractive under 1990 sediment conditions is Alternative C (Transfer of Allison, Broadway and Westside WWTP discharges as well as 70 mgd capacity river diversion to the Delta Area). This alternative would restore 25,722 acre-feet per year of the 1990 firm yield at a unit cost of $52.99 per acre-foot per year. However, additional analyses were performed on the five municipal options under year 2040 reservoir sediment conditions which suggest that Alternative C may not be the most economical option in the future. These analyses are presented in the following section.

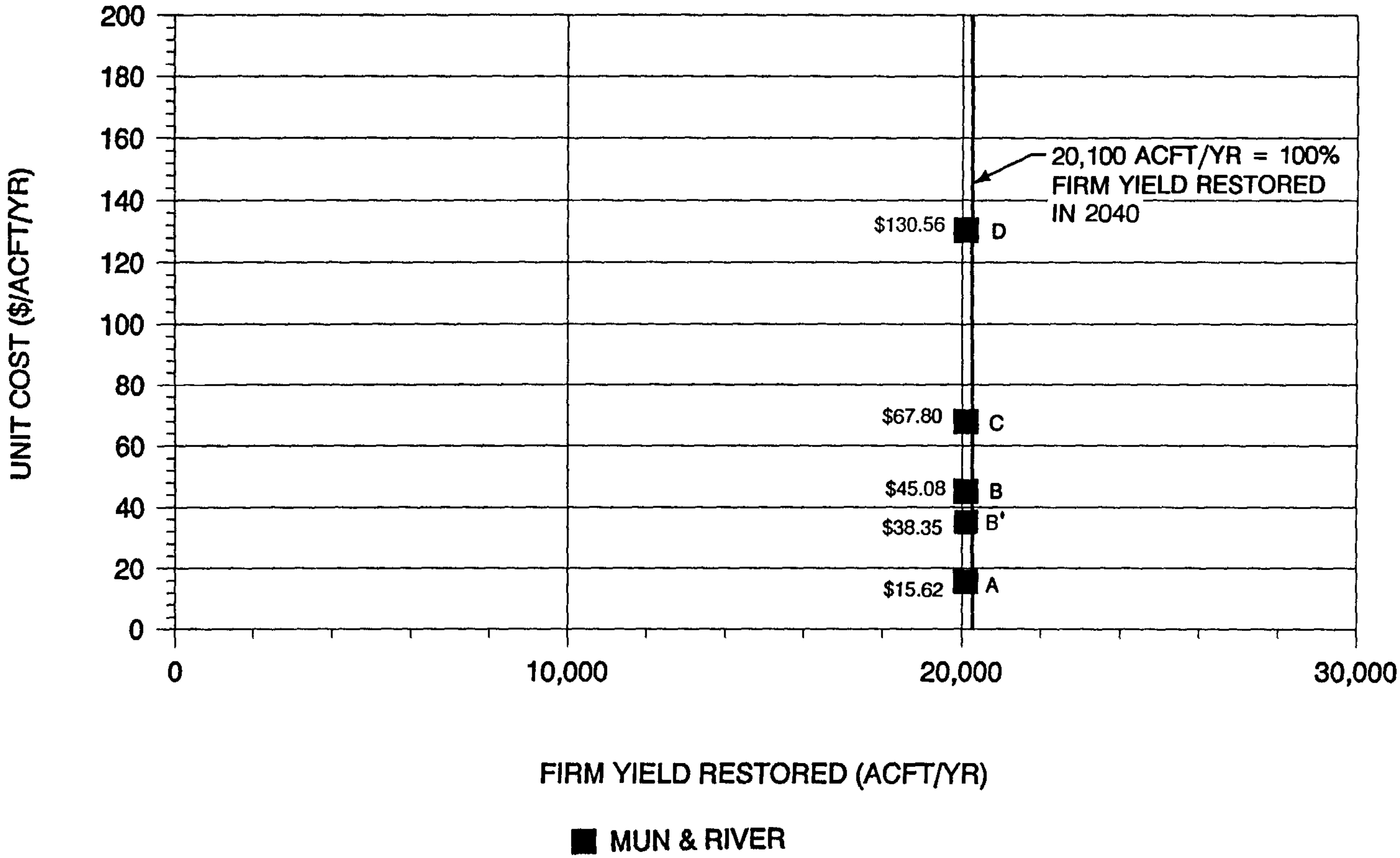
11.3 Evaluation of Combined Alternative - Year 2040 Sedimentation Conditions for Choke Canyon and Lake Corpus Christi

In the previous discussions, the analyses were based upon 1990 CC/LCC Reservoir sediment conditions. For this section, yield estimates were made for estimated Year 2040 CC/LCC Reservoir sediment conditions. Under these conditions, without releases to the estuary, the Year 2040 yield is estimated at 198,195 acre-feet per year. With estimated Year 2040 sediment, and with the TWC Release Order of March 9, 1992, the Year 2040 yield is estimated at 178,095 acre-feet per year or 20,100 acre-feet per year less. When the effects of the combined municipal wastewater and river diversion projects (Alternatives A, B, B′, C, and D) were taken into account, the analyses showed that each of these alternatives would have restored 100 percent of the 20,100 acre-feet of yield lost as a result of the TWC Release Order (Table 11-5 and Figure 11-5). The costs per acre-foot of yield recovered in 2040, expressed in 1990 prices, would be $15.62 for Alternative A, $45.08 for Alternative B, $38.35 for Alternative B′, $67.80 for Alternative C, and $130.56 for Alternative D. Thus, these analyses for Year 2040 conditions indicate that Alternative A (i.e., Allison WWTP Discharge and Calallen River diversion to Nueces Delta) would provide full recovery of the year 2040 yield at a minimal unit cost could, in the long run, prove to be the most cost-effective alternative to pursue.

TABLE 11-5
Summary of Flow Volumes and Yield Restoration for Combined Alternatives in Year 2040

Combined Alternative	Description	Return Flow to Bay (mgd)	Municipal Flow to Delta (mgd)	Industrial Flow to Delta (mgd)	Maximum River Flow to Delta (mgd)	Productivity Factors		System Yield Restored (ac-ft/year)	Percentage of System Yield Restored*
						WW to Delta	River to Delta		
A. (SS-1/R)	Allison WWTP Discharge and River Diversion to ND**	1.46	2.80	0.00	80	5	3	20,100	100.0
B. (SS-2/R)	Allison & Broadway WWTP's Discharge and River Diversion to ND**	1.46	8.80	0.00	70	5	3	20,100	100.0
B'. (SS-1 & WO-I/R)	Allison & Westside WWTP's Discharge and River Diversion to ND**	1.46	5.80	0.00	80	5	3	20,100	100.0
C. (SS-2 & W-1/R)	Allison, Broadway & Westside WWTP's Discharge and River Diversion to ND**	1.46	11.80	0.00	70	5	3	20,100	100.0
D. (SS-2 & WO-1/R)	Allison, Broadway, Westside & Oso WWTP's Discharge and River Diversion to ND**	1.46	20.80	0.00	50	5	3	20,100	100.0

*Percentage of reduction (20,100 ac-ft/yr) in CC/LCC System firm yield due to Texas Water Commission - Interim Order using 2040 sediment conditions, which is restored by diversion of flows to the Nueces Delta.
**ND means Nueces Delta.



DELTA PRODUCTIVITY FACTORS
EFFLUENT (5) & RIVER (3)

HDR Engineering, Inc.

NAISMITH ENGINEERING, INC.
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CORPUS CHRISTI TEXAS

NUECES ESTUARY REGIONAL WASTEWATER PLANNING STUDY PHASE 2
UNIT COST SUMMARY - COMBINED RIVER & WASTEWATER DIVERSION ALTERNATIVES - YEAR 2040
FIGURE 11-5

12.0 RECOMMENDATIONS

Based upon the results of this Phase II Regional Wastewater Planning Study, the following recommendations are made:

1. **Establish a Municipal Wastewater Diversion Demonstration Project from the Allison Wastewater Treatment Plant to the South Lake Area of the Nueces Delta:** The construction of an 18" PVC pipeline from the Allison Wastewater Treatment Plant northward across the Nueces River and westward to a location in Nueces Bay known as South Lake (Tidal Segment 2482) is recommended. This project would have the capacity to deliver approximately 2.8 mgd (average flow) of treated municipal effluent to the demonstration project area. Total capital cost for the construction of this project would include necessary connections at the Allison Wastewater Treatment Plant, construction of a Nueces river crossing, placement of approximately 7,800 lineal feet of effluent pipeline, and construction of a demonstration project area, for a total cost of $978,200. It is estimated that final design to construction completion will require approximately 11 to 12 months. Permitting requirements and easement acquisition should be initiated at the start of the final design in order to facilitate construction at the earliest possible date. The City of Corpus Christi should begin at once to seek permission from the TWC to relocate the Allison Wastewater Treatment Plant discharge location from its current location in the Nueces River to the proposed discharge area at South Lake. It is anticipated that this permit modification request will be in the form of a temporary discharge permit to be used for monitoring of the discharge effluent into the demonstration area. Continued use of this location for the Allison Wastewater Treatment Plant outfall will be determined after continuous monitoring

throughout the four-year monitoring period. Easements and right-of-way requirements to construct the pipeline demonstration area will be required from approximately six individual land owners. This project is described in detail in Section 3.2 of this report.

The diversion of about 2.8 mgd of treated municipal wastewater from the Nueces River to the upper tidal flats of South lake in Rincon Delta is recommended since it would provide a significant source of freshwater and nutrients to enhance emergent plant and phytoplankton growth. Discharged water should be dispersed over a broad area of several acres with provisions for aerial or spraying applications in addition to discharge into shallow receiving ponds. The discharged waters will flow through South Lake and disperse into the brackish marsh ponds and channels and the existing Federal mitigation area before entering Nueces Bay. New emergent vegetation will appear in and around the retention ponds and phytoplankton primary production rates will be enhanced in South Lake and in the lower marsh. The overall productivity (emergent vegetation and phytoplankton) of several hundred acres of Rincon Delta will be increased relative to the current status.

The benefits of increased primary production in the Delta will extend into Nueces Bay and beyond. The upper trophic levels of benthic and water column organisms that consume plankton and detritus will become established and further provide food for predator populations. The interchange of food materials between a bay and marsh will influence many portions of the bay ecosystem, but especially the higher trophic levels including many of the important fish and shellfish species. The increased food availability and lower salinity will also increase the habitat potential of the marsh for larval and immature stages of many marine and estuarine organisms.

2. **Establish a Nueces River Diversion Demonstration Project from the Calallen pool to Upper Rincon Bayou of the Nueces Delta:** It is recommended that a 12" PVC pipeline be constructed from the San Patricio Municipal Water District, W. A. Edwards Pump Station location, northward along the Nueces River, and then eastward across U.S. Highway 77 to the proposed discharge area. This pipeline, along with necessary water system appurtenances, and electrical and pump station requirements, would be capable of delivering approximately 2.8 mgd (average flow) of Nueces River water to the upper delta. Total cost of this project is estimated at $371,000. It is estimated that final design to completion of construction will require approximately 11 to 12 months. The permitting requirements should begin at the same time as the final design in order to facilitate construction activities at the earliest possible time. Approval will be required from the property owners within the demonstration area. This includes approval from the San Patricio Municipal Water District for use of an existing pipeline easement and pump station plant site, as well as pipeline easements from the McGregor estate and the Thomas E. Finch heirs tract. This project is described in detail in Section 3.1 of this report.

3. **Establish a Nueces River Diversion Demonstration Project through Existing Facilities of the O.N. Stevens Water Treatment Plant at Calallen:** The Phase II Study addressed the feasibility of diverting fresh water from the Nueces River through the existing facilities at the O.N. Stevens Water Treatment Plant located at Calallen. This project would use the existing infrastructure to divert approximately 3 mgd part of the way to a location in Nueces Bay. The recommended project includes utilizing an existing 36" drain line from

the O.N. Stevens Treatment Plant to the existing sludge lagoons located between the Nueces River and IH 37. Additionally, it is recommended that an 18" pipeline be constructed across the Nueces River to Nueces Bay halfway between the upper portion of Rincon Bayou and South Lake. It is estimated the total project capital cost will be approximately $551,000. An evaluation of the pipeline placement to tie this alternative demonstration project to Rincon Bayou and to the South Lake area was evaluated. Cost and construction requirements are detailed in Section 3.3 of this report. Potential relocation of water treatment sludges from current disposal lagoons to the estuary area was investigated. Further analysis, research, and permitting will be required prior to implementation.

4. **Potentials to Reroute Wastewater Flows Within the Corpus Christi Wastewater Collection System:** It was determined through the Phase II Study effort that several alternates exist for the City of Corpus Christi with regard to collection and treatment options for its wastewater system. Depending on results from the Allison Wastewater Diversion Demonstration Project, there could be significant opportunities to lower wastewater treatment costs through rerouting of flows wtihin the system, with diversion of larger quantities of effluent to Nueces Delta in the future. It is recommended that Corpus Christi request that TWC consider holding in abeyance modifications to wastewater discharge permits currently being held by the City of Corpus Christi Westside Treatment Plant until the proposed wastewater demonstration project of recommendation number one has been in operation long enough to provide information about the effects of such effluent upon the estuary. If it is determine through the use of demonstration project that a higher

nutrient loading is preferred, then the City could consider relocating more of the wastewater to the delta and utilizing available financing to construct necessary transmission facilities in lieu of upgrading plant effluent quality. Increased flow along with biological loading on several of the City's wastewater treatment plants will trigger more stringent discharge requirements depending of the allowable loading to the receiving water bodies (i.e., Oso Creek).

5. **Continue Scientific Data Collection and Monitoring of the Nueces Delta and Nueces Bay.** Data collection and monitoring should be carefully designed so as to fully measure and document delta and estuarine responses to freshwater releases and river and wastewater demonstration project diversions to the delta and bay. The evaluations of potential sources of brackish groundwater and storm water for diversion to Nueces Delta do not show these to be feasible alternatives, thus no recommendations are made with respect to implementation of such projects. The costs of gaging and metering the presently ungaged drainage basins which discharge into Nueces and Corpus Christi Bays appears to be too high to recommend at this time. For purposes of making better estimates of the quantities and timing of this source of freshwater, a mathematical equation was estimated using historic data from precipitation stations of the Coastal Bend area. It is recommended that this equation be used in the future for this purpose. The equation is found in Section 6.7 of the report.

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