Engineering Report

TEXAS WATER DEVELOPMENT BOARD

and

CITY OF BAY CITY, TEXAS

COTTONWOOD CREEK FLOOD PROTECTION PLAN

City of Bay City, Matagorda County, Texas
TWDB Contract No. 90-483-763

October, 1990

Prepared By

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October 30, 1990

OCT 31 1990

Mr. G. E. (Sonny) Kretzschmar
Executive Administrator
Texas Water Development Board
P.O. Box 13231 Capitol Station
1700 N. Congress Avenue
Austin, Texas 78711-3231

Re: City of Bay City, Texas
Cottonwood Creek Flood Protection Plan
TWDB Contract No. 90-483-763

Dear Mr. Kretzschmar:

Transmitted herewith are twelve (12) copies of the final engineering report for the Cottonwood Creek Flood Protection Plan. The report was given final approval by the City Council of Bay City on Monday, October 29, 1990.

Thank you for your participation and assistance in this project. The eventual construction of the proposed project will provide relief to area residents who have experienced flooding in past years.

Sincerely,

Charles A. Kalkomey, P.E.
Texas Registration No. 46208

CAK:tp

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October 18, 1990

Mayor Tommy Z. LeTulle and
Council Members
City of Bay City
1901 Fifth Street
Bay City, Texas 77414

Re: City of Bay City, Texas
Cottonwood Creek Flood Protection Plan
TWDB Contract No. 90-483-763

Dear Mayor LeTulle and Council:

Transmitted herewith are thirty (30) copies of the final engineering report for the Cottonwood Creek Flood Protection Plan. Upon your approval, twelve (12) copies should be forwarded to the Executive Administrator of the Texas Water Development Board.

We thank the City of Bay City for their assistance and cooperation in the preparation of this report. We especially acknowledge Mr. Jon Abshier, Director of Public Works, for his valuable insight and contributions.

We also recognize Matagorda County Drainage District No. 1 for their support of the project.

Thank you for the opportunity to work with the City on this project. We look forward to the possibility of working with the you and others to implement the Cottonwood Creek Flood Protection Plan.

Sincerely,

Charles A. Kalkomey, P.E.
Texas Registration No. 46208

CAK:tp

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EXECUTIVE SUMMARY

This report provides the results of an investigation into flood protection plans for the upper portion of Cottonwood Creek in the City of Bay City, Matagorda County, Texas. The study was jointly authorized by the Texas Water Development Board and the City.

Several methods of reducing the flooding and resulting damages along Cottonwood Creek were reviewed, including plans presented in previous studies. It was found that a diversion of flows from Cottonwood Creek to the Colorado River is an acceptable plan that will reduce flooding, and can be constructed with local funding.

Five alternatives, each with four different design capacities, were evaluated to accomplish the diversion to the Colorado River. All of the alternatives provided the same relief to flooding based on the 100-year storm. Construction costs, as well as potential savings in the reduction of flood damages, were developed for each alternative. Benefit/cost ratios were then computed for comparison of the alternatives.

Based on costs and consideration for the general welfare of the public, Alternative V was selected as the preferred plan for construction of the proposed diversion facility. The total cost of this alternative is $3,225,000. Construction of the project can be funded locally by phasing the project over a four year period.

I. INTRODUCTION

A. AUTHORIZATION

On December 14, 1989, the Texas Water Development Board (TWDB) approved an application by the City of Bay City (City) for funding of a planning grant to develop a flood protection plan for an area along the upper reaches of Cottonwood Creek in Matagorda County, Texas. On January 25, 1990, the City entered into a contract with the TWDB to receive financial assistance, and, as a joint and cooperative undertaking with the TWDB, to develop this flood protection plan. On same date, the City executed an agreement with Pledger Kennedy Rogers Kalkomey - Consulting Engineers to assist in developing the plan.

B. OBJECTIVES AND SCOPE

The major objectives of this study to develop a flood protection plan for the upper portion of Cottonwood Creek were:

1. Collect data on flooding along Cottonwood Creek within the study area.

2. Develop hydrological and hydraulic data for the watershed.

3. Evaluate alternatives, with associated costs and benefits, for providing flood protection along Cottonwood Creek within the study area.

4. Develop a recommended flood protection plan, with legal and financial requirements for implementation.

5. Prepare and submit a report to the City and TWDB.

Discussion of the detailed analysis, along with a recommended plan and related costs and benefits, are described in the following sections.

II. BACKGROUND INFORMATION

A. GENERAL

The Cottonwood Creek Watershed has a history and potential for severe flood damage during periods of excessive rainfall. This is due to the relatively flat terrain in the watershed, which results in low runoff velocities, the proximity of the watershed to the Gulf of Mexico, which results in high annual rainfall (inches per year) and increases the potential for high intensity storm occurrences, and the heavy urban development within the City of Bay City, which results in higher levels of runoff and increases the potential for monetary damage.

B. LOCATION

Bay City is located on the Gulf Coast in the eastern portion of Matagorda County. The City is at the crossroads of State Highway 35 and State Highway 60. Several major rail lines also intersect the City. Figure 1, Vicinity Map, on Page 4, shows the general location of Bay City.

The Cottonwood Creek Watershed is the upper end of the Peyton Creek Watershed, a tributary of East Matagorda Bay. Cottonwood Creek flows generally in a north-south direction, crossing through the downtown section of Bay City. All of the watershed lies within Matagorda County, and also within the jurisdictional areas of Matagorda County Drainage District No. 1 and Matagorda County Conservation and Reclamation District No. 1.

The Planning Area is the upper 5.5 square miles of the Cottonwood Creek Watershed, upstream of the former Southern Pacific Railroad right-of-way which passes in an east-west

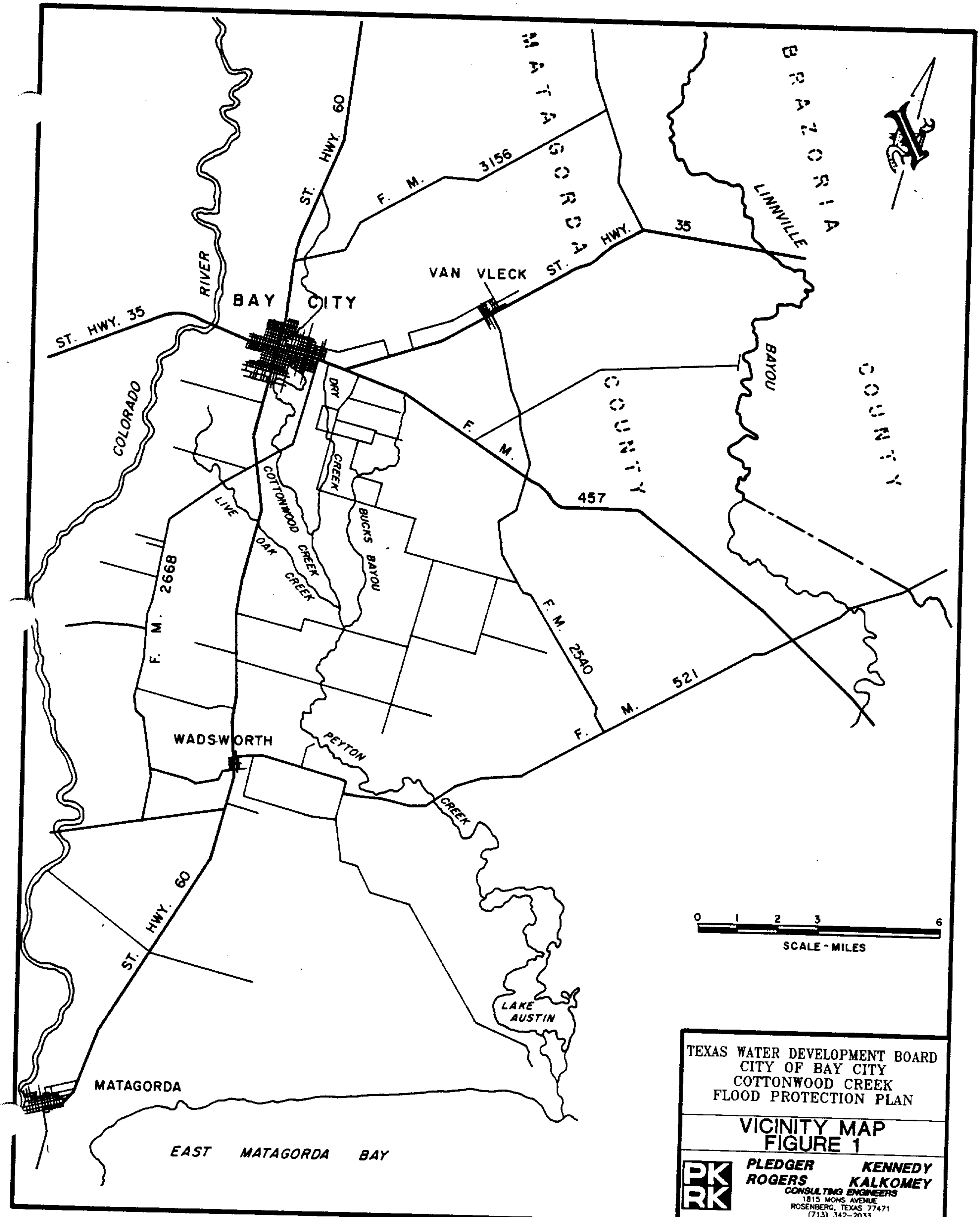
MATAGORDA
BRAZORIA
COUNTY
COUNTY
ST. HWY. 60
F. M. 3156
ST. HWY. 35
VAN VLECK
BAY CITY
LINNVILLE
BAYOU
RIVER
COLORADO
DRY
CREEK
COTTONWOOD CREEK
LIVE OAK CREEK
BUCKS BAYOU
F. M. 457
F. M. 2668
F. M. 2540
F. M. 521
WADSWORTH
PEYTON CREEK
ST. HWY. 60
LAKE AUSTIN
MATAGORDA
EAST MATAGORDA BAY
0 1 2 3 6
SCALE - MILES
TEXAS WATER DEVELOPMENT BOARD
CITY OF BAY CITY
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FIGURE 1
PK RK
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direction through the heart of the City. This right-of-way, containing approximately 27 acres of land, has been purchased by the City of Bay City, and provides a direct access from Cottonwood Creek to the Colorado River.

C. TOPOGRAPHY

The topography of the Cottonwood Creek Watershed is relatively flat with a gentle slope to the south and southeast. Elevations vary from approximately 60 feet above sea level north of the City to approximately 25 feet of elevation at the mouth of Cottonwood Creek. These elevations were obtained from the United States Geological Survey (U.S.G.S.) 7.5 minute quadrangle maps (Reference 1) of the area.

D. SOIL CHARACTERISTICS

The majority of the soils within the Cottonwood Creek Watershed are classified as a part of the Lake Charles-Bernard soil group. The soils in the very upper extreme of the watershed fall into the Edna-Telferner group. Both of these soil groups are poorly drained, and belong to the hydrologic group "D", as defined by the Soil Conservation Service (SCS).

E. CLIMATE

The climate of Matagorda County can be summarized as semitropical with warm summers and mild winters. The average daily maximum temperature is 79° F, and the average daily minimum is 62° F. There are an average of 76 days during the year in which the temperature exceeds 90° F, and only 11 days in which the temperature drops below 32° F.

Matagorda County experiences a mean rainfall amount of 43 inches per year. The most rainfall received during one year was in 1979, when almost 72 inches were recorded in the County.

F. PREVIOUS FLOOD PROTECTION PLANS

Cottonwood Creek is the only means of drainage relief for the majority of the City of Bay City. Areas of the watershed north of the City experience flooding due to the channel restrictions within the incorporated area. The total watershed includes a large area south of the City, which eventually drains to Peyton Creek, through Lake Austin, and into East Matagorda Bay. Flooding problems in the watershed are compounded by the lack of adequate drainage at this outlet.

Conventional methods for accommodating the flood flows have been found to be too costly for the citizens in the area. Because Cottonwood Creek traverses the downtown section of the City of Bay City, access along the existing creek is restricted by the encroachment of current improvements. These improvements include buildings, both commercial and residential, streets, and underground utilities. The acquisition of additional right-of-way through the City, containing these improvements, has been too costly. The alternative to obtaining the additional right-of-way is to concrete line the channel, increasing its capacity. This alternative has also been found to be a financial burden on the taxpayers of the area. Therefore, the leaders of the area have been searching for a cost-effective alternative to address the flooding problems along Cottonwood Creek.

In 1970, the U.S. Army Corps of Engineers (COE) completed and released a Survey Report on Peyton Creek, Texas Flood Control (Reference 2). The total project cost in the recommended plan was $8,100,000, and included construction work on Bucks Bayou and Peyton Creek. Extrapolated to 1990 costs, this figure could more than double.

In 1973, Brown & Root, Inc. prepared a study for Matagorda County Conservation and Reclamation District No. 1 entitled, Preliminary Drainage Study, Peyton Creek Watershed (Reference 3). Although this report looked at a diversion to the Colorado River, the recommended plan did not include this diversion. Instead, major channel improvements were recommended for Cottonwood Creek and Peyton Creek. At a project cost of $3,618,750 in 1973, this cost would be significantly higher today.

A high level, flood flow channel to the Colorado River continues to be considered by local officials as a possible means of reducing the amount of flood waters which must negotiate the small channel and restricted bridges and culverts along the channel. However, a route to the river was always a major obstacle due to the land ownership in the area. When the City was presented with an option to purchase the Southern Pacific Railroad right-of-way, they quickly responded, seizing the opportunity to secure this access to the Colorado River. This opened the door for a further look into the benefits of the diversion channel.

III. FLOOD MITIGATION

A. GENERAL

Flood mitigation is the act or process of reducing the degree or intensity of a flood event. This section discusses structural and non-structural alternatives to reduce flood damages.

B. ALTERNATIVES

Little can be done to prevent a major flood occurrence. However, damage to crops and personal property can be minimized for various statistical storm flows. The key to the amount of flood damage mitigation possible is a function of several items. These items are:

1. Statistical definition of the storm occurrence to be mitigated (i.e., 5-yr., 10-yr., 25-yr., 100-yr., etc. storms).

2. The potential for property damage sustained as a result of a flood.

3. The financial ability of the citizens affected by the storm occurrence.

4. The physical characteristics and properties of the watershed.

5. The willingness of the governmental entity to act upon the flood problem.

Several measures for reducing flood damage during major flood occurrences are commonly used. These methods are:

1. Reduction of peak flow by reservoirs.

2. Confinement of the flow within a predetermined channel by levees.

3. Reduction of the peak flood stage by increasing velocities as a result of channel improvements.

4. Diversion of flood waters through channels or floodways.

5. Temporary evacuation of the flood plain.

6. Floodproofing of specific properties and structures.

7. Reduction of flood runoff by land management.

8. Runoff retention management.

9. Flood Insurance Program.

Typically, the use of only one of these alternatives does not significantly reduce flood damages within a given watershed. Most solutions involve a combination of plans. However, conditions within the Cottonwood Creek Watershed render some of these alternatives ineffective.

Because the watershed is relatively flat, it is impractical to construct a reservoir to contain and reduce peak flows. The amount of land area required for this alternative would be large because of a lack of elevation differential available for use by such a reservoir.

Although some of the channels of Cottonwood Creek have high banks which act as levees, the raising of water levels within the channel to contain the flows would seriously impact the ability of areas adjacent to the channel to drain into the creek. The flooding from this alternative could be potentially more severe than flooding under current conditions.

Previous reports have evaluated increasing channel capacities by channel improvements which would increase flow velocities. The Brown & Root, Inc. report (Reference 3), discussed previously, specifically included concrete channel lining. However, the costs of this alternative are prohibitive.

Temporary evacuations of the flood plain reduce the potential for loss of human life. However, ample notice is necessary to allow residents to accomplish this. Because of the small size of the watershed, Cottonwood Creek responds very quickly, and the time available for evacuation is very short. Also, the watershed does not experience dangerous flow velocities and depths that normally are associated with the potential for loss of life.

Floodproofing is an alternative that can reduce monetary damages from storm events. The cost of such efforts would have to be borne by the private property owners. Because of the number of structures involved in the Cottonwood Creek Watershed, this alternative would not be very effective, as it would involve the support and cooperation of a large number of residents, many of whom do not have the financial resources to make such improvements.

Reduction of runoff by land management pertains to various types of vegetation utilized to slow overland flows, thereby reducing peak flow rates. The most significant contribution of flows into the upper portion of the Cottonwood Creek Watershed comes from within the City of Bay City. This urbanization produces more concrete than vegetation as ground cover, and not much can be accomplished in these developed areas to reduce runoff by land management. Those areas outside of the City are mostly farming and grazing areas. These agricultural land uses, especially the land which is actively used in the growing of rice, already offer some reduction of flows.

It is the loss of these agricultural areas that add to the flooding problems within the Cottonwood Creek Watershed. Runoff retention management is an alternative that should be utilized as these agricultural land uses evolve into urban land patterns. This can be used to keep current peak flows from rising as development occurs, but does not address the current flooding problems.

The Flood Insurance Program, as administered through the Federal Emergency Management Agency (FEMA), incorporates two concepts which reduce flood damages. The first is virtually prohibiting the building or rebuilding of structures within areas of high velocities known as floodways. The second is requiring building slabs or floor heights to be raised to a level above the flood elevations, reducing the potential for damage from flood waters getting into these structures. Both the City of Bay City and Matagorda County are in the Flood Insurance Program, and a floodway has been established for Cottonwood Creek. The enforcement of this program by local building officials should be continued, reducing the potential for additional flood damages in the future. However, this alternative does little to alleviate existing problems and flooding.

This study specifically considers the alternative of diversion of flows, and more specifically the affect of diverting a portion of the storm flows of Cottonwood Creek along the former Southern Pacific Railroad right-of-way to the Colorado River. Due to development within the City, this is the only viable method of flood abatement that would impact current flooding conditions. Other alternatives have proven to be too costly, or do not address current problems.

C. SUMMARY

The City of Bay City and Matagorda County should carefully consider development restrictions within the Cottonwood Creek watershed as it pertains to storm runoff. Further uncontrolled development within the watershed will increase runoff amounts. This in turn can exacerbate the flooding conditions in Bay City. Many cities now require the construction of runoff retention structures for residential subdivisions and commercial developments to prevent runoff from increasing from the existing undeveloped condition. In effect, the flood conditions remain unchanged, and do not become worse.

IV. METHODOLOGY

A. GENERAL

The following section describes the models and methods utilized to establish the flooding potential along Cottonwood Creek. Sources of the data base and procedures used to construct the models are addressed.

B. HYDROLOGY

1. General

Hydrology is the study of the movement of water over and through the ground surface. The responsiveness of a given area subjected to a preselected synthetic rainfall event results in a peak discharge rate for that area. This responsiveness is expressed in terms of the amount of rainfall absorbed into or stored on the ground versus the quality of rainfall travelling over ground surfaces and into drainage facilities such as open channels and reservoirs.

Peak flood discharge rates can be computed in various manners. Two generally accepted methods are through the use of a computer model of the watershed and empirical equations developed for certain watersheds based on specific watershed characteristics.

2. Drainage Areas

The Cottonwood Creek Watershed is depicted in Exhibit 1, Cottonwood Creek Watershed. As shown, Cottonwood Creek is the major drainageway in the basin. It is joined by Dry Creek and Live Oak Creek in the lower portion of the watershed, just prior to Cottonwood Creek becoming Peyton Creek. Table 1, on Page 15, lists the acreage within each subbasin of the Cottonwood Creek Watershed.

3. Peak Discharge Rates

During the initial phases of the study, efforts were undertaken to locate the COE HEC-1 Flood Hydrograph Package (Reference 4) model of the Cottonwood Creek Watershed. However, this model was not created for use in the FEMA Flood Insurance Study (FIS) for the City of Bay City (Reference 5) or for the unincorporated areas of Matagorda County (Reference 6). Therefore, no attempt was made to generate this hydrologic model due to the possibility that a satisfactory agreement with the FEMA FIS discharge rates might not be achievable. It was beyond the scope of this report to verify or disprove the established regulatory discharge rates.

According to the FEMA FIS for both Bay City and Matagorda County, peak discharge rates for Cottonwood Creek were based on USGS Water Investigations 3-73, Effects of Urbanization on Floods in the Houston, Texas, Metropolitan Area (Reference 7). This is a regional method based on regression analysis. The method relates drainage area and percentage of impervious area to peak discharge by empirical equations developed for the Houston Metropolitan Area. Since the Bay City area is

TABLE 1

COTTONWOOD CREEK WATERSHED ACREAGES

SUBBASIN	AREA (acres)
Dry Creek	3,320
Cottonwood Creek	7,760
Live Oak Creek	7,310
Total Watershed	18,390

geographically close to Houston and similar in drainage basin characteristics, this method was adopted for application in the FIS. The peak discharge rate from rural drainage areas upstream of Bay City were generated based on USGS report 77-110, Techniques for Estimating the Magnitude and Frequency of Floods in Texas (Reference 8). This regional method relates drainage area and channel slope to peak discharge by empirical equations developed for a large portion of Texas.

Therefore, the peak discharge rates adopted in the FEMA FIS for Bay City and Matagorda County were utilized for this study on Cottonwood Creek. Peak discharge rates for various points within the Cottonwood Creek Watershed are given in Table 2, found on Page 17.

C. HYDRAULICS

1. General

In order to determine the effects of any proposed diversion channel from Cottonwood Creek to the Colorado River, it was necessary to compute water surface elevations during storm events along the main channel of Cottonwood Creek. The most commonly accepted method of accomplishing this task is the use of COE HEC-2 Water Surface Profiles (Reference 9) computer modeling package. This method was utilized for computations along Cottonwood Creek.

Another widely accepted method of calculating the water surface elevations is by use of the slope-area method, which employs Manning's Equation. This method was utilized for the sizing of the diversion channel to the Colorado River.

TABLE 2

COTTONWOOD CREEK SUMMARY OF DISCHARGES

STREAM LOCATION	DRAINAGE AREA (sq. mi.)	PEAK DISCHARGES (cfs)		
		10-YEAR	50-YEAR	100-YEAR
At Stream Mile 0.47	19.0	4,200	6,300	7,100
At Stream Mile 1.16	17.0	3,200	4,600	5,200
At Hammon Road	10.1	2,500	3,500	4,000
At 4th Street	6.1	1,200	1,700	2,000
At 10th Street	5.5	760	1,100	1,300
At FM 3156	2.5	365	510	560

2. Cottonwood Creek Model

The FEMA FIS HEC-2 model for Cottonwood Creek was obtained from Greehorne & O'Maron, Inc., a contractor for FEMA located in Greenbelt, Maryland. The model data was provided on micro-fiche, which was input into a new computer model. The output from the new model was verified against the information from FEMA to insure the new model was identical to the original. This model was then used as a base for all other HEC-2 analyses.

The crossections utilized in the FIS for Bay City and Matagorda County were plotted on a base map. These sections were then used to plot the flood plain areas within the study area, and would be further used to determine the limits of flood plain reductions resulting from the introduction of the diversion channel into the system.

3. Diversion Channel Computations

The diversion channel was analyzed as both an open ditch design and a combination open ditch and underground conduit. Each of these alternatives were analyzed at four different flow rates. The diversion facilities capacities were computed using Mannings Equation:

$$Q=\frac{1.49}{n} A R^{2/3} S^{1/2}$$

where Q is the flow rate in cubic feet per second,
A is the channel area is square feet,
R is the hydraulic radius,
S is the channel slope in foot per feet,
and n is the roughness coefficient.

D. ECONOMIC ANALYSIS

1. General

The economics of a proposed project such as this plays an important role in not only how the project is completed, but possibly whether or not the project is even undertaken. Therefore, it was important to determine the economics of the alternatives considered in this study.

2. Costs

The costs associated with the completion of each alternative were determined. The construction costs were based on data gathered from similar projects, as well as from discussions with material suppliers and construction contracting companies in the area. Construction contingencies were added to allow for unforeseen conditions and design uncertainties at this time. Finally engineering costs were added for design and construction phase services.

3. Benefits

The purpose of the project is to reduce flooding within the Cottonwood Creek Watershed. Accordingly, there are economic values that can be assigned to the benefits resulting from the project.

To determine these benefit values, the number and type of structures (houses, businesses) were identified. Using current tax rates from the Matagorda County Appraisal District, the assessed values of these improvements were determined. Damage costs were then assigned to the structures to determine the benefits realized by reducing the flood plain areas for each alternative.

A benefit/cost ratio for each alternative was computed comparing the benefits of the reduction in damages to the construction costs of the project. These ratios could then be used to assist in the selection of a recommended alternative.

E. LEGAL/FINANCIAL CONSIDERATIONS

1. General

The requirements of other governmental agencies and entities may impact the project, and additional environmental analysis, permits, and fees are sometimes involved. In a like manner, the financing of the work may require approvals of State regulatory agencies, and may involve special financial and legal consultants.

2. Legal Requirements

There are several possible areas of a project such as this one that may require coordination with other state or federal agencies. The purpose of the project is to divert storm water flows from one watershed to another. The project also involves a navigable stream, and has an impact on tidal waters. The items are all regulated by federal and state agencies, and discussions were held with various groups to identify the approvals needed for implementation of the project.

3. Financial Requirements

Unless the project can be financed out of operational funds of the City and various County entities, there will be a need for long term financing of the work. Therefore, consideration was given to the possible sale of bonds and their associated costs.

V. RESULTS

A. GENERAL

This section describes the various alternatives and methods utilized to establish existing flooding limits along Cottonwood Creek within the study area. Benefits and costs of each alternative, as well as the legal and financial requirements for the project implementation, are discussed.

B. PEAK FLOOD DISCHARGES

1. General

Once peak flood discharge rates for Cottonwood Creek were established, the decision had to be made as to how much of the flow could be diverted to the Colorado River. Various rates were initially investigated, and several were analyzed in detail.

2. Cottonwood Creek Discharges

As previously discussed in Section IV. of this report, the Cottonwood Creek discharges as adopted in the FEMA FIS for Bay City and Matagorda County were accepted for use in this study. The 100-year and 10-year storm flows were included in the analysis of the diversion facility.

3. Diversion Facility Discharges

Based on several preliminary computations using the COE HEC-2 model for Cottonwood Creek, it was found that a range of diversion flows existed in which significant changes occurred to the 100-year flood plain along

Cottonwood Creek. A drop in the flood plain elevation began with about a 400 cfs diversion. More than a 700 cfs diversion did not continue to significantly lower the of flood plain elevations along the creek channel. Preliminary calculations on the channel itself indicated that the upper limit for utilizing an open ditch channel section was approximately 700 cfs. Further support for this range of diversion flows came from the previously mentioned COE report on Peyton Creek (Reference 2). The report stated the capacity of the existing Cottonwood Creek channel was approximately that of the 10-year storm. At the point of diversion, the 10-year discharge, according to the FEMA FIS, is 760 cfs. The 100-year discharge is 1,300 cfs at the same point. If the creek had a capacity for a 10-year storm flow, the excess flow from the 100-year storm event would be the difference in these two values, or 540 cfs. Based on all the above, a range of 400 cfs to 700 cfs was selected. This range was divided in 100 cfs increments for analysis of the diversion facility in each alternative.

C. ALTERNATIVES

1. General

Five alternatives were selected for study in this report. The alternatives were derived from local input and engineering judgement. Diversion flow rates of 400 cfs, 500 cfs, 600 cfs, and 700 cfs were analyzed for each of the alternatives.

Alternative I consists of an open channel from Cottonwood Creek to the Colorado River. Flows from the creek would be diverted to the channel by a pump station constructed on the creek bank.

Alternative II utilizes a storm sewer for the portion of the diversion facility through the corporate limits of Bay City. This storm sewer would be installed from Cottonwood Creek to Moore Avenue. From this point, an open channel would be constructed to the river. A pump station would again be used to divert the flows.

Alternative III is a modification of Alternative II in that the storm sewer is replaced with a force main system. Instead of a gravity flow condition, the pump station would pump the storm flows to Moore Avenue, where the open ditch section would begin and carry the flows to the river.

Alternative IV is similar to Alternative I in than an open channel section is utilized the entire length of the diversion route. However, instead of a pump station, a weir inlet structure at Cottonwood Creek would be used to divert the storm flows.

Alternative V is similar to Alternative II in its use of storm sewer from Cottonwood Creek to Moore Avenue, and then an open channel to the Colorado River. However, as in Alternative IV, the weir inlet structure is used to divert the flows in lieu of the pump station.

Exhibit 2, Diversion Channel Location, depicts the location of the proposed facility in relation to the City.

2. <u>Alternative I</u>

As stated above, Alternative I consists of a open ditch from Cottonwood Creek to the Colorado River. There are six existing streets which must cross this channel -

State Highway 60, Avenue E, Avenue D, Avenue C, Moore Avenue, and Twelfth Street. Preliminary calculations on structure design for these crossings indicated high head losses if culverts were used. Therefore, bridge structures are recommended for these crossings.

The pump station design consists of low head, high volume pumps to divert the storm water. Included in the design are an auxillary power supply and a building to enclose the facility.

Approximately 860 feet east of the Colorado River, the channel crosses a Lower Colorado River Authority (LCRA) Canal. The diversion flows would be routed under the canal through a drop pipe structure utilizing corrugated pipe.

Because the flows are being diverted to the Colorado River, there is concern that, should the river be at a 100-year flood stage, it would "back-up" into the diversion channel and into Bay City. A protection levee now contains these high river floods, protecting the City. The structure at the LCRA canal discussed above would create a "hole" in this levee. Therefore, this drop pipe structure will include flood gates which will maintain the integrity of the protection levee.

At a point approximately 200 feet east of the river, the diversion channel crosses Willis Ditch, an existing drainage facility from the nortwest portion of Bay City. This ditch flows southerly to the river. A second drop pipe outlet structure is proposed at this location to control erosion at the river. The storm flows will then enter the river downstream of the diversion facility through the Willis Ditch.

The construction of the diversion facility will require the relocation of several utility lines. There are water lines, gas lines, a sanitary sewer line, and utility cables which cross the route and will require adjustment.

3. <u>Alternative II</u>

Alternative II is similar to Alternative I in all respects except that a portion of the open channel is replaced by an underground storm sewer. Preliminary design calculations indicate that it will require twin reinforced concrete boxes to convey the various design flows. However, five of the bridges are eliminated by the use of the storm sewer. Only the Twelfth Street bridge remains within the open channel section of the project from Moore Avenue to the river.

The pump station design, LCRA canal crossing, outlet structure, and utility line relocations are similar to those contained in Alternative I.

4. <u>Alternative III</u>

Alternative III replaces the gravity storm sewer system with pressure conduits to convey the storm flows from Cottonwood Creek to Moore Avenue. The conduits would have a circular crossection, and would discharge into the upstream end of the open channel section just west of Moore Avenue.

The pump design in this alternative is different due to the headlosses in the system. Pumps chosen for this station must be capable of overcoming large system losses, which increase pump size, motor size, and operating costs.

The remainder of the design of this alternative is identical to the first two alternatives, with the exception of additional erosion protection at the discharge points of the force main.

5. <u>Alternative IV</u>

This alternative is similar to the first alternative in that it employs an open ditch from Cottonwood Creek to the Colorado River. The major difference in the two is this alternative deletes the pump station. Instead of this facility, a broad-crested weir structure is used to control the diversion channel flows.

The weir structure would be constructed in a channel which would branch southwestward from Cottonwood Creek. The structure itself would be concrete, with a concrete apron on both the upstream and downstream faces of the weir. The branch channel would be lined with stone riprap for erosion protection.

The open channel downstream of the weir would differ from the channel in Alternative I in depth. In order to maintain a positive head on the weir from Cottonwood Creek, the channel downstream of the weir is approximately 3 feet deeper than that in Alternative I.

The remainder of Alternative IV, bridges, outlet structure, etc., is similar in content to Alternative I.

6. <u>Alternative V</u>

Alternative V actually combines Alternatives II and IV. This design alternative uses the box storm sewer from

Alternative II in combination with the weir inlet structure from Alternative IV. The pumping station is thereby eliminated from the design.

The remainder of this design, bridges, outlet structures, etc., is identical to Alternative II.

Table 3, on Page 29, summarizes the various components of these alternatives.

D. PROJECT COSTS

Construction costs for each flow design within each alternative were compiled. These were based on unit costs for the various components of each design alternative. Contingencies (15 percent) and engineering costs were also included to develop total project costs.

Tables 4 - 7, on Pages 30 - 33, indicate the costs for Alternative I. Total project costs for this alternative vary from $2,553,000 to $3,312,000.

Tables 8 - 11, on Pages 34 - 37, illustrate the project costs for Alternative II. The storm sewer portion of the alternative increases the costs, resulting in total costs from $3,172,000 to $4,306,000, for 400 cfs to 700 cfs diversion, respectfully.

Tables 12 - 15, on Pages 38 - 41, list the costs for Alternative III. Because of the more costly pressure pipe, these project costs vary from $2,668,000 to $5,085,000.

Tables 16 - 19, on Pages 42 - 45, indicate the costs for Alternative IV. Although there is substantial savings in the use of the weir inlet control structure, there is an increase

TABLE 3
DIVERSION CHANNEL DESIGN ALTERNATIVES

		CHANNEL DESIGN			INLET STRUCTURE	
ALTERNATIVE	DESIGN FLOW(cfs)	OUTLET STRUCTURE TO MOORE AVENUE	MOORE AVENUE TO COTTONWOOD CREEK	OUTLET STRUCTURE (no. of pipes)	PUMP STATION (no. of pumps)	WEIR STRUCTURE (length in feet)
I	400	Open Ditch	Open Ditch	2 - 66" x 48"	3 @ 45,000 gpm	N/A
	500	Open Ditch	Open Ditch	3 - 66" x 48"	4 @ 45,000 gpm	N/A
	600	Open Ditch	Open Ditch	3 - 66" x 48"	5 @ 45,000 gpm	N/A
	700	Open Ditch	Open Ditch	4 - 66" x 48"	7 @ 45,000 gpm	N/A
II	400	Open Ditch	2 - 10' x 5' RCBC	2 - 66" x 48"	3 @ 45,000 gpm	N/A
	500	Open Ditch	2 - 10' x 6' RCBC	3 - 66" x 48"	4 @ 45,000 gpm	N/A
	600	Open Ditch	2 - 10' x 7' RCBC	3 - 66" x 48"	5 @ 45,000 gpm	N/A
	700	Open Ditch	2 - 10' x 8' RCBC	4 - 66" x 48"	7 @ 45,000 gpm	N/A
III	400	Open Ditch	3 - 48" FM	2 - 66" x 48"	3 @ 45,000 gpm	N/A
	500	Open Ditch	4 - 48" FM	3 - 66" x 48"	4 @ 45,000 gpm	N/A
	600	Open Ditch	4 - 54" FM	3 - 66" x 48"	4 @ 56,000 gpm	N/A
	700	Open Ditch	6 - 54" FM	4 - 66" x 48"	6 @ 52,500 gpm	N/A
IV	400	Open Ditch	Open Ditch	2 - 66" x 48"	N/A	20.0
	500	Open Ditch	Open Ditch	3 - 66" x 48"	N/A	16.0
	600	Open Ditch	Open Ditch	3 - 66" x 48"	N/A	12.5
	700	Open Ditch	Open Ditch	4 - 66" x 48"	N/A	9.5
V	400	Open Ditch	2 - 10' x 5' RCBC	2 - 66" x 48"	N/A	20.0
	500	Open Ditch	2 - 10' x 6' RCBC	3 - 66" x 48"	N/A	16.0
	600	Open Ditch	2 - 10' x 7' RCBC	3 - 66" x 48"	N/A	12.5
	700	Open Ditch	2 - 10' x 8' RCBC	4 - 66" x 48"	N/A	9.5

TABLE 4

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE I - 400 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	130,100	C.Y.	Channel Excavation	$3.50	$455,350
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$625,000	$625,000
9.	1	L.S.	Outlet Control Structure	$38,000	$38,000
10.	1	L.S.	LCRA Canal Crossing	$50,000	$50,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,073,350
	CONTINGENCIES				$311,000
	ENGINEERING				$168,650
	TOTAL ESTIMATED COST				$2,553,000

TABLE 5

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE I - 500 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	140,000	C.Y.	Channel Excavation	$3.50	$490,000
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$725,000	$725,000
9.	1	L.S.	Outlet Control Structure	$56,000	$56,000
10.	1	L.S.	LCRA Crossing	$68,000	$68,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,244,000
	CONTINGENCIES				$336,600
	ENGINEERING				$180,400
	TOTAL ESTIMATED COST				$2,761,000

TABLE 6

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE ALTERNATIVE I - 600 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	147,000	C.Y.	Channel Excavation	$3.50	$514,500
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$860,000	$860,000
9.	1	L.S.	Outlet Control Structure	$56,000	$56,000
10.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000
SUBTOTAL					$2,403,500
CONTINGENCIES					$360,500
ENGINEERING					$194,000
TOTAL ESTIMATED COST					$2,958,000

TABLE 7

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE I - 700 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	160,500	C.Y.	Channel Excavation	$3.50	$561,750
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$1,075,000	$1,075,000
9.	1	L.S.	Outlet Control Structure	$70,000	$70,000
10.	1	L.S.	LCRA Canal Crossing	$80,000	$80,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,691,750
	CONTINGENCIES				$403,750
	ENGINEERING				$216,500
	TOTAL ESTIMATED COST				$3,312,000

TABLE 8

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE II - 400 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	23,000	C.Y.	Channel Excavation	$3.50	$80,500
2.	2,600	L.F.	2-10′ x 5′ C850 RCBC	$590	$1,534,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$625,000	$625,000
6.	1	L.S.	Outlet Control Structure	$38,000	$38,000
7.	1	L.S.	LCRA Canal Crossing	$50,000	$50,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,601,700
	CONTINGENCIES				$390,300
	ENGINEERING				$180,000
	TOTAL ESTIMATED COST				$3,172,000

TABLE 9

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE II - 500 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	25,500	C.Y.	Channel Excavation	$3.50	$89,250
2.	2,600	L.F.	2-10' x 6' C850 RCBC	$640	$1,664,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$725,000	$725,000
6.	1	L.S.	Outlet Control Structure	$56,000	$56,000
7.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,876,450
	CONTINGENCIES				$431,450
	ENGINEERING				$198,100
	TOTAL ESTIMATED COST				$3,506,000

TABLE 10

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE II - 600 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	27,500	C.Y.	Channel Excavation	$3.50	$96,250
2.	2,600	L.F.	2-10' x 7' C850 RCBC	$680	$1,768,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$860,000	$860,000
6.	1	L.S.	Outlet Control Structure	$56,000	$56,000
7.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$3,122,450
	CONTINGENCIES				$468,350
	ENGINEERING				$215,200
	TOTAL ESTIMATED COST				$3,806,000

TABLE 11

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE II - 700 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	31,100	C.Y.	Channel Excavation	$3.50	$108,850
2.	2,600	L.F.	2-10′ x 8′ C850 RCBC	$740	$1,924,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$1,075,000	$1,075,000
6.	1	L.S.	Outlet Control Structure	$70,000	$70,000
7.	1	L.S.	LCRA Canal Crossing	$80,000	$80,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$3,532,050
	CONTINGENCIES				$529,850
	ENGINEERING				$244,100
	TOTAL ESTIMATED COST				$4,306,000

TABLE 12

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE III - 400 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	62,200	C.Y.	Channel Excavation	$3.50	$217,700
2.	2,600	L.F.	3-48" Conc. Pressure Pipe	$370	$962,000
3.	3	EA.	Air Release Manhole	$2,000	$6,000
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$625,000	$625,000
6.	1	L.S.	Outlet Control Structure	$38,000	$38,000
7.	1	L.S.	LCRA Canal Crossing	$50,000	$50,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,168,700
	CONTINGENCIES				$325,300
	ENGINEERING				$174,000
	TOTAL ESTIMATED COST				$2,668,000

TABLE 13

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE III - 500 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	62,200	C.Y.	Channel Excavation	$3.50	$217,700
2.	2,600	L.F.	4-48" Conc. Pressure Pipe	$490	$1,274,000
3.	4	EA.	Air Release Manhole	$2,000	$8,000
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$725,000	$725,000
6.	1	L.S.	Outlet Control Structure	$56,000	$56,000
7.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,618,700
	CONTINGENCIES				$392,800
	ENGINEERING				$180,500
	TOTAL ESTIMATED COST				$3,192,000

TABLE 14

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE III - 600 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	62,200	C.Y.	Channel Excavation	$3.50	$217,700
2.	2,600	L.F.	4-54" Conc. Pressure Pipe	$640	$1,664,000
3.	4	EA.	Air Release Manhole	$2,500	$10,000
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$860,000	$860,000
6.	1	L.S.	Outlet Control Structure	$56,000	$56,000
7.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$3,145,700
	CONTINGENCIES				$471,800
	ENGINEERING				$217,500
	TOTAL ESTIMATED COST				$3,835,000

TABLE 15

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE III - 700 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	62,200	C.Y.	Channel Excavation	$3.50	$217,700
2.	2,600	L.F.	6-54" Conc. Pressure Pipe	$940	$2,444,000
3.	6	EA.	Air Release Manhole	$2,500	$15,000
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Pump Station w/ Pumps, Controls, Auxillary Power in Concrete Building	$1,075,000	$1,075,000
6.	1	L.S.	Outlet Control Structure	$70,000	$70,000
7.	1	L.S.	LCRA Canal Crossing	$80,000	$80,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$4,171,700
	CONTINGENCIES				$625,700
	ENGINEERING				$287,600
	TOTAL ESTIMATED COST				$5,085,000

TABLE 16

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE IV - 400 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	250,000	C.Y.	Channel Excavation	$3.50	$875,000
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$110,000	$110,000
8.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc.	$250,000	$250,000
9.	1	L.S.	Outlet Control Structure	$60,000	$60,000
10.	1	L.S.	LCRA Canal Crossing	$38,000	$38,000
11.	1	L.S.	Utility Relocations	$50,000	$50,000
				$20,000	$20,000
SUBTOTAL					$1,928,000
CONTINGENCIES					$289,200
ENGINEERING					$156,800
TOTAL ESTIMATED COST					$2,374,000

TABLE 17

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE IV - 500 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	250,000	C.Y.	Channel Excavation	$3.50	$875,000
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc.	$65,000	$65,000
9.	1	L.S.	Outlet Control Structure	$56,000	$56,000
10.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000
SUBTOTAL					$1,969,000
CONTINGENCIES					$295,350
ENGINEERING					$158,650
TOTAL ESTIMATED COST					$2,423,000

TABLE 18

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE IV - 600 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	250,000	C.Y.	Channel Excavation	$3.50	$875,000
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc.	$70,000	$70,000
9.	1	L.S.	Outlet Control Structure	$56,000	$56,000
10.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000

SUBTOTAL	$1,974,000
CONTINGENCIES	$296,100
ENGINEERING	$158,900
TOTAL ESTIMATED COST	$2,429,000

TABLE 19

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE IV - 700 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	250,000	C.Y.	Channel Excavation	$3.50	$875,000
2.	1	L.S.	Hwy 60 Bridge	$195,000	$195,000
3.	1	L.S.	Ave. E Bridge	$110,000	$110,000
4.	1	L.S.	Ave. D Bridge	$110,000	$110,000
5.	1	L.S.	Ave. C Bridge	$110,000	$110,000
6.	1	L.S.	Moore Ave. Bridge	$110,000	$110,000
7.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
8.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc.	$75,000	$75,000
9.	1	L.S.	Outlet Control Structure	$70,000	$70,000
10.	1	L.S.	LCRA Canal Crossing	$80,000	$80,000
11.	1	L.S.	Utility Relocations	$20,000	$20,000
SUBTOTAL					$2,005,000
CONTINGENCIES					$300,750
ENGINEERING					$161,250
TOTAL ESTIMATED COST					$2,467,000

TABLE 20

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE V - 400 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	33,400	C.Y.	Channel Excavation	$3.50	$116,900
2.	2,600	L.F.	2-10'x 5' C850 RCBC	$590	$1,534,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc	$65,000	$65,000
6.	1	L.S.	Outlet Control Structure	$38,000	$38,000
7.	1	L.S.	LCRA Canal Crossing	$50,000	$50,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
	SUBTOTAL				$2,078,100
	CONTINGENCIES				$311,700
	ENGINEERING				$143,200
	TOTAL ESTIMATED COST				$2,533,000

TABLE 21

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE V - 500 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	42,300	C.Y.	Channel Excavation	$3.50	$148,050
2.	2,600	L.F.	2-10'x 6' C850 RCBC	$640	$1,664,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc	$70,000	$70,000
6.	1	L.S.	Outlet Control Structure	$56,000	$56,000
7.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
SUBTOTAL					$2,280,250
CONTINGENCIES					$342,050
ENGINEERING					$157,700
TOTAL ESTIMATED COST					$2,780,000

TABLE 22

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE V - 600 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	49,200	C.Y.	Channel Excavation	$3.50	$172,200
2.	2,600	L.F.	2-10'x 7' C850 RCBC	$680	$1,768,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc	$75,000	$75,000
6.	1	L.S.	Outlet Control Structure	$56,000	$56,000
7.	1	L.S.	LCRA Canal Crossing	$68,000	$68,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000

SUBTOTAL	$2,413,400
CONTINGENCIES	$362,000
ENGINEERING	$166,600
TOTAL ESTIMATED COST	$2,942,000

TABLE 23

COTTONWOOD CREEK DIVERSION CHANNEL COST ESTIMATE
ALTERNATIVE V - 700 CFS DESIGN FLOW

ITEM NO.	QUANTITY	UNIT MEASURE	DESCRIPTION	UNIT COST	EXTENSION
1.	62,200	C.Y.	Channel Excavation	$3.50	$217,700
2.	2,600	L.F.	2-10'x 8' C850 RCBC	$740	$1,924,000
3.	6	EA.	Storm Sewer Manhole	$700	$4,200
4.	1	L.S.	Twelfth St. Bridge	$250,000	$250,000
5.	1	L.S.	Inlet Control Structure w/ Weir, Entrance Channel Concrete Rip Rap, etc	$80,000	$80,000
6.	1	L.S.	Outlet Control Structure	$70,000	$70,000
7.	1	L.S.	LCRA Canal Crossing	$80,000	$80,000
8.	1	L.S.	Utility Relocations	$20,000	$20,000
SUBTOTAL					$2,645,900
CONTINGENCIES					$396,900
ENGINEERING					$182,200
TOTAL ESTIMATED COST					$3,225,000

in costs for the additional excavation required to obtain the necessary channel depths. Total project costs vary from $2,374,000 to $2,467,000 for Alternative IV.

Tables 20 - 23, on Pages 46 - 49, show the project costs for Alternative V. The use of the storm sewer increases these costs over those for Alternative IV. Project costs are estimated to vary from $2,533,000 to $3,225,000.

Table 24, on Page 51, summarizes the project costs for each alternative for the various flows. The least expensive alternative is Alternative IV for a 400 cfs diversion, at $2,374,000. The most expensive option in Alternative III, at a 700 cfs diversion, which is estimated to cost $5,085,000.

E. OPERATION AND MAINTENANCE COSTS

1. General

As with any public works project, there are annual costs associated with the operation and maintenance of the constructed facility. These costs are largely dependant upon unpredictable events each year, namely the weather and related rainfall amounts and intensities. However, based on engineering judgements, an estimate of these annual costs was made.

There are two main components of the operation and maintenance costs for the alternatives analyzed. The first of these is the maintenance of the open ditch section of the diversion facility. The second is the pump station proposed in three of the alternatives.

TABLE 24

COTTONWOOD CREEK DIVERSION CHANNEL COSTS
SUMMARY OF ALL ALTERNATIVES

ALTERNATIVE NO.	DIVERSION DESIGN DISCHARGE			
	400 cfs	500 cfs	600 cfs	700 cfs
I	$2,553,000	$2,761,000	$2,958,000	$3,312,000
II	$3,172,000	$3,506,000	$3,806,000	$4,306,000
III	$2,668,000	$3,192,000	$3,835,000	$5,085,000
IV	$2,374,000	$2,423,000	$2,429,000	$2,467,000
V	$2,533,000	$2,780,000	$2,942,000	$3,225,000

2. Open Ditch Operation and Maintenance Costs

Proper maintenance of an open ditch section involves both annual mowing and the spraying of herbicides to reduce the growth of vegetation. If an adequate spraying program is maintained, the number of times the ditch will require mowing each year will be reduced. However, both of these activities are influenced by the amount of rainfall the area receives during the growth season.

Based on the concept of a combination of spraying and mowing, normal maintenance of the ditch section can be accomplished with two sprayings and two mowings each year. In Alternatives I and IV, which incorporate an open ditch for the entire length of the project, it is estimated that the annual cost for the maintenance of this length of ditch is $4,000. Under Alternatives II, III, and V, the length of the open ditch is reduced. The annual cost of maintaining this facility is estimated at $2,000.

There is also periodic maintenance on open ditches to correct or repair erosion problems that will occur. Again, the magnitude of the problem is influenced by unpredictable events that transpire during the life of the project. For the purposes of this study, an annual cost of $3,000 is estimated for this maintenance cost.

There are other minor costs in the maintenance of an open ditch, such as spraying for vectors and clean-up costs for illegal dumping. These costs were estimated at $1,000 per year.

The storm sewer section of Alternatives II and V should require only minimal amounts of maintenance during a normal year. An occasional cleaning of junction boxes or manholes should comprise the majority of the maintenance on the storm sewer. An estimated annual cost of $1,000 was used for this work.

3. Pump Station Operation and Maintenance Costs

The two major components of the pump station are the pumps and their motors, and the auxiliary power generator. Both of these items will require periodic maintenance and will have operational expenses.

The pumps and motors operation and maintenance costs are comprised of two parts. The first in the annual cost of the electricity required to operate the motors. This cost is dependent upon the length of time the motors run, which in turn is dependent upon the rainfall amounts received. The second part of this cost pertains to the care of the pumps and motors. Items such as bearings and seals will require service and replacement, and other small repairs will be experienced throughout the life of the station.

The power generator in the station will be called upon to work when normal electrical power is not available. Because of the infrequency of this type of occurrence, scheduled maintenance of this facility is imperative to insure its operation when needed.

Assumptions were made with respect to the yearly operation of the pumps within the station. Based on an average electrical cost of $25.00 per hour of operation, total electrical costs were assigned to the pumps in each alternative. Normal maintenance was estimated at $600 per year per pump and motor. Maintenance of the power generator was estimated at $1,000 per year.

Table 25 on page 55 summarizes the annual operation and maintenance costs for each flow rate design for each alternative. These costs were not included in the benefit/cost ratio calculations contained in this report because it would not change the final conclusions and actual costs are unpredictable.

F. FLOOD PLAIN IMPACTS

1. General

City maps were utilized to determine the impacts on the 100-year flood plain as a result of diverting storm flows from Cottonwood Creek. Once the areas of flooding were determined, based on the projected water surface elevations, the number of houses, businesses, etc., within the flood plain could be determined.

2. Limits of Flood Plain Impact

Based on the HEC-2 model for Cottonwood Creek, water surface elevations for each diversion flow rate were computed. Based on these elevations, and the width of the flood plain at select crossections along the creek, it was found that the areas outside of the corporate limits of Bay City were not significantly impacted by the proposed diversion facility.

TABLE 25

ANNUAL OPERATION AND MAINTENANCE COSTS
COTTONWOOD CREEK DIVERSION FACILITY

	ANNUAL OPERATION AND MAINTENANCE COSTS			
ALTERNATIVE	400 cfs	500 cfs	600 cfs	700 cfs
I	$ 14,000	$ 16,000	$ 18,000	$ 22,000
II	$ 13,000	$ 15,000	$ 17,000	$ 21,000
III	$ 13,000	$ 15,000	$ 17,000	$ 21,000
IV	$ 8,000	$ 8,000	$ 8,000	$ 8,000
V	$ 7,000	$ 7,000	$ 7,000	$ 7,000

Table 26, on Page 57, lists proposed 100-year water surface elevations at prominent locations on Cottonwood Creek. Hammond Road is near the southern boundary of the City, and Golden Avenue is near the northern boundary.

Table 27, on Page 58, takes the same information and illustrates the reductions in water surface elevations. As this also shows, most of the impact of the diversion facility is between Hammond Road and Golden Avenue, or within the City Limits of Bay City.

Therefore, for the purposes of this report, and the analysis of the various alternatives, the impacts of any of the design alternatives were limited to the portion of the watershed within the City Limits of Bay City. Should one of the diversion alternatives be constructed, and additional structural improvements be made on Cottonwood Creek, future impacts to the flood plain outside the City are possible.

Exhibit 3, 100-Year Flood Plain Limits, illustrates the extent of the reduction in the 100-year flood plain area for each of the diversion facility design flows. Table 28, on Page 59, lists the acreage for each of these flood plains within the City. As shown, there is a reduction of 375 acres to 620 acres, depending on the diversion amount.

TABLE 26

WATER SURFACE ELEVATIONS
100-YEAR STORM

LOCATION	WATER SURFACE ELEVATIONS (feet) WITH DIVERSION CHANNEL DESIGN ALTERNATIVES				
	0 CFS	400 CFS	500 CFS	600 CFS	700 CFS
Cottonwood Creek at Live Oak Creek	25.0	24.9	24.9	24.9	24.9
AT & SF RR	33.5	33.3	33.3	33.3	33.2
FM Hwy. 2668	38.9	38.7	38.6	38.6	38.5
Hammon Road	42.1	41.7	41.5	41.4	41.2
AT & SF RR	47.2	46.9	46.8	46.7	46.6
Cottonwood St.	49.2	48.9	48.8	48.7	48.6
Missouri Pacific RR	49.8	49.3	49.2	49.1	48.9
Fourth St.	50.0	49.5	49.4	49.2	49.1
Hwy. 35	50.7	50.0	49.8	49.6	49.3
Diversion Structure	51.4	50.5	50.2	49.9	49.6
Tenth St.	51.9	51.0	50.8	50.5	50.3
Ave. J & 12th St.	52.1	51.3	51.1	51.0	50.8
Grace St.	52.3	51.6	51.4	51.3	51.2
Golden Ave.	52.4	51.8	51.7	51.6	51.5
Gulf, Colorado & Sante Fe RR	54.3	54.2	54.1	54.1	54.1
FM Hwy. 3156	54.5	54.5	54.5	54.4	54.4

TABLE 27

WATER SURFACE ELEVATION DIFFERENCES
100-YEAR STORM

LOCATION	DIFFERENCE IN WATER SURFACE ELEVATIONS (feet) WITH DIVERSION CHANNEL DESIGN ALTERNATIVES				
	0 CFS	400 CFS	500 CFS	600 CFS	700 CFS
Cottonwood Creek at Live Oak Creek	0	-0.1	-0.1	-0.1	-0.1
AT & SF RR	0	-0.2	-0.2	-0.2	-0.3
FM Hwy. 2668	0	-0.2	-0.3	-0.3	-0.4
Hammon Road	0	-0.4	-0.6	-0.7	-0.9
AT & SF RR	0	-0.3	-0.4	-0.5	-0.6
Cottonwood St.	0	-0.3	-0.4	-0.5	-0.6
Missouri Pacific RR	0	-0.5	-0.6	-0.7	-0.9
Fourth St.	0	-0.5	-0.6	-0.8	-0.9
Hwy. 35	0	-0.7	-0.9	-1.1	-1.4
Diversion Structure	0	-0.9	-1.2	-1.5	-1.8
Tenth St.	0	-0.9	-1.1	-1.4	-1.6
Ave. J & 12th St.	0	-0.8	-1.0	-1.1	-1.3
Grace St.	0	-0.7	-0.9	-1.0	-1.1
Golden Ave.	0	-0.6	-0.7	-0.8	-0.9
Gulf, Colorado & Sante Fe RR	0	-0.1	-0.2	-0.2	-0.2
FM Hwy. 3156	0	0	0	-0.1	-0.1

TABLE 28

CITY OF BAY CITY FLOOD PLAIN AREAS
100-YEAR STORM

DIVERSION QUANTITY (cfs)	TOTAL AREA WITHIN FLOOD PLAIN (acres)	REDUCTION IN FLOOD PLAIN AREA (acres)
0	1,425	0
400	1,050	375
500	965	460
600	905	520
700	805	620

3. Number of Structures Affected

A total of 1,300 structures were identified by a review of aerial photographs and the Matagorda County Appraisal District records as being within the limits of the 100-year storm flood plain. Based on modeling results for the diversion of 400, 500, 600 and 700 cfs, a total of 463, 555, 662 and 794 structures, respectively, were removed from the projected flood limit. A tabulation of the number of structures which are affected by the 100-year storm is provided in Table 29, found on Page 61.

G. BENEFIT/COST ANALYSIS

A review of Matagorda County Appraisal District records was performed to determine the potential monetary damage a 100-year flood occurrence would cause and the respective savings should a flood water diversion project be constructed. The diversion flows considered were 400, 500, 600 and 700 cfs. The 1990 appraisal values for those structures which are located in the predicted 100-year flood occurrence limits is $52,049,000. This total potential monetary damage only considers the improved value of the property affected. Diversions of storm flows of 400, 500, 600 and 700 cfs reduces the appraised improvements value located within the flood plain to $31,723,000, $28,241,000, $25,632,000 and $20,067,000, respectively.

Benefits realized by the citizens, should one of these diversion options be constructed, is not the total value of the improvements removed from the flood plain. The benefits analysis assumed that damage sustained during a 100-year flood occurrence would amount to twenty percent (20%) of the value of the residential structures, fifteen percent (15%) of the

TABLE 29

STRUCTURES WITHIN COTTONWOOD CREEK FLOOD PLAIN IN CITY OF BAY CITY 100-YEAR STORM FLOOD PLAIN

TYPE OF IMPROVEMENT	NO. OF STRUCTURES AFFECTED BY 100-YEAR STORM	NO. OF STRUCTURES AFFECTED AFTER VARIOUS DIVERSIONS			
		400 cfs	500 cfs	600 cfs	700 cfs
Residential	1,099	678	599	503	386
Commercial	170	132	120	109	94
Public	31	27	26	26	26
TOTAL	1,300	837	745	638	506

value of the commercial establishments, and ten percent (10%) of the value of the public properties. Based on this damage analysis, the projected benefit for each diversion option and each structure designation is provided in Table 30, found on Page 63.

The benefit values developed and displayed in Table 30 can be compared with the estimated cost for the five individual alternatives that were proposed. The cost estimates associated with each of the five alternatives were compared with the projected benefits to determine a benefit/cost ratio. The resulting benefit/cost ratios are provided in Table 31, on Page 64.

A benefit/cost ratio of greater than one (1) indicates that the citizens would realize a benefit from the proposed projects if a 100-year flood occurs. A benefit/cost ratio of less than one (1) indicates that the citizens would not realize a benefit from the proposed project if a 100-year flood occurs. The benefit/cost ratios provided in Table 31 indicate that if a 100-year storm occurs, then less money would be spent on a channel diversion project than would be realized in flood damages.

Based on the results provided in Table 31, Alternative IV will have the greatest benefit for the citizens which could be affected by a 100-year flood occurrence. Alternatives V and I would be the next beneficial alternatives to the citizens. Alternatives II and III appear to be marginal as to the benefit the citizens could realize if these projects were constructed.

TABLE 30

CITY OF BAY CITY FLOOD DAMAGE BENEFITS
100-YEAR STORM FLOOD PLAIN

TYPE OF IMPROVEMENT	MONETARY BENEFITS FROM REDUCED FLOODING WITH DIVERSION CHANNEL DESIGN ALTERNATIVES			
	400 CFS	500 CFS	600 CFS	700 CFS
Residential	$2,761,000	$3,112,000	$3,521,000	$4,164,000
Commercial	$393,000	$570,000	$651,000	$792,000
Public	$390,000	$441,000	$447,000	$588,000
TOTAL	$3,554,000	$4,123,000	$4,619,000	$5,544,000

TABLE 31

COTTONWOOD CREEK DIVERSION CHANNEL
BENEFIT/COST RATIO
SUMMARY OF ALL ALTERNATIVES

ALTERNATIVE NO.	DIVERSION DESIGN DISCHARGE			
	400 CFS	500 CFS	600 CFS	700 CFS
I	1.392	1.493	1.562	1.674
II	1.120	1.176	1.214	1.288
III	1.332	1.292	1.204	1.090
IV	1.497	1.702	1.902	2.247
V	1.403	1.483	1.570	1.719

H. RECOMMENDED PLAN

As previously discussed, the alternative with the highest benefit/cost ratio is Alternative IV, with a diversion flow of 700 cfs. This alternative involves an open ditch from Cottonwood Creek to the Colorado River, with a weir inlet control structure at the creek. However, the existence of an open ditch through a developed portion of the City creates other concerns that do not lend themselves to simple dollar evaluations.

The City of Bay City must also be concerned with the public's health, safety, and welfare that would result from action they may take. The City must also look at long term goals and plans to insure that actions do not counteract these goals and plans.

The concept of an open ditch through a developed portion of the City does raise legitimate concerns for the safety and welfare of the public. The presence of the ditch is an invitation for young children to play in the facility during both flow and non-flow conditions. Large open ditches, especially those well maintained, are a gathering point for activities by the users of motorcycles, skate boards, all terrain vehicles, etc. Because of vehicular traffic at the road crossings of the ditch, there is always the potential for a serious accident to occur if a vehicle does not successfully negotiate the bridge.

The potential for liability of the City if a serious accident were to occur involving the open ditch does exist. Because it is impossible to place a value on a human life, there is not a straight-forward method of evaluating the costs of these concerns and liabilities.

Long term City goals and plans include the opening of Ninth Street as a major street from Moore Avenue on the west side of town to the east side of town. This would provide another east-west thoroughfare to relieve traffic loads on State Highway 35. Ninth Street is at the same location as the Southern Pacific Railroad occupied west of Cottonwood Creek, and is the site of the proposed diversion. The construction of an open ditch between Moore Avenue and Cottonwood Creek would prohibit the construction of this thoroughfare, without later filling in the ditch. This would ultimately drive the total costs of the project above an affordable level, and the majority of the costs of construction of the ditch section and bridges would be lost and unsalvagable. If Ninth Street were to be opened as a major thoroughfare in the future, this section of the diversion channel would require construction as an underground storm sewer.

Therefore, the City prefers the construction of Alternative V, at a diversion flow of 700 cfs. Although the costs of the alternative are higher, the overall analysis of the project yields this to be the preferred option.

I. FINANCING AND IMPLEMENTATION

1. General

Although this study was done for the City of Bay City, other local governmental agencies have expressed a need for the proposed project. They have also expressed an interest in assisting with the funding of the construction. This sharing of costs reduces the financial burden on the others, and greatly enhances the ability to fund the construction locally.

The other local governmental entities are Matagorda County Drainage District No. 1, Matagorda County Conservation and Reclamation District No. 1, and Matagorda County Commissioners' Court. The work on this study has been coordinated with these entities.

2. General Fund

In order to finance the cost of this project through the general fund, the construction work would have to be completed in phases. However, this type of project lends itself to this type of an approach.

At a total estimated project cost of $3,225,000, for Alternative V, at a diversion rate of 700 cfs, the construction of the diversion facility could be scheduled over four years. The first year's cost would be approximately $895,000, and would include total project engineering, the construction of the outlet control structure, the LCRA crossing, the Twelfth Street bridge, and channel excavation to Moore Avenue. Construction in the second year would build about 1,000 linear feet of the storm sewer box culverts from Moore Avenue to just east of Avenue B at a cost of approximately $850,000. In the third year, another 1,000 linear feet of the box culvert would be constructed at an approximate cost of $850,000. This third year's work would carry the project across Avenue E. The forth and final year of the project would see the completion of the box culverts and the construction of the inlet weir control structure at a cost of approximately $630,000.

With proper planning, the four taxing entities involved can participate in these costs without seriously impacting each entities' budget. The percentage of each entities' involvement in the yearly costs are subject to negotiations between the entities and their respective financial responsibilities and obligations at that time.

3. General Obligation Bonds

As previously stated, another means of financing the project is through the sale of bonds. These bonds are then repaid by ad valorem taxes collected by the taxing entity. However, the public reaction to the sale of bonds, based on current conditions, is probably negative. The passing of a bond issue by Matagorda County Drainage District No. 1, Matagorda County Conservation and Reclamation District No. 1, and Matagorda County Commissioner's Court would be very difficult. These entities cover areas larger than the area of Bay City immediately impacted by the proposed diversion project. Therefore, the voters in the other areas within these entities would not be in support of raising their taxes to pay for a project that would benefit those people within the City.

Although the passing of a bond issue by the City would be a difficult task due to the current tax load on the citizens, it is an option for the financing of the project. Two financial scenarios were developed for presentation.

The first is if the City would assume the entire cost of the project themselves, without assistance from the other county governments. Table 32, on Page 69, shows the payments that would be required each year for twenty years if $3,270,000 dollars of bonds were sold. This figure is based on an estimated cost of $3,225,000, with

TABLE 32

DEBT SERVICE RETIREMENT SCHEDULE
$3,270,000 BOND ISSUE

YEAR ENDING	PRINCIPAL	INTEREST @ 7.35%	TOTAL DEBT SERVICE	TAX RATE REQUIRED
1992	$ 75,000	$360,518	$435,518	0.127
1993	85,000	234,833	319,833	0.093
1994	90,000	228,585	318,585	0.093
1995	95,000	221,970	316,970	0.092
1996	105,000	214,988	319,988	0.093
1997	110,000	207,270	317,270	0.092
1998	115,000	199,185	314,185	0.091
1999	125,000	190,733	315,733	0.092
2000	135,000	181,545	316,545	0.092
2001	145,000	171,623	316,623	0.092
2002	155,000	160,965	315,965	0.092
2003	170,000	149,573	319,573	0.093
2004	180,000	137,078	317,078	0.092
2005	195,000	123,848	318,848	0.093
2006	205,000	109,515	314,515	0.091
2007	220,000	94,448	314,448	0.091
2008	240,000	78,278	318,278	0.093
2009	255,000	60,638	315,638	0.092
2010	275,000	41,895	316,895	0.092
2011	295,000	21,683	316,683	0.092
TOTAL	$3,270,000	$3,189,165	$6,459,165	

legal and financial advisor fees added. The interest rate on the bonds was calculated at 7.35 percent, which was based on the City's current financial condition. Based on current City property value of $343,909,880, and a 95 percent collection rate, the City would be required to raise taxes by almost $0.10 to repay the bonds. The current city tax rate is $0.615. Therefore, the additional taxes would represent a 16 percent increase in the overall tax rate.

The second possible option is the City would assume the additional cost of the box culvert storm sewer, and the other county entities would fund the balance of the project. This option is realistic because the City prefers the storm sewer for reasons not directly connected to the success of the proposed project. The debt service requirement for the difference in cost between Alternative IV and Alternative V (at 700 cfs) is shown in Table 33 on Page 71. Again, legal and financial advisor fees were added to the $758,000 construction costs. Using the same basis for collection, the resulting tax rate would average $0.022. This would result in a 3.7 percent increase in the overall City tax rate.

J. REGULATORY REQUIREMENTS

The regulatory agencies who will review this project will be the Texas Water Commission (TWC), the Lower Colorado River Authority, and the United States Army Corps of Engineers. The TWC would specifically be concerned with the total amount of water that would be removed from the Cottonwood/Peyton Creek Watershed. Several downstream landowners have water rights for irrigation purposes. The TWC would require that a Transbasin Diversion Permit be submitted and approved prior to

TABLE 33

DEBT SERVICE RETIREMENT SCHEDULE
$780,000 BOND ISSUE

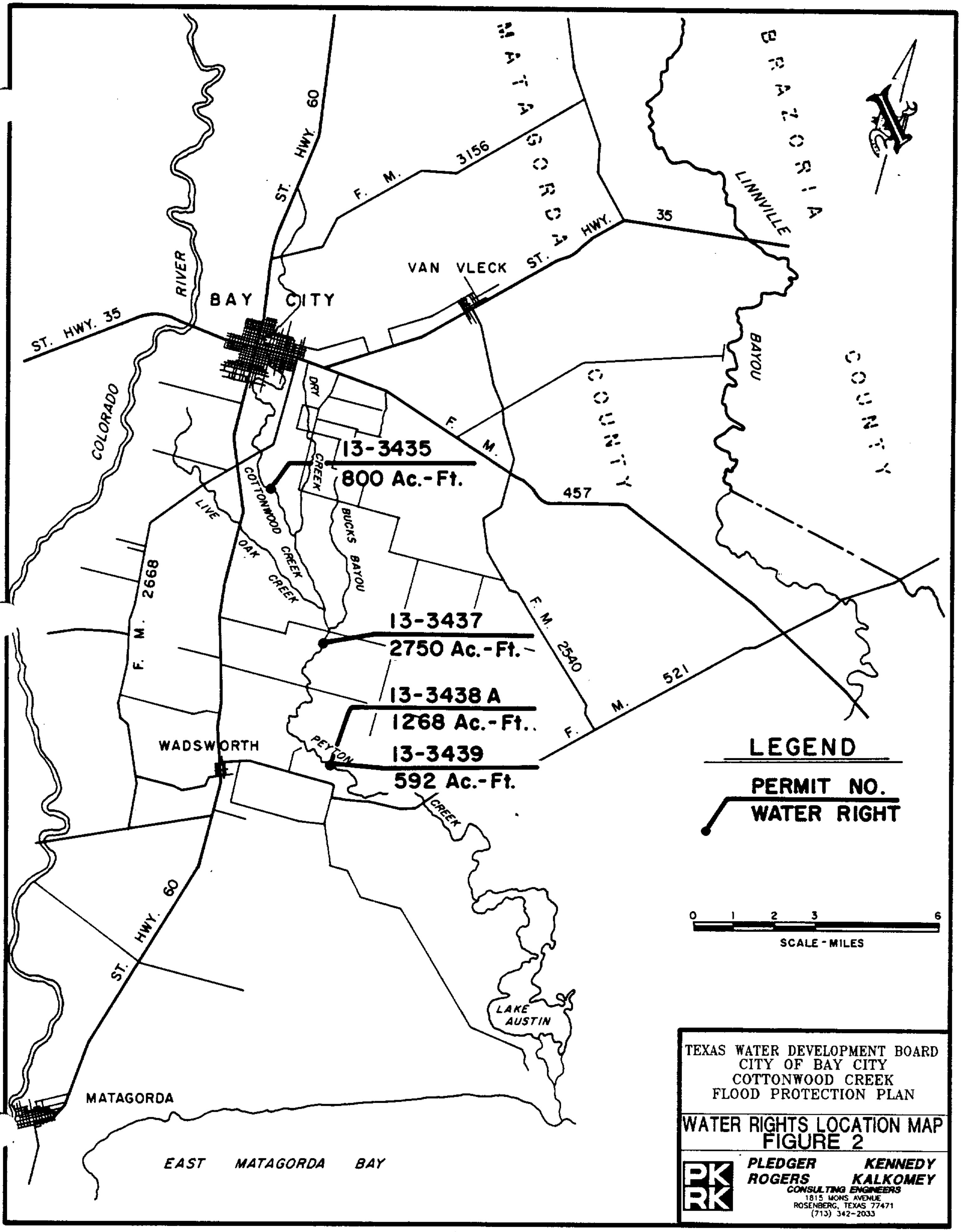
YEAR ENDING	PRINCIPAL	INTEREST @ 7.35%	TOTAL DEBT SERVICE	TAX RATE REQUIRED
1992	$ 15,000	$85,995	$100,995	0.029
1993	20,000	56,228	76,228	0.022
1994	20,000	54,758	74,758	0.022
1995	25,000	53,288	78,288	0.023
1996	25,000	51,450	76,450	0.022
1997	25,000	49,613	74,613	0.022
1998	30,000	47,775	77,775	0.023
1999	30,000	45,570	75,570	0.022
2000	35,000	43,365	78,365	0.023
2001	35,000	40,793	75,793	0.022
2002	35,000	38,220	73,220	0.021
2003	40,000	35,648	75,648	0.022
2004	45,000	32,707	77,708	0.023
2005	45,000	29,400	74,400	0.022
2006	50,000	26,093	76,093	0.022
2007	55,000	22,418	77,418	0.023
2008	55,000	18,375	73,375	0.021
2009	60,000	14,333	74,333	0.022
2010	65,000	9,923	74,923	0.022
2011	70,000	5,145	75,145	0.022
TOTAL	$780,000	$761,093	$1,541,093	

construction of this project. A copy of the permit application would also be sent to the Texas Parks and Wildlife Department (TP&W) for comment. The TP&W would be specifically concerned with the effect the diversion would have upon the salinity of East Matagorda Bay and the amount of nutrients that would not be delivered to the coastal wetlands during peak storm flow.

Preliminary studies indicate the amount of water diverted from East Matagorda Bay during a 100-year storm occurrence would be less than one percent (1%) of the total flow if the maximum amount of 700 cfs is diverted. This percentage of the total flow continues to reduce as the frequency of storm occurrence increases. Essentially no water is diverted from a storm with frequency of 10 years or less.

Four (4) Certificates of Adjudication of Water Rights have been granted within the Cottonwood/Peyton Creek Watershed below the proposed point of diversion. These water rights are associated with agricultural irrigation and are noted on Figure 2, on Page 73. The total amount of water reserved by these four certificates is 4,810 acre-feet. Therefore, the proposed diversion project should have no effect upon these permittees' water rights. However, the TWC will notify these individuals should a Transbasin Diversion Permit be submitted. A public hearing may be required to inform the public as to the effects of this proposed project.

Currently the TWC requires four (4) to six (6) months to review and approve an administratively complete permit application. The flow chart depicting the review process for the Transbasin Diversion Permit Application is attached as Figure 3, on Page 74.


MATAGORDA COUNTY
BRAZORIA COUNTY
ST. HWY. 60
F. M. 3156
ST. HWY. 35
35
LINNVILLE BAYOU
VAN VLECK
BAY CITY
RIVER
COLORADO
DRY CREEK
COTTONWOOD CREEK
LIVE OAK CREEK
BUCKS BAYOU
F. M. 457
F. M. 2668
F. M. 2540
F. M. 521
13-3435
800 Ac.-Ft.
13-3437
2750 Ac.-Ft.
13-3438 A
1268 Ac.-Ft.
13-3439
592 Ac.-Ft.
WADSWORTH
PEYTON CREEK
LEGEND
PERMIT NO.
WATER RIGHT
0 1 2 3 6
SCALE - MILES
LAKE AUSTIN
MATAGORDA
EAST MATAGORDA BAY
TEXAS WATER DEVELOPMENT BOARD
CITY OF BAY CITY
COTTONWOOD CREEK
FLOOD PROTECTION PLAN
WATER RIGHTS LOCATION MAP
FIGURE 2
PLEDGER KENNEDY
ROGERS KALKOMEY
CONSULTING ENGINEERS
1815 MONS AVENUE
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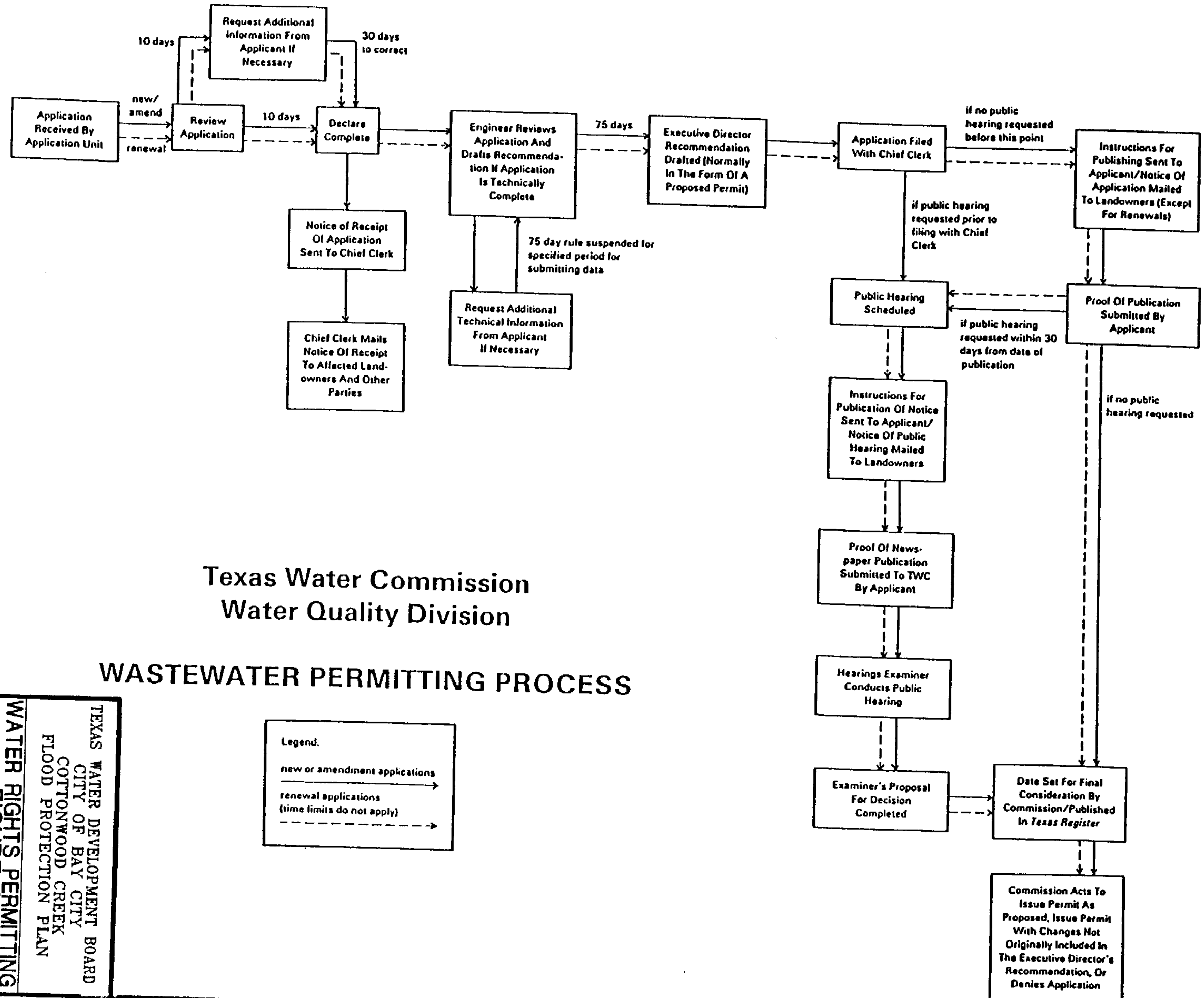

Texas Water Commission
Water Quality Division

WASTEWATER PERMITTING PROCESS

TEXAS WATER DEVELOPMENT BOARD
CITY OF BAY CITY
COTTONWOOD CREEK
FLOOD PROTECTION PLAN

WATER RIGHTS PERMITTING
FIGURE 3

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jurisdiction with respect to the quality of the water accepted. The LCRA is concerned about the amount of sediment that could be diverted. They have a dam on the Colorado River directly below State Highway 35 for irrigation purposes. The LCRA would review this project to assure themselves that any increased sedimentation would not adversely affect this structure and the corresponding pump station.

However, a degradation of the quality of the water in the Colorado River is not anticipated as a result of the operation of the diversion facility. Although base flow rates in the river can be low (less than 100 cfs) during dry, summer months, the addition of flows to the river via the diversion facility will be sporadic. If the Colorado River flows are high, the amount of water added to the river from the diversion facility will be insignificant when compared to the base river flow. Under this same senario, it is unlikely that LCRA will be operating their pumping facility below State Highway 35, because water for irrigation purposes will not be required. Although the introduction of additional pollutants, such as fertilizers, pesticides, hydrocarbons, etc., into the Colorado River is possible, the amounts of these pollutants is anticipated to be small as compared to the overall system.

The COE will require that two (2) permits be filed with the Galveston District Office. The permits are a Section 404 Permit and a Section 10 Permit. The Section 404 Permit refers to the placement of dredge spoils where the proposed diversion channel meets the Colorado River. The Section 10 Permit is required since the COE must certify that the proposed outlet structure does not pose a navigatable hazard on the Colorado River.

K. SECONDARY BENEFITS

In addition to receiving benefits on a 100-year storm from the construction of the diversion facility, the impact upon the 10-year storm event was studied. The reduction in the water surface elevations along the channel through Bay City has a significant impact on the size of the resulting flood plain.

On Exhibit 4, 10-Year Flood Plain Limits, the projected flood plain with no diversion and with a 400 cfs diversion are deliniated. The 400 cfs diversion is the maximum diversion that can be obtained with the recommended Alternative V design at 700 cfs (100-year storm event). As the exihibit shows, downstream of the diversion point, the majority of the flood plain is contained within the channel banks.

The number of structures within this area was also identified. The construction of the proposed diversion facility would result in the removal of approximately 183 structures from the flood plain. Applying the same economic factors as with the 100-year storm event, the benefit derived from the project would be $1,368,635.

Above the diversion point, the diversion project does not impact the 10-year flood plain. The season for this apparently is a result of channel restrictions at 10^{th} Street and Grace Street. If the diversion facility is constructed, improvements to these structures will result in additional benefits to the area.

The area will receive additional secondary benefits from the construction of the diversion facility. These benefits are not easy to quantify, but do provide further justification for the project.

Because construction of the diversion facility will lower flood levels, fewer roads will sustain damages, and those that will still be within flooded areas should experience less damage. The movement of vehicles within the City during major storm events will be enhanced due to the reduction in flood levels. Communication and electrical lines are buried underground throughout the area. The loss of service during and immediately after flooding conditions have occurred results in not only inconviences, but also requires funds to facilitate repairs. Likewise, water and sanitary sewer lines can be affected during and after flooding conditions. The inflow of storm waters into water wells or damaged water lines can present health hazards to the public and usually require the expedature of unallocated funds to quickly initiate repairs. The encroachment of storm flows into the sanitary sewer system increases operational costs at treatment plants. Pollutants in the storm waters could also upset the bacteriological balance of the plant components, creating further public health concerns from the improper treatment of sewage flows. Flooding conditions can leave areas of standing water which can turn into breeding areas for mosquitos. These insects can spread disease, and programs to control them can be costly.

VI. SUMMARY

A. CONCLUSIONS

1. Conventional structural alternatives to improve Cottonwood Creek have been reviewed in previous years and, due to current constraints and encroachments caused by urbanization, are too costly to be funded locally.

2. Non-structural means of providing relief by flood mitigation can help in reducing future runoff quantities and flood damage, but do not adequately address current flooding problems in the Cottonwood Creek Watershed.

3. A diversion of high level flood flows is the only economical means of providing flood protection in the upper Cottonwood Creek Watershed.

4. The use of the former Southern Pacific Railroad right-of-way from Cottonwood Creek to the Colorado River is an appropriate location of the proposed diversion. Although the diversion facility may be rendered ineffective at the 100-year flood stage of the river, the possibility of this occurring at the same time the Cottonwood Creek Watershed receives a 100-year storm is very remote.

5. The construction of the proposed diversion facility with a design capacity of 700 cfs will significantly reduce the limits of flooding and the water surface elevations within the majority of the City of Bay City. Significant impacts are also received on a 10-year storm level.

6. The estimated construction cost of the preferred Alternative V is $3,225,000 in 1990 dollars. The one time benefits received during a 100-year storm event is estimated at $5,544,000, or a benefit/cost ratio of 1.719.

7. The project could be constructed from the general operating fund, with construction costs shared by the City of Bay City, Matagorda County Drainage District No. 1, Matagorda County Conservation and Reclamation District No. 1, and Matagorda County Commissioner's Court. The project could be phased over four years, at an average annual cost of $810,000.

B. RECOMMENDATIONS

It is recommended that:

1. The preferred Alternative V be constructed, and the project be phased over a four year period to accommodate local funding abilities.

2. The four governmental agencies that could be responsible for the funding of this project come to an agreement as to the funding amounts that can be dedicated to the project.

3. That engineering services be authorized to prepare complete construction plans and specifications for the phased construction of the proposed facility.

4. That all necessary permits and all state and federal agency permits be applied for and obtained.

5. Once completed, the City and County should submit engineering data to FEMA and request that the Flood Insurance Rate Maps for Cottonwood Creek be revised to reduce the flood plain limits and elevations.

6. The City and others should continue to provide drainage improvements in the Cottonwood Creek Watershed by removing restrictions in the natural channel upstream of the diversion point.

VII. REFERENCES

1. 7.5 Minute Series Topographic Maps, U.S. Department of the Interior Geological Survey, Scale 1:24000, contour interval 5 feet: Lake Austin, Texas, 1952 (photorevised 1972), Bay City, Texas, 1952 (photorevised 1972), Bay City NE, Texas, 1952 (photorevised 1972), Wadsworth, Texas, 1952 (photorevised 1972), Van Vleck, Texas, 1952 (photorevised 1980).

2. Survey Report on Peyton Creek, Texas Flood Control, U.S. Army Engineer District Galveston, Corps of Engineers, 1970.

3. Preliminary Drainage Study Peyton Creek Watershed, Brown & Root, Inc., 1973.

4. HEC - 1 Flood Hydrograph Package, Users Manual, U.S. Department of the Army, Corps of Engineers, Hydrological Engineering Center, Computer Program 723-X6-L2010, Davis, California, September 1981, Revised January, 1985.

5. Flood Insurance Study, City of Bay City, Texas, Federal Emergency Management Agency, June 5, 1985.

6. Flood Insurance Study, Matagorda County, Texas, Federal Emergency Management Agency.

7. Effects of Urbanization on Floods in the Houston, Texas, Metropolitan Area, U.S. Department of the Interior, Geological Survey, Water Resources Investigations 3-73, Steven L. Johnson and Douglas M. Sayre, Washington, D.C., April, 1973.

8. Technique for Estimating the Magnitude and Frequency of Floods in Texas, U.S. Department of the Interior, Geological Survey, Water Resources Investigations 77-110, E.E. Schroeder and B.C. Massey, Washington, D.C.

9. HEC-2 Water Surface Profiles, Users Manual, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, California, August, 1979.

Cottonwood Creek Flood Protection Plan
City of Bay City, Matagorda County, Texas
Contract No. 90-483-763 October 1990

The following maps are not attached to this report. Due to their size, they could not be copied. They are located in the official file and may be copied upon request.

Cottonwood Creek Watershed Exhibit 1

Diversion Channel Location Exhibit 2

100-Year Flood Plain Limits Exhibit 3

10-Year Flood Plain Limits Exhibit 4

Recommended Diversion Plan Exhibit 5

Please contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.