MASTER DRAINAGE PLAN REPORT

ON

MUSTANG BAYOU, CHOCOLATE BAYOU, DITCH C-1, DITCH M-1, NEW BAYOU, HALLS BAYOU, CHIGGER CREEK, DITCH D-4 AND DICKINSON BAYOU WATERSHEDS

PREPARED FOR

BRAZORIA COUNTY CONSERVATION & RECLAMATION DISTRICT NO. 3

AND

THE TEXAS WATER DEVELOPMENT BOARD

PREPARED BY

SNOWDEN ENGINEERING, INC.

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SNOWDEN ENGINEERING, INC.
Houston • Pearland, Texas

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I. Introduction

A. General

The Brazoria County Conservation and Reclamation District No. 3 (the District) and the Texas Water Development Board (the Board) contracted with Snowden Engineering, Inc. in June 1987 to perform a Master Drainage Plan for the District. The study includes: 1) Preparation of the existing hydrologic and hydraulic models for Mustang Bayou, Ditch M-1, New Bayou, Chocolate Bayou, Ditch C-1, Halls Bayou, Chigger Creek, Dickinson Bayou, and Ditch D-4; 2) Development of flood damage abatement measures for each of the streams studied and evaluation of the benefit-to-cost ratio for all the measures; 3) Recommendation of the best features of the most feasible alternatives for each watershed, and 4) Preparation of a drainage manual to assist developers in the design of drainage improvements.

The Phase One Study has been completed which includes Mustang Bayou, Ditch M-1, New Bayou, Chocolate Bayou, and Ditch C-1. A preliminary report on the Phase One Study was submitted to the District and the Board in December 1988. The report describes the flooding

problems for each of these streams and analyzes all flood damage abatement measures including the structural, non-structural and no action alternatives.

The Phase Two Study has also been completed which included Halls Bayou, Chigger Creek, Ditch D-4 and Dickinson Bayou. A preliminary report on the Phase Two Study was submitted to the District and the Board in May 1989. The report describes the flooding problems for each of these streams and analyzes all flood damage abatement measures including the structural, non-structural, and no action alternatives. The purpose of this report is to evaluate results of Phases One and Two and combine the best features of the most feasible alternatives for each watershed analyzed in the two phases.

B. Authorization and Acknowledgement

This project was authorized by both the District and the Board. Snowden Engineering, Inc. wishes to express its sincere appreciation for the cooperation and assistance received from the District, the Board and the local officials during the study period.

II. Background Consideration

A. General Location

The District encompasses approximately 180 square miles of land in northeast Brazoria County. The District is bounded by Chocolate Bayou on the west, Chocolate Bay on the south, the Brazoria/Galveston County line on the east and essentially the American Canal on the north as shown on Exhibit I.

1. Mustang Bayou: Mustang Bayou runs through the center of the District. The headwater of Mustang Bayou is inside the city limits of Missouri City which is located in Fort Bend County. The bayou flows in a southeast direction through the county line, the Cities of Manvel, Alvin and Hillcrest Village and outfalls in Chocolate Bay in the southeast corner of the District. An area of approximately 62 square miles south of FM 2004 (including Ditch M-1 and New Bayou) drains from the headwater to the south of the confluence with New Bayou. Exhibit II shows the drainage boundaries of Mustang Bayou, Ditch M-1, New Bayou, Ditch C-1 and Chocolate Bayou.

2. Ditch M-1: A man-made tributary of Mustang Bayou, Ditch M-1 originates in the western part of Alvin and outfalls in Mustang Bayou approximately 6 miles southeast of Alvin. Ditch M-1 provides a certain capacity for drainage of the south and west portions of the City of Alvin. A total of 7.8 square miles of drainage area is covered by Ditch M-1.

3. New Bayou: A relief channel to Ditch C-1 (main tributary of Chocolate Bayou), New Bayou originates from Ditch C-1 near County Road 169 and outfalls into Mustang Bayou near FM 2004 with a drainage area of 8.5 square miles.

4. Chocolate Bayou: The headwaters are located north of Texas State Highway (SH) 6 approximately 1.4 miles west of the City of Manvel. The headwaters of the West Fork Chocolate Bayou begin near Arcola in southeast Fort Bend County and outfall into Chocolate Bayou approximately 2.5 miles south of FM 1128. The total drainage area of Chocolate Bayou at FM 2004 is 170 square miles including Ditch C-1.

5. Ditch C-1: A man-made tributary of Chocolate Bayou, Ditch C-1 originates at the northwest corner of the District near Manvel and flows southeasterly along the Brazos River Authority (BRA) Canal, formerly known as the Briscoe Canal, for approximately 8.2 miles then turns south and outfalls into Chocolate Bayou near Liverpool. The total drainage area of Ditch C-1 is 20 square miles.

6. Halls Bayou: Halls Bayou runs along the east side of the District near the Galveston/Brazoria County line. The headwater is located north of the Missouri Pacific Railroad and southeast of Hillcrest Village. The bayou flows in a southeasterly direction through County Road (CR) 165, BRA Canal, Halls Bayou Road, FM 2004 to Halls Lake and Chocolate Bay. A total drainage area of approximately 30 square miles is included in the Halls Bayou watershed to FM 2004. Exhibit II shows the drainage boundary for Halls Bayou, Chigger Creek, Dickinson Bayou and Ditch D-4.

7. Chigger Creek: Chigger Creek runs along the northeast corner of the District. The headwater is located at the east side of Mustang Bayou and

the City of Manvel. The creek flows in an easterly direction through the District to Brazoria County Drainage District No. 4 and outfalls into Clear Creek. A total drainage area of approximately 2.5 square miles is included in the Chigger Creek watershed within the District's boundary as shown on Exhibit II.

8. Dickinson Bayou: In this study, Dickinson Bayou only covers about one mile in length and is at the most upstream portion of the Bayou. The headwater of Dickinson Bayou is located on State Highway (SH) 35 south of Chigger Creek. The bayou flows in a southeastern direction through the BRA Canal and to the Galveston County line. A total drainage area of approximately 0.5 square miles is included in the Dickinson Bayou watershed to the Galveston/Brazoria County line as shown on Exhibit II.

9. Ditch D-4: Ditch D-4 is a man-made tributary of Dickinson Bayou. The ditch originates from Chigger Creek at CR 99 and flows in a southeasterly direction through CR 152, CR 144, the A.T.S.F. Railroad, SH 409, SH 35, and SH 528 to the County line as shown on Exhibit II. A total

drainage area of approximately 4.8 square miles is included in the Ditch D-4 watershed to the Galveston/Brazoria County line.

B. Land Use

The District is predominantly rural farm and ranch land, although various petro-chemical industries have been established at the lower reaches of the major streams. The Cities of Manvel and Alvin are within the District boundary; Liverpool, Arcola and portions of Missouri City are within the boundary of the study area. The main components of SH 288, the South Freeway, which crosses the study area have been completed and the construction of grade separation is underway. Significant development is expected to occur along the South Freeway corridor.

C. Topographic Features

Topography of the study area slopes generally from the northwest toward the southeast with a very mild slope of 0.04 percent. The elevation rises from the Mean Sea Level (MSL) at Chocolate Bay to approximately 75 feet MSL in the uppermost part of the study area. Most of the drainage area flows to the southeast

through Chocolate Bayou, Mustang Bayou and New Bayou. Natural drainage patterns have been altered throughout the District by the construction of supplemental drainage channels and irrigation canals. The levees enclosing the BRA Canal, which was constructed in the 1940's, have effectively blocked overland sheet flow in several locations of the study area.

D. Soil Characteristics

Within the study area, a great portion of the surface soil is classified as Lake Charles or Bernard-Edna except a small portion south of FM 2004 which belongs to Edna-Aris, Francitas-Narta and Harris-Veston. All of the soils are compiled of clay and loam and are poorly drained and have very low permeability. Rice and soybeans are the main cultivated crops.

E. Flooding Problems

During the past years, the drainage system within the study area has been inadequate for numerous rainfall events. Widespread flooding has caused physical damage to dwellings, crops, bridges, and roads estimated to be in the millions of dollars. Residential and commercial damage from tropical storm

"Claudette" (July 1979) which brought 26 inches of rain in 24 hours in the Mustang Bayou Watershed was estimated to be at $20 million. Other major flooding events occurred in July 1939, October 1949, March 1957, September 1973, September 1979, and August 1983. For many years the area was primarily for agricultural use only; but as urbanization occurred in the watershed, the potential for more serious flood damage in the study area increased. Extensive improvements will be required to eliminate the existing flooding problems and provide adequate drainage for future development in the study area.

F. Prior Studies

Various studies conducted previously for portions of these watersheds are as follows:

1. "Tropical Storm Claudette" by U.S. Army Corps of Engineers, Galveston, Texas, September 1980.

2. "Flood Damage Prevention, Feasibility Report for Dickinson Bayou Watershed, Texas" by U.S. Army, Corps of Engineers, Galveston, Texas.

3. "Flood Control Planning Study on Chigger and Cowarts Creek for the Brazoria County Drainage District No. 4 and the Texas Water Development Board" by COENCO, Inc., December 1986.

4. "Drainage Master Plan for Brazoria County C&R 3" by Turner, Collie, & Braden, Inc. August 1974.

5. "Report on Investigation of Outfall Channel for Mustang Bayou" by Turner, Collie, & Braden, July 1975.

6. "Engineering Report for Brazoria County C&R 3" by Baker and Lawson, April 1980.

7. "Floodplain Information, Chocolate Bayou, Brazoria County Texas" by U.S. Army, Corps of Engineers, Galveston, Texas, June 1971.

8. "Flood Insurance Study of Brazoria County, Texas" by U.S. Federal Emergency Management Agency, August 1986.

9. "High Flood Hazard Area Studies, Alvin, Texas" by U.S. Army, Corps of Engineers, Galveston, Texas, September 1986.

10. "Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures" by U.S. Army, Corps of Engineers, March 1978.

III. Existing Condition

A. General

All streams in the study area have inadequate capacity for a 25-year or 100-year frequency flood. The most serious flooding problem in the study area occurred in the vicinity of the most populated area, the City of Alvin. This is due to the limited right-of-way of Mustang Bayou and the heavy growth of vegetation inside the banks. Inside the Alvin city limits, high density residential and commercial buildings also form a blockage of the flow's path. The hydrologic and hydraulic analyses for the existing conditions of each stream studied are explained as shown in the following sections.

B. Hydrologic Analysis

In order to define the current flooding condition for each stream, HEC-1 models were developed for each watershed. These models were then adjusted for the reach routing based on the results of HEC-2 model multiple runs. The 25-year and 100-year flows thus calculated from the HEC-1 model will be used in the HEC-2 model at each control point for the calculation

of the 25-year and 100-year water surface profiles along each stream.

The input parameters for HEC-1 model includes drainage area, length of water course, slope of water course, slope of watershed, Manning's coefficient, and percentage of impervious area for each subwatershed. Additional information such as rainfall distribution for a 24 hour period, initial rainfall loss and constant loss through the period will be input as a constant parameter through each subwatershed. Two major items that will reflect the shape of the hydrographs were the time of concentration (Tc) and the storage coefficient (R). These two variables are calculated based on the equations adopted by Fort Bend County Drainage District. The flows that generated from the HEC-1 model were used to input the HEC-2 model for hydraulic calculations. Exhibits III through V show the locations of each watershed and control points for the HEC-1 model. Tables I through VI show the input parameters at each control point from each subwatershed. Tables VII through IX show the 25-year and 100-year discharges at each control point for each subwatershed. Appendix I through VI show the printouts for HEC-1 models for each watershed.

C. Hydraulic Analysis

In order to calculate the 25-year and 100-year water surface profiles and the flooding limits along each stream, the HEC-2 model was used to perform the computations. The primary input data required for the HEC-2 model is the cross section data of the stream and the overbanks. For streams such as Mustang Bayou, Chocolate Bayou, and Halls Bayou, the latest computer model from the Federal Emergency Management Agency (FEMA) was updated to reflect the existing condition. All other streams were based upon the surveyed cross sections by Snowden Engineering, Inc. The overbank extensions were based on U.S.G.S. quadrant map with adjustments to 1979 elevations.

The results of the HEC-2 model were used to develop flood plain maps and water surface profiles for each stream. Exhibits VI through VIII show the flooding limits for the existing 25-year and 100-year frequency flood for each stream. Exhibits IX through XVII show the corresponding water surface profile along the streams. Appendix VII through XV show the HEC-2 printouts for each studied stream.

IV. Proposed Improvements

A. General

This Master Drainage Plan presents the drainage improvements for each studied watershed under the existing condition as well as the fully developed condition with onsite detention to control increased runoff from future development. Various proposed alternatives for drainage improvements have been studied and presented in the summary of Phase I and Phase II. To combine the best features of the most feasible alternatives for each watershed in the two phases of studies is the key to the recommendation of the proposed improvements. Based on the summary report for Phase I and II, almost all improvement alternatives for the major streams and tributaries have a cost-to-benefit ratio less than one except Chigger Creek and Dickinson Bayou. Hence, it becomes impractical to determine the best alternatives based only on the economical factors. The recommendations of the proposed improvements for each stream should then be based on the feasibility of the solution.

B. Hydrologic Analysis

The study is based on the existing land development conditions. All future development will require on-site detention to retard the developed flow to its undeveloped condition. The major factor that will change the flow along the stream is the proposed channel improvement on the stream. The HEC-1 input is thus adjusted by a new set of reach routing information obtained from the revised HEC-2 model (or proposed improvement model) multiple runs. The new flows resulting from these HEC-1 runs will be used to input to the HEC-2 model for the hydraulic calculations.

C. Hydraulic Analysis

The revised HEC-2 model for each stream reflects the proposed improvements and the new 25- year and 100-year discharges from the HEC-1 run. The results of these HEC-2 runs will be used to estimate the construction cost and to evaluate the feasibility of the alternatives.

D. Recommended Plans

Due to the wide spread flooding problem in the study area and the large drainage area covering a minimum of 270 square miles, a District-wide flood forecasting or flood warning system is recommended for immediate action. This is a warning system to determine the imminent flooding and to warn the public and organizations of assistance in the temporary evacuation of persons and personal property. The most elaborate warning system utilizes remote sensors to transmit real-time rainfall and water level data to a microcomputer. The microcomputer is used to coordinate the data acquisition, management, analysis and communication tasks. An automated stream flow forecast system can also be operated by the microcomputer. With all this information, the District can accurately track storm conditions and forecast potential problem areas for the emergency evacuation plan.

It is recommended that 32 stations be installed in the study area as shown in Exhibits XVIII through XX. Based on an estimated cost of $5,000.00 for each station, the total will be $160,000.00 for the stations (or sensors). A software package and an IBM-AT PC microcomputer will cost approximately $20,000.00. A

central station and personnel for operation, maintenance and inspection will be required on a permanent basis.

The following recommendations for each watershed are based on the feasibility of the improvements and the phasing plan of each stream.

1. Mustang Bayou:

Four major factors that contribute to the flooding problem and limit the degree of channel improvements are:

a. Upstream contributing area from Fort Bend County.

b. Limited rights-of-way in the City of Alvin.

c. Limited rights-of-way at the reservoir.

d. Tidal flooding.

The recommended plan on Mustang Bayou is based on the existing condition upstream from the Fort Bend County/Brazoria County Line and the existing top

of bank width on Mustang Bayou within the Alvin city limits. A 40 foot bottom width earthen channel with 3:1 side slopes is recommended from the Ft. Bend/Brazoria County Line (Sec. BA on the existing flood plain map) to an irrigation canal (Sec AT). A 60 foot bottom width earthen channel is recommended from the irrigation canal to a proposed regional detention pond (Sec A). A proposed 150 acre regional detention site is recommended at this natural bend area. Downstream from the proposed pond, the 60 foot bottom earthen channel will be extended to the city limits of Alvin (Sec O). From the city limits to County Route (CR) 160 (Sec W), a concrete lined section with a 20 foot bottom width having 2:1 side slopes is recommended to match the existing top of bank due to the limited expansion on each side of the bank. Downstream of CR 160, a 100 foot bottom width earthen channel is recommended to the southern limit of the Farms of Texas reservoirs (Sec G). A 200 foot bottom width earthen channel is recommended from this section to the confluence with New Bayou. Downstream from the confluence (Sec C), a 300 foot bottom width earthen ditch is recommended to just upstream of Persimmon Bayou (Sec A). This recommended plan will confine the

100-year flood in the bank from the Fort Bend/Brazoria County line to FM 2004 except for tidal flooding which will still extend upstream of the existing reservoir. Exhibit XVIII shows the proposed improvement plan for this stream and Exhibit XXI shows the 100-year water surface profile along this stream. The estimated excavation quantity is 15.2 million cubic yards and the concrete lined channel is 5.3 miles. The total estimated construction cost will be $51.6 million including the replacement of bridge structures, which is estimated to be 47 units. The required right-of-way of 200 feet near the uppermost part of Mustang Bayou near the county line to 440 feet downstream near FM 2004 will be acquired by the District for construction purposes. Appendix XVI shows the HEC-1 printouts for the Mustang Bayou Watershed at the proposed condition. Appendix XXII shows the HEC-2 printouts on Mustang Bayou for the proposed condition.

2. Ditch M-1

The major factors that contribute to the flooding problem and limit the degree of channel improvements in this watershed are:

a. Limited right-of-way of the existing two foot bottom width ditch inside the City of Alvin.

b. Overloaded storm sewer systems and the two foot bottom width concrete lined ditch.

c. Limited capacity of the existing 7-72" CMP under the BRA Canal crossing.

The recommended plan on Ditch M-1 is based on the improved drainage system inside the City of Alvin to limit the drainage area to the capacity of the existing concrete lined channel. By doing this, no improvements will be required upstream from the existing concrete lining ditch. Downstream from this ditch to State Highway (SH) 35, a 20 foot bottom width concrete lined channel with 2:1 side slopes is recommended. Downstream from SH 35 to the confluence with Mustang Bayou, a 60 foot bottom width earthen channel is recommended

together with additional 3-72" CMP underneath the BRA Canal crossing.

This recommended plan will confine the 100-year flood within the banks all along the channel. The estimated excavation quantity is 1.9 million cubic yards and the concrete lined channel is 1.2 miles. The total construction cost estimate is $9.0 million including the replacement of bridge structures, which is estimated to be 13 units. The required right-of-way of 120 feet to 210 feet will be acquired by the District for construction purposes. Exhibit XVIII shows the proposed improvement plan and Exhibit XXII shows the proposed 100-year water surface profile along the channel. Appendix XXIII shows the HEC-2 printouts on Ditch M-1 for the proposed condition.

3. New Bayou

New Bayou is one of very few streams that has a fairly large capacity compared to the other streams studied. The recommended plan on New Bayou is based on zero diversion from either Ditch M-1 or Ditch C-1. The recommended plan calls for a 20 foot bottom width earthen channel from CR 169

(Sec L) to BRA Canal crossing (Sec H), a 60 foot bottom width earthen channel downstream to the Missouri Pacific Railroad crossing (Sec C) and a 100 foot bottom width earthen channel to the confluence with Mustang Bayou (Sec A). This recommended plan will confine the 100-year flood in the bank except the downstream area subjected to tidal flooding. The estimated excavation quantity is 0.8 million cubic yards and the estimate construction cost is $1.7 million including a bridge replacement at the dirty road (Sec I). Required right-of-way of 150 feet to 240 feet will be acquired by the District for construction purposes. Exhibit XVIII shows the proposed improvement plan and Exhibit XXIII shows the proposed 100-year water surface profile along the stream. Appendix XXIV shows the HEC-2 printouts on New Bayou for the proposed condition.

4. Chocolate Bayou

The major factors that contribute to the flooding problem and limit the degree of channel improvements are:

a. Upstream contributing area from Fort Bend County.

b. The continuous meandering of the bayou.

c. Tidal flooding.

The recommended plan for Chocolate Bayou contains both regional detention ponds and channel improvement applications. These regional detention ponds are proposed on West Fork Chocolate Bayou, Unnamed Tributary, and Hayes Creek at the confluence with Chocolate Bayou. The detention area of the 3 ponds is 250 acres, 150 acres and 200 acres, respectively. The channel improvements begin downstream from the BRA Canal to Rifle Range Road with a 50 foot bottom width earthen channel, a 100 foot bottom width from Rifle Range Road downstream to Hayes Road and a 200 foot bottom width earthen channel from this point to SH 35 and a 300 foot

bottom width earthen channel from SH 35 to FM 2004.

This recommended plan will contain 100-year flood in the bank all along the channel except for tidal flooding which will still extend upstream of SH 35. Exhibit XIX shows the proposed improvement plan for Chocolate Bayou and Exhibit XXIV shows the 100-year water surface profile along the bayou. The estimated excavation quantity is 32 million cubic yards including the regional detention ponds. The total construction cost estimate is $66.7 million including the replacement of bridge structures, which is estimated to be 18 bridge units. The required right-of-way from 160 feet to 500 feet will be acquired by the District for construction purposes. Appendix XVII shows the HEC-2 printouts for Chocolate Bayou Watershed at the proposed condition. Appendix XXV shows the HEC-2 printouts for Chocolate Bayou at the proposed condition.

5. Ditch C-1

The recommended plan for Ditch C-1 is a 20 foot bottom width earthen channel from Tankersley Road

to Old Rifle Road and a 40 foot bottom width earthen channel for Old Rifle Road to the confluence with Chocolate Bayou.

This recommended plan will confine the 100-year flood in the bank all along the ditch except the downstream area which is subject to tidal flooding. Exhibit XIX shows the proposed improvement plan for Ditch C-1 and Exhibit XXV shows the 100-year water surface profile along the ditch. The estimated excavation quantity is 3.2 million cubic yards. The total construction cost estimate is $8.8 million including the replacement of bridge structures, which is estimated to be 16 units. The required right-of-way from 140 feet to 240 feet will be acquired by the District for construction purposes. Appendix XXVI shows the HEC-2 printouts for Ditch C-1 at the proposed condition.

6. Halls Bayou

The recommended plan on Halls Bayou is a 20 foot bottom width earthen channel from County Road (CR) 159 to CR 165 and 50 foot bottom width from CR 165 to the pipeline crossings approximately 1 mile

upstream from Halls Bayou Road. Downstream from the pipeline crossings, a 100 foot bottom width earthen channel is recommended for approximately 3 miles toward the south with no improvement on channel for approximately 1.5 miles until it hits FM 2004. South of FM 2004, a 200 foot bottom width earthen channel is recommended for a distance of approximately 1 mile.

This recommended plan will confine the 100-year flood in the bank except the area downstream from Halls Bayou Road which is still subject to tidal flooding. Exhibit XX shows the proposed improvement plan and Exhibit XXVI shows the 100-year water surface profile along the bayou. The estimated excavated quantity is 2.3 million cubic yards. The total construction cost estimate is $5.7 million including the replacement of bridge structures, which is estimated to be 4 units. The required right-of-way from 150 feet to 350 feet will be acquired by the District for construction purposes. Appendix XVIII shows the HEC-1 printouts for Halls Bayou Watershed at the proposed condition. Appendix XVII shows the HEC-2 printouts for Hall Bayou at the proposed condition.

7. Chigger Creek

Because the existing creek drains into Brazoria County Drainage District No. 4 and Clear Creek in Galveston County, a detention pond at the District boundary and channel improvement upstream are recommended. Approximately 30 acres of detention area will be required to regulate the flow inside the District before it drains downstream. A 10 foot bottom width earthen channel is recommended from the detention pond to the entire length of the ditch.

This recommended plan is based on the downstream channel having been improved from the District boundary and the discharge from the District will not be increased more than the existing condition. The proposed improvement under this condition will confine a 100-year flood within the bank. The estimated excavation quantity is 0.63 million cubic yards. The total construction cost estimate is $1.92 million including the replacement of bridge structures, which is estimated to be 5 units. The required right-of-way of 150 feet along the ditch and the required detention pond area will be acquired by the District. Exhibit

XX shows the proposed improvement plan and Exhibit XXVII shows the 100-year water surface profile along the creek. Appendix XIX shows the HEC-1 printouts for the Chigger Creek Watershed at the proposed condition. Appendix XXVIII shows the HEC-2 printouts for Chigger Creek at the proposed condition.

7. Dickinson Bayou

Dickinson Bayou drains into Galveston County at the District boundary (the county line). A detention pond at the District boundary and channel improvements upstream are recommended. Approximately a 5 acre detention area will be required to regulate the flow inside the District before it drains downstream. A 10 foot bottom width earthen channel is recommended from the detention pond to SH 35. Exhibit XX shows the proposed improvement plan and Exhibit XXIX shows the 100-year water surface profile along the creek. Appendix XXI shows the HEC-1 printouts for Dickinson Bayou Watershed at the proposed condition. Appendix XXX shows the HEC-2 printouts for Dickinson Bayou at the proposed condition.

This recommended plan is also based on the downstream channel having been improved from the District boundary and the discharge from the District will not be increased more than the existing condition. The proposed improvement under this condition will confine the 100-year flood within the bank. The estimated excavation quantity is 0.1 million cubic yards. The total construction cost estimate is $0.5 million including the replacement of bridge structures, which is estimated to be 3 units. The required right-of-way of 110 feet to 130 feet along the ditch and the required detention pond area will be acquired by the District.

8. Ditch D-4

Ditch D-4 drains into Dickinson Bayou in Galveston County through the District boundary which matches with the county line. A detention pond at the District boundary and channel improvements upstream are recommended. Approximately a 50 acre detention area will be required to regulate the flow inside the District before it drains downstream. A 6 - 10 foot bottom width earthen ditch is recommended from CR 99 to CR 144 and a 20 foot

bottom earthen ditch from CR 144 to the A.T.S.F. Railroad. Downstream from the railroad to the detention pond, a 40 foot bottom width earthen ditch is recommended. Exhibit XX shows the proposed improvement plan and Exhibit XXVIII shows the 100-year water surface profile along the ditch.

This recommended plan again is based on the assumption that the downstream channel has been improved from the District boundary and the discharge from the District will not be increased more than the existing condition. The proposed improvements under this condition will confine the 100-year flood within the bank. The estimate excavation quantity is 1.6 million cubic yards. The estimated construction cost is $4.6 million including the replacement of bridge structures, which is estimated to be 9 units. The required right-of-way of 140 feet to 180 feet along the ditch and the required detention pond will be acquired by the District. Appendix XX shows the HEC-1 printouts on Ditch D-4 Watershed for the proposed condition. Appendix XXIX shows the HEC-2 printouts on Ditch D-4 for the proposed condition.

V. Conclusion

Snowden Engineering, Inc. prepared the results contained this report in accordance with accepted professional engineering and surveying practices and sound hydrologic and hydraulic principles. We, therefore, feel the results contained herein reflect the proper alternatives for the respective watersheds.

Snowden Engineering, Inc. is grateful to Brazoria County Conservation and Reclamation District No. 3 and the Texas Water Development Board for their assistance in preparing this report.

TABLE I - INPUT PARAMETERS FOR MUSTANG BAYOU WATERSHED

Subarea No.	Drainage Area (Mi^2)	Length of Watercourse(Mi)	Slope of Watercourse (Ft/Mi)	Slope of Watershed (Ft/Mi)	Manning's n	% of Impervious Area	Tc	R
1	0.62	1.4	0.8	<20		3.5	1.5	11.9
2	0.27	1.0	0.6	<20		35.0	0.8	2.1
3	0.18	1.2	2.0	<20		0	1.3	5.2
4	0.37	1.5	2.0	<20		1.8	1.2	6.4
5	0.25	1.0	1.5	<20		35.0	0.4	1.6
6	0.07	0.7	2.0	<20		0	0.6	6.3
7	0.35	1.0	2.0	<20		0	2.1	9.9
8	0.24	1.0	2.0	<20		0	1.2	8.0
9	0.21	0.7	2.0	<20		0	0.5	7.3
(The above Tc and R values were based on Harris County Methodology)								
9A	1.30	2.46	1.27	2.64	0.048	1.0	2.46	12.99
9B	1.93	2.27	0.71	2.40	0.052	2.0	2.65	15.71
10	1.11	0.95	3.55	2.64	0.048	6.0	0.96	5.01
(The above Tc and R values were based on Fort Bend County Methodology)								
1	4.14	4.4	0.89	2.20	0.047	1.0	3.19	20.82
2	5.60	4.6	1.30	4.40	0.052	1.0	3.96	18.16
3	5.26	5.2	2.52	3.77	0.050	4.4	3.95	13.97
4	5.75	5.3	1.64	2.64	0.056	6.0	3.61	18.99
5	3.11	2.7	4.10	6.60	0.082	45.0	1.83	4.05
6	2.90	3.8	1.82	3.30	0.065	25.0	2.52	10.44
7	2.43	3.8	3.07	3.77	0.056	1.0	3.69	13.24
8	3.63	3.9	0.84	2.64	0.055	1.0	4.01	29.34
9	1.98	3.1	1.69	2.93	0.043	1.0	2.69	12.08
10	4.08	3.9	1.42	1.32	0.042	3.0	1.0	17.02
(The above Tc and R values were based on Fort Bend County Methodology with minor adjustments)								

TABLE II - INPUT PARAMETERS FOR DITCH M-1

Subarea No.	Drainage Area (Mi^2)	Length of Watercourse(Mi)	Slope of Watercourse (Ft/Mi)	Slope of Watershed (Ft/Mi)	Manning's n	% of Impervious Area	Tc	R
M-1	0.14	0.55	4.54	2.93	0.044	17.5	0.51	2.37
M-2	1.02	1.93	5.55	5.28	0.049	32.5	1.10	2.92
M-3	0.68	1.60	5.22	6.60	0.051	20.0	1.53	3.42
M-4	1.74	2.73	4.23	5.28	0.045	8.6	2.36	6.28
M-5	2.18	3.03	4.65	5.87	0.053	4.5	3.22	7.79
M-6	0.38	1.67	2.81	3.30	0.047	1.0	1.87	7.62
M-7	1.65	2.42	4.45	2.93	0.048	1.0	1.90	8.71

TABLE III - INPUT PARAMETERS FOR NEW BAYOU

Subarea No.	Drainage Area (Mi^2)	Length of Watercourse(Mi)	Slope of Watercourse (Ft/Mi)	Slope of Watershed (Ft/Mi)	Manning's n	% of Impervious Area	Tc	R
N-1	1.50	2.20	2.28	2.64	0.049	1.0	1.98	15.70
N-2	2.40	3.10	2.50	3.30	0.046	1.0	2.48	14.02
N-3	1.75	2.95	2.96	3.77	0.047	1.0	2.81	9.93
N-4	1.33	1.67	1.35	3.30	0.045	1.0	2.28	9.06
N-5	1.56	2.95	1.19	2.64	0.047	1.0	2.74	14.42

TABLE IV - INPUT PARAMETERS FOR CHOCOLATE BAYOU

Subarea No.	Drainage Area (Mi^2)	Length of Watercourse(Mi)	Slope of Watercourse (Ft/Mi)	Slope of Watershed (Ft/Mi)	Manning's n	% of Impervious Area	Tc	R
1	1.39	3.40	3.29	3.77	0.048	1.0	3.0	15.00
2	5.92	5.38	2.67	2.64	0.054	1.2	3.42	19.50
3	12.46	6.52	3.03	4.80	0.064	3.2	6.04	17.31
4-1	15.07	6.97	2.75	2.64	0.074	1.8	4.97	32.80
4	13.42	9.47	2.77	3.77	0.068	1.0	7.44	26.31
5	2.76	3.71	3.64	3.77	0.085	1.0	4.84	17.54
6	7.47	8.71	3.01	2.64	0.060	1.0	4.74	24.96
7	0.98	1.59	3.62	3.52	0.081	1.0	2.74	10.35
8	14.13	8.33	2.75	3.30	0.050	1.0	4.96	20.11
9	14.40	6.52	2.19	3.30	0.830	1.0	6.92	28.08
10	14.20	8.03	2.62	3.50	0.080	2.0	6.88	26.05
11	11.50	12.57	2.09	2.64	0.078	1.0	8.00	42.13
12	3.69	4.02	1.87	4.40	0.066	2.9	5.30	16.15
13	7.96	6.97	3.34	4.80	0.040	1.0	4.43	12.70
14	11.92	10.23	3.03	2.93	0.039	4.0	3.81	18.18
15	12.72	7.20	3.58	4.40	0.039	1.0	3.90	13.26

TABLE V - INPUT PARAMETERS FOR DITCH C-1

Subarea No.	Drainage Area (Mi^2)	Length of Watercourse(Mi)	Slope of Watercourse (Ft/Mi)	Slope of Watershed (Ft/Mi)	Manning's n	% of Impervious Area	Tc	R
C-1	1.0	1.14	2.19	2.64	0.054	1.0	1.50	7.88
C-2	1.12	1.52	3.13	2.26	0.063	8.4	1.32	8.38
C-3	3.37	3.18	3.69	4.40	0.054	5.4	3.06	9.33
C-4	3.73	3.56	2.97	4.22	0.054	5.0	3.36	10.92
C-5	2.68	3.64	3.71	4.11	0.054	4.8	3.10	10.09
C-6	0.88	2.35	2.64	3.02	0.054	1.0	2.47	10.75
C-7	2.64	4.39	3.70	2.93	0.057	13.0	2.40	11.08
C-8	2.27	3.48	2.11	2.26	0.058	1.0	2.55	16.69
C-9	2.29	2.65	3.86	3.30	0.060	1.0	2.69	10.98

TABLE VI - INPUT PARAMETERS FOR HEC-1 MODEL

SUB AREA NO.	DRAINAGE AREA (Mi2)	LENGTH OF WATERCOURSE (Mi)	SLOPE OF WATERCOURSE (Ft/Mi)	SLOPE OF WATERSHED (Ft/Mi)	MANNING'S n	% OF IMPERVIOUS AREA	Tc	R
			HALLS BAYOU					
1	1.44	1.33	3.8	4.4	0.05	1	1.93	5.9
2	0.47	0.53	2.8	3.96	0.05	1	1.16	3.94
3	2.2	1.8	3.0	3.30	0.05	1	2.01	8.17
4	6.7	3.6	2.5	3.77	0.065	1	6.00	21.6
5	8.59	5.2	2.2	3.50	0.065	1	5.18	19.6
6	10.42	7.4	1.6	2.40	0.065	1	5.3	29.6
7	3.2	3.0	2.0	3.3	0.04	1	3.4	13.5
			CHIGGER CREEK					
1	1.32	2.1	3.8	4.4	0.05	1	2.49	7.61
2	0.77	1.9	3.7	4.4	0.05	1	2.37	7.24
3	0.44	1.0	4.0	4.4	0.05	1	1.61	4.91
			DICKINSON BAYOU					
1	0.06	0.75	2.7	2.7	0.05	1	1.09	5.45
2	0.20	0.65	3.1	4.0	0.05	1	1.27	4.30
3	0.18	0.75	2.7	2.5	0.05	1	1.0	5.56
			DITCH D-4					
1	1.18	1.5	3.6	4.4	0.05	2	2.05	6.18
2	0.76	1.4	3.55	3.5	0.05	2	1.71	6.47
3	1.54	2.7	2.46	3.5	0.05	1	2.83	10.69
4	0.64	1.6	2.85	3.77	0.05	1	2.1	7.45
5	0.72	1.6	2.23	3.77	0.05	2	2.12	7.49

TABLE VII - MUSTANG BAYOU WATERSHED

Control	Drainage Area (Mi^2)	25-Year Discharge(CFS)	100-Year Discharge(CFS)	Location
0	6.91	831	1080	At County Line
1	11.05	1203	1623	At SH 288
2	16.65	1801	2437	At FM 1128
3	21.91	2159	3096	Near SH 6
4	27.66	2354	3374	At M.P.R.R.
5	30.77	2286	3283	At SH 35
6	33.67	3011	3900	At CR 160
7	36.10	3234	4191	At confluence w/Ditch M-1
	(The above flows are on Mustang Bayou)			
M-1	0.14	142	178	At W. Dumble Rd.
M-2	1.16	974	1245	At South St.
M-3	1.84	1051	1252	At SH 35
M-4	3.58	1678	2040	At Pipeline Crossing
M-5	5.76	1960	2451	At BRA Canal
M-6	6.14	2007	2299	At M.P.R.R. (Diversion Point)
M-7	7.79	1399	1601	At confluence w/Mustang Bayou
	(The above flows are on Ditch M-1)			
8	47.52	4832	6088	At confluence w/ Persimmon Bayou
	(The above flow is on Mustang Bayou)			
N-1	1.50	1297	1537	At M.P.R.R.
N-2	3.90	1632	2034	At BRA Canal
N-3	5.65	1676	2131	At M.P.R.R.
N-4	6.98	1743	2216	At M.P.R.R.
N-5	8.54	1841	2363	At confluence w/Mustang Bayou
	(The above flows are on New Bayou, flows include diversion from Ditch M-1 and C-1)			
9	58.04	6799	8649	At confluence w/New Bayou
10	62.12	7101	9039	At confluence w/ Persimmon Bayou
	(The above flows are on Mustang Bayou)			

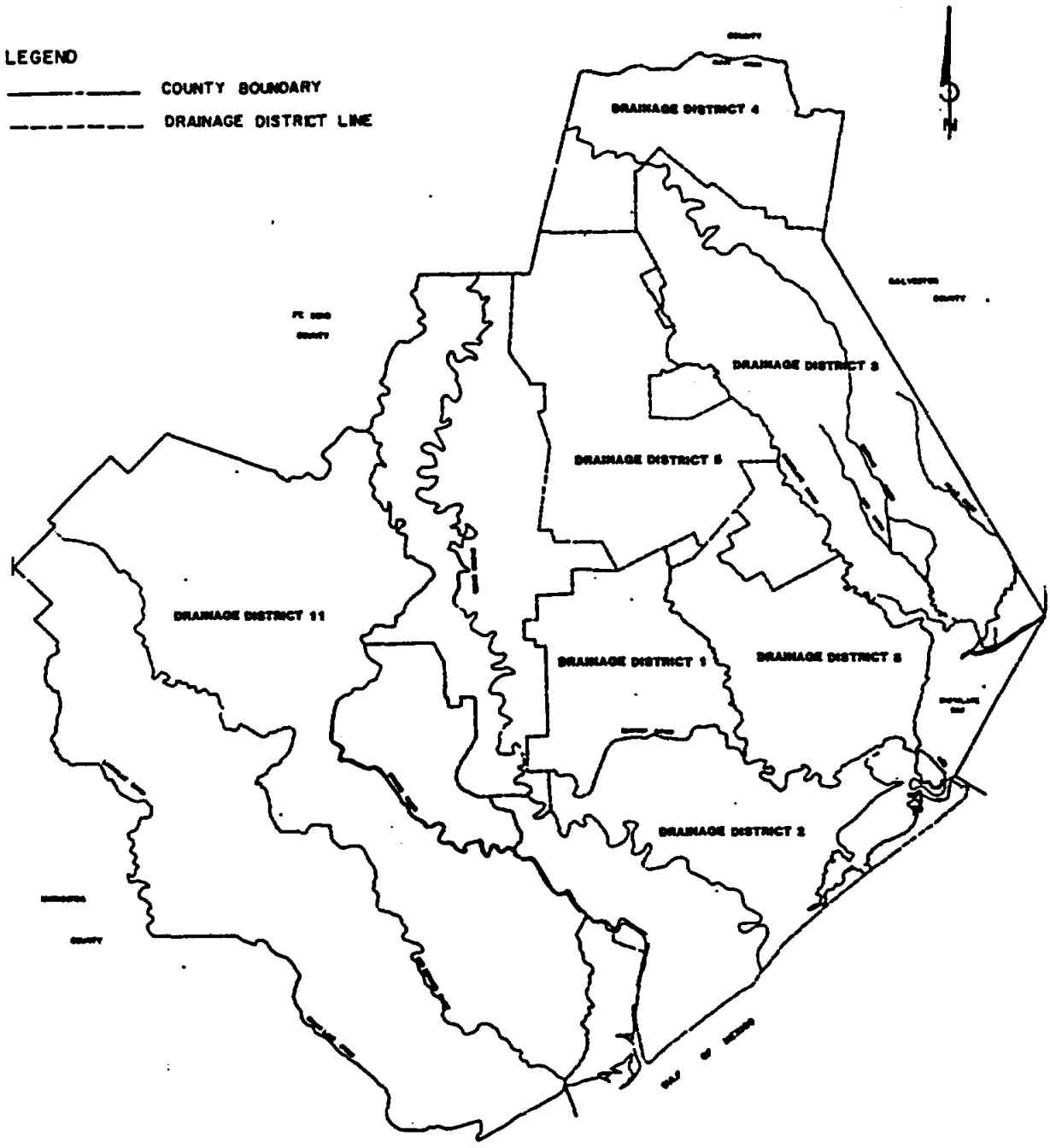
TABLE VIII - CHOCOLATE BAYOU WATERSHED

Point of Control	Drainage Area (Mi^2)	25-Year Discharge(CFS)	100-Year Discharge(CFS)	Location
1	1.39	321	429	At A.T.& S.F. R.R.
2	7.31	1401	1878	At Rifle Range Rd.
3	19.77	3061	4244	At upstream confluence w/W. Fork Choc. Bayou
4	48.26	5937	8178	At downstream confl. w/W. Fork Choc. Bayou
5	51.02	6232	8561	At upstream confluence w/ unnamed tributary
6	58.49	7027	9621	At downstream confl. w/unnamed tributary
7	59.47	7109	9716	At upstream confluence w/ Hayes Creek
8	73.60	8767	11928	At downstream confl. w/ Hayes Creek
9	88.00	9659	13368	At 800 ft downstream of FM 1462
10	102.20	10283	14403	At SH 35
11	113.70	10660	14931	At confluence w/ Ditch C-1
		(The above flows are on Chocolate Bayou)		
C-1	1.00	396	525	At FM 1128
C-2	2.12	521	708	At M.P.R.R.
C-3	5.49	1521	1993	At Farm Rd.
C-4	9.22	2194	2857	At Herring Rd.
C-5	11.90	2379	3836	At FM 1462
C-6	12.78	2445	3744	At SH 35
C-7	15.42	2536	3551	At BRA Canal
C-8	17.69	2725	3830	At confluence w/ New Bayou (Diversion Point)
C-9	19.98	2582	3614	At confluence w/ Chocolate Bayou
		(The above flows are on Ditch C-1)		
12	137.37	13048	17504	At confluence w/ Corner Bayou
13	145.33	13102	16889	At confluence w/ Pleasant Bayou
14	157.25	13347	16685	At Pipeline Crossing
15	169.97	13559	16865	At FM 2004
		(The above flows are on Chocolate Bayou)		

TABLE IX - HEC-1 RESULTS

CONTROL POINT	DRAINAGE AREA (Mi2)	25-YEAR DISCHARGE (CFS)	100-YEAR DISCHARGE (CFS)	LOCATION
		HALLS BAYOU		
1	1.44	710	933	CR 159
2	1.91	998	1310	CR 164
3	4.11	1807	2114	Canal
4	10.81	2775	3546	
5	19.40	4297	5570	Halls Bayou Rd.
6	29.82	5539	7292	Cloud Bayou
7	33.02	6029	8053	Oak Ditch
		CHIGGER CREEK		
1	1.32	530	701	CR 98
2	2.09	703	993	CR 99
3	2.53	689 (440)	1022 (720)	Dist. Boundary
		DICKINSON BAYOU		
1	0.06	32	42	Hwy 35
2	0.26	129	170	Canal
3	0.44	213	281	County Line
		DITCH D-4		
1	1.18	561 (800)	738 (1020)	CR 144
2	1.94	884 (1120)	1172 (1450)	R.R.
3	3.48	1346 (1580)	1780 (2060)	R.R.
4	4.12	1539 (1770)	2065 (2350)	Hwy 35
5	4.84	1481 (1720)	1986 (2270)	County Line

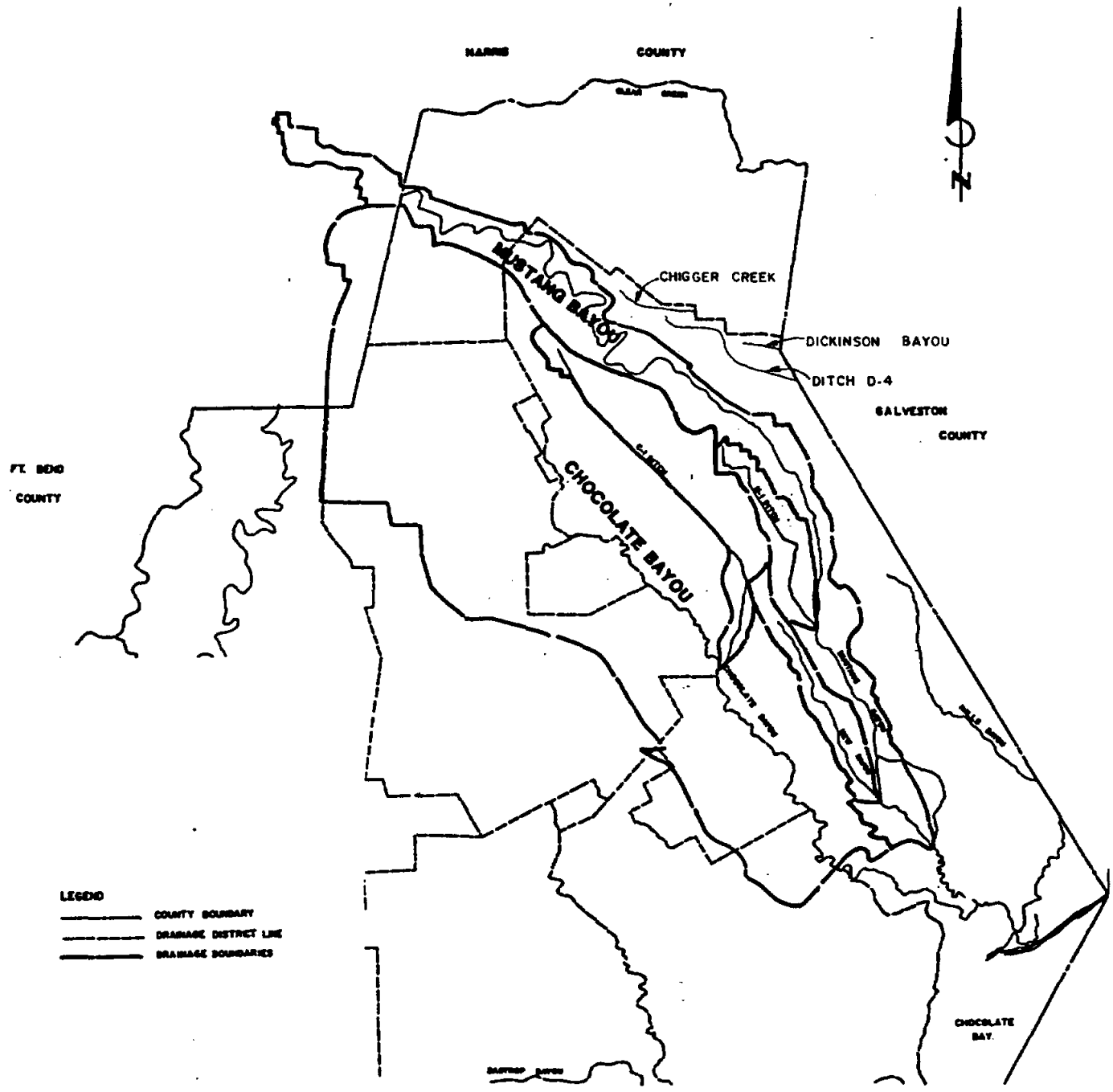
NOTE: Numbers in ( ) show the adjusted flow due to the diversion on Chigger Creek to Ditch D-4.



SNOWDEN ENGINEERING, INC.
CONSULTING ENGINEERS
HOUSTON - PEARLAND, TEXAS

BRAZORIA COUNTY
DRAINAGE DISTRICTS MAP

JOB NO.: 87-061	DATE: NOV. 1988	SHEET: 1



SNOWDEN ENGINEERING, INC.
CONSULTING ENGINEERS
HOUSTON - PEARLAND, TEXAS

DRAINAGE BOUNDARIES

JOB NO.: 87-061	DATE: NOV. 1988	EXHIBIT: II

Master Drainage Plan Report on Mustang Bayou, Chocolate Bayou, Ditch C-1, Ditch M-1 New Bayou, Halls Bayou, Chigger Creek, Ditch D-4 and Dickinson Bayou Watersheds

Volume 1 of 3

Contract #FP 8-483-519

The following maps are not attached to this report. They are located in the official file and may be copied upon request.

Map 1 - Mustang Bayou Watershed Subwatershed Exhibit III A
Mustang Bayou watershed & Subwatershed Exhibit III B
Chocolate bayou Watershed - Exhibit IV
Watershed & Subwatershed - Exhibit V
Mustang Bayou & New Bayou - Exhibit VI
Flood Limits on Chocolate Bayou Exhibit VII
Flood Limits - Exhibit VIII
Mustang Bayou Exhibit IX
Exhibit IX Cont.
Exhibit X
Exhibit XI
Exhibit XII
Exhibit XIII
Exhibit XIV
Exhibit XVI
Exhibit XVII

Mustang Bayou Watershed Exhibit XVIIIA
Exhibit XVIIIB
Chocolate Bayou Watershed Exhibit XIX
Exhibit XX
Mustang Bayou Exhibit XXI
Exhibit XXII
Exhibit XXIV
Exhibit XXV
Exhibit XXVI
Exhibit XXVII
Exhibit XXVIII
Exhibit XXIX

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