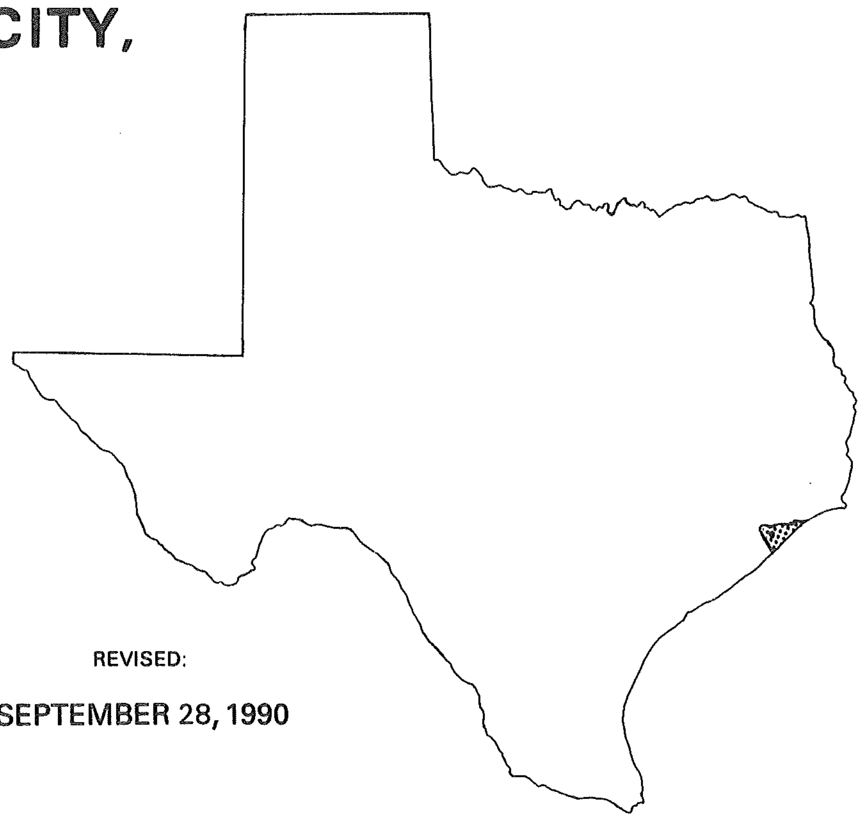
FLOOD INSURANCE STUDY

WAVE HEIGHT ANALYSIS

CITY OF LEAGUE CITY, TEXAS

GALVESTON COUNTY



REVISED:

SEPTEMBER 28, 1990

Federal Emergency Management Agency

COMMUNITY NUMBER - 485488

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program (NFIP) have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Part or all of this FIS may be revised and republished at any time. In addition, part of this FIS may be revised by the Letter of Map Revision (LOMR) process, which does not involve republication or redistribution of the FIS. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS components.

Initial Flood Insurance Study Effective Date: June 5, 1970

Flood Insurance Study Revised: July 1, 1974
September 12, 1975
June 17, 1977
May 2, 1983
September 28, 1990

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FLOOD INSURANCE STUDY
CITY OF LEAGUE CITY, GALVESTON COUNTY, TEXAS

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study investigates the existence and severity of flood hazards in the City of League City, Galveston County, Texas, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of the community that will be used to establish actuarial flood insurance rates and assist the community in their efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the state (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this Flood Insurance Study are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

The hydrologic and hydraulic analyses in this study represent a revision of the original analyses prepared by Tetra Tech, Inc., for the Federal Emergency Management Agency (FEMA), under Contract No. H-4788. The work for the original study was completed in July 1981. The hydrologic and hydraulic analyses for Bordens Gully and Magnolia Bayou in this revision were prepared by Van Sickle, Michelson & Klein, Inc. The work for this revision was completed in July 1988.

1.3 Coordination

The following were contacted for coordination in the development of the original study: the City of League City, Galveston County, Clear Lake Area Chamber of Commerce, Houston-Galveston Area Council, the National Oceanic and Atmospheric Administration (NOAA), the Texas Highway Department, the Texas State Department of Water Resources, the Galveston District of the U. S. Army Corps of Engineers (COE), the U. S. Geological Survey (USGS), and the Soil Conservation Service (SCS).

On June 3, 1982, the results of the original study were reviewed at a final Consultation and Coordination Officer's (CCO) meeting held with representatives of Tetra Tech, Inc. (the study contractor), the city, and FEMA.

2.0 AREA STUDIED

2.1 Scope of Study

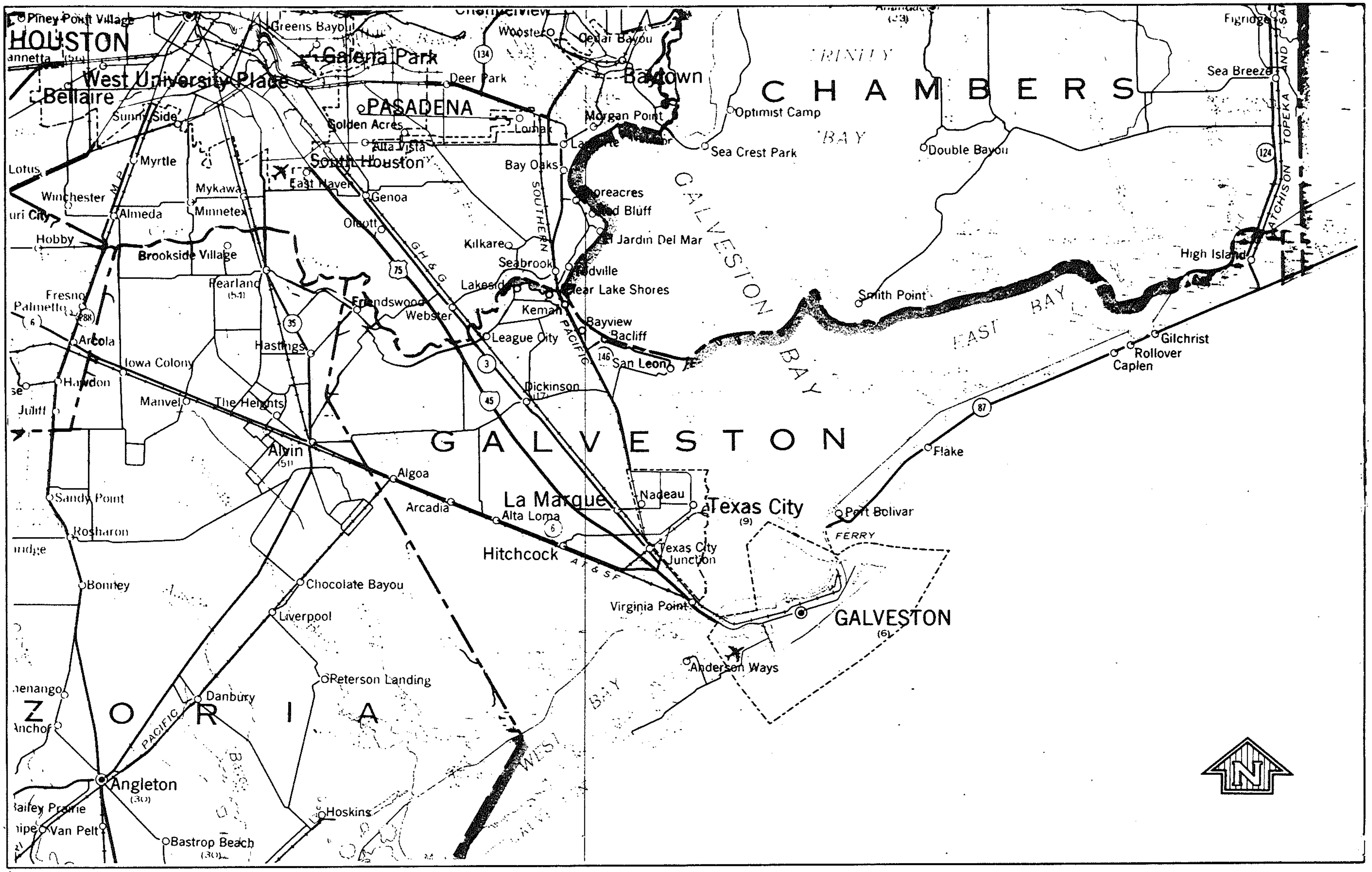
This Flood Insurance Study covers the incorporated area of the City of League City, Galveston County, Texas. The area of study is shown on the Vicinity Map (Figure 1).

The detailed analyses in the original study included coastline flooding due to hurricane-induced storm surge. Both the open coastal surge and its inland propagation were studied; in addition, the added effects of wave heights was considered.

The following flooding sources were studied by detailed methods: Clear Creek, from a point approximately 4.55 miles upstream of its confluence with Galveston Bay to the corporate limits; Benson Bayou, from the downstream corporate limits to State Route 3; Magnolia Creek, from its confluence with Clear Creek to a point approximately 100 feet upstream of an unnamed road; Unnamed Tributary of Clear Creek, from its confluence with Clear Creek to a point approximately 1,200 feet upstream of Colonial Court North; Dickinson Bayou, from Algoa Friendswood Road to the upstream corporate limits; Magnolia Bayou, from the downstream corporate limits to a point approximately 3,200 feet upstream of FM 646; Bordens Gully, from the downstream corporate limits to a point approximately 2,900 feet upstream of FM 646; and the entire shoreline of Galveston Bay/Clear Lake within the community.

In this revision, Magnolia Bayou and Bordens Gully were restudied by detailed methods to incorporate updated topographic information and updated hydrologic and hydraulic analyses. The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction.

All or portions of the following flooding sources were studied by approximate methods: Unnamed Tributary of Clear Creek, Magnolia Creek, Dickinson Bayou, and Bordens Gully. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and the City of League City.



FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

APPROXIMATE SCALE

8 0 8 16 24 MILES

VICINITY MAP

FIGURE 1

2.2 Community Description

The City of League City occupies an area of approximately 44.3 square miles in the southeastern portion of Texas, in the northeastern region of Galveston County (Reference 1). It is situated approximately 30 miles southeast of Houston and approximately 40 miles northwest of Galveston. It is bordered by the unincorporated areas of Harris County to the north, the Cities of Clear Lake Shores and Kemah to the east, the unincorporated areas of Galveston County to the east and south, and the City of Friendswood and the unincorporated areas of Brazoria County to the west.

The City of League City was incorporated in 1962. The 1980 population of the city was 16,578, which represents a 53 percent increase over the 1970 population of 10,818 (References 2 and 3). This population growth is associated with the growth of the Houston metropolitan area.

Development in the city is primarily residential. Most tourist areas are located in the northeastern, western, and central portions of the city, and most recreational areas are located in the northeastern portion. Commercial development is located throughout the city; there is no zoning in the area. Current industrial development consists of a proposed industrial park to be located near the airport. The leading employer in the area, the National Aeronautics and Space Administration, is located to the north of the city. A garment factory and terminal base for export and import contribute to the economy of the community.

The major stream within the city is Clear Creek, which flows generally towards the east through the northern portion of the community, from the vicinity of northeastern Fort Bend County into Clear Lake/Galveston Bay. Its watershed, an area of approximately 260 square miles, is approximately 45 miles long (Reference 4). Benson Bayou, Magnolia Bayou, and Bordens Gully are tributaries to Dickinson Bayou; these streams flow through the southeastern portion of the city. Robinson Bayou, Magnolia Creek, and Unnamed Tributary of Clear Creek flow towards the north, through the central portion of the city.

League City is located in the humid-subtropical climatic zone, which is characterized by mild winters and warm summers. Rainfall is abundant and quite evenly distributed throughout the year. The heaviest rains usually occur during the hurricane season, which extends from approximately June through October. Average annual precipitation in the region is approximately 44 inches, and the average annual temperature is approximately 68 degrees Fahrenheit (Reference 5).

Soils in League City are clayey and loamy, and are categorized in the Lake Charles-Bernard and the Beaumont-Morey-Lake Charles soil associations, which have low infiltration rates and high runoff potential. The soils are classified in Soil Conservation Service (SCS) Group D for hydrologic purposes (References 6 and 7). The most common vegetation in the area is sage grass; tidal marsh along the bayous supports a growth of salt-loving weeds and grasses. Cropland and woodland are abundant in the area.

League City lies within the Gulf Coastal Plain and is characterized by relatively flat, featureless terrain. Elevations in the community range from sea level to approximately 35 feet in the western portion of the city.

The land in League City is subject to subsidence, primarily due to high-volume well water withdrawal in the surrounding area. Between 1943 and 1978, the approximate loss of ground elevation was between 4 and 5 feet. In the years between 1973 and 1978, the land has subsided approximately 0.50 to 0.75 foot (References 8 and 9).

2.3 Principal Flood Problems

Flooding in the City of League City results primarily from overflow of the streams (caused by rainfall runoff), ponding, and sheet flow, and from tidal surge and associated wave action (caused by hurricanes and tropical storms). Not all storms that pass close to the city produce extremely high tides. Similarly, storms that produce extreme conditions in one area may not necessarily produce critical conditions in other portions of the community. Under certain conditions, tides generated at the mouth of Clear Creek in Galveston Bay/Clear Lake can intrude far upstream. Rainfall that usually accompanies hurricanes can aggravate the tidal flood situation. Because of the flatness of the terrain, many inland areas are subject to shallow flooding during heavy rainfalls.

Land-surface subsidence in the area of League City is also a principal problem because it is causing previously non-flood-prone areas to be subject to inundation by high tides (Reference 9).

Storms passing Texas in the vicinity of League City have produced severe floods as well as structural damage. Brief descriptions of several significant tropical storms follow; these provide historical information to which flood hazards and the projected flood depths can be compared (References 10, 11, 12, 13, 14, 15, and 16).

<u>September 4-14, 1961</u> (Hurricane Carla)

This hurricane, considered to be one of the major Gulf hurricanes of this century, crossed the Texas shoreline near Port O'Connor.

Minimum barometric pressure at Texas City was 29.26 inches. Hurricane Carla caused maximum tide levels of 9.3 feet above mean sea level (msl) in the Gulf at Galveston, and water-surface elevations along the western shore of Galveston Bay reached approximately 14 feet msl. During the four-day period from September 9-12, recorded rainfall at Galveston was 15.32 inches, and at Crabb, 9.26. Water levels in homes in the League City area reached 2 to 3 feet.

July 24-27, 1979 (Tropical Storm Claudette)

Tropical Storm Claudette, an upper air low pressure cell, originated in the Atlantic Ocean near Puerto Rico and moved towards the west, into the Gulf of Mexico. It brought gale-force winds and heavy rainfall to many parts of southeastern Texas, causing severe flooding along streams and coastal areas. Within a 48-hour period, League City received 24.9 inches of rainfall. Estimated tides were between four and five feet in Galveston Bay and its upper reaches. League City was severely affected by the storm, and approximately 2,000 residents in the low-lying areas between Interstate Route 45 (Gulf Freeway) and Galveston Bay were evacuated. Clear Creek, normally 100 to 150 feet wide where it flows under the Gulf Freeway, was more than one mile wide on July 26. The creek inundated the Freeway with water two feet deep. League City sustained over six million dollars in damage to approximately 200 structures. Almost all areas of the city, and all new subdivisions, were flooded, as was the main sewer plant. On July 28, President Carter declared six counties, including Galveston County, to be major disaster areas.

September 19, 1979

Heavy rain from this storm caused Clear Creek to overflow its banks, and many subdivisions in League City were evacuated. In areas such as Bayridge and Glen Cove, many streets became impassable.

June 4 and 5, 1981

On June 4, a tropical depression formed over the western Gulf of Mexico. Thunderstorms spawned by the depression brought heavy rains over southeast Texas on June 5, then moved eastward into the Gulf of Mexico and Louisiana. The ground throughout southeast Texas had already been saturated by recent rains, thereby increasing the flooding from this storm. Many communities suffered extensive flood damage. The heaviest rainfall and most of the flooding was reported in communities near the coast, including: Galveston, Texas City, Baytown, Pasadena, Bay City, Wharton, Liberty, and Pearland. The western end of Galveston Island recorded nine inches of rainfall; Dickinson recorded seven inches; Alvin recorded 3.92 inches; Alta

Loma recorded 5.65 inches; and Hitchcock recorded 7.38 inches. In Baytown, where nine inches of rainfall was reported, most arterial roads were inundated on June 5. Minor flooding was reported in League City.

2.4 Flood Protection Measures

To alleviate flooding along Clear Creek, plans are being considered for both enlargement and rectification of the existing channel, and for the opening of a diversion channel at the mouth of Clear Lake. Since these flood protection measures are still in the planning stages, they have not bee considered in this study.

Nonstructural flood protection measures in League City consist of a flood ordinance that places controls on the types of development and related activities permissible in the city.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10, 2, 1, and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency relationships for each flooding source studied in detail affecting the community.

Flood magnitudes and frequency values for areas subject to flooding from Clear Creek were available from the Galveston District of the COE (Reference 4). For Bordens Gully and Magnolia Bayou in this revision, flood-frequency discharge values were determined using the COE HEC-1 computer program (Reference 17).

The determination of inundation caused by passage of a hurricane storm surge was approached by the Joint Probability Method (Reference 18). The storm populations were described by probability distributions of five parameters that influence surge heights. These were central pressure depression (which measures the intensity of the storm), radius to maximum winds, forward speed of the storm, shoreline crossing point, and crossing angle. These characteristics were described statistically, based on an analysis of observed storms in the vicinity of Galveston County. Primary sources of data for this analysis were the National Weather Service, the National Hurricane Research Project, and the Mariners Weather Log (References 19, 20, 21, 22, and 23). A summary of the parameters used for the Galveston County area is presented in Table 1.

Maximum wave crest elevations associated with the 10- and 100-year events were determined using the National Academy of Sciences method (Reference 24).

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 2, "Summary of Discharges."

TABLE 2 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-YEAR	50-YEAR	100-YEAR	500-YEAR
CLEAR CREEK					
At mouth	260.8	24,562	33,224	37,144	53,000
At confluence of Magnolia Bayou	174.6	14,140	19,285	21,910	31,100
BENSON BAYOU					
At corporate limits	3.2	1,215	1,550	1,670	2,000
MAGNOLIA CREEK					
At mouth	4.1	1,060	1,450	1,660	2,650
UNNAMED TRIBUTARY OF CLEAR CREEK					
At mouth	3.1	890	1,220	1,390	2,150

CENTRAL PRESSURE DEPRESSION (Millibars)	5	15	25	35	45	55	65	75	85	95	105
PROBABILITY: ENTERING EXITING PARALLEL	0.16	0.16	0.17	0.10	0.14	0.07	0.08	0.07	0.02	0.02	0.01
STORM RADIUS (Nautical Miles)			20					35			
PROBABILITY			0.8					0.2			
FORWARD SPEED (Knots)			8		14			20			
PROBABILITY: ENTERING EXITING PARALLEL			0.63		0.28			0.09			
CROSSING ANGLE (Degrees)			21		-24			-69			
PROBABILITY			0.29		0.28			0.43			
FREQUENCY OF OCCURRENCE	1.99×10^{-3} storms/nautical miles/years										

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CITY OF LEAGUE CITY, TX

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PARAMETER VALUES FOR SURGE ELEVATION COMPUTATIONS

TABLE 1

TABLE 2 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-YEAR	50-YEAR	100-YEAR	500-YEAR
BORDENS GULLY					
At a point approximately 1,250 feet upstream of corporate limits	1.8	710	850	1,080	1,400
MAGNOLIA BAYOU					
At a point approximately 1,650 feet upstream of corporate limits	5.5	1,830	2,760	2,600	3,380

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

For areas subject to flooding directly from the Gulf of Mexico/Galveston Bay/Trinity Bay, the standard coastal surge model was used to simulate the coastal surge generated by any chosen storm (that is, any combination of the five storm parameters defined previously). Performing such simulations for a large number of storms, each of known total probability, permits the establishment of the frequency distribution of surge height as a function of coastal location. These distributions incorporate the large scale surge behavior but do not include an analysis of the added effects associated with much finer scale wave phenomena such as wave heights, setup, or runup. The astronomic tide for the region is then statistically combined with the computed storm surge to yield recurrence intervals of total water level (Reference 25).

This model uses a grid pattern approximating the geographic features of the study area and the adjoining areas. Subsidence prior to 1975 was considered in this study (Reference 26). Surges were computed using grids of five nautical miles for the open coast computations and 1.5 miles for the Galveston Bay computations.

Data for the model grid systems and for the wave height calculations were obtained from USGS quadrangle sheets, a topographic map of the Clear Lake area, NOAA nautical charts, and from aerial photographs (References 27, 28, 29, 30, 31, 32, 33, and 34).

For the streams studied by detailed methods in the original study and in this revision, water-surface elevations of floods of the selected recurrence intervals were computed using the COE HEC-2 step-backwater computer program (References 35 and 36). Starting water-surface elevations for Benson Bayou, Magnolia Creek, and Unnamed Tributary of Clear Creek were set equal to normal depth. Cross sectional data for Magnolia Creek and Unnamed Tributary of Clear Creek were obtained from the Galveston District of the COE. Cross sectional data for Benson Bayou were obtained from field surveys and USGS topographic maps (Reference 27). For Bordens Gully and Magnolia Bayou in this revision, starting water-surface elevations were determined from the backwater elevation of Dickinson Bayou. Cross sectional data used in this revision were obtained from field surveys; elevations were adjusted to the 1984 vertical datum due to subsidence. Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals. Flood profiles for Clear Creek were obtained from the Galveston District of the COE (Reference 4).

Channel roughness factors (Manning's "n") used in the hydraulic computations were chosen by engineering judgment based on field observations, aerial photographs of the streams and floodplain areas, and USGS Water Supply Paper 1849 (Reference 37). For the streams studied by detailed methods, the channel "n" values ranged from 0.020 to 0.080, and overbank "n" values ranged from 0.080 to 0.150.

All elevations are referenced to the National Geodetic Vertical Datum of 1929 (NGVD), 1984 adjustment. Elevation reference marks used in this study are shown on the maps.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

3.3 Wave Height Analysis

The methodology for analyzing the effects of wave heights associated with coastal storm surge flooding is described in the National Academy of Sciences report (Reference 24). This method is based on three major concepts. First, depth-limited waves in shallow water reach a maximum breaking height that is equal to 0.78 times the stillwater depth. The wave crest is 70 percent of the total wave height above the stillwater level. The second major concept is that wave height may be diminished by dissipation of energy due to the presence of obstructions such as sand dunes, dikes and seawalls, buildings, and vegetation. The amount of energy dissipation is a function of the physical characteristics of the obstruction and is determined by procedures described in Reference 24. The third major concept is that wave height can be regenerated in open fetch areas due to the transfer of wind energy to the water. This added energy is related to fetch length and depth.

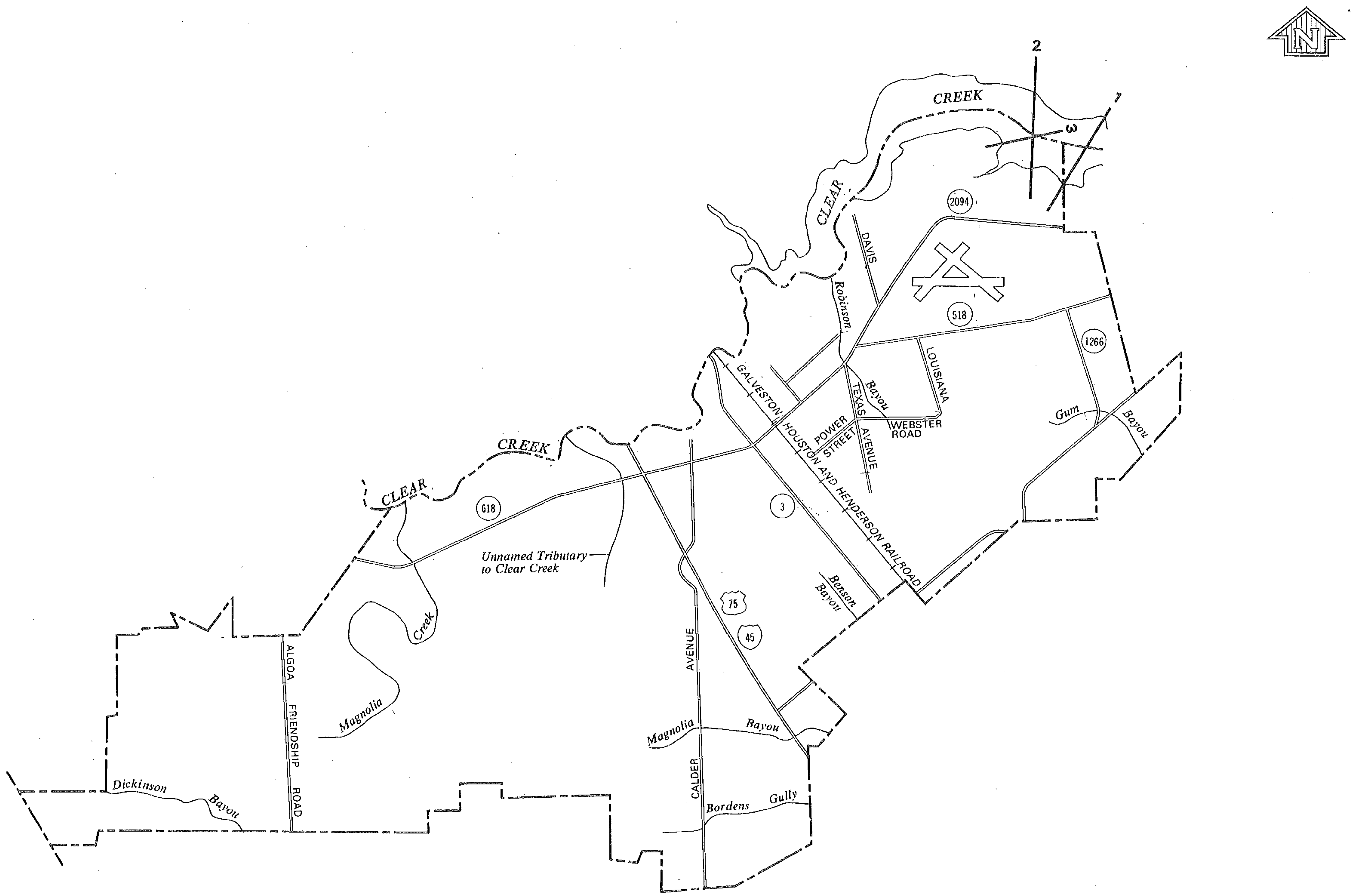
Wave heights were computed along transects (cross section lines) that were located along the coastal areas, as illustrated in Figure 2, in accordance with the Users Manual for Wave Height Analysis (Reference 38). The transects were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, they were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects.

The transects were continued inland until the wave was dissipated or until flooding from another source with equal or greater elevation was reached. Along each transect, wave heights and elevations were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. The stillwater elevations for the 100-year flood were used as the starting elevations for these computations. Wave heights were calculated to the nearest 0.1 foot, and wave elevations were determined at whole-foot increments along the transects. Areas with a wave component three feet or greater were designated as velocity zones. Other areas subject to wave action were designated as A Zones with base flood elevations adjusted to include wave crest elevations.

Figure 3 is a profile for a typical transect illustrating the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave elevations being diminished by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Actual wave conditions in the City of League City may not necessarily include all the situations illustrated in Figure 3.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The National Flood Insurance Program encourages State and local governments to adopt sound floodplain management programs. Therefore, each Flood Insurance Study produces maps designed to assist communities in developing floodplain management measures.



TRANSECT LOCATION MAP

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TEXAS
GALVESTON COUNTY

FIGURE 2

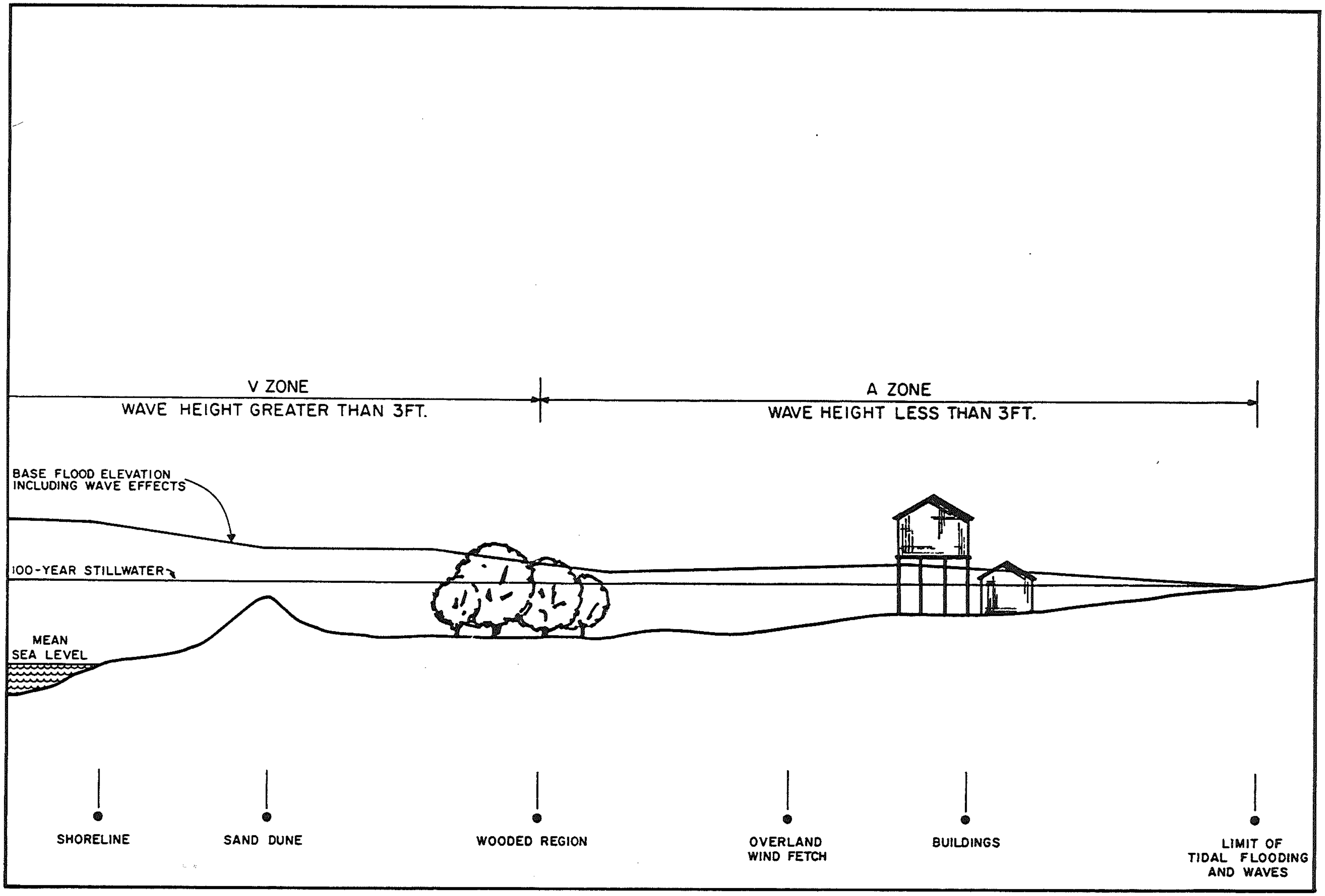


FIGURE 3
TYPICAL TRANSECT SCHEMATIC

4.1 Flood Boundaries

To provide a national standard without regional discrimination, the 1 percent annual chance (100-year) flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2 percent annual chance (500-year) flood is employed to indicate additional areas of flood risk in the community. For each stream studied in detail, the 100- and 500-year floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps and aerial photographs (Reference 27, 28, 34, 39, 40, and 41).

For the flooding sources studied by approximate methods, the 100-year floodplain boundaries were delineated using the previously printed Flood Insurance Study for the City of League City (Reference 39).

The 100- and 500-year floodplain boundaries are shown on the Flood Boundary and Floodway Map (Exhibit 2). In cases where the 100- and 500-year floodplain boundaries are close together, only the 100-year floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the National Flood Insurance Program, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 100-year floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 100-year flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as a minimum standard that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed on the basis of equal conveyance reduction from each side of the floodplain. The results of these computations are tabulated at selected cross sections for each stream segment for which a floodway is computed (Table 3).

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)[2]	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY[3]	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Clear Creek								
A	4.61	2,436	15,886	1.4	11.3	6.1	6.9	0.8
B	5.23	2,090	24,158	0.9	11.3	6.2	7.0	0.8
C	5.83	727	5,040	4.3	11.3	6.6	7.4	0.8
D	6.03	1,523	11,113	2.0	11.3	7.2	8.2	1.0
E	6.24	1,594	8,233	2.7	11.3	7.3	8.3	1.0
F	6.78	1,063	8,118	2.7	11.4	7.8	8.7	0.9
G	7.10	913	13,323	1.6	11.4	8.4	9.3	0.9
H	7.41	925	10,640	2.0	11.4	8.5	9.4	0.9
I	7.68	1,337	11,230	1.9	11.4	8.6	9.5	0.9
J	7.86	1,125	13,241	1.6	11.4	8.7	9.6	0.9
K	8.39	1,990	3,921	5.4	11.4	9.0	9.9	0.9
L	8.65	1,016	11,069	1.9	12.1	9.8	10.6	0.8
M	8.77	930	10,828	2.0	12.1	9.9	10.7	0.8
N	8.97	1,250	13,287	1.6	12.1	10.0	10.8	0.8
O	9.38	575	6,436	3.2	12.1	10.3	11.1	0.8
P	9.59	905	9,878	2.1	12.1	10.4	11.2	0.8
Q	9.90	1,315	13,890	1.5	12.1	10.6	11.4	0.8
R	10.12	865	9,845	2.1	12.1	10.7	11.5	0.8
S	10.26	440	4,720	4.4	12.2	10.8	11.7	0.9
T	10.61	988	10,935	1.9	12.5	11.7	12.5	0.8
U	10.99	999	11,388	1.8	13.0	12.2	13.1	0.9
V	11.39	860	11,869	1.7	13.2	12.4	13.3	0.9
W	11.68	689	9,327	2.2	13.4	12.7	13.6	0.9
X	11.91	722	9,181	2.2	13.5	12.9	13.8	0.9
Y	12.26	931	11,654	1.8	13.7	13.3	14.2	0.9

[1] Miles above mouth
[2] Floodway width extends beyond corporate limits
[3] Combined flooding effects from Galveston Bay and Clear Creek

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX
(GALVESTON CO.)

FLOODWAY DATA

CLEAR CREEK

TABLE 3

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Clear Creek (cont.)								
Z	12.52	804[2]	9,729	2.1	13.9[3]	13.5	14.4	0.9
AA	12.92	1,200[2]	12,904	1.6	14.2[3]	13.8	14.8	1.0
AB	13.43	670[2]	8,805	2.3	14.5[3]	14.3	15.2	0.9
Benson Bayou								
A	9,800	73	492	3.4	15.4	15.4	16.1	0.7
B	14,150	420	1,417	1.2	17.8	17.8	18.4	0.6
Magnolia Creek								
A	150	45	299	5.5	14.5[3]	7.4	8.4	1.0
B	2,550	83	443	3.7	14.5[3]	11.9	12.6	0.7
C	3,600	50	318	5.2	14.5[3]	13.8	14.2	0.4
D	4,000	50	355	4.7	14.5[3]	14.5	14.9	0.4
E	6,400	43	267	6.2	19.5	19.5	20.2	0.7
F	7,730	50	300	4.6	22.9	22.9	23.4	0.5
G	9,301	560	960	1.4	26.7	26.7	27.5	0.8

[1]Feet above mouth
[2]Floodway width extends beyond corporate limits
[3]Combined flooding effects from Galveston Bay and Clear Creek

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX
(GALVESTON CO.)

FLOODWAY DATA

CLEAR CREEK-BENSON BAYOU-MAGNOLIA CREEK

TABLE 3

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Unnamed Tributary of Clear Creek								
A	0	80	623	2.2	13.2[2]	4.8	5.8	1.0
B	900	80	597	2.3	13.2[2]	5.1	6.0	0.9
C	1,340	44	241	5.8	13.2[2]	5.1	6.0	0.9
D	1,990	41	214	6.5	13.2[2]	7.3	7.5	0.2
E	2,430	44	193	7.2	13.2[2]	8.7	8.8	0.1
F	3,370	40	228	6.1	13.2[2]	12.1	12.2	0.1
G	4,470	40	276	5.0	14.0	14.0	14.4	0.4
H	5,870	39	174	8.0	18.6	18.6	18.8	0.2
I	6,310	40	219	6.3	21.4	21.4	21.5	0.1
J	8,160	136	556	2.9	23.7	23.7	24.6	0.9

[1]Feet above mouth.
[2]Combined flooding effects from Galveston Bay and Clear Creek.

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX
(GALVESTON CO.)

FLOODWAY DATA

UNNAMED TRIBUTARY OF CLEAR CREEK

TABLE 3

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Magnolia Bayou								
A	9,317	102	874	3.0	14.9	14.9	15.2	0.3
B	9,586	93	710	3.7	15.4	15.4	15.5	0.1
C	11,826	116	869	2.6	17.1	17.1	18.1	1.0
Bordens Gully								
A	8,532	120	651	1.6	15.4	15.4	15.8	0.4
B	11,450	107	500	1.5	16.1	16.1	16.6	0.5

[1] Feet upstream of confluence with Dickinson Bayou

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

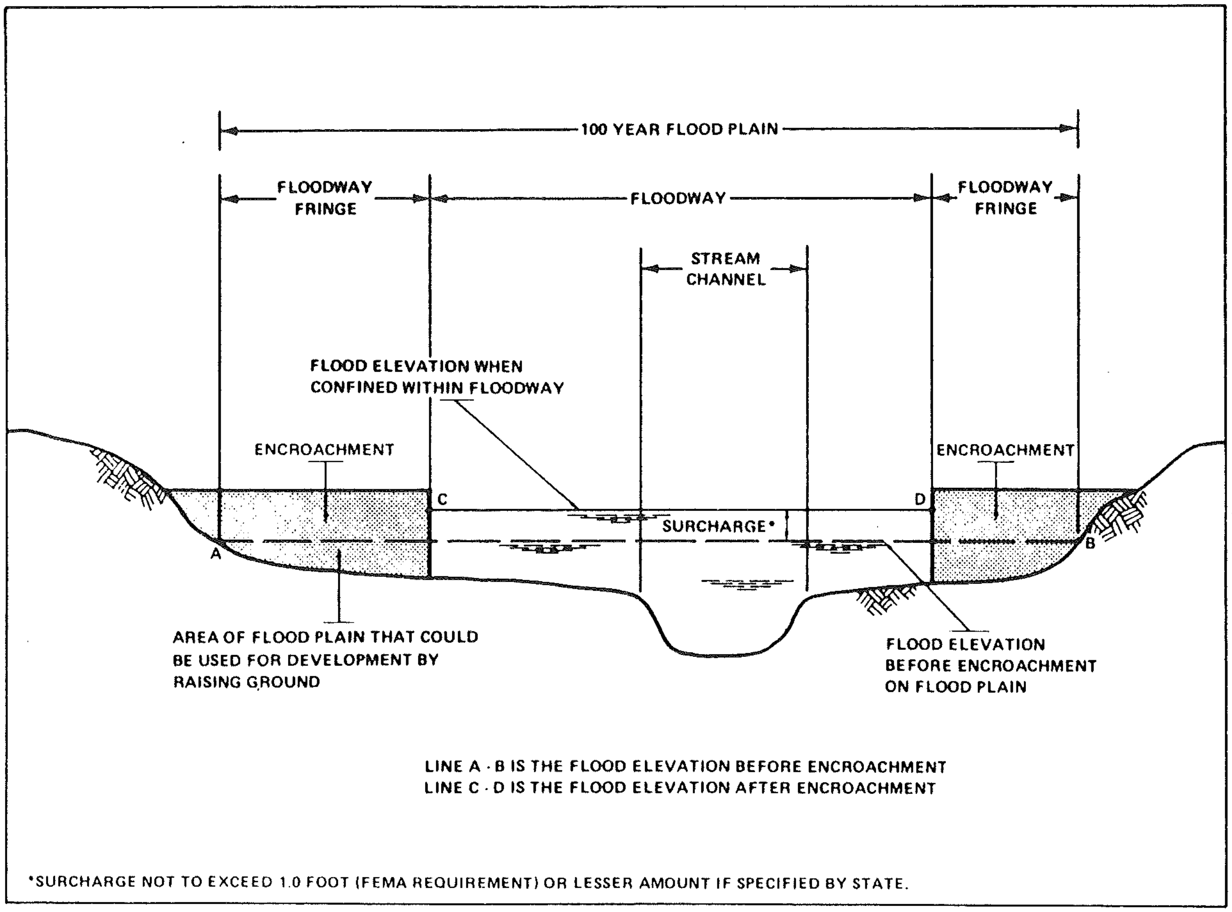
FLOODWAY DATA

MAGNOLIA BAYOU - BORDENS GULLY

TABLE 3

As shown on the Flood Boundary and Floodway Map (Exhibit 2), the floodway boundaries were computed at cross sections. Between cross sections, the boundaries were interpolated. In cases where the floodway and 100-year floodplain boundaries are either close together or collinear, only the floodway boundary has been shown.

The area between the floodway and 100-year floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 4.



FLOODWAY SCHEMATIC — Figure 4

4.3 Base Flood Elevations

Areas within the communities studied by detailed engineering methods have base flood elevations established in A and V Zones. These are the elevations of the base (100-year) flood relative to NGVD. In coastal areas affected by wave action, base flood elevations are generally maximum at the normal open shoreline. These elevations generally decrease in a landward direction at a rate dependent on the presence of obstructions capable of dissipating the wave energy. Where possible, changes in base flood elevations have been shown in one-foot increments on the FIRM. However, where the scale did not permit, two- or three-foot increments were sometimes used. Base flood elevations shown in the wave action areas represent the average elevation within the zone. These elevations vary from 11 to 14 feet NGVD in the incorporated area of League City and are shown on the FIRM. Current program regulations generally require that all new construction be elevated such that the first floor, including basement, is above the base flood elevation in A and V Zones.

4.4 Velocity Zones

The COE has established the three-foot breaking wave as the criterion for identifying coastal high hazard zones (Reference 42). This was based on a study of wave action effects on structures. This criterion has been adopted by FEMA for the determination of V Zones. Because of the additional hazards associated with high-energy waves, the NFIP regulations require much more stringent floodplain management measures in these areas, such as elevating structures on piles or piers. In addition, insurance rates in V Zones are higher than those in A Zones with similar numerical designations.

The location of the V Zone is determined by the three-foot breaking wave as discussed above. The detailed analysis of wave heights performed in this study allowed a much more accurate location of the V Zone to be established. The V Zone generally extends inland to the point where the 100-year flood depth is insufficient to support a three-foot breaking wave.

5.0 INSURANCE APPLICATION

To establish actuarial insurance rates, data from the engineering study must be transformed into flood insurance criteria. This process includes the determination of reaches, Flood Hazard Factors, and flood insurance zone designations for each flooding source studied in detail in the City of League City.

5.1 Reach Determinations

Reaches are defined as sections of floodplain that have relatively the same flood hazard, based on the average weighted difference in water-surface elevations between the 10- and 100-year floods. This difference may not have a variation greater than that indicated in the following tabulation for more than 20 percent of the reach:

Average Difference Between 10- and 100-Year Floods	Variation
Less than 2 feet	0.5 foot
2 to 7 feet	1.0 foot
7.1 to 12 feet	2.0 feet
More than 12 feet	3.0 feet

The locations of the reaches determined for the flooding sources of the City of League City are shown on the Flood Profiles (Exhibit 1) and summarized in Table 4.

Reaches are defined as sections of floodplain that have relatively the same flood hazard. In tidal areas, reaches are limited to the distance for which the 100-year flood elevation does not vary more than 1.0 foot. Using these criteria, one reach was required for the flooding sources of the City of League City. The location of this reach is shown on the Flood Insurance Rate Map and summarized in Table 5.

In areas where a wave height analysis was performed, reaches were determined for areas of the coastline, represented by a transect or group of transects, which have the same physical characteristics.

5.2 Flood Hazard Factors

The Flood Hazard Factor (FHF) is used to establish relationships between depth and frequency of flooding in any reach. This relationship is then used with depth-damage relationships for various classes of structures to establish actuarial insurance rate tables.

The FHF for a reach is the average weighted difference between the 10- and 100-year flood water-surface elevations rounded to the nearest one- half foot, multiplied by 10, and shown as a three-digit code. For example, if the difference between water-surface elevations of the 10- and 100-year floods is 0.7 foot, the FHF is 005; if the difference is 1.4 feet, the FHF is 015; if the difference is 5.0 feet, the FHF is 050. When the difference between the 10- and 100-year flood water-surface elevations is greater than 10.0 feet, it is rounded to the nearest whole foot.

FLOODING SOURCE	PANEL[1]	ELEVATION DIFFERENCE[2] BETWEEN 1% (100-YEAR) FLOOD AND			FLOOD HAZARD FACTOR	ZONE	BASE FLOOD ELEVATION[3] (FEET NGVD)
		10% (10-YEAR)	2% (50-YEAR)	0.2% (500-YEAR)			
Clear Creek							
Reach 1[4]	0010	-5.1	-1.6	+3.2	050	A10	11
Reach 2[4]	0010	-3.8	-1.5	+2.7	040	A8	12
Reach 3[4]	0005,0010, 0025,0030	-3.1	-1.0	+3.5	030	A6	Varies
Benson Bayou							
Reach 1	0030	-1.3	-0.3	_0.5	015	A3	Varies
Magnolia Creek							
Reach 1	0025	-1.3	-0.4	+1.4	015	A3	Varies
Unnamed Tributary of Clear Creek							
Reach 1	0025,0030	-1.5	-0.5	+1.4	015	A3	Varies
Dickinson Bayou							
Reach 1	0025	-1.1	-0.3	+0.6	010	A2	Varies
Magnolia Bayou							
Reach 1	0030	*	*	*	025	A5	Varies
Bordens Gully							
Reach 1	0030	*	*	*	015	A3	Varies

[1]Flood Insurance Rate Map Panel [2]Weighted Average [3]Rounded to Nearest Foot

[4]Combined flooding effects from Galveston Bay and Clear Creek.

*Information not available, zones obtained from previous FIRM (6/17/77)

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

FLOOD INSURANCE ZONE DATA

CLEAR CREEK-BENSON BAYOU-MAGNOLIA CREEK-UNNAMED TRIBUTARY OF CLEAR CREEK-DICKINSON BAYOU-MAGNOLIA BAYOU-BORDENS GULLY

TABLE 4

FLOODING SOURCE	TRANSECTS	PANELS	STILLWATER ELEVATIONS				FLOOD HAZARD FACTOR[1]	ZONE[1]	BASE FLOOD ELEVATION[2] (FEET NGVD)
			10-YR	50-YR	100-YR	500-YR			
Galveston Bay/ Clear Lake	1-3	0011 0011	4.8 4.8	9.6 9.6	11.3 11.3	14.7 14.7	100 070	V20 A14[3]	14 11-13
	N/A	0010,0011,0013	4.8	9.6	11.3	14.7	065	A13	11

1-Includes the effects of Wave Action, where applicable.

2-Due to map scale limitations, Base Flood Elevations (BFEs) shown on the Flood Insurance Rate Map may represent average elevation for the zone depicted.

3-Weighted Average

TABLE 5

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

COASTAL FLOOD INSURANCE ZONE DATA

GALVESTON BAY/CLEAR CREEK

5.3 Flood Insurance Zones

Flood insurance zones and zone numbers are assigned based on the type of flood hazard and the FHF, respectively. A unique zone number is associated with each possible FHF, and varies from 1 for a FHF of 005 to a maximum of 30 for a FHF of 200 or greater.

Zone A:	Special Flood Hazard Areas inundated by the 100-year flood, determined by approximate methods; no base flood elevations shown or FHFs determined.
Zones A2,A3,A5, A6,A8,A10,A13, and A14:	Special Flood Hazard Areas inundated by the 100-year flood; with base flood elevations shown, and zones subdivided according to FHFs.
Zone V20:	Special Flood Hazard Areas along coasts inundated by the 100-year flood that have additional velocity hazards associated with waves of 3-foot amplitude or greater; with base flood elevations shown, and zones subdivided according to FHFs.
Zone B:	Areas between the Special Flood Hazard Areas and the limits of the 500-year flood; areas that are protected from the 100- or 500-year floods by dike, levee, or other water control structure; areas subject to certain types of 100-year shallow flooding where depths are less than 1.0 foot; and areas subject to 100-year flooding from sources with drainage areas less than 1 square mile. Zone B is not subdivided.
Zone C:	Areas of minimal flooding; not subdivided.

Flood elevation differences, FHFs, flood insurance zones, and base flood elevations for the flooding sources studied in detail in the community are shown in Table 4.

5.4 Flood Insurance Rate Map Description

The Flood Insurance Rate Map for the City of League City is, for insurance purposes, the principal result of the Flood Insurance Study. This map contains the official delineation of flood insurance zones and base flood elevations. Base flood elevation lines show the locations of the expected whole-foot water-surface elevation of the base (100-year) flood. The base flood elevations and zone numbers are used by insurance agents, in conjunction with structure elevations and characteristics, to assign actuarial insurance rates to structures and contents insured under the National Flood Insurance Program.

6.0 OTHER STUDIES

Because it is based on more up-to-date analyses, this study supersedes the previously printed Flood Insurance Study for the City of League City (Reference 39).

Flood Insurance Studies are currently being prepared for Harris County and incorporated areas, Brazoria County and incorporated areas, and the unincorporated areas of Galveston County (References 43, 44, and 45). The results of those studies will be in exact agreement with the results of this study.

Flood Insurance Studies have been prepared for the Cities of Clear Lake Shores, Kemah, and Friendswood (References 46, 47, and 48).

Land-surface subsidence investigations have been performed for Texas, and the Galveston District COE has prepared a National Shoreline Study (References 8, 9, 49, and 50). Previous 100-year hurricane surge elevations were determined for the Gulf Coastal Engineering Research Center in 1969, and by the Galveston District of the COE in 1979 (References 51 and 52).

7.0 LOCATION OF DATA

Information concerning the pertinent data used in preparation of this study can be obtained by contacting FEMA, the Natural and Technological Hazards Division, Federal Regional Center, 800 North Loop 288, Denton, Texas 76201-3698.

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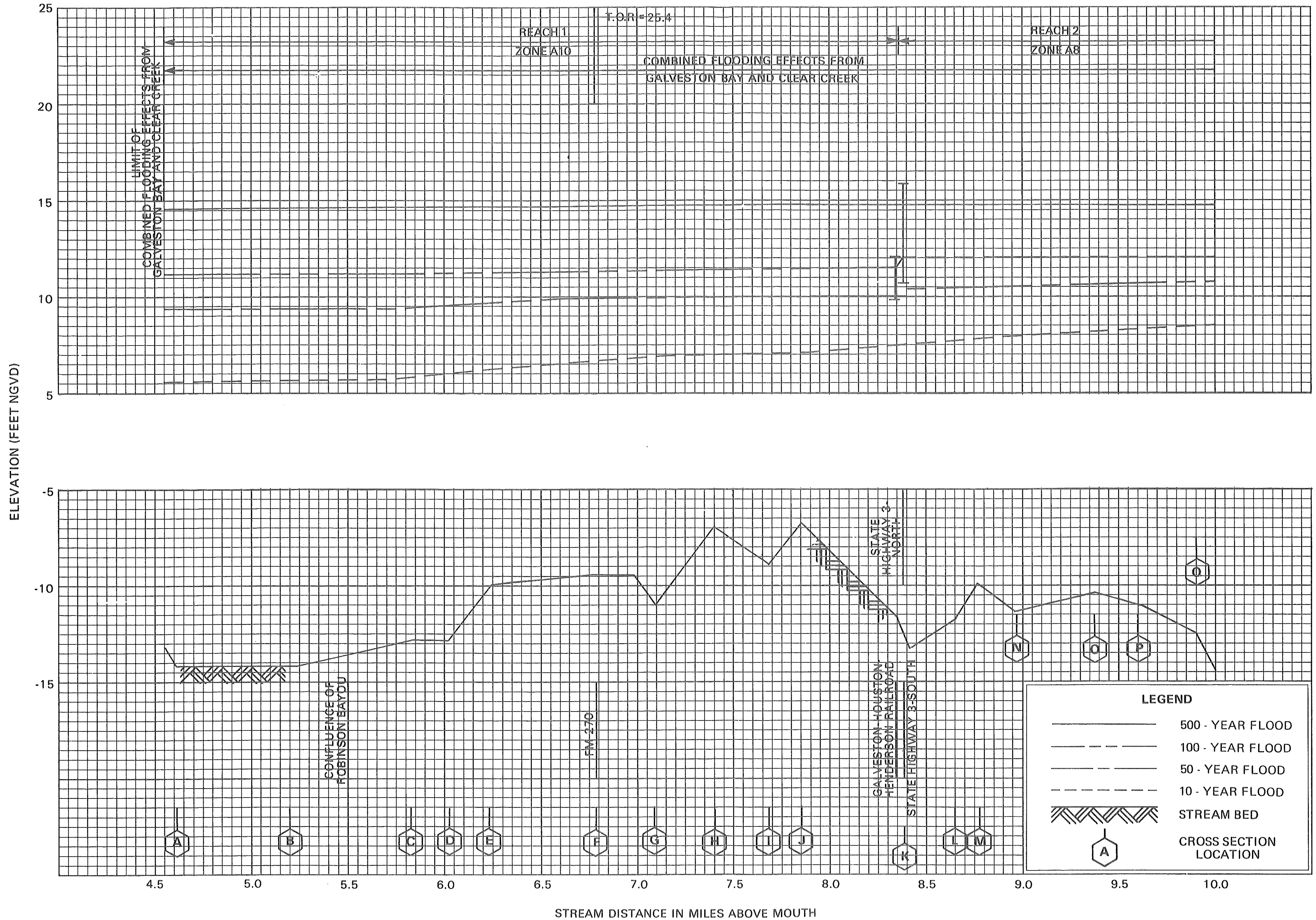

FLOOD PROFILES

CLEAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO)

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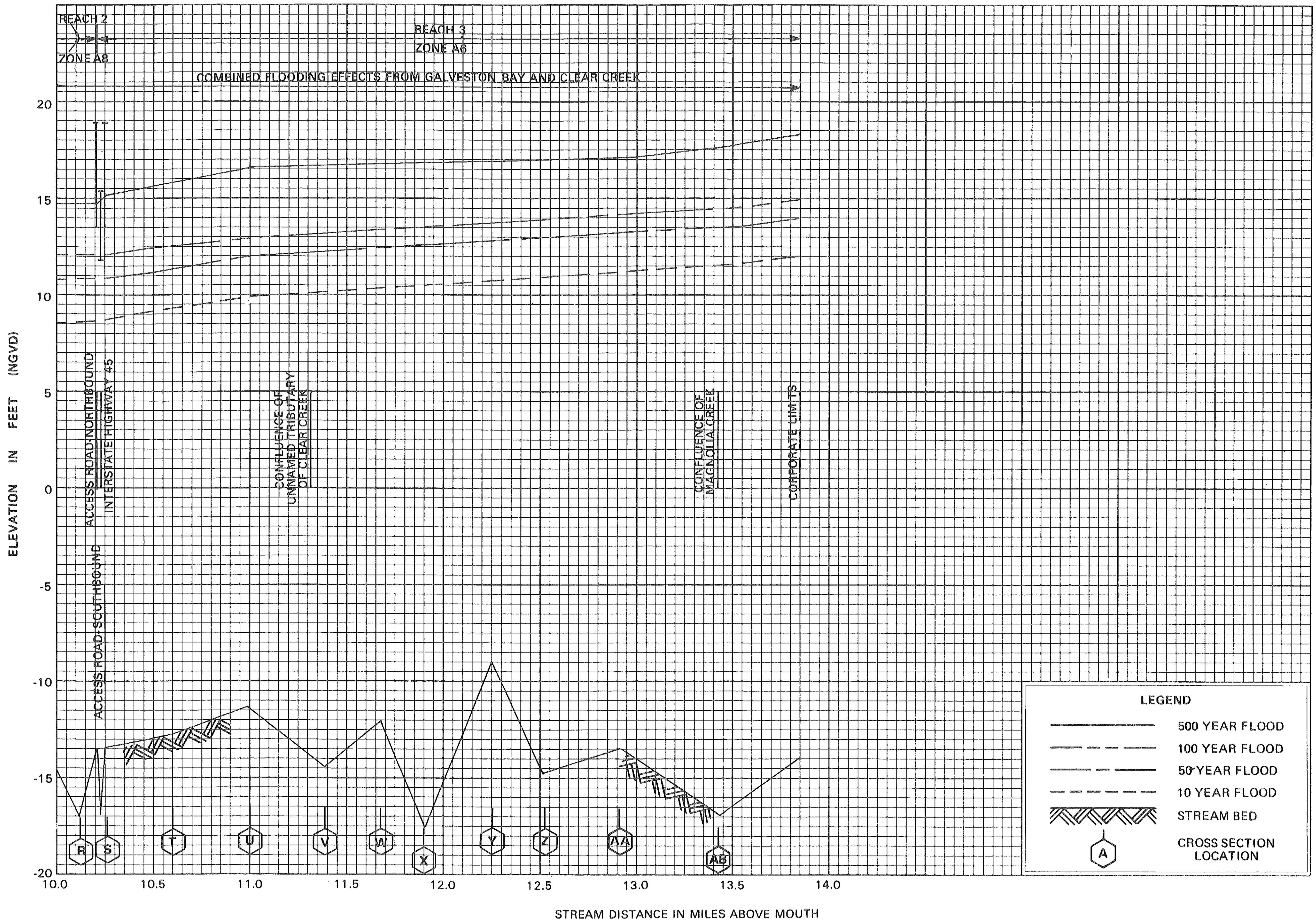

FLOOD PROFILES

CLEAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO)

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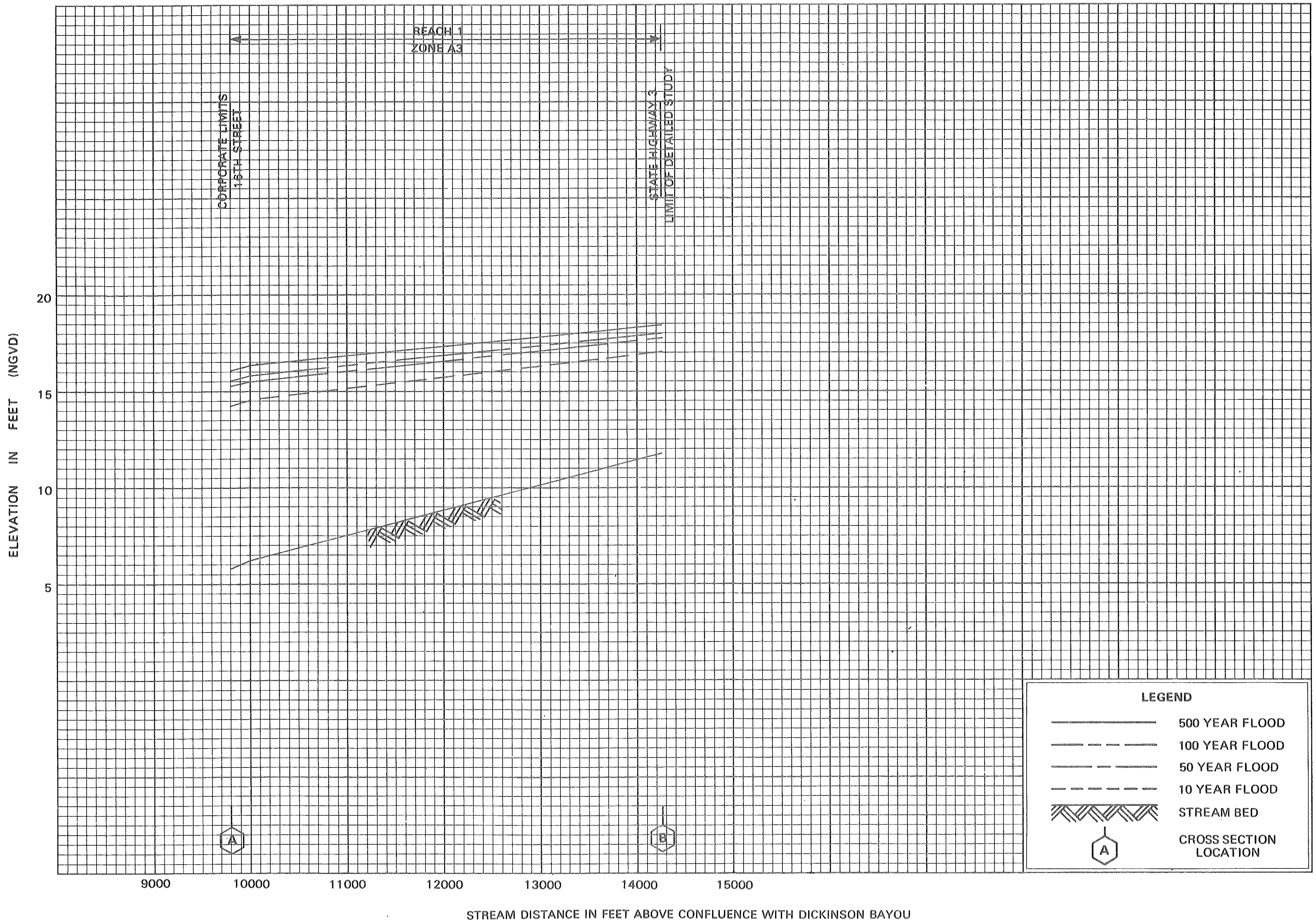


FLOOD PROFILES

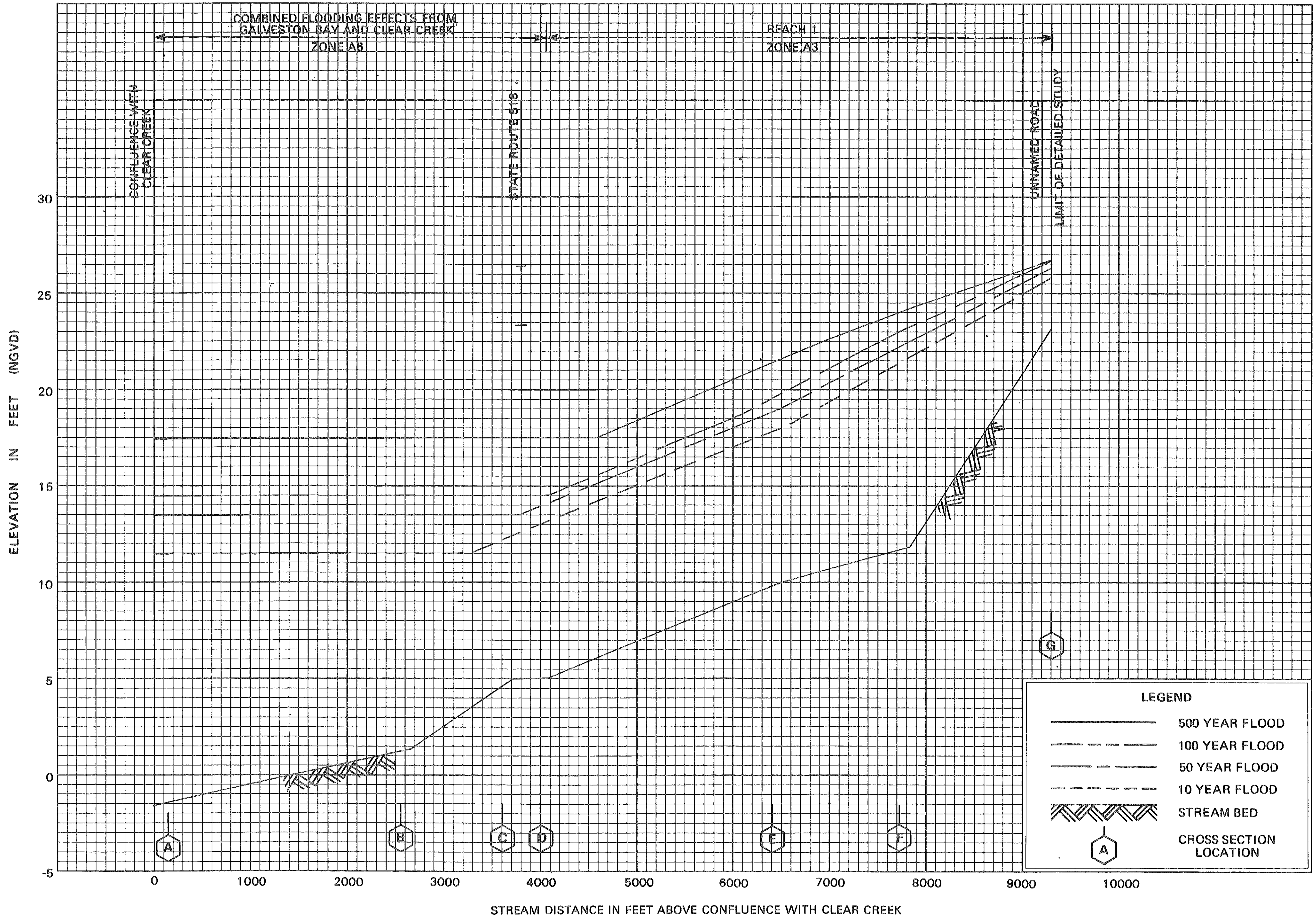
BENSON BAYOU

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

03P



FEDERAL EMERGENCY MANAGEMENT AGENCY

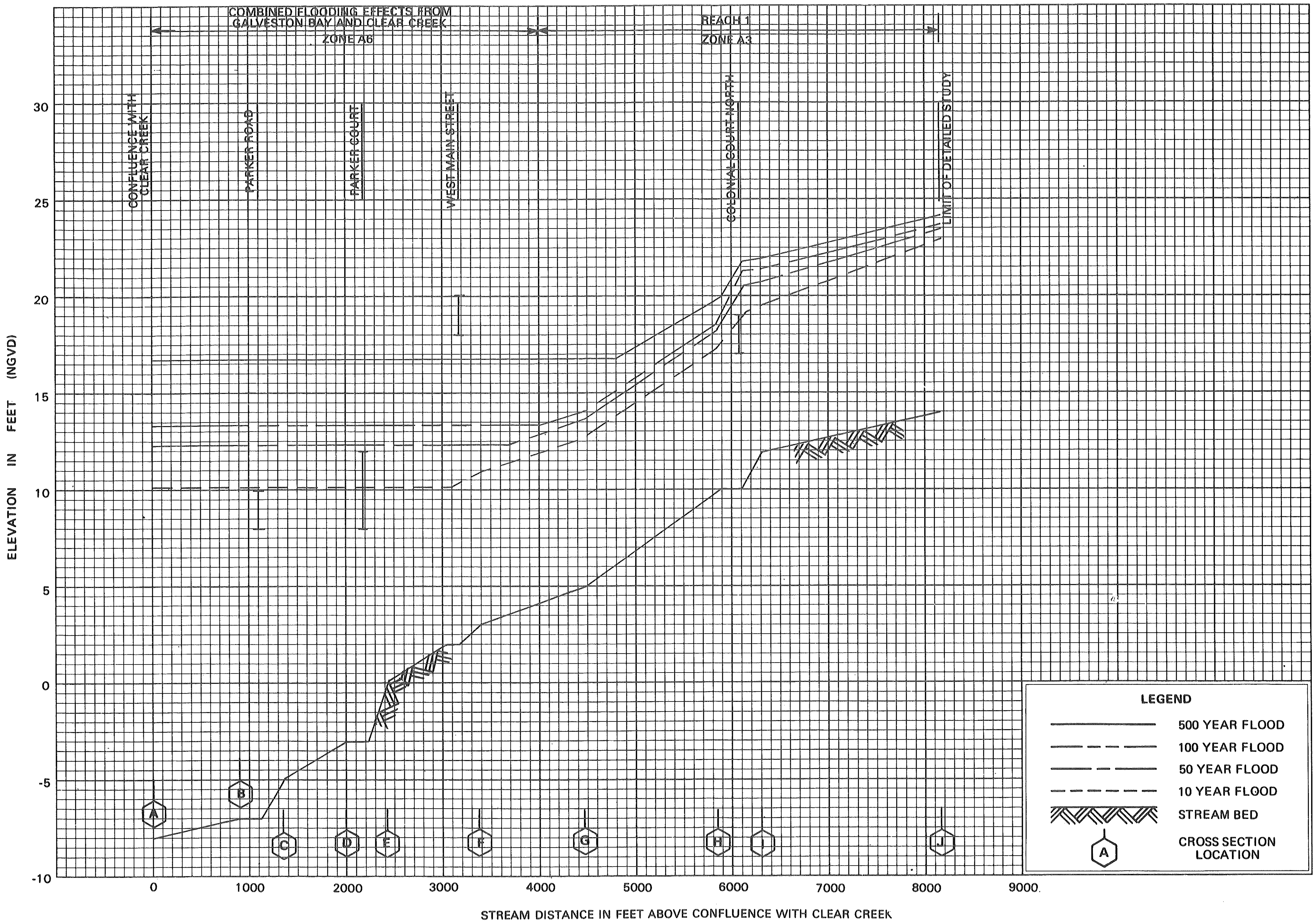
CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

FLOOD PROFILES

MAGNOLIA CREEK

04P



FLOOD PROFILES

UNNAMED TRIBUTARY OF CLEAR CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

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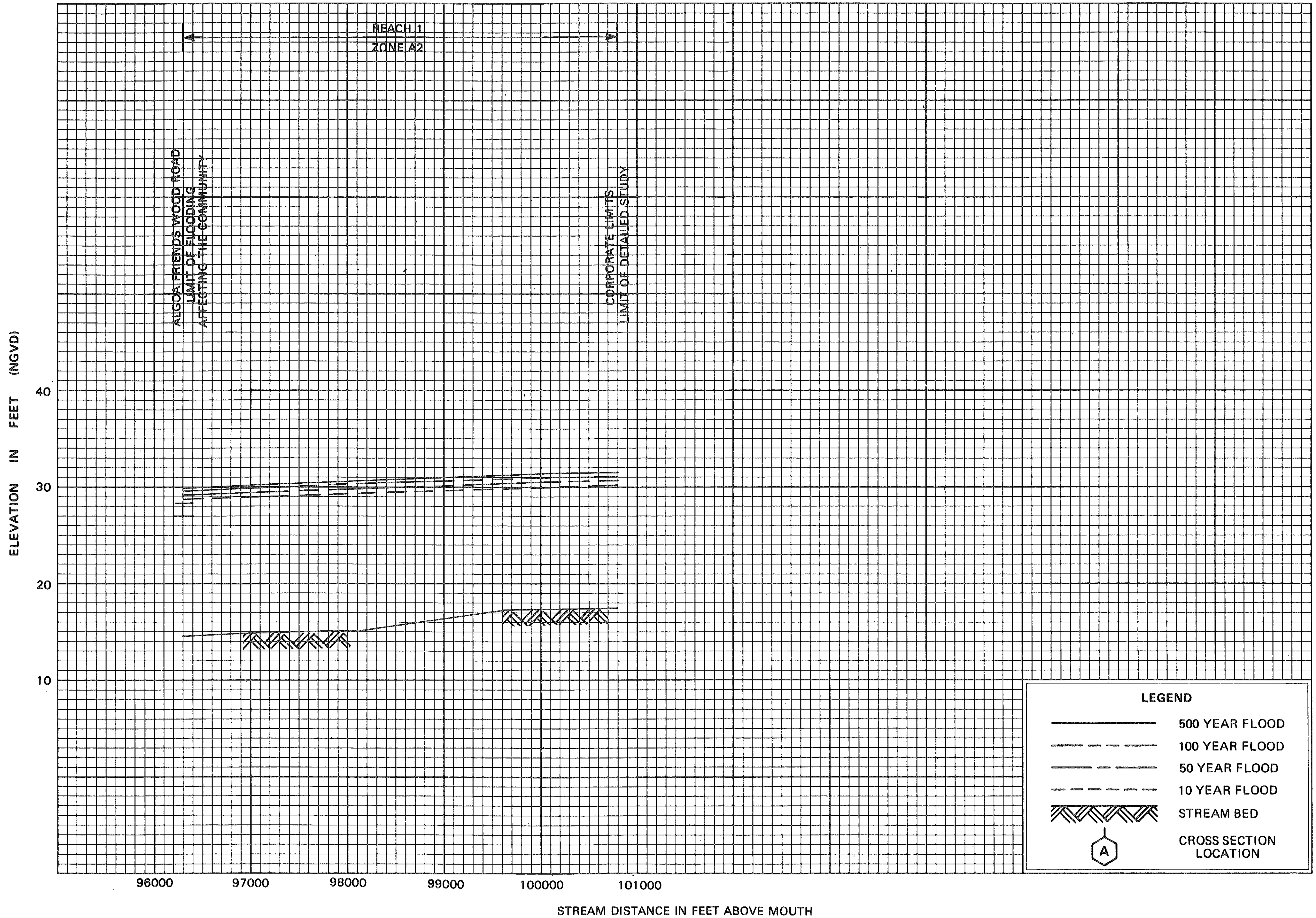

FLOOD PROFILES

DICKINSON BAYOU

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

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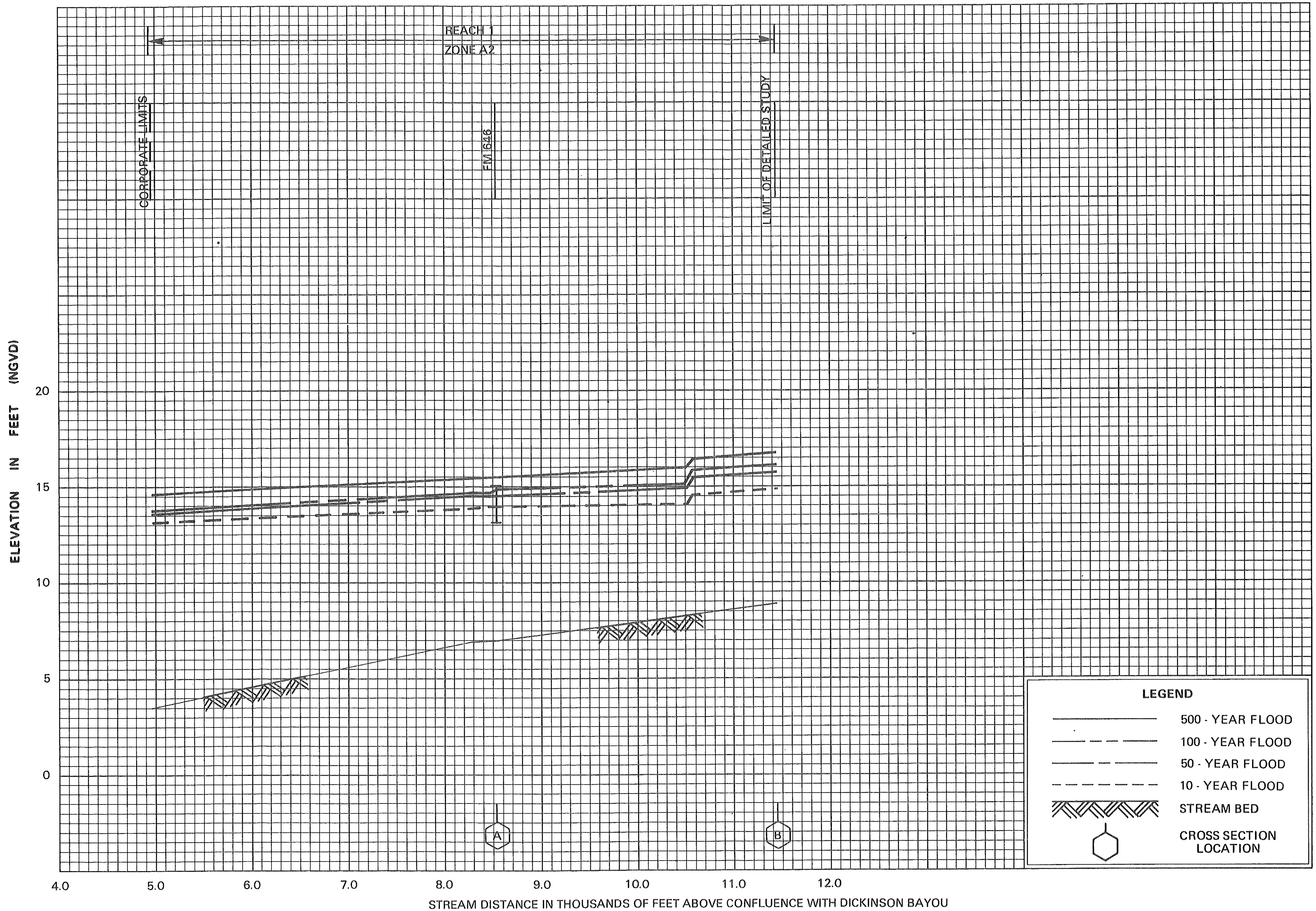

FLOOD PROFILES

BORDENS GULLY

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX
(GALVESTON CO.)

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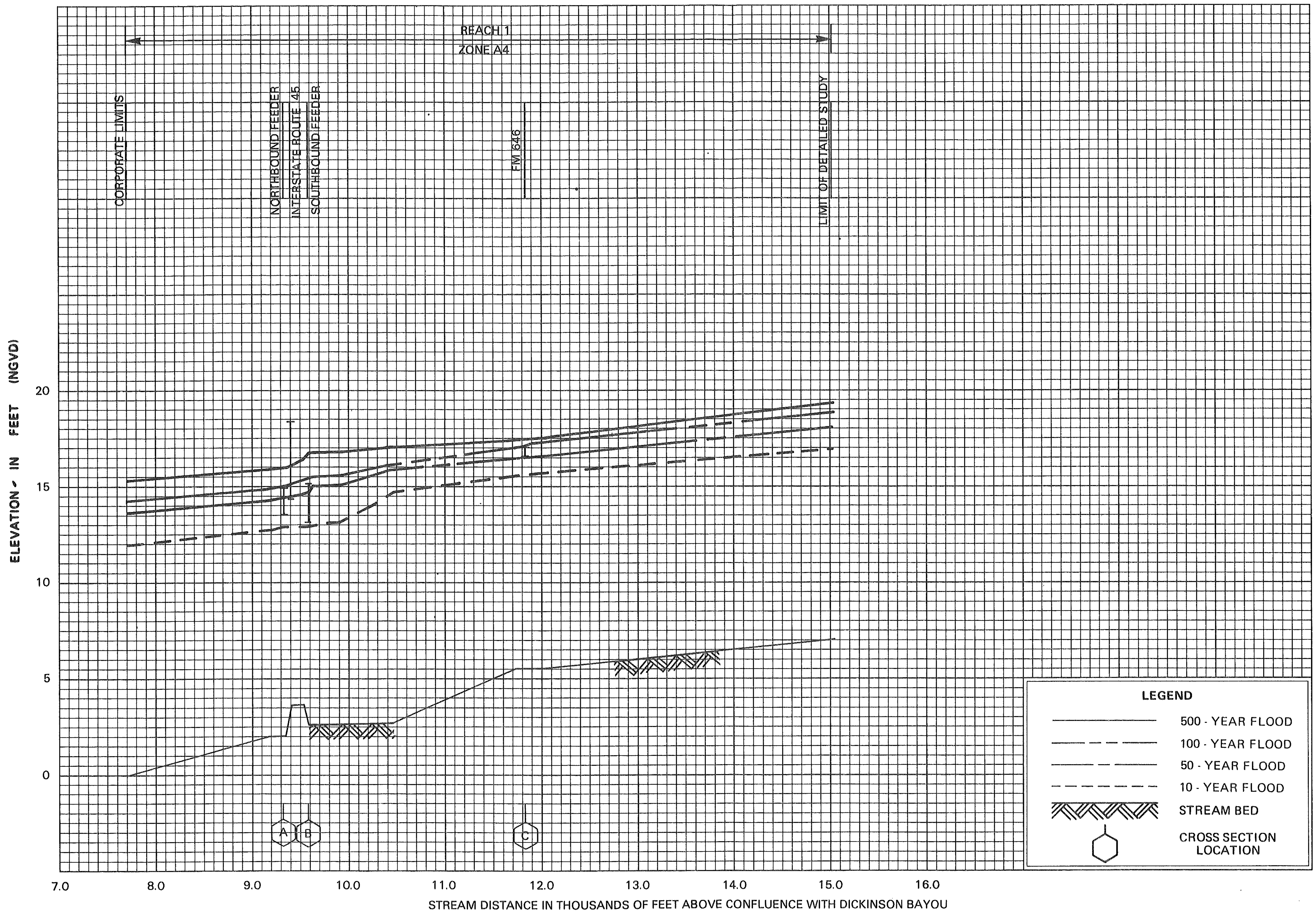

FLOOD PROFILES

MAGNOLIA BAYOU

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF LEAGUE CITY, TX

(GALVESTON CO.)

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