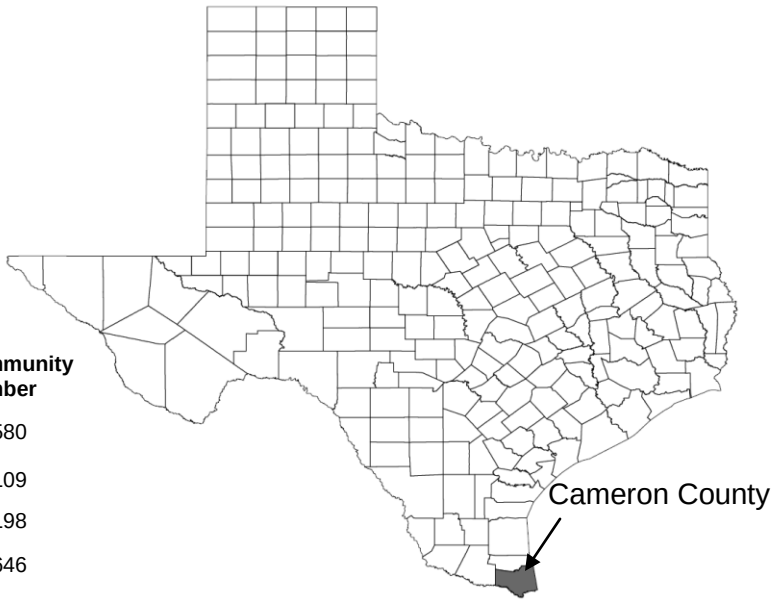
FLOOD INSURANCE STUDY

CAMERON COUNTY, TEXAS

AND INCORPORATED AREAS
VOLUME 1 OF 2



Community Name	Community Number	Community Name	Community Number
Bayview, Town of	480102	Palm Valley, City of *	481580
Brownsville, City of	480103	Port Isabel, City of	480109
Cameron County (Unincorporated Areas)	480101	Primera, Town of *	481198
		Rancho Viejo, Town of	481646
Combes, Town of	480104	Rangerville, Town of	480110
Harlingen, City of	485477	Rio Hondo, City of	480112
Indian Lake, Town of	481695	San Benito, City of	480113
La Feria, City of	480106	Santa Rosa, City of	480114
Laguna Vista, Town of	485483	South Padre Island, City of	480115
Los Fresnos, City of	480108		
Los Indios, City of	480105		

* No Special Flood Hazards Identified

PRELIMINARY JUNE 4, 2015

EFFECTIVE DATE:

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
48061CV001A

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study 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 Flood Insurance Study may be revised and republished at any time.

In addition, part of this Flood Insurance Study may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the Flood Insurance Study. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current Flood Insurance Study components.

Selected Flood Insurance Rate Map panels for this community contain information that was previously shown separately on the corresponding Flood Boundary and Floodway Map panels (e.g., floodways, cross sections). In addition, former flood hazard zone designations have been changed as follows:

Old Zone(s)	New Zone
Al through A30	AE
VI through V30	VE
B	X

ATTENTION: On FIRM panels 0100, 0125, 0150, 0175, 0250, 0255, 0260, 0265, 0270, 0290, 0300, 0325, 0350, 0400, 0410, 0425, 0430, 0435, 0440, 0445, 0465, 0475, 0500, 0560, 0575, 0580, 0585, 0590, 0595, 0625, and 0675, the International Boundary and Water Commission (IBWC) levee systems for the Arroyo Colorado, North Floodway and Rio Grande have not been demonstrated by the community or levee owner to meet the requirements of Section 65.10 of the NFIP regulations in 44 CFR as it relates to the levee's capacity to provide 1-percent-annual-chance flood protection. The subject areas are identified on FIRM panels (with notes and bounding lines) and in the FIS report as potential areas of flood hazard data changes based on further review.

FEMA has updated levee analysis and mapping procedures for non-accredited levees. Until such time as FEMA is able to initiate a new flood risk project to apply the new procedures, the flood hazard information on the aforementioned FIRM panels that are affected by the IBWC levees are being added as a snapshot of the prior effective information presented on the FIRMs and FIS reports dated June, 1978 and December 1, 1978 for the City of Brownsville; December 1, 1980 and June 1, 1981 for the City of Rio Hondo; February 3, 1981 and August 3, 1981 for the City of Harlingen; November 5, 1980 and January 19, 1982 for the City of

San Benito; August 19, 1986 for the City of Los Fresnos; September 15, 1983, March 18, 1991, May 4, 1992 and March 9, 1999 for the unincorporated Areas of Cameron County. As indicated above, it is expected that affected flood hazard data within the subject area could be significantly revised. This may result in floodplain boundary changes, 1-percent-annual-chance flood elevation changes, and/or changes to flood hazard zone designations.

The effective FIRM panels (and the FIS report) will again be revised at a later date to update the flood hazard information associated with the IBWC levees when FEMA is able to initiate and complete a new flood risk project to apply the updated levee analysis and mapping procedures.

Initial Countywide FIS Effective Date: _____

TABLE OF CONTENTS

VOLUME 1

Page

1.0 INTRODUCTION 1

1.1 Purpose of Study 1
1.2 Authority and Acknowledgments 1
1.3 Coordination 4

2.0 AREA STUDIED 5

2.1 Scope of Study 5
2.2 Community Description 7
2.3 Principal Flood Problems 11
2.4 Flood Protection Measures 16

3.0 ENGINEERING METHODS 18

3.1 Hydrologic Analyses 19
3.2 Hydraulic Analyses 22
3.3 Coastal Analysis 24
3.3.1 Storm Surge Analysis and Modeling 24
3.3.2 Statistical Analysis 25
3.3.3 Stillwater Elevations 26
3.3.4 Wave Height Analysis 26
3.4 Vertical Datum 35

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS 35

4.1 Floodplain Boundaries 35
4.2 Floodways 36

5.0 INSURANCE APPLICATIONS 40

6.0 FLOOD INSURANCE RATE MAP 40

7.0 OTHER STUDIES 41

8.0 LOCATION OF DATA 41

9.0 BIBLIOGRAPHY AND REFERENCES 44

FIGURES

Figure 1: Transect Schematic 27
Figure 2: Transect Location Map 29
Figure 3: Floodway Schematic 37

TABLE OF CONTENTS (Continued)

VOLUME 1 (Continued)

TABLES

	Page
Table 1: Initial and Final CCO Meetings	5
Table 2: Streams Studied by Detailed Methods	6
Table 3: Letters of Map Change (LOMCs)	7
Table 4: Historical High-Water Mark Elevations	14
Table 5: Summary of Discharges	20
Table 6: Manning's "n" Values	23
Table 7: Coastal Data	31
Table 8: Floodway Data Tables	38
Table 9: Community Map History	42

EXHIBITS

Exhibit 1 – Flood Profiles

Arroyo Colorado at Rio Hondo	Panels 01P
Arroyo Colorado	Panels 02P-03P
Cameron County Drainage Ditch #1	Panels 04P-05P
Main Ditch No. 2	Panels 06P-08P
Tributary 1 to Arroyo Colorado	Panel 09P
Tributary 2 to Arroyo Colorado	Panel 10P
Tributary 3 to Arroyo Colorado	Panel 11P

VOLUME 2

EXHIBITS

Exhibit 2 – 0.2-Percent-Annual-Chance Wave Envelopes

Transect 1	Panels 01P-04P
Transect 2	Panels 05P-08P
Transect 3	Panels 09P-12P
Transect 4	Panels 13P-16P
Transect 5	Panels 17P-20P
Transect 6	Panels 21P-24P
Transect 7	Panels 25P-28P
Transect 8	Panels 29P-32P
Transect 9	Panels 33P-36P
Transect 10	Panels 37P-40P
Transect 11	Panels 41P-44P
Transect 12	Panels 45P
Transect 13	Panels 46P-49P

Transect 14 Panels 50P-51P

VOLUME 2

EXHIBITS (Continued)

Transect 15 Panels 52P-55P
Transect 16 Panels 56P-57P
Transect 17 Panels 58P-59P
Transect 18 Panels 60P-61P
Transect 19 Panels 62P-65P
Transect 20 Panels 66P-69P
Transect 21 Panels 70P-73P
Transect 22 Panels 74P-77P
Transect 23 Panels 78P-81P
Transect 24 Panels 82P-85P
Transect 25 Panels 86P-89P
Transect 26 Panels 90P-93P
Transect 27 Panels 94P
Transect 28 Panels 95P
Transect 29 Panels 96P
Transect 30 Panels 97P-100P
Transect 31 Panels 101P
Transect 32 Panels 102P-103P
Transect 33 Panels 104P-105P
Transect 34 Panels 106P-109P
Transect 35 Panels 110P-111P
Transect 36 Panels 112P-113P
Transect 37 Panels 114P-115P
Transect 38 Panels 116P-117P
Transect 39 Panels 118P-119P
Transect 40 Panels 120P-121P
Transect 41 Panels 122P-123P
Transect 42 Panels 124P-125P
Transect 43 Panels 126P-127P
Transect 44 Panels 128P-131P
Transect 45 Panels 132P-136P
Transect 46 Panels 137P-141P
Transect 47 Panels 142P-145P
Transect 48 Panels 146P-150P
Transect 49 Panels 151P-155P
Transect 50 Panels 156P-157P
Transect 51 Panels 158P-159P
Transect 52 Panels 160P-161P
Transect 53 Panels 162P-163P

Exhibit 3 – Flood Insurance Rate Map Index
Flood Insurance Rate Map

FLOOD INSURANCE STUDY
CAMERON COUNTY, TEXAS AND INCORPORATED AREAS

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) report revises and supersedes the FIS reports and/or Flood Insurance Rate Maps (FIRMs) in the geographic area of Cameron County, Texas, including the Cities of Brownsville, Harlingen, La Feria, Los Fresnos, Los Indios, Palm Valley, Port Isabel, Rio Hondo, San Benito, Santa Rosa, and South Padre Island; the Towns of Bayview, Combes, Indian Lake, Primera, Rancho Viejo, Rangerville, and Laguna Vista; and the unincorporated areas of Cameron County (hereinafter referred to collectively as Cameron County), 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. This information will also be used by Cameron County to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP), and by local and regional planners to further promote sound land use and floodplain development. Minimum floodplain management requirements for participation in the NFIP 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.

The FIRM and FIS report for this first time countywide study have been produced in digital format. Flood hazard information was converted to meet the Federal Emergency Management Agency (FEMA) FIRM database specifications and Geographic Information System (GIS) format requirements. The flood hazard information was created and is provided in a digital format so that it can be incorporated into a local GIS and be accessed more easily by the community.

Please note that the on the effective date of this study the City of Palm Valley and the Town of Primera do not have any identified Special Flood Hazard Areas (SFHAs). This does not preclude future determinations of SFHAs that could be necessitated by changed conditions affecting the community (i.e. annexation of new lands) or the availability of new scientific or technical data about flood hazards.

Please also note that FEMA has identified one or more levees in this jurisdiction that have not been demonstrated by the community or levee owner to meet the requirements of 44 CFR Section 65.10 of the NFIP regulations (44CFR65.10) as it relates to the levee's capacity to provide 1-percent-annual-chance flood protection. As such, temporary actions are being taken until such time as FEMA is able to initiate a new flood risk project to apply new levee analysis and mapping procedures. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information.

1.2 Authority and Acknowledgments

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

This FIS was prepared to include the unincorporated areas and incorporated communities within Cameron County into a countywide FIS. Information on the authority and acknowledgments for each of these studies, compiled from their previous effective narratives, is shown below.

Brownsville, City of	The June 1978 study was conducted by Lockwood, Andrews and Newnam, Inc., at the request of the Federal Insurance Administration (FIA), U. S. Department of Housing and Urban Development (Reference 1). Authority and financing are contained in Contract No. H-1900 between the contractor and the FIA.
Cameron County (Unincorporated Areas)	In the original study, the hydrologic and hydraulic analyses were prepared by Lockwood, Andrews, and Newnam, Inc. for FEMA, under Contract No. H-1900. The work for the original study was completed in February 1973. The hydrologic and hydraulic analyses for the Gulf of Mexico and Laguna Madre were prepared by Dewberry & Davis in November 1976. For the 1980 coastal hazard analyses, stillwater elevations were computed by Roy F. Weston, Inc., for FEMA, under Contract No. H-4789. That work was completed in March 1980. The wave height analysis was prepared by Bernard Johnson, Inc. under agreement with FEMA. In the March 1999 restudy, a revised hydraulic analysis and erosion analysis were prepared by Dewberry & Davis, for FEMA, under Contract No. EMW89-C-2906 (Reference 2). This work was completed in December 1989.
Harlingen, City of	The hydrologic and hydraulic analyses for the February 3, 1981 study were performed by Roy F. Weston, Inc., for the FIA, under Contract No. H-4789 (Reference 3). This work was completed in October 1979. Survey and topographic data for this study were collected and compiled by Urban Engineering, Corpus Christi, Texas, under subcontract to Roy F. Weston, Inc.
Laguna Vista, Town of	No authority and acknowledgement information available.
Port Isabel, City of	The September 1975 study was conducted by Turner, Collie & Braden, Inc., Consulting Engineers, Houston, Texas, at the request of the FIA, U. S. Department of Housing and Urban Development. Authority and financing is contained in Contract No. H-3695 between the Contractor and the FIA (Reference 4).
Rio Hondo, Town of	The hydrologic and hydraulic analyses for the December 1, 1980 study were performed by Roy F. Weston, Inc., for the FIA, under Contract No. H-4789 (Reference 5). This work was completed in December 1979. Survey and topographic data were collected and compiled by Urban Engineers, Corpus Christi, Texas, under subcontract to Roy F. Weston, Inc.

San Benito, City of	The hydrologic and hydraulic analyses for the November 5, 1980 study were performed by Roy F. Weston Inc. for the FIA, under Contract No. H-4789 (Reference 6). This study was completed in September 1979. The Flood Hazard Boundary Map (FHBM) for the City of San Benito was published on November 5, 1976 by the FIA. The City of San Benito was in agreement with that FHBM.
Santa Rosa, City of	The hydrologic and hydraulic analyses for the November 1980 study were performed by Roy F. Weston, Inc., for the FIA, under Contract No. H-4789 (Reference 7). This study was completed in September 1979. The FHBM for the City of Santa Rosa was published on May 17, 1974 by the FIA, and revised on April 2, 1976. The City of Santa Rosa was in agreement with that FHBM.
South Padre Island, City of	The hydrologic and hydraulic analyses for the original May 2, 1991 study were prepared by Roy F. Weston, Inc., for the FEMA, under Contract No. H-4789 (Reference 8). That work was completed in March 1980. The wave-height analysis in the original study was prepared by Bernard Johnson, Inc., for FEMA. Field-survey data for the original study were collected and compiled by Urban Engineers, of Corpus Christi, under subcontract from Roy F. Weston, Inc. Dewberry & Davis prepared a revised hydraulic analysis and an erosion analysis for FEMA using data from surveys conducted by Corona Engineering & Surveying and Quilio Engineering Company. Dewberry & Davis also prepared topographic mapping from aerial photography. That work was completed in October 1989. The hydrologic and hydraulic analyses for the March 9, 1999 restudy were performed by Espey, Huston, and Associates, Inc., for FEMA, under Contract No. EMT-95-C-0299 (Reference 9). This restudy was completed in October 1996.

There are no previous FIS or FIRMs for the Cities of La Feria, Los Indios, and Palm Valley and the Towns of Bayview, Combes, Indian Lake, Primera, Rancho Viejo, and Rangerville; and no previous FIS for the City of Los Fresnos; therefore the previous authority and acknowledgement information for these communities is not included in this FIS.

For this first time countywide FIS

As part of this first countywide study, MAPVI compiled existing data to convert the previous FISs into digital format and performed detailed hydrologic, hydraulic, and coastal hazard analyses for FEMA, under contract No. EMT-2002-CO-0052. Hydrologic and hydraulic analyses were performed for Cameron County Drainage Ditch #1, and Main Ditch No. 2. This work was completed in December 2011.

Additional work to update the FIS and FIRMs with information about de-accredited levees was done by Risk Assessment and Mapping and Planning Partners (RAMPP) under contract No. HSFE06-12-J001 in April 2014.

Base map information shown on this FIRM was derived from multiple sources. This information was compiled from the U.S. Geological Survey, 1989, National Geodetic Survey, 2004, Cameron County Appraisal District, 2011, and the Texas Natural Resources Information System, 2010. Additional information was photogrammetrically compiled at a scale of 1:6,000 from National Agriculture Imagery Program aerial photography dated 2010.

The projection used in the preparation of the FIRMs was Texas State Plane, Zone South (FIPS 4205). The horizontal datum used was North American Datum of 1983 (NAD83), GRS80 spheroid. The vertical datum was the North American Vertical Datum of 1988 (NAVD88). Differences in datum, projection or State Plane zones used in the projection of the FIRMs for adjacent jurisdictions may result in slight positional differences across jurisdictional boundaries. These differences do not affect the accuracy of these FIRMs.

1.3 Coordination

The initial Consultation Coordination Officer's (CCO) meeting was held with representatives from FEMA, the community, and the study contractor to explain the nature and purpose of a FIS, and to identify the streams to be studied by detailed methods. The final CCO meeting was held with representatives from FEMA, the community and the study contractor to review the results of the study. All problems raised in the meeting have been addressed in this study.

The dates of the pre-countywide initial and final CCO meetings held for Cameron County and the incorporated communities within its boundaries are listed in Table 1, "Initial and Final CCO Meetings."

For this countywide FIS, an initial CCO meeting was held on April 7, 2005, and was attended by representatives of the community, the study contractor, and FEMA. The final CCO meeting was held on _____, and was attended by representatives of the community, the study contractor, and FEMA.

Table 1: Initial and Final CCO Meetings

COMMUNITY NAME	FIS DATE	INITIAL MEETING	FINAL MEETING
Brownsville, City of	June 1978	*	*
Cameron County (Unincorporated Areas)	March 15, 1983 March 9,1999	* March 2, 1989	* March 29, 1990
Harlingen, City of	February 3, 1981	May 1978	September 11, 1980
Laguna Vista, Town of	March 15, 1983	*	*
Port Isabel, City of	September 1975	*	*
Rio Hondo, City of	December 1, 1980	May 1978	July 10, 1980
San Benito, City of	November 5, 1980	May 1978	April 24, 1980
Santa Rosa, City of	November 1980	May 1978	May 17, 1974
South Padre Island, City of	May 2, 1991 March 9,1999	March 2, 1989 *	March 29, 1990 March 18, 1998

* Data Not Available

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the geographic area of Cameron County, Texas, including the incorporated communities listed in Section 1.1.

Table 2, "Flooding Sources Studied by Detailed Methods," lists the streams that were studied by detailed methods. The areas studied by detailed methods were selected with priority given to all known flood hazards and areas of projected development or proposed construction.

Approximate analyses were applied to numerous streams in the county, including the remaining portions of selected flooding sources studied by detailed methods. Approximate analyses were used to study those areas having a low development potential or minimal flooding hazards. The scope and methods of study were proposed to, and agreed upon, by FEMA and the communities.

This FIS includes coastal flooding due to hurricane-induced storm surge. Both the open coast and inland propagation were studied; in addition, the added effects of wave heights and erosion were considered. For streams affected by both riverine and tidal flooding, combined probability analysis was conducted to arrive at elevations created by flood occurrences caused by both types of flooding.

Table 2: Streams Studied by Detailed Methods

Stream/Shallow Flooding Area	Limits of Detailed Study
Arroyo Colorado	From a point approximately 32 miles upstream of its mouth to its confluence with Tributary 3 to Colorado Arroyo
	From a point approximately 23.5 miles upstream of its mouth to approximately 0.8 miles upstream from Colorado Avenue
Cameron County Drainage Ditch #1	From a point approximately 3.8 miles west from San Martin Lake to approximately 340 upstream from Foust Road
Main Ditch No. 2	From a point approximately 4.6 miles west from San Martin Lake to approximately 3.3 miles upstream from Old Port Isabel Road
Tributary 1 to Arroyo Colorado	From its confluence with Arroyo Colorado to approximately 950 feet upstream from Treasure Lake Road
Tributary 2 to Arroyo Colorado	From its confluence with Arroyo Colorado to approximately 2,300 feet upstream from U.S. Highways 77 and 83
Tributary 3 to Arroyo Colorado	From its confluence with Arroyo Colorado to approximately 200 feet upstream from Tyler Avenue

This FIS also incorporates, where applicable, the determinations of letters issued by FEMA resulting in map changes (Letter of Map Revision [LOMR], and Letter of Map Revision Based on Fill [LOMR-F]). LOMRs incorporated as part of this countywide update have been shown in Table 3, Letters of Map Change (LOMCs)," and are reflected in Table 8, "Floodway Data," Exhibit 1, "Flood Profiles," and Exhibit 3, "Flood Insurance Rate Map."

Streams studied by detailed methods that were not re-studied as part of this map update may include a profile baseline on the FIRM. The profile baselines for these streams were based on the best available data at the time of their study and are depicted as they were on the previous FIRMs. In some cases the transferred profile baseline may deviate significantly from the channel or may be outside of the floodplain.

Table 3: Letters of Map Change (LOMCs)

Case Number	Effective Date	Flooding Source	Community	Panel
99-06-1249P	7/26/1999	Shallow Flooding	Cameron County (Unincorporated Areas)	48061C0475F
03-06-106A	12/6/2002	Ponding	City of Harlingen	48061C0265F 48061C0270F
03-06-1549P	6/24/2003	Tributary 3 to Arroyo Colorado	Cameron County (Unincorporated Areas)	48061C0265F
04-06-A123A	9/24/2004	Horseshoe Lake	City of Harlingen	48061C0265F
08-06-0829A	3/4/2008	Ponding	Cameron County (Unincorporated Areas)	48061C0595F
09-06-1474A	5/19/2009	Shallow Flooding	Cameron County (Unincorporated Areas)	48061C0595F

2.2 Community Description

Cameron County is the southernmost county in Texas. It is bordered by Hidalgo County to the west, Willacy County to the north, the Gulf of Mexico to the east, and Mexico to the south. The population of the county was found to be 406,220 in the 2010 Census (Reference 10). Cameron County's climate is subtropical and subhumid, with hot summers and mild winters. Temperatures range from an average low of 50°F to 69°F in January and from an average high of 75°F to 94° F in July. Rainfall averages twenty-six inches per year. Snowfall is exceedingly rare. The growing season lasts 320 days, with the first freeze in mid-December and the last in late January (Reference 11).

Cameron County covers approximately 905 square miles, with an elevation range from sea level to sixty feet. Along the eastern edge of the county the soils are sandy and saline, with some cracking clay. The remainder of the county has brownish to reddish soils, with loamy to clayey surface layers and clayey subsoils. Vegetation along the eastern edge of the county is typical of the Gulf Prairie and Marsh vegetation areas, with marsh grasses, bluestems, and grama grasses predominating. The vegetation of the rest of the county is like that of the South Texas Plains area, with small trees, brush, weeds, and grasses found in abundance. Mesquite, live oak, post oak, and shrubs also grow densely in some areas. Between 41 and 50 percent of the county is considered prime farmland (Reference 11).

The economy of Cameron County is based primarily on agriculture, manufacturing, tourism, and shipping. Agriculture and the closely related livestock industry are the greatest money-producing operations in the county. Agricultural commodities include vegetables, grain sorghum, cotton, and citrus crops.

Tourism is an important facet of the area's economy. A mild year-round climate and the international flavor of border town activities add to the region's popularity as a resort, convention, and retirement area. There are many historic towns, missions, and other points of interest in the Rio Grande Valley that serve as tourist attractions.

Cameron County is served by three important shipping facilities. Port Harlingen, located on the Arroyo Colorado, furnishes shipping facilities for barge and small vessel traffic. Port Brownsville is the most significant transportation facility in the area. It is a major deepwater seaport with channel depth and terminal facilities that compare favorably with the best on the Gulf Coast. Annual tonnage is over 4.5 million, with world-wide service via 66 steamship and tanker lines. The port is the southern terminus of the U. S. inland

waterway system, with service by eight common carrier barge lines, plus private and specialized carriers. Port Isabel and Port Brownsville, combined, are said to be the shrimping capital of the world. There are approximately 500 shrimping trawlers based at these ports, and several seafood processing and freezing plants.

Other industries contributing to the economy of the Cameron County region are the canning, frozen foods, and packing industries, cotton gins, cottonseed oil mills, agricultural fertilizer and chemical plants, and garment factories. The oil and gas industries also contribute to the income of the county, with distribution centers located at Rio Hondo on the Harlingen Ship Channel. In addition, industrial chemical companies have distribution centers at Rio Hondo and Port Brownsville.

Precipitation and the flow of the Rio Grande supply a majority of the farmers and ranchers with adequate water of fair quality for domestic and livestock uses, except for periods of prolonged drought that lower the quality of the water. To supplement the supply, some farmers and ranchers excavate pits or "dug-out" ponds to catch precipitation or surface runoff, while others make use of drainage ditches that pass through their pasture or range lands.

Municipal, industrial, recreational, and agricultural water supplies are primarily obtained from the flow of the Rio Grande. These supplies are adequate for present municipal and domestic uses, but during drought periods are not adequate to sustain other uses.

Minor supplemental irrigation and domestic supplies are obtained from ground water. Several municipalities and some small industrial developments use this source. Ground water is generally of very low quality.

Cameron County lies within the geographic region called the Lower Rio Grande Valley. Over hundreds of years, the Rio Grande has changed its course through this delta region, and this meandering has laid down alternating patterns of erosion and deposition, creating numerous channel remnants called "resacas." These resacas are important in the county for their role in water storage for irrigation and collection of local flood runoff.

There are three principal waterways in the county; the Rio Grande, the North Floodway, and the Arroyo Colorado Floodway. The Rio Grande, the sixth largest river in North America, rises in southwestern Colorado and flows generally towards the southeast almost 1,900 miles to the Gulf of Mexico. Along its lower 1,250 miles below El Paso, the river forms the border between the United States and Mexico. At various locations, the boundary has been stabilized by construction of reservoirs, installation of bank protection, and other similar means.

City of Brownville: Brownsville, the southernmost City in Texas, contains 21 square miles within its corporate limits. The population in 2010 was 175,023 (Reference 10). Brownsville is county seat of Cameron County and is located across the Rio Grande from Matamoros, Tamaulipas, at the southernmost tip of Texas.

The designated flooding areas throughout the city abound with commercial, industrial and residential developments. Some crop lands and pasture lands are subject to inundations in the northern areas of the city. In addition many city streets, state highways, and public utilities cross through the flooding areas.

Municipal, industrial, recreational, and agricultural water supplies are chiefly obtained from the flows of the Rio Grande. These supplies are adequate for the present municipal and domestic uses, but during drought periods, are not adequate for the other uses.

City of Harlingen: The City of Harlingen is situated approximately 225 miles south of San Antonio and 325 miles southwest of Houston. It is located at the junction of two railroad lines, the Southern Pacific and the Missouri Pacific, and the intersection of two major highways, U.S. Routes 77 and 83. The corporate area of the city is about 34 square miles.

As a pioneer developer of the Lower Rio Grande Valley, Lon C. Hill, Sr. came to the area in 1900 and purchased 41,000 acres of land from owners of the King Ranch, where the City of Harlingen is now located. Mr. Hill was instrumental in making possible the construction of the St. Louis, Brownsville, and Mexico Railroad (now part of the Missouri Pacific System) into the Valley in 1904. The railroads' plans provided for the establishment of a townsite near the point where the railroad would cross the Arroyo Colorado. The City of Harlingen was incorporated there in 1910.

The population of the City of Harlingen was only 1,783 in 1920, but it grew to 12,124 during the ensuing 10 years. In 1960, the census was 41,207 and the City of Harlingen ranked as the second largest city in the Valley. With the closing of Harlingen Air Force Base in 1963, a population decline occurred and the 1970 census showed 33,503 inhabitants. The city has fully recovered from the loss and the January 1978 population of the City was 45,800 (Reference 12). In 2000, the community had 57,564 inhabitants and 2,549 businesses (Reference 11). The population in 2010 was 64,849 (Reference 10).

Topography of the area ranges from flat to rolling. The steeper slopes occur in the rough and broken areas adjacent to the Arroyo Colorado. Homes have been constructed on some of these areas on steeper slopes. Elevations range from about 45.7 feet NAVD88 in the center of the City of Harlingen to about zero feet NAVD88 in the bottom of the Arroyo Colorado.

Town of Laguna Vista: Laguna Vista is on State Highway 100 and Farm Road 510 twenty miles east of San Benito and five miles northwest of Port Isabel overlooking Laguna Madre in eastern Cameron County. The community was settled in the early 1800s by Mexican salt traders who transported salt through the region to northern Mexico. Ranchers followed the traders, and eventually a community was formed. In July 1958 the citizens of the community voted forty-four to zero to incorporate. By 1983 the estimated population of Laguna Vista was 632 and 1,166 in 1992. The population in 2010 was 3,117 (Reference 10).

City of Port Isabel: The Port Isabel area was settled by Mexican ranchers by 1770. In the 1840's Port Isabel became a port-of-entry for westbound California goldseekers. For a short time after the port was deepened in the 1930's, it was oil and cotton shipping center, but much of its shipping was diverted after completion of the deepwater port at Brownsville. While shipping is still an active enterprise, Port Isabel now serves mainly as a resort and fishing city.

In 1980, Port Isabel had an estimated population of 3,603 and 155 businesses. During the 1980s the town continued to attract tourists. Recreational opportunities included fishing, boating, and hunting. In 1989 the port handled 263,335 short tons of cargo. In 1990 Port Isabel had a population of 4,467 and a school, although the number of businesses had declined. The town continued to support itself from the shrimping and fishing industry as well as the tourist industry. The population in 2010 was 5,006 (Reference 10).

The City of Port Isabel is a tidewater community on a headland projecting into Laguna Madre and connected to the mainland only by State Highway 100. This island-like structure is an extension of low coastal plains forming the mainland to the west. The city

is protected from the open sea by elongated natural barrier islands-South Padre and Brazos Islands. It is linked to the sea through Brazos Santiago Pass, an inlet to the Gulf of Mexico.

Port Isabel is on the point where Texas Highway 100 meets the Laguna Madre in southeastern Cameron County, sixteen miles northeast of Brownsville. The City of Port Isabel is bordered on the north and east by the open water of Laguna Madre, a shallow bay of the Gulf of Mexico. To the south is Port Isabel Channel and to the west are tidal sand and mudflats with shallow, meandering saltwater channels. The Brownsville Ship Channel and the Intracoastal Waterway meet at Port Isabel. Natural land elevations within the corporate limits range from 0 feet mean sea level (msl) to about 20 feet msl. Most of the land lies between elevations 5 and 15 msl. The city has commercial establishments along the main thoroughfares and residential developments along the secondary streets.

City of Rio Hondo: The City of Rio Hondo is situated approximately 225 miles south of San Antonio and 315 miles southwest of Houston, in Cameron County. It is on the banks of the Arroyo Colorado, about 8 miles northeast of Harlingen. The corporate area of the town is about 1.5 square miles.

The City is about fifty years old and is a key point on the barge canal going from the Intracoastal Waterway to the Port of Harlingen. Several oil companies and other industrial firms maintain warehouses in Rio Hondo. However, agriculture is the mainstay of the area's economy.

The population of Rio Hondo was approximately 1,200 in 1980 (Reference 13). The population in 2010 was 2,356 (Reference 10). Most residential areas are located in the center of the city, along the Arroyo Colorado or in the eastern section (Reference 13). Other land uses along the stream include cropland, rangeland, and beaches or mud flats.

Topography of the area ranges from flat to rolling. The steeper slopes occur in the rough and broken areas adjacent to the Arroyo Colorado. Elevations range from about 29.7 feet NAVD88 in the center of Rio Hondo to about 13.7 feet NAVD88 in the bottom of the Arroyo Colorado.

City of San Benito: The City of San Benito is located in the Lower Rio Grande Valley, in Cameron County, on the southern Texas Gulf Coast. The corporate limits occupy approximately 11.2 square miles and borders Harlingen on the southwest.

Residential development is scattered throughout the corporate limits. According to the U.S. Census Bureau, the population of San Benito decreased from 16,422 in 1960 to 15,176 in 1970 (Reference 14). The population in 2010 was 24,250 (Reference 10).

The City of San Benito has no rivers or major drainage channels in or immediately around the corporate limits, which provide for stormwater drainage. The Resaca Los Fresnos which meanders through the city is actually controlled as a reservoir. Water, pumped from the banks of the Rio Grande, is stored within the levees of the Resaca at an elevation greater than the surrounding land. The water is released as necessary and flows by gravity for irrigation farming.

The original study of Resaca Los Fresnos assumed that the water level within the Resaca is maintained below levee flood stages and that no structural failure of the levees occurs. However, these levees do not have certification to provide flood protection as required by FEMA.

City of Santa Rosa: Santa Rosa is at the intersection of Farm Road 506 and State Highway 107, six miles north of La Feria. The corporate limits of Santa Rosa occupy approximately 0.6 square miles and are situated approximately 9 miles northwest of Harlingen, Texas. (Reference 11)

The majority of the residential development is located in the western portion of the corporate limits of the west of F.M. 506. According to the U.S. Census Bureau, the population of Santa Rosa decreased from 1,572 in 1960 to 1,466 in 1970 (Reference 14). The population in 2010 was 2,873 (Reference 10).

No rivers or major drainage channels exist in or immediately around the corporate limits. Drainage is impeded by a relatively flat topography. Throughout the county, the terrain slopes toward the Gulf of Mexico at about 1.0 foot per mile.

City of South Padre Island: South Padre Island is a resort community on Park Road 100 at the southernmost tip of Padre Island in Cameron County. It is flanked on three sides by the Gulf of Mexico, Brazos Santiago Pass, and the Laguna Madre. Brownsville is eighteen miles southwest. (Reference 11)

The City of South Padre Island is located in southern Texas, on the southern tip of South Padre Island, in Cameron County. It is bordered by the unincorporated areas of Cameron County. The land area of the city is approximately 1.8 square miles, of which 65 percent is devoted to low-density residential use. Most residences are along the coast in this resort community. High-rise condominiums, hotels, apartment complexes, commercial buildings, and canals designed for pleasure boating have also been constructed in South Padre Island. The population was 350 in 1970, and increased to 1,677 by 1990 (References 15 and 16, respectively). The population in 2010 was 2,816 (Reference 10). The economy of the city is based on residential land development and tourism.

2.3 Principal Flood Problems

Three factors that contribute to inland flooding in Cameron County are topography, soils, and development. The region's flat topography combined with regions of relatively high alluvial deposits left over from the migration of the Rio Grande cause bowl-like features in the topography called resacas. These resacas fill up with water during large rainfall events and result in large areas of flooding. Second, there is an abundance of clay-rich soils throughout the area that inhibits water from being infiltrated. Sheet flow and poor drainage facilities contribute to flooding in the form of backups behind elevated ditches, elevated canals, levees, roads, blocked culverts, and other obstructions to natural drainage ways. These manmade obstructions block natural flows and cause inundation of large areas. The built-up floodwater dissipates into canals and drainage ditches and eventually drains into the floodways, the Laguna Madre, or other natural storage areas. Finally, perhaps the largest issue compounding the flooding problem, particularly in Brownsville, is rapid development and growth. This type of rapid growth increases the drainage density and further reduces the already minimal soil permeability, resulting in higher runoff peaks and volumes (Reference 17).

Shallow flooding can occur as a result of runoff from heavy local rains which coincide with flood flows on the Rio Grande. Under these circumstances, the Arroyo Colorado receives diversion floodwaters from the Rio Grande and the resulting high water levels in the Arroyo Colorado make it necessary to close sluice gates on the local drainage structure outlets. Without an outlet, the local drainage channels back-up and overflow creating shallow flooding conditions over large areas.

Within Cameron County, the North Floodway and the Arroyo Colorado are part of the interior U. S. Floodway System, which is operated by the International Boundary and Water Commission. This floodway system is comprised of reservoirs, dams, levees, flow-ways, and flow diversion structures. The purpose of the system is to divert the tremendous flood discharges of the Rio Grande into a series of floodways in the U.S. and Mexico and to safely transport the floodwaters to Laguna Madre and the Gulf of Mexico.

Flood-producing storms can occur in the county at any time of the year. These usually are caused by local storms of high intensity. Wide-spread flooding is associated with storm covering a large area and with heavy rainstorms that accompany hurricane. Major floods occurred in 1955, 1957, and 1958, and 1961 (Hurricane Carla), 1967 (Hurricane Beulah), 1980 (Hurricane Allen), 1982, 1984, 1987, 1988 (Hurricane Gilbert), 1999 (Hurricane Bret), 2005 (Hurricane Emily), 2007, 2008 (Hurricane Dolly), 2010 (Hurricane Alex and Tropical Storm Hermine).

Cameron County is susceptible to tropical cyclones.Tropical cyclones are accompanied by high winds, high tides, large waves, and usually heavy rainfall. Cyclonic winds result from the low central pressure of the tropical storm which drains the air toward the center in a spiral pattern. When the wind speeds reach 75 mph, the tropical cyclone is designated a hurricane. When these winds blow over the shallow offshore shelf, water is driven shoreward where it "piles up." This piling up of water is referred to as storm surge. The total hurricane storm surge consists of a rise in the water level caused by the wind stress and an increase in elevation from the reduction in atmospheric pressure in the storm center, all superimposed on the local astronomical tide. Wind-driven waves, which accompany the surge, can add significantly to its effect, but are not included in storm surge computations.

The high winds, while exceedingly damaging in themselves, are not as destructive in low coastal areas as are waves and currents produced by the wind, inundation resulting from high surges, and the battering effects of debris carried by storm induced currents. The surges caused by tropical cyclones vary considerably, depending on the size and intensity of the storm and the relative location of the center of the cyclone.

Storms in 1857 and 1867 hit the Texas coast in the Cameron County area. During July and August 1913, three hurricanes crossed the southern Texas coastal area. The first, in early July, caused a 5-foot storm surge along the Cameron County shoreline; the second, in early August, caused a 4.5-foot storm surge; and the last, in late August, crossed the coast at Port Isabel, causing an 11-foot surge and 12 million dollars in damages (Reference 18).

In 1967, the Lower Rio Grande Valley was hit with a storm that presented a severe test to the structural integrity of the U. S. Floodway System. Hurricane Beulah produced winds and rainfall that were unprecedented for the region. At the head of the valley (150 miles west of Brownsville), a river discharge of 220,000 cubic feet per second (cfs) was recorded. Of this, 126,000 cfs were diverted into the U. S. Floodway System. Due to a structural failure on the Main Floodway, near Mercedes, the 126,000 cfs were divided equally between the North Floodway and the Arroyo Colorado. This amount was in excess of the design capacity for the Arroyo Colorado, and resulted in the flooding of 1,600 residences and other structures at Harlingen. Eight thousand people were evacuated from Harlingen and 20,000 acres of highly productive agricultural land were inundated. Flood flows in the North Floodway and the Rio Grande did not exceed top-of-levee stages (Reference 18).

Torrential rains from Hurricane Beulah (as much as 30 inches in less than one week), caused runoff that inundated 630,000 acres of coastal lowlands as it reached elevations of approximately 7.5 feet. The winds from Hurricane Beulah reached speeds of greater than 120 miles per hour and 115 tornadoes were spawned by the hurricane. Due to lack of natural drainage-ways and the saturation of the ground, standing water was in evidence for several weeks. It caused damage to roads, interfered with traffic, and created a health hazard. A total of 29 counties in southern Texas were declared disaster areas as a result of Hurricane Beulah (Reference 18).

A significant source of major flooding in the county is caused by tidal surge and wave attack. Tidal surge is a flooding condition resulting from a rise in coastal waters. The rise itself is usually not accompanied by a velocity hazard. Wave attack is a condition that does not include velocity hazards. It is created by wind and air pressure acting on surge depths. Tidal surge and wave attack during Hurricane Beulah destroyed property at all developed coastal and inland coastal areas. South Padre Island, Laguna Vista, Port Isabel, and the Brownsville and Harlingen turnarounds all suffered severe damage to harbor facilities, boats (both pleasure and commercial craft), resort facilities, and residential structures (Reference 18).

Hurricane Beulah was considered to be approximately a 1-percent-annual-chance storm. Flooding damage to Cameron County can occur from storms far less severe than Hurricane Beulah, which could create much shallow flooding and ponding damage to agricultural areas.

Damages to the county attributable to the 1967 storm have been estimated as follows: by tidal overflow - 0.8 million dollars; by wind and wind-driven rain - 19 million dollars; and by flooding from floodways and inadequate drainage - 16 million dollars, for a total of almost 16 million dollars (Reference 18). Total damages from Hurricane Beulah over the four-county area of the Lower Rio Grande Valley were estimated at 82 million dollars.

Hurricane Allen began as a low-pressure system over West Africa and became the season's first hurricane on Sunday, August 3, 1980. Before making landfall near Brownsville one week later, the storm had churned its way from the Caribbean Sea to the coast of Texas as a Category 5 hurricane, the most severe classification. The storm suddenly weakened just hours before it moved inland. However, it was still strong enough to cause almost 300 million dollars in damage and to alter the landscape for years. Hundreds of families in coastal communities and inland towns lost their homes to the wind and surge, or suffered severe flood damage from the torrential rains accompanying the storm. Nine counties in southern Texas were declared major disaster areas (Reference 19).

From September 16 to 19, 1984 heavy rains, some exceeding 20 inches, fell on the lower Rio Grande Valley. Cameron County experienced the worst flooding since Hurricane Beulah in 1967. It was estimated that more than 50 percent of the eastern one-half of Cameron County was underwater (Reference 17).

Hurricane Bret made landfall in Kenedy County, approximately 30 miles north of Cameron County, as a category 4 storm on August 23, 1999. A storm surge of up to 8.8 feet was reported along the south Texas coast. The heavy rains accompanying the storm caused notable river flooding in the Rio Grande Valley. South Padre Island reported 3.88 inches of rainfall during the storm. Total damage from the storm was estimated at $60 million (Reference 20).

Table 4, "Historical High-Water Mark Elevations," at the end of this section, shows elevations of significant historic floods at selected locations, in feet NAVD88 (References 18, 19, and 21).

Table 4: Historical High-Water Mark Elevations

Event	City of Port Isabel	City of South Padre Island	Town of Laguna Vista	Port Brownsville	Mouth of Arroyo Colorado	Boca China
Storm September 14, 1919	7.7		7.7			
Storm July 1933	4.7		4.7			
Storm August 4, 1933	4.2		4.2			
Storm September 4, 1933	10.7		10.7			
Storm August 25, 1945	2.7		2.7			
Hurricane Carla September 12, 1961	4.1	4.9	4.1	3.5, 4.0, 3.1		
Hurricane Beulah September 20, 1067	6.0	7.1, 4.2	6.0	7.7	5.0	7.2
Hurricane Celia August 3, 1970	2.7		2.7			
Hurricane Allen August 9, 1980	7.3	5.6	8.1			5.6
Hurricane Gilbert September 16, 1988	3.4					

City of Brownsville: The City of Brownsville study area is flat, varying in elevation from 20 feet msl on the east to about 35 feet msl on the west. Natural drainage patterns have been significantly altered by construction of elevated irrigation canals, elevated ditches, levees, roads, and railroads throughout the City.

In 1967 Hurricane Beulah struck the lower Rio Grande Valley and produced winds and rainfall quantities unprecedented for the region. Extensive local flooding was experienced from sheet flows and ponding conditions in Brownsville. Water buildups occurred behind elevated canals, ditches, roads and other obstructions to natural drainageways. Flooding in the Rio Grande did not exceed top of levee stages. Total damages inflicted to the City of Brownsville from Hurricane Beulah (including wind damage) have been estimated at $835,000.

The 2006 Brownsville Flood Protection Plan identifies the main source of flooding in Brownsville as the inadequacy of the two main man-made ditches (Cameron County Drainage District No. 1 Ditch No. 1 and North Main Drain) to drain excess runoff during storm events. Other flood-prone areas located away from the main channels are a result of an inadequate secondary drainage system, but are identified as a lower priority (Reference 17).

City of Harlingen: The City of Harlingen is very fortunate in that flooding is not a wide spread problem. The main storm season for the area extends from June to October (hurricane season). During these times, intense rainfall may occur for short periods of time, with an associated quick rise in the water depth of a stream. This situation may cause some road flooding, but major flood damages have not typically been suffered.

The lack of severe flooding conditions in the City of Harlingen is attributable to the upstream control of flow in the Arroyo Colorado. The Arroyo Colorado flow is a regulated amount of the flow of the Rio Grande. There are some minor ponding upstream of structures across the three tributaries to the Arroyo Colorado.

Road flooding is caused primarily by inadequate drainage. At some locations, flooding levels are increased due to limited carrying capacity of stream culverts. During storm events, trees, trash, and other debris may be washed away and carried downstream, collecting on bridges and obstructing stream flow.

The accumulation of debris greatly reduces the capacity of bridges and culverts increasing flooding into unpredictable areas, increasing velocity of flow immediately downstream, and eroding culvert entrances and bridge approach embankments. During hurricane Beulah, however, the North Floodway diversion structure failed and flooding above the 1-percent-annual-chance flood level occurred. The water level at the Missouri Pacific Railroad reached about 40 feet. The computed 1-percent-annual-chance flood level is about 23 feet. There have been no reports of shallow flooding in the City of Harlingen. Since the occurrence and amount of debris are indeterminate factors, only the physical characteristics of the stream and its structures were considered in the previous studies for Harlingen.

City of Port Isabel: A large part of Port Isabel is subject to inundation by abnormally high tides. State Highway 100, the only road leading inland from Port Isabel, is also subject to inundation by storm tides which can isolate the city from the remainder of the mainland.

Port Isabel is subject to flooding from storm tides affecting the Laguna Madre, an extension of the Gulf of Mexico. The most severe floods result from tropical cyclones which are most likely to occur during the months of June through September. However, Port Isabel is subject to some flooding from abnormally high storm tides during any season.

City of Rio Hondo: Rio Hondo is very fortunate in that flooding is not a wide-spread problem. The main storm season for the area extends from June to October (hurricane season). During these times, intense rainfall may occur for short periods of time, with an associated quick rise in the water depth of a stream. This situation may cause some road flooding, but major flood damages have not typically been suffered.

The lack of severe flooding conditions in Rio Hondo is attributable to the upstream control of flow in the Arroyo Colorado. Road flooding is caused primarily by inadequate drainage. During storm events, trees, trash, and other debris may be washed away and carried downstream, collecting on bridges and obstructing stream flow. The accumulation of debris greatly reduces the capacity of bridges and culverts, increasing flooding into unpredictable areas, increasing velocity of flow immediately downstream, and eroding culvert entrances and bridge approach embankments. Since the occurrence and amount of debris are indeterminate factors, only the physical characteristics of the stream and its structures were considered in the previous study for Rio Hondo.

City of San Benito: Following Hurricane Beulah, several isolated areas within the city were subjected to shallow flooding. The instances of shallow flooding were caused by the combination of heavy rains and insufficient drainage resulting in several areas of ponding.

Some of the sites in the central portion of the city that did exhibit shallow flooding were between two and six square blocks. These areas are not low elevations receiving

excessive runoff from adjoining areas and would not be subject to shallow flooding if sufficient local drainage ditches or storm sewers were available.

The remaining isolated sites which exhibited flooding from Hurricane Beulah are on the northern, southern, and western sides of the city and are natural low areas. One area is of a residential nature, one is agricultural, and one surrounds a drainage channel.

City of South Padre Island: The principal flooding sources for the City of South Padre Island are the Gulf of Mexico and Laguna Madre. The South Padre Island area has suffered damage from hurricanes, as described above.

2.4 Flood Protection Measures

Within this jurisdiction, there are one or more levees that have not been demonstrated by the communities or levee owner to meet the requirements of 44CFR65.10 of the NFIP regulations as it relates to the levee's capacity to provide 1-percent-annual-chance flood protection. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information.

The flood flows that accompanied Hurricane Beulah created a substantial test for the IBWC floodway systems of the United States and Mexico in the Cameron County area. As a result, shortcomings in the two systems were recognized and the need for improvements became apparent.

Studies made in 1968 and agreed upon by the United States and Mexico recommended a new design flood having a peak discharge of 250,000 cfs at the head of the valley. After allowance for reductions in peak discharge due to channel storage, and for the Rio Grande capacity at Brownsville-Matamoros (Mexico) (20,000 cfs), each country planned to divert one-half or 105,000 cfs of the design flood.

Modifications to the IBWC U. S. Floodway System as a consequence of the 1968 studies consisted of raising levees where necessary along the Rio Grande, Main, and North Floodways; removing floodway restrictions; construction of a new Hackney Inlet to divert floodwaters from the Rio Grande into a section of what will be the new entrance to the U. S. system; improving the existing Hackney Floodway; closing Mission Floodway; and construction of Retamal Dam (55 miles west of Brownsville).

To assure that protection would be provided to all developments along the Arroyo Colorado and particularly to the City of Harlingen, the 1968 plan for project improvements also included dividing the United States' 105,000 cfs design flood portion so that four-fifths of the flow (84,000 cfs) would go to the North Floodway and one-fifth (21,000 cfs) would go to the Arroyo Colorado. The 21,000 cfs amount to be diverted to the Arroyo Colorado is the discharge criterion for this floodway that was originally developed in 1962. This discharge will have a stage 10.8 feet lower at the U. S. Route 83 bridge in Harlingen than the 1967 flood stage (Reference 22).

The modified floodway system provides a higher degree of protection to municipalities, irrigated farms, transportation facilities, mineral resources, and distribution facilities of irrigation districts. Of course, some damages could occur if a future flood substantially exceeds the design flood.

Prior to 1965, flood control measures in Cameron County on the local level focused only on small areas. In 1965, Cameron County commissioned the necessary engineering surveys, locations or relocations, designs, and cost estimates for a system of multiple-purpose main drains and major laterals required to reduce damages caused by floodwater, salinity, and inadequate drainage, and to furnish outlets for removal of excess water for

all of Cameron County. There were two purposes of this design study. The first was to help finance the improvements. The second was to furnish the Soil Conservation Service with the necessary engineering information required for the development of three watershed work plans, to include all of Cameron County. This new system was designed to provide adequate drainage for a 5-year, 24-hour storm. The system is able to only minimally handle storms of greater severity.

Local drainage canals collect rainfall runoff from adjacent areas and discharge into the Floodway System. Canals that drain into the Main and North Floodways through the levees have gated structures. These must be closed infrequently when large floodwater diversions are being made from the Rio Grande. This is beneficial in preventing inundation from Rio Grande floodwaters, but can create sizable local runoff buildups behind the levees.

Finally, land use on the inland side of the levees is such that floodwaters will be relatively unrestricted; the land is used primarily for recreation and agriculture. In urban areas, such as at Brownsville, development has occurred in past decades on the land side of the levees, with the levees providing protection. Agricultural usage between the river and the levees does not include homes or other buildings other than irrigation district pumping plants that are flood-proofed.

Due to the structural modifications in the U. S. Floodway System, future flood patterns will be significantly different from those experienced in the past. Based upon experience from the 1967 storm and subsequent system improvements, this report assumes that no structural failures will occur in the floodway system during future major floods. On the basis of this assumption, and given that local runoff cannot enter the floodways, flow entering the county by the Floodway System will not contribute to flooding in the study area.

City of Brownsville: A Flood Protection Plan was developed for the City of Brownsville in 2006 (Reference 17). The purpose of this plan was to develop a flood protection plan for the main drainage systems within the City of Brownsville. The proposed plan included both structural and non-structural options. It is designed to reduce the extent and depth of the floodplain within the planning area in a cost-effective manner in addition to preventing a worsening of flooding conditions as development in the area ensues. Among the recommendations of this plan was the creation of a regional drainage control agency with taxing authority to focus responsibility, accountability and authority at a single point. Another recommendation included the development of technically based drainage ordinances to control the unregulated impact of future developments in a cost-effective and consistent manner across the entire watershed system. The recommended structural options mainly included the construction of detention ponds, especially multi-use detention ponds. In some areas where detention ponds alone were not adequate to cost-effectively limit flooding, channel modifications including widening and concrete lining of drainage ditches were recommended.

City of Harlingen: The City of Harlingen has no major structures which are intended solely for flood control. Flow in the Arroyo Colorado is controlled by the North Floodway diversion structure.

City of Port Isabel: There are no flood protection works existing, planned, or under construction for the City of Port Isabel. However, ordinances passed by the City Council of Port Isabel require that a protective device, barrier, shoreway or seawall be installed, erected or constructed at waterside by landowners to protect and prevent the washing

away of lots in Port Isabel. These improvements provide some safety from frequent smaller storms, but do not provide protection from major storms.

City of Rio Hondo: Rio Hondo has no major structures which are intended solely for flood control. The City Council of Rio Hondo has adopted a Flood Hazard Prevention Ordinance, Number 128.

City of San Benito: The City of San Benito has no major structural facilities which are intended primarily for flood control. Storm sewers and drainage ditches transport stormwater out of the corporate limits to the north and east. The local drainage capabilities were sufficient to handle almost all of the stormwater associated with Hurricane Beulah, except as previously noted. Since that time, considerable improvements have been made to the underground drainage system. The drainage improvements have increased the capacity and rate at which stormwater is drained from the city. The improvements also provided increased drainage capacity in areas under new development.

The City of San Benito has specific ordinances regarding development in flood prone areas. Industrial/commercial development must be constructed above the base flood elevation. Residential development is not allowed within the 1-percent-annual-chance floodplain.

City of Santa Rosa: The City of Santa Rosa has no major structural facilities which are intended primarily for flood control. Drainage ditches transport stormwater out of the corporate limits to the North Floodway located approximately 4 miles north of the city. The local storm drainage system is not capable of handling the significant volumes of water associated with a major storm and therefore, provide only partial drainage, due to insufficient depth and capacities. Additionally, when major storms coincide with flooding of the Rio Grande, the North Floodway is used for diversion of Rio Grande floodwaters and therefore eliminates the only major drainage system available to Santa Rosa.

The City of Santa Rosa does not directly monitor or control land development within the corporate limits.

City of South Padre Island: Many individual bulkheads exist along the gulf side of South Padre Island but do not form a continuous barrier. Several non-structural measures also exist. The community has an evacuation plan for use in the event of an approaching hurricane. This plan and other precautionary measures are widely publicized. In addition, floodplain zoning regulations specify that the first floor of structures must be elevated above the 1-percent-annual-chance flood level.

3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods 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-annual-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 1-percent-annual-chance (100-year) flood in any 50-year period is approximately 40 percent (4 in 10); 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.

Note: Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner to meet the requirements of 44CFR65.10 as it relates to the levee's capacity to provide 1-percent-annual-chance flood protection. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency relationships for the flooding sources studied in detail affecting the county. Many of the incorporated communities within, and the unincorporated areas of Cameron County, had a previously printed FIS report. The hydrologic analyses described in those reports have been compiled and are summarized below.

Previous Approximate Studies

For the approximate studies in Cameron County, the county was initially divided into ten sub-watersheds defined by the topography. Each sub-watershed was then partitioned into five to fifteen individual areas for study. For the City of Brownville, the city was divided into three sub-watersheds defined by the topography. Each sub-watershed was then partitioned into individual areas for study.

For each area of study, rainfall-runoff relationships were determined for various frequencies and durations. Rainfall data were obtained from U. S. Weather Bureau Technical Paper No. 40 (Reference 23). The percent chance of occurrence of meteorological events was determined using probability paper.

Runoff flows for each of the storms considered were determined by use of the Cypress Creek formula, Q=CM5/6, with appropriate corrections to convert removal rates to peak discharge where Q = required capacity in cfs, C = drainage coefficient, and M = drainage area in square miles (Reference 24). This technique was developed for specific use in estimating flood peak flow rates from flatland areas. Flatland is defined as land where the natural surface drainage is inadequate.

Values of "C" for input into the formula were derived for cropland, urban areas, and range land areas. These values were determined using the Stephens and Mills formula, C = 16.39 + 14.75R, where "R" is rainfall excess in inches (Reference 24).

No hydrologic analysis was made for the drainage basin of the Rio Grande. Due to available regulation, stage maximums in the Rio Grande and North Floodway should not go over the tops of levees, and stage maximums in the Arroyo Colorado should not go over the tops of banks for a 0.2-percent-annual-chance flood event.

Previous Detailed Studies

The Cypress Creek formula was also used to determine the stream flows in Tributaries 1-3 to Arroyo Colorado in the City of Harlingen.

There are no gages on any of the tributaries to the Arroyo Colorado. Therefore, several standard methodologies that are generally accepted for engineering studies in Texas were

used for determination of flood flows at ungaged stream locations. Stream flow values for the Arroyo Colorado were obtained from the International Boundary and Water Commission (United States Section) (Reference 25).

For shallow flooding in the Cities of San Benito and Santa Rosa, detailed analyses were carried out to establish and delineate the extent of shallow flooding for floods of the selected recurrence interval.

Peak discharge-drainage area relationships for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods for each stream studied by detailed methods are presented in Table 5 – Summary of Discharges."

For this first time countywide FIS

For this study, alternative regional regression equations were used to estimate peak discharges for the hydrologic analyses (Reference 26). These equations were derived based on minimization of the PRESS (Prediction Error Sum of Squares) statistics and power transformation of the drainage area.

Peak discharge-drainage area relationships for the 10-, 2-, 1-, and 0.2-percent-annual-chance floods for each stream studied by detailed methods are presented in Table 5 – Summary of Discharges."

Table 5: Summary of Discharges

		PEAK DISCHARGES (cfs)			
FLOODING SOURCE AND LOCATION	**DRAINAGE AREA (sq. miles)**	**10%-ANNUAL-CHANCE**	**2%-ANNUAL-CHANCE**	**1%-ANNUAL-CHANCE**	**0.2%-ANNUAL-CHANCE**
ARROYO COLORADO	(1)	2,000	6,000	13,000	21,000(2)
CAMERON COUNTY DRAINAGE DITCH #1					
At a point approximately 2.75 miles downstream from State Highway 48	23.58	2,360	3,506	4,236	5,525
At Old Port Isabel Road	12.68	1,445	2,095	2,497	3,222
At a point approximately 0.04 miles downstream of U.S. Highway 77/83 (3)	5.62	1,445	2,095	2,497	3,222
MAIN DITCH NO. 2					
At a point approximately 1.72 miles downstream of Old Port Isabel Road	65.24	*	*	4,530	*
At a point approximately 0.25 miles upstream of FM 1847 (3)	31.86	*	*	2,884	*

(1) Flow in the Arroyo Colorado is a regulated amount that is diverted from the Rio Grande; therefore, drainage area is not applicable.
(2) 21,000 cfs is the design storm value (143 years return period) used by the International Boundary and Water Commission (Reference 25).
(3) This stream or point lies within an area that has not been updated on the FIMR at this time due to the presence of levees that have not yet been demonstrated to meet the requirements of NFIP Regulation Section 65.10. Please refer to the Notice to Flood Insurance Study Users page at the front of the FIS for more information.
* Data not available.

Table 5: Summary of Discharges (continued)

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10%-ANNUAL-CHANCE	2%-ANNUAL-CHANCE	1%-ANNUAL-CHANCE	0.2%-ANNUAL-CHANCE
NORTH MAIN DITCH [1]					
At confluence with Resaca De La Palma	5.36	998	1,325	1,540	1,904
At a point approximately 0.32 miles downstream of Southmost Road	3.88	850	1,133	1,314	1,625
At a point approximately 0.28 miles downstream of International Boulevard	1.53	505	659	754	928
At U.S. Highway 77/83	0.70	240	292	325	385
PAREDES TRACK DRAINAGE DITCH [1]					
At a point approximately 2.22 miles downstream of San Jose Road	7.23	610	1,098	1,350	2,077
At a point approximately 1.52 miles upstream of San Jose Road	1.70	185	302	360	526
RESACA DE LA PALMA – BASIN 1 [1]					
At a point approximately 0.11 miles downstream of Southmost Road	0.24	*	*	33	[1]
RESACA DE LA PALMA – BASIN 3 [1]					
At a point approximately 0.1 miles downstream of Brownie Avenue	0.12	*	*	23	[1]
RESACA LOS CUATES [1]					
At a point approximately 1.14 miles downstream of FM 1847	4.13	143	211	243	332
At FM 1575	2.88	121	178	206	281
At a point approximately 158 feet downstream of FM 803	2.11	75	104	118	156
RESACA LOS FRESNOS [1]					
At a point approximately 2.98 miles downstream of State Highway 345	2.51	*	*	175	*

[1] This stream or point lies within an area that has not been updated on the FIMR at this time due to the presence of levees that have not yet been demonstrated to meet the requirements of NFIP Regulation Section 65.10. Please refer to the Notice to Flood Insurance Study Users page at the front of the FIS for more information.

* Data not available.

Table 5: Summary of Discharges (continued)

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10%-ANNUAL-CHANCE	2%-ANNUAL-CHANCE	1%-ANNUAL-CHANCE	0.2%-ANNUAL-CHANCE
RESACA RANCHO VIEJO [1]					
At a point approximately 6.8 miles downstream of FM 1732	51.61	*	*	2,078	*
At a point approximately 4.11miles downstream of FM 1732	38.55	*	*	1,263	*
At a point approximately 1.1 miles upstream of FM 1421	29.21	*	*	1,489	*
SAN BENITO CANAL #2 [1]					
At a point approximately 0.11 miles downstream of FM 732	3.98	*	*	426	*
TRIBUTARY 1 TO ARROYO COLORADO	1	340	450	510	650
TRIBUTARY 2 TO ARROYO COLORADO	1.85	395	525	595	760
TRIBUTARY 3 TO ARROYO COLORADO	1.45	330	440	500	640

[1] This stream or point lies within an area that has not been updated on the FIMR at this time due to the presence of levees that have not yet been demonstrated to meet the requirements of NFIP Regulation Section 65.10. Please refer to the Notice to Flood Insurance Study Users page at the front of the FIS for more information.

* Data not available.

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. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS report in conjunction with the data shown on the FIRM.

Cross sections were determined from topographic maps and field surveys. All bridges, dams, and culverts were field surveyed to obtain elevation data and structural geometry. All topographic mapping used to determine cross sections are referenced in Section 4.1.

The hydraulic analyses for all studies were based on unobstructed flow. The flood elevations shown on the Flood Profiles (Exhibit 1) are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). Flood profiles were drawn showing computed water surface elevations to an accuracy of 0.5 feet for floods of the selected recurrence intervals. For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the FIRM (Exhibit 3).

Channel and overbank roughness factors (Manning's "n") used in the hydraulic computations were estimated by engineering judgment and based on field observation at each cross section and adjusted with known high-water marks and stream gage rating curves where possible (Reference 27). Table 6, "Manning's "n" Values", shows the channel and overbank "n" values for the streams studied by detailed methods.

Table 6: Manning's "n" Values

STREAM	CHANNEL "N" VALUE	OVERBANK "N" VALUE
Arroyo Colorado	0.025-0.050	0.035-0.090
Cameron County Drainage Ditch #1	0.027-0.085	0.035-0.127
Main Ditch No. 2	0.035	0.05-0.07
North Main Ditch	0.033-0.040	0.058-0.073
Paredes Track Drainage Ditch	0.030-0.053	0.040-0.063
Resaca De La Palma	0.040	0.132
Resaca Los Cuates	0.027	0.078
Resaca Los Fresnos	0.035-0.049	0.045-0.055
Resaca Rancho Viejo	0.030-0.046	0.072-0.14
San Benito Canal #2	0.045	0.055
Tributary 1 to Colorado Arroyo	0.025-0.050	0.035-0.090
Tributary 2 to Colorado Arroyo	0.025-0.050	0.035-0.090
Tributary 3 to Colorado Arroyo	0.025-0.050	0.035-0.090

For each community within Cameron County that has a previously printed FIS report, the hydraulic analyses described in those reports have been compiled and are summarized below.

Previous Studies

Due to available flow regulation, peak discharges for all frequency flows should not exceed top-of-levee stage for the Rio Grande, the North Floodway, or the Arroyo Colorado. No study was made to determine water-surface elevations in these waterways, and because there are no defined drainage channels outside of the regulated floodways, no water-surface profiles were provided for the previous study.

For all areas subject to flood flows, stage-discharge relationships were computed by use of Manning's formula (Reference 27) for all approximate studies. This formula was applied to controlling sections at varying intervals along the drainage ways. Roughness coefficients for input into Manning's formula were estimated on the basis of field inspection and engineering judgment.

Ponding depths for small flooding areas were determined through the use of the double end area method (Reference 24). In most instances involving standing water, some combination of Manning's and volumetric methods was employed to determine flooding depths.

In the undeveloped areas north of the North Floodway, flooding extents were based upon past flooding histories. This flooding is created by buildups behind the levees, not from flows over the levees.

For the Arroyo Colorado, water-surface elevations of floods were developed using the HEC-2 computer step-backwater model (Reference 28). The starting water-surface elevation for the Arroyo Colorado was determined by the slope-area method, calibrated to existing high water marks. Starting water-surface elevations for Tributaries 1, 2, and 3 to Arroyo Colorado were determined from the Arroyo Colorado backwater curve.

For the shallow flooding studied in the Cities of San Benito and Santa Rosa, the Hurricane Beulah report (Reference 18) was accepted as initially depicting the areas of 1-percent-annual-chance flood inundation. Field reconnaissance, interviews, local input, and other existing data provided further information of a more specific nature. These data, combined with recorded high water marks and field surveys determined the actual and potential NAVD88 elevations of shallow flooding for the 1-percent-annual-chance flood event. The combined data was evaluated along with the prior FHBM to identify flood hazard zone designations and base flood elevations or average depths of inundation, to the nearest whole foot, wherever applicable

Countywide Study

For this countywide study, the new hydraulic analyses were conducted for Cameron County Drainage Ditch #1, and Main Ditch No. 2. These analyses were conducted using Watershed Information SystEm (WISE) and HEC-RAS software (References 29 and 30).

3.3 Coastal Analysis

The hydraulic characteristics of coastal flood sources were analyzed to provide estimates of flood elevations for selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown in the coastal data tables and flood profiles provided in the FIS Report.

3.3.1 Storm Surge Analysis and Modeling

For areas subject to coastal flood effects, the 10-, 2-, 1-, and 0.2-percent-annual-chance stillwater elevations were taken directly from a detailed storm surge study documented in Flood Insurance Study: Coastal Counties, Texas Intermediate Submission 2 – Scoping and Data Review prepared by the U.S. Army Corps of Engineers (USACE) (Reference 31). This storm surge study was completed in November 2011.

The Advanced Circulation (ADCIRC) model for coastal ocean hydrodynamics developed by the USACE was applied to calculate stillwater elevations for coastal Texas. The ADCIRC model uses an unstructured grid and is a finite element long wave model. It has the capability to simulate tidal circulation and storm surge propagation over large areas and is able to provide highly detailed resolution in areas of interest along shorelines, open coasts and inland bays. It solves three dimensional equations of motion, including tidal potential, Coriolis, and non-linear terms of the governing equations. The model is formulated from the depth-averaged shallow water equations for conservation of mass and momentum which result in the generalized wave continuity equation.

In performing the coastal analyses, nearshore waves were required as inputs to wave runup and overland wave propagation calculations, and wave momentum (radiation stress) was considered as contribution to elevated water levels (wave setup). The Steady State Spectral Wave (STWAVE) model was used to generate and transform waves to the

shore for the Texas Joint Storm Surge (JSS) Study. STWAVE is a finite difference model that calculates wave spectra on a rectangular grid. The model outputs zero-moment wave height, peak wave period (Tp), and mean wave direction at all grid points and two-dimensional spectra at selected grid points. STWAVE includes an option to input spatially variable wind and storm surge field. Storm surge significantly alters wave transformation and generation for the hurricane simulations in shallow-flooded areas.

STWAVE was applied on five grids for the Texas JSS: NE, CE, SW, NEn, and CEn. Three large grids (NE, CE, SW) with offshore boundaries at depths near 100 feet (30 meters) encompassed the entire coast of Texas and applied the efficient half-plane version of STWAVE (which must approximately align with the shoreline). Two nested grids (NEn and CEn) covered Galveston Bay and Corpus Christi Bay and applied the fullplane version of STWAVE to allow generation of wind waves in all directions. Notably, memory requirements for the full-plane model precluded its use for the large grids with offshore boundaries. The input for each grid includes the bathymetry (interpolated from the ADCIRC domain), surge fields (interpolated from ADCIRC surge fields), and wind fields (interpolated from the ADCIRC wind fields, which apply land effects to the base wind fields). The wind and surge applied in STWAVE are spatially and temporally variable for all domains. STWAVE was run at 30-minute intervals for 93 quasi-time steps (46.5 hours).

The ADCIRC model computational domain and the geometric/topographic representation developed for the Joint Coastal Surge effort was designated as the TX2008 mesh. This provided a common domain and mesh from the Texas-Mexico border to western Louisiana, extends inland across the floodplains of Coastal Texas (to the 30- to 75-foot contour NAVD88), and extends over the entire Gulf of Mexico to the deep Atlantic Ocean. The TX2008 domain boundaries were selected to ensure the correct development, propagation, and attenuation of storm surge without necessitating nesting solutions or specifying ad hoc boundary conditions for tides or storm surge. The TX2008 computational mesh contains more than 2.8 million nodes and nodal spacing varies significantly throughout the mesh. Grid resolution varies from approximately 12 to15 miles in the deep Atlantic Ocean to about 100 ft. in Texas. Further details about the terrain data as well as the ADCIRC mesh creation and grid development process can be found in *Flood Insurance Study: Coastal Counties, Texas Intermediate Submission 2 – Scoping and Data Review* (Reference 31).

3.3.2 Statistical Analysis

The Joint Probability Method (JPM) is a simulation methodology that relies on the development of statistical distributions of key hurricane input variables such as central pressure, radius to maximum wind speed, maximum wind speed, translation speed, track heading, etc., and sampling from these distributions to develop model hurricanes. The resulting simulation results in a family of modeled storms that preserve the relationships between the various input model components, but provides a means to model the effects and probabilities of storms that historically have not occurred.

Due to the excessive number of simulations required for the traditional JPM method, the JPM-Optimum Sampling (JPM-OS) was utilized to determine the stillwater elevations associated with tropical events. JPM-OS is a modification of the JPM method and is intended to minimize the number of synthetic storms that are needed as input to the ADCIRC model. The methodology entails sampling from a distribution of model storm parameters (e.g., central pressure, radius to maximum wind speed, maximum wind speed, translation speed, and track heading) whose statistical properties are consistent with

historical storms impacting the region, but whose detailed tracks differ. The methodology inherently assumes that the hurricane climatology over the past 60 to 65 years (back to 1940) is representative of the past and future hurricanes likely to occur along the Texas coast.

A set of 446 storms (two sets of 152 low frequency storms + two sets of 71 higher frequency storms) was developed by combining the "probable" combinations of central pressure, radius to maximum winds, forward speed, angle of track relative to coastline, and track. Tracks were defined by five primary tracks and four secondary tracks. Storm parameters for synthetic storms are provided in Table 11 of *Flood Insurance Study: Coastal Counties, Texas Intermediate Submission 2 – Scoping and Data Review* (Reference 31). The estimated range of storm frequencies using the selected parameters was between the 10%- and 0.2%-annual-chance storm events. The ADCIRC-STWAVE modeling system was validated using five historic storms: Hurricanes Carla (1961), Allen (1980), Bret (1999), Rita (2005), and Ike (2008).

3.3.3 Stillwater Elevations

The results of the ADCIRC model and JPM-OS provided 10-, 2-, 1-, and 0.2-percent-annual-chance stillwater elevations which include wave setup effects. Stillwater elevations are assigned at individual ADCIRC mesh nodes throughout the Texas coast. Triangular Irregular Networks (TINs) and raster datasets were built from these nodes for use in wave analysis and floodplain mapping.

An Independent Technical Review (ITR) was performed on the overall storm surge study process. This review process was performed in accordance with USACE regulations. The ITR team was composed of experts in the fields of coastal engineering and science, and was engaged throughout the study. Appendix K of *Flood Insurance Study: Coastal Counties, Texas Intermediate Submission 2 – Scoping and Data Review* includes all comments received from the ITR panel, as well as responses to those comments (Reference 31).

3.3.4 Wave Height Analysis

Using storm surge study results, wave height analysis was performed to identify areas of the coastline subject to overland wave propagation or wave runup hazards. Figure 1, "Transect Schematic," shows a cross section for a typical coastal analysis transect, illustrating the effects of energy dissipation and regeneration of wave action over inland areas. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Figure 1 also illustrates the relationship between the local stillwater elevations, the ground profile, and the location of the VE/AE Zone boundary at the limit of 3 ft. breaking waves. This inland limit of the coastal high hazard area is delineated to ensure that adequate insurance rates apply and appropriate construction standards are imposed, should local agencies permit building in this coastal high hazard area. Actual wave conditions in Cameron County may not necessarily include all the situations illustrated in Figure 1.

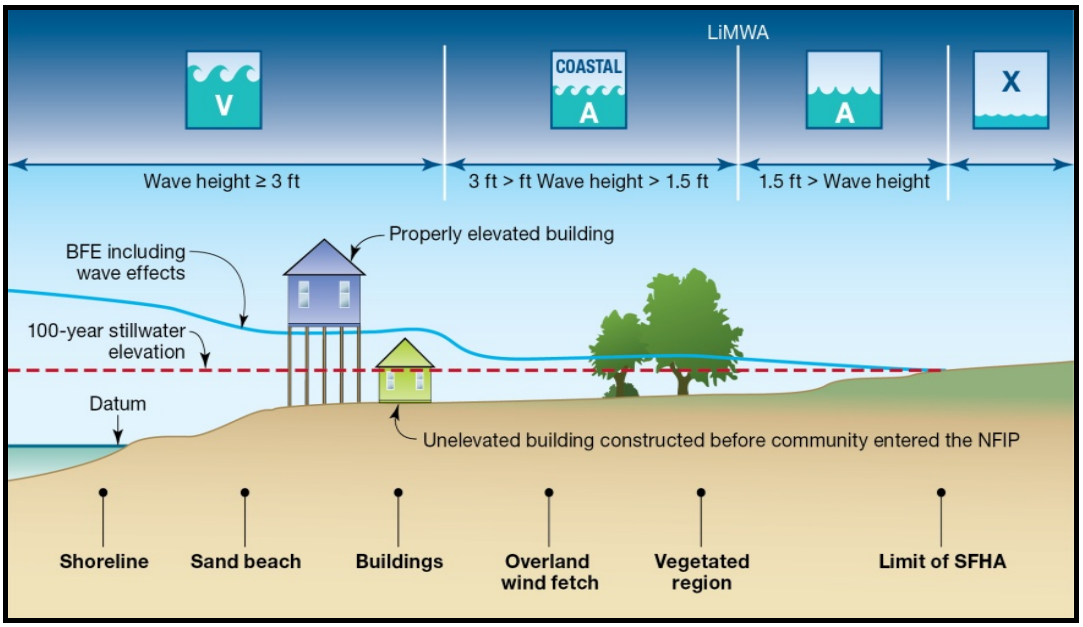


Figure 1: Transect Schematic

It has been shown in laboratory tests and observed in field investigations that wave heights as little as 1.5 feet can cause damage to and failure of typical Zone AE construction. Therefore, for advisory purposes only, a Limit of Moderate Wave Action (LiMWA) boundary has been added in coastal areas subject to wave action. The LiMWA represents the approximate landward limit of the 1.5-foot breaking wave.

The effects of wave hazards in the Zone AE between the Zone VE (or shoreline in areas where VE Zones are not identified) and the limit of the LiMWA boundary are similar to, but less severe than, those in Zone VE where 3-foot breaking waves are projected during a 1-percent-annualchance flooding event.

In areas where wave runup elevations dominate over wave heights, such as areas with steeply sloped beaches, bluffs, and/or shore-parallel flood protection structures, there is no evidence to date of significant damage to residential structures by runup depths less than 3 feet. However, to simplify representation, the LiMWA was continued immediately landward of the VE/AE boundary in areas where wave runup elevations dominate. Similarly, in areas where the Zone VE designation is based on the presence of a primary frontal dune or wave overtopping, the LiMWA was also delineated immediately landward of the Zone VE/AE boundary.

Hydraulic analyses, considering storm characteristics and the shoreline and bathymetric characteristics of the coastal flooding sources studied, were carried out to provide estimates of the elevations of floods of selected recurrence intervals along each of the shorelines.

As of 1989, FEMA defines a “coastal high hazard area” as an area of special flood hazards extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action (i.e., wave heights greater than or equal to 3 feet) from storms or seismic sources. The “primary frontal dune” is defined as a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. Primary fontal dunes were included in Transects 1 through 36 and

Transects 44 through 50. The inland limit of the primary frontal dune occurs at the point where there is a distinct change from a relatively steep slope to a relatively mild slope. Transects 37 through 43 and 51 through 53 do not have primary frontal dunes.

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 32) This methodology is based on the following 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 prescribed in the User's Manual for Wave Height Analysis. (Reference 33) 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, "Transect Location Map". 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.

Each transect was taken perpendicular to the shoreline and extended inland to a point where wave action ceased. Along each transect wave heights and elevations were computed considering the combined effects of changes in ground elevations, vegetation, and physical features. The topographic information utilized was obtained from Light Detection and Ranging (LiDAR) from the Texas Water Development Board (Reference 34). Additionally which was collected from 2005-2006, bathymetric data provided by Arcadis and comprised primarily of the National Ocean Service's (NOS) Estuarine Bathymetry was incorporated for coastal analyses. For areas outside of the coverage of the LiDAR data set, the best topographic data available was determined to be Digital Elevation Models (DEMs) obtained from the U.S. Department of Agriculture Geospatial Data Gateway Server. The data sets consisted of a DEM of 30-meter or better data.

The land-use and land cover data were obtained through field reconnaissance and aerial photographs. Wave heights were calculated to the nearest 0.1 foot, and wave crest elevations were determined at whole-foot increments along the transects.

FEMA's coastal guidelines required modelers to consider adjustments to transect ground profiles which accounts for storm-induced erosion of sand dune and ridges, including the primary frontal dune. There are no notable coastal structures providing flood protection within Cameron County, so there was no further investigation by MAPVI into potential structural failures. An erosion analysis was conducted for both the 1- and 0.2-percent-annual-chance scenarios along Transects 1 through 36 and Transects 44 through 50, where primary frontal dunes exist.

TRANSECT LOCATION MAP

FEDERAL EMERGENCY MANAGEMENT AGENCY

CAMERON COUNTY, TX
AND INCORPORATED AREAS

FIGURE 2

Wave height calculation used in this study follows the methodology described in the Appendix D of the 2003 FEMA Guidelines and Specifications for Flood Hazard Mapping Partners (Reference 35). WHAFIS 4.0 was used to calculate overland wave height propagation and establish base flood elevations. In addition to the 1-percent-annual-chance event, the 0.2-percent-annual-chance event was also modeled with WHAFIS 4.0. The 0.2-percent wave height results are not included on the FIRMs but are provided as wave transect profiles in this FIS. Stillwater elevations were applied to each ground station along a transect and input to WHAFIS. The stillwater elevations were obtained from the storm surge study at each station where return periods were calculated and values were interpolated between stations to transect locations. Wave setup was not calculated separately because wave setup was included in the base stillwater elevations from the storm surge analysis.

Wave runup was calculated at selected transects where the slope was steeper than 1 on 15. FEMA (2005) "Procedure Memorandum No. 37" (Reference 36) now recommends the use of the 2-percent wave runup for determining base flood elevations. The 2-percent wave runup was determined using the Technical Advisory Committee for Water Retaining Structures (TAW) method (Reference 37) for slopes steeper than 1 on 8 and RUNUP 2.0 was utilized for slopes between 1 on 8 and 1 on 15. For wave runup at the crest of a slope that transitions to a plateau or downslope, runup values were determined using the "methodology for wave runup on a hypothetical slope" as described in Appendix D of the 2003 FEMA Guidelines and Specifications for Flood Hazard Mapping Partners (Reference 35).

Along each transect, wave envelopes were computed considering the combined effects of changes in ground elevation, vegetation, and physical features. The 0.2-percent-annual-chance wave envelopes have been included as Exhibit 2. Between transects, elevations were interpolated using topographic maps, land-use and land-cover data, and engineering judgment to determine the aerial extent of flooding. The results of the calculations are accurate until local topography, vegetation, or cultural developments within the community undergo major changes. The transect data for Cameron County is presented in Table 7, "Coastal Data," where the flood hazard zone and base flood elevations for each transect flooding source is provided. This table also describes the location of each transect and provides the 10-, 2-, 1-, and 0.2-percent-annual-chance stillwater elevations at the start of the transect and the range found along the length of the transect.

The combined effects of the surge plus riverine runoff were determined in accordance with the procedures in the 2007 FEMA Guidelines and Specifications for Flood Hazard Partners – Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update (Reference 38). The combined probability was determined graphically at lettered cross sections for affected streams. The probability was used to map the water surface elevations that would tie-in between the riverine and coastal flooding.

Table 7 - Coastal Data

Community Name	Transect	Description	Latitude & Longitude at Start of Transect	Starting Stillwater Elevations (feet NAVD 88) Range of Stillwater Elevations (feet NAVD 88)				Zone Designation and BFE (feet NAVD 88)
				10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
Cameron County	1	Willacy County / Cameron County Boundary	(26.388762, -97.218329)	4.4 2.5-4.4	7.8 3.6-7.8	9.8 4.5-9.8	13.0 7.1-13.0	VE 8-14 AE 5-11
Cameron County	2	South Padre Island to North Cameron County	(26.368789, -97.213334)	4.4 2.3-4.4	7.7 3.5-7.7	9.2 4.9-9.2	12.9 7.3-12.9	VE 8-14 AE 5-11
Cameron County	3	South Padre Island to North Cameron County	(26.097728, -97.161779)	3.5 2.8-3.5	6.4 3.3-6.5	9.8 3.9-9.8	15.0 6.9-15.0	VE 9-15 AE 4-11
Cameron County	4	South Padre Island to North Cameron County	(26.358692, -97.211409)	4.3 2.1-4.3	7.7 2.7-7.7	9.0 5.9-9.0	12.9 6.0-12.9	VE 9-14 AE 7-10
Cameron County	5	South Padre Island to North Cameron County	(26.348147, -97.207882)	4.3 2.3-4.3	7.7 2.9-7.7	9.8 6.4-9.8	12.8 5.5-13.6	VE 9-15 AE 7-11
Cameron County / City of Port Isabel	6	South Padre Island to North Cameron County	(26.323801, -97.201362)	4.3 2.8-4.3	7.6 2.9-7.6	9.3 3.0-9.3	12.8 4.3-12.8	VE 8-14 AE 3-11
Cameron County / City of Port Isabel	7	South Padre Island to Laguna Atascosa	(26.29881, -97.195633)	4.3 2.8-4.3	7.6 2.8-7.6	9.4 3.3-9.4	12.7 5.1-12.7	VE 8-14 AE 3-11
Cameron County / City of Port Isabel	8	South Padre Island to Laguna Atascosa	(26.274807, -97.190095)	4.3 2.9-4.3	7.5 2.7-7.5	9.6 3.6-9.6	12.6 4.6-17.0	VE 9-15 AE 4-11
Cameron County / City of Port Isabel	9	Ocean Blvd to General Brant Rd	(26.249723, -97.184939)	4.2 2.9-4.2	7.5 4.5-7.5	9.7 5.6-9.8	12.5 7.2-13.9	VE 8-15 AE 6-11
Cameron County / City of Port Isabel	10	Ocean Blvd to General Brant Rd	(26.22236, -97.179735)	4.2 2.8-4.2	7.4 4.0-7.4	8.7 5.3-8.7	12.5 7.0-12.5	VE 8-13 AE 5-10
Cameron County / City of Port Isabel / City of Brownsville	11	Ocean Blvd to Ted Hunt Rd	(26.201325, -97.176626)	4.2 2.8-4.2	7.4 3.9-7.4	9.0 5.3-9.5	12.4 6.9-13.6	VE 8-14 AE 5-11
Cameron County / City of Port Isabel	12	Ocean Blvd to Laguna Madre	(26.172002, -97.172924)	4.2 2.8-4.2	7.4 4.1-7.4	9.4 5.8-9.4	12.5 7.5-12.5	VE 8-14 AE 6-11
Cameron County / City of Port Isabel / City of Brownsville	13	Ocean Blvd to Ted Hunt Rd	(26.167052, -97.171805)	4.2 2.9-4.2	7.4 4.6-7.4	8.5 6.2-11.0	12.5 7.0-18.0	VE 8-13 AE 7-11
Cameron County / City of Port Isabel / City of South Padre Island	14	Ocean Blvd to Laguna Madre	(26.160272, -97.171064)	4.2 3.1-4.2	7.4 4.6-7.4	9.3 5.5-9.3	12.4 7.6-13.6	VE 8-14 AE 6-11
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville	15	Ocean Blvd to Ted Hunt Rd	(26.153811, -97.169976)	4.2 2.3-4.2	7.4 4.3-7.4	9.3 6.3-10.7	12.4 7.1-15.5	VE 9-14 AE 7-11
Cameron County / City of South Padre Island	16	Padre Blvd near White Sands to Laguna Madre	(26.147258, -97.169225)	4.2 3.2-4.2	7.4 5.3-7.4	9.2 6.2-9.2	12.5 7.6-13.7	VE 11-14 AE 6-11
Cameron County / City of South Padre Island	17	Padre Blvd near Villa Doce Dr to Laguna Madre	(26.141051, -97.16862)	4.2 3.1-4.2	7.4 4.9-7.4	8.7 6.3-8.7	12.4 8.1-13.6	VE 10-13 AE 7-10
Cameron County / City of South Padre Island	18	Padre Blvd near Sunset Dr to Laguna Madre	(26.134815, -97.167757)	4.2 3.3-4.2	7.4 4.3-7.4	9.1 5.9-9.1	12.4 8.2-13.6	VE 9-15 AE 6-13

Table 7 - Coastal Data (Cont'd)

Community Name	Transect	Description	Latitude & Longitude at Start of Transect	Starting Stillwater Elevations (feet NAVD 88) Range of Stillwater Elevations (feet NAVD 88)				Zone Designation and BFE (feet NAVD 88)
				10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista	19	Gulf Blvd near Coronado to FM 510	(26.13139, -97.167102)	4.2 2.7-4.2	7.4 4.2-7.4	9.1 5.8-10.1	12.4 7.5-13.9	VE 9-14 AE 6-12
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista /City of Bayview	20	Gulf Blvd near Georgia Ruth Dr to FM 2480	(26.128359, -97.166633)	4.2 2.7-4.2	7.4 4.2-7.4	8.9 5.8-10.8	12.5 7.6-15.3	VE 9-14 AE 6-13
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista /City of Bayview	21	Gulf Blvd near Capricorn Dr to FM 2480	(26.125152, -97.166137)	4.2 2.9-4.2	7.4 4.2-7.4	8.5 5.8-11.0	12.5 7.8-14.7	VE 9-14 AE 6-12
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista /City of Bayview	22	Gulf Blvd near Venus Ln to FM 2480	(26.121695, -97.165631)	4.2 3.0-4.2	7.4 4.0-7.4	9.0 5.9-11.3	12.5 8.0-15.3	VE 9-14 AE 6-12
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista /City of Bayview	23	Gulf Blvd near Oleander St to FM 2480	(26.11816, -97.164977)	4.2 2.8-4.2	7.4 4.2-7.5	9.5 6.1-11.5	12.5 8.2-15.5	VE 9-15 AE 6-12
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista /City of Bayview	24	Gulf Blvd near Atol St to FM 2480	(26.114597, -97.164431)	4.1 3.5-4.1	7.4 4.1-7.4	9.5 5.9-9.8	12.5 8.3-14.0	VE 9-15 AE 6-11
Cameron County / City of Port Isabel / Town of South Padre Island / City of Brownsville / Village of Laguna Vista	25	Gulf Blvd near Kingfish St to FM 1847	(26.110486, -97.163804)	4.1 2.5-4.1	7.4 4.0-7.4	9.4 6.4-9.4	12.5 8.2-13.3	VE 9-14 AE 6-11
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista	26	Gulf Blvd near Amberjack St to Los Fresnos	(26.107352, -97.163393)	4.1 3.3-4.1	7.4 4.4-7.4	9.2 5.9-9.2	12.5 8.7-13.1	VE 9-14 AE 6-11
Cameron County / City of South Padre Island	27	Gulf Blvd near Tarpon St to Laguna Madre	(26.103621, -97.162736)	4.1 3.7-4.1	7.4 4.4-7.4	9.2 6.0-9.2	12.5 9.0-12.5	VE 10-14 AE 6-10
Cameron County / City of South Padre Island	28	Gulf Blvd near Palm St to Laguna Madre	(26.101082, -97.162294)	4.1 3.7-4.1	7.4 4.5-7.4	9.3 6.8-9.3	12.5 8.3-13.3	VE 11-14 AE 7-11
Cameron County / City of South Padre Island	29	Gulf Blvd near Haas St to Laguna Madre	(26.094457, -97.161273)	4.1 3.4-4.1	7.3 5.7-7.5	9.3 7.3-9.3	12.4 8.4-13.2	VE 11-14 AE 8-11

Table 7 - Coastal Data (Cont'd)

Community Name	Transect	Description	Latitude & Longitude at Start of Transect	Starting Stillwater Elevations (feet NAVD 88) Range of Stillwater Elevations (feet NAVD 88)				Zone Designation and BFE (feet NAVD 88)
				10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville / Village of Laguna Vista	30	Padre Blvd north of SH 100 to SH 100	(26.090721, -97.160488)	4.1 3.7-4.1	7.3 3.1-7.3	9.2 3.9-9.2	12.4 6.7-13.3	VE 10-14 AE 4-11
Cameron County / City of South Padre Island	31	Padre Blvd at SH 100 to Laguna Madre	(26.087264, -97.159188)	4.1 3.8-4.1	7.3 5.0-7.3	9.2 5.7-9.2	12.4 9.1-12.7	VE 11-14 AE 6-11
Cameron County / City of Port Isabel / City of South Padre Island	32	Padre Blvd south of SH 100 to SH 100	(26.083951, -97.15841)	4.1 3.6-4.2	7.4 3.9-7.4	9.1 6.1-9.1	12.4 9.6-12.7	VE 10-14 AE 6-11
Cameron County / City of Port Isabel / City of South Padre Island	33	Padre Blvd south of SH 100 to SH 48	(26.081301, -97.158356)	4.1 2.6-4.3	7.7 4.8-7.7	9.7 6.3-9.8	13.4 8.5-13.4	VE 10-15 AE 6-12
Cameron County / City of Port Isabel / City of South Padre Island / City of Brownsville	34	Padre Blvd to inland of Port Isabel	(26.078433, -97.157651)	4.0 3.4-4.1	7.5 3.2-7.5	9.6 4.2-9.6	13.2 6.5-13.2	VE 6-15 AE 4-11
Cameron County / City of Port Isabel	35	Isla Blanca Park to Port Rd	(26.074423, -97.156618)	4.1 3.3-4.1	7.4 5.4-74	9.1 6.1-9.1	12.4 8.7-13.4	VE 10-14 AE 6-10
Cameron County / City of Port Isabel	36	Isla Blanca Park to Port Rd	(26.071268, -97.155439)	4.2 3.6-4.2	7.5 5.0-7.5	9.1 6.5-9.1	12.4 9.4-12.6	VE 10-14 AE 7-11
Cameron County / City of Port Isabel	37	SH 100 near Madison St to SH 4	(26.082177, -97.25557)	4.2 2.1-4.6	5.7 3.6-7.7	8.7 5.6-10.5	11.9 8.9-13.9	VE 8-13 AE 5-12
Cameron County / City of Port Isabel	38	SH 100 near Lincoln St to SH 4	(26.079929, -97.246111)	4.2 4.2-4.5	6.9 3.7-8.4	8.7 5.2-12.3	11.5 8.6-16.3	VE 8-15 AE 5-14
Cameron County / City of Port Isabel	39	N Shore Dr near 3rd St to inland of Port Isabel	(26.078341, -97.227065)	4.2 3.5-4.2	6.8 5.1-6.8	8.2 6.2-8.5	10.8 9.6-12.0	VE 10-12 AE 6-11
Cameron County / City of Port Isabel	40	N Shore Dr near 1st St to inland of Port Isabel	(26.078636, -97.220302)	4.1 4.1-4.3	6.7 5.6-7.1	8.3 6.6-8.9	10.5 8.7-12.0	VE 10-13 AE 7-11
Cameron County / City of Port Isabel	41	N Shore Dr near Gomez St to inland of Port Isabel	(26.079058, -97.213286)	4.1 3.6-4.2	6.6 5.0-6.8	8.1 5.1-8.6	10.3 8.8-11.5	VE 10-12 AE 5-10
Cameron County / City of Port Isabel	42	Houston St and Tarnava Dr to inland of Port Isabel	(26.078613, -97.208486)	4.1 3.6-4.1	6.5 5.1-6.8	7.9 7.7-8.4	10.1 9.7-11.6	VE 10-12 AE 8-10
Cameron County / City of Port Isabel	43	Queens Point Dr and Adams St to inland of Port Isabel	(26.077043, -97.201404)	4.1 3.5-4.2	6.5 3.6-7.2	8.1 6.4-9.0	10.1 9.5-12.2	VE 10-12 AE 6-11
Cameron County / City of Port Isabel / City of Brownsville	44	South of the Brownsville Ship Channel Jetty to inland of Port Isabel	(26.062255, -97.151464)	4.1 3.5-4.4	7.2 2.7-7.3	9.2 3.6-9.3	12.2 5.6-12.7	VE 7-14 AE 4-11

Table 7 - Coastal Data (Cont'd)

Community Name	Transect	Description	Latitude & Longitude at Start of Transect	Starting Stillwater Elevations (feet NAVD 88) Range of Stillwater Elevations (feet NAVD 88)				Zone Designation and BFE (feet NAVD 88)
				10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
Cameron County / City of Port Isabel / City of Brownsville	45	South of the Brownsville Ship Channel Jetty to Old Port Isabel Rd	(26.045579, -97.152273)	4.1 3.6-4.3	7.3 3.2-7.4	9.1 5.4-9.2	12.5 8.1-12.5	VE 8-14 AE 6-11
Cameron County / City of Brownsville	46	Brazos Island State Park to Old Port Isabel Rd	(26.014971, -97.151759)	4.1 2.5-4.6	7.4 3.4-7.8	9.2 5.7-11.0	12.7 9.4-14.6	VE 9-14 AE 6-11
Cameron County	47	SH 4 to SH 48	(25.990974, -97.149452)	4.1 3.6-5.0	7.4 5.5-8.4	9.7 6.4-11.6	12.8 9.9-15.0	VE 10-15 AE 7-13
Cameron County / City of Brownsville	48	South of SH 4 to FM 511	(25.982228, -97.148623)	4.1 3.3-5.1	7.4 5.5-8.7	9.8 8.2-12.4	12.9 11.5-15.9	VE 10-16 AE 8-14
Cameron County / City of Brownsville	49	South of SH 4 to FM 511	(25.973479, -97.147776)	5.0 3.3-5.3	8.2 4.4-9.1	9.2 6.3-12.2	13.1 10.4-17.3	VE 11-14 AE 6-14
Cameron County	50	Cameron County / Mexico Boundary	(25.960138, -97.146592)	4.1 3.5-4.1	7.5 6.0-7.5	9.7 8.5-9.7	13.2 10.9-13.2	VE 11-15 AE 9-12
Cameron County / City of South Padre Island	51	Laguna Madre to the Gulf of Mexico near E Hibiscus St	(26.115612, -97.17342)	3.2 3.2-4.2	5.4 4.4-7.4	6.8 6.0-9.3	9.3 8.7-12.5	VE 9-10 AE 6-10
Cameron County / City of South Padre Island	52	Laguna Madre to the Gulf of Mexico south of SH 100	(26.081514, -97.168564)	3.9 3.9-4.1	6.4 4.1-7.4	7.7 7.2-9.4	9.8 8.5-13.5	VE 10-12 AE 8-10
Cameron County / City of South Padre Island	53	Laguna Madre to the Gulf of Mexico north of White Sands	(26.144689, -97.178347)	3.2 3.2-4.2	5.4 4.4-7.4	6.3 6.3-9.3	8.2 8.2-13.6	VE 9 AE 7-10

3.4 Vertical Datum

All FIS reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum used for newly created or revised FIS reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the finalization of the NAVD88, many FIS reports and FIRMs are now prepared using NAVD88 as the referenced vertical datum.

Flood elevations shown in this FIS report and on the FIRM are referenced to the NAVD88. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. Some of the data used in this revision were taken from the prior effective FIS reports and FIRMs and adjusted to NAVD88. This may result in differences in base flood elevations (BFEs) across the county boundaries between the counties.

To accurately convert flood elevations for Cameron County from the prior NGVD29 to the current NAVD88 datum, the following procedure was implemented. Coordinate points were obtained for the county, and were converted using the NGS Corpscon software version 6 (Reference 39). The conversion factor from NGVD29 to NAVD88 in Cameron County is – 0.32 feet.

For additional information regarding conversion between the NGVD29 and NAVD88, visit the National Geodetic Survey website at http://www.ngs.noaa.gov, or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey, SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282

To obtain current elevation, description, and/or location information for benchmarks shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov.

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. Therefore, each FIS provides 1-percent-annual-chance (100-year) flood elevations and delineations of the 1- and 0.2-percent-annual-chance (500-year) floodplain boundaries and 1-percent-annual-chance floodway to assist communities in developing floodplain management measures. This information is presented on the FIRM and in many components of the FIS report, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevations tables. Users should reference the data presented in the FIS report as well as additional information that may be available at the local map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent-annual-chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent-annual-chance flood is employed to indicate additional areas of flood risk in the community. For each stream studied by detailed methods, the 1- and 0.2-percent-annual-chance floodplain boundaries have been delineated using the flood elevations determined at each cross section.

Between cross sections for previous studies in the City of Harlingen, the boundaries were interpolated using standard 7.5 minute U.S. Department of the Interior, Geological Survey quadrangles enlarged to a scale of 1" = 1,000’ with a contour interval of five feet (Reference 40). Between cross sections for previous studies in the City of Rio Hondo, the boundaries were interpolated using standard 7.5 minute U.S. Department of the Interior, Geological Survey quadrangles enlarged to a scale of 1" = 600' with a contour interval of 5 feet (Reference 41).

Between cross sections for this countywide study, the boundaries of the 1-percent-annual-chance flood have been delineated using the flood elevations determined during field surveys and interpolation of 1-foot contours derived from LiDAR data collected from 2005-2006 (Reference 34).

For the coastal areas of Cameron County, the inland limit of the 1-percent-annual-chance floodplain and the location of the Zone VE/Zone AE boundary have been adjusted, as appropriate, using new elevation data obtained for producing the updated FIRM panels. The inland limit of the VE zone has been adjusted as appropriate based on the definitions for the coastal high hazard area in 44 Code of Federal Regulation (CFR) 59.1.

The 1- and 0.2-percent-annual-chance floodplain boundaries are shown on the FIRM (Exhibit 3). On this map, the 1-percent-annual-chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, AH, AO, and VE), and the 0.2-percent-annual-chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent-annual-chance floodplain boundaries are close together, only the 1-percent-annual-chance 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.

For the streams studied by approximate methods, only the 1-percent-annual-chance floodplain boundary is shown on the FIRM (Exhibit 3).

Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner to meet the requirements of 44CFR65.10 of the NFIP regulations as it relates to the levee’s capacity to provide 1-percent-annual-chance flood protection. As such, the floodplain boundaries in this area were taken directly from the previously effective FIRMs and are subject to change. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information on how this may affect the floodplain boundaries shown on the FIRM.

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 NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management.

Under this concept, the area of the 1-percent-annual-chance 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 1-percent-annual-chance flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1 foot, provided that hazardous velocities are not produced. The floodways in this FIS are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this FIS report and on the FIRM were computed for certain stream segments on the basis of equal-conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations have been tabulated for selected cross sections (Table 8, "Floodway Data"). The computed floodways are shown on the FIRM (Exhibit 3). In cases where the floodway and 1-percent-annual-chance floodplain boundaries are either close together or collinear, only the floodway boundary has been shown.

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage and heightens potential flood hazards by further increasing velocities. A listing of stream velocities at selected cross sections is provided in Table 8. To reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway.

The area between the floodway and 1-percent-annual-chance 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 1-percent-annual-chance flood more than 1 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 3. Along streams where floodways have not been computed, the community must ensure that the cumulative effect of development in the floodplains will not cause more than a 1.0-foot increase in the BFEs at any point within the county.

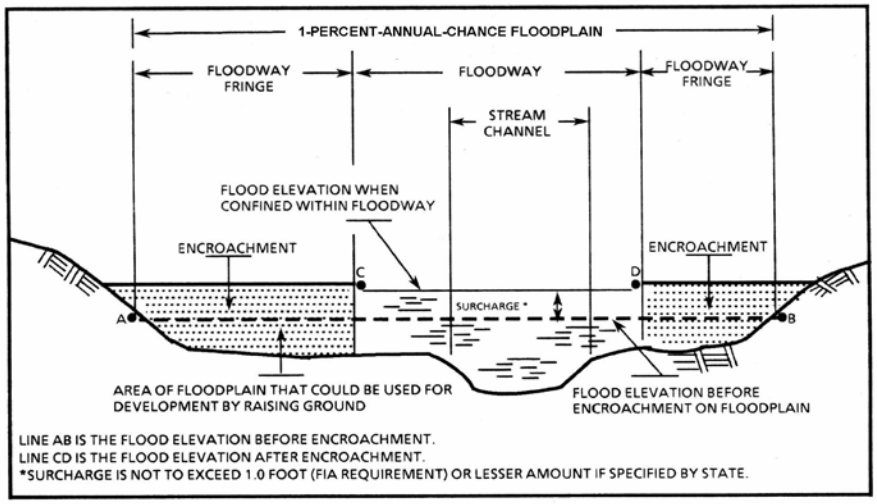


Figure 3: Floodway Schematic

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	**DISTANCE**	**WIDTH (FEET)**	**SECTION AREA (SQUARE FEET)**	**MEAN VELOCITY (FEET PER SECOND)**	**REGULATORY**	**WITHOUT FLOODWAY**	**WITH FLOODWAY**	**INCREASE**
Arroyo Colorado[3]								
A	123,900[1]	295	7,470	1.7	14.3	14.3	15.2	0.9
B	127,200[1]	265	6,750	1.9	14.4	14.4	15.3	0.9
C	128,470[1]	285	7,305	1.8	14.5	14.5	15.5	1.0
D	131,860[1]	300	8,550	1.5	14.6	14.6	15.6	1.0
E	171,260[1]	255	3,665	3.5	20.2	20.2	21.0	0.8
F	174,140[1]	230	3,815	3.4	21.3	21.3	22.0	0.7
G	176,035[1]	190	3,735	3.5	22.0	22.0	22.7	0.7
H	178,660[1]	205	3,570	3.6	22.5	22.5	23.2	0.7
I	180,580[1]	230	4,100	3.1	23.4	23.4	24.0	0.6
J	183,280[1]	130	2,825	4.6	23.7	23.7	24.3	0.6
K	184,780[1]	255	4,640	2.8	24.1	24.1	24.7	0.6
L	188,600[1]	205	4,085	3.2	25.6	25.6	26.2	0.6
M	188,965[1]	205	3,895	3.3	25.8	25.8	26.4	0.6
N	190,065[1]	430	6,505	2.0	26.3	26.3	26.9	0.6
O	191,905[1]	320	5,490	2.4	26.7	26.7	27.3	0.6
P	195,065[1]	195	3,400	3.8	27.5	27.5	28.1	0.6
Tributary 1 to Arroyo Colorado[3]								
A	730[2]	165	1,840	0.3	32.6	32.6	33.6	1.0
B	2,030[2]	245	2,455	0.2	32.6	32.6	33.6	1.0
C	4,230[2]	110	795	0.6	33.0	33.0	33.5	0.5
D	5,130[2]	205	1,600	0.3	33.0	33.0	33.5	0.5

[1]Stream distance in feet above mouth [2]Stream distance in feet above confluence with Arroyo Colorado

[3] This stream lies within an area that has not been updated on the FIRM at this time due to the presence of one or more levees that have not been demonstrated to meet the requirements of 44CFR65.10 of the NFIP regulations. Please refer to the Notice to Flood Insurance Study Users page at the front of the FIS report for more information.

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY

CAMERON COUNTY, TX AND INCORPORATED AREAS

FLOODWAY DATA

ARROYO COLORADO - TRIBUTARY 1 TO ARROYO COLORADO

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE FLOOD WATER-SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	**DISTANCE[1]**	**WIDTH (FEET)**	**SECTION AREA (SQUARE FEET)**	**MEAN VELOCITY (FEET PER SECOND)**	**REGULATORY**	**WITHOUT FLOODWAY**	**WITH FLOODWAY**	**INCREASE**
Tributary 2 to Arroyo Colorado[2]								
A	1,300	55	85	6.9	28.3	28.3	28.3	0.0
B	1,740	60	310	1.9	33.1	33.1	33.1	0.0
Tributary 3 to Arroyo Colorado[2]								
A	900	45	190	2.6	31.9	31.9	32.5	0.6
B	3,910	45	205	2.5	35.5	35.5	38.4	0.9
C	5,630	50	240	2.0	36.6	36.6	37.1	0.5
D	7,055	30	105	4.8	37.9	37.9	38.2	0.3
E	8,095	70	270	1.9	39.8	39.8	40.8	1.0
F	11,215	115	380	1.3	41.1	41.1	41.7	0.6

[1]Stream distance in feet above confluence with Arroyo Colorado

[2] This stream lies within an area that has not been updated on the FIRM at this time due to the presence of one or more levees that have not been demonstrated to meet the requirements of 44CFR65.10 of the NFIP regulations. Please refer to the Notice to Flood Insurance Study Users page at the front of the FIS report for more information.

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY

CAMERON COUNTY, TX AND INCORPORATED AREAS

FLOODWAY DATA

TRIBUTARY 2 TO ARROYO COLORADO - TRIBUTARY 3 TO ARROYO COLORADO

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS report by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base BFEs or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS report by detailed methods. In most instances, whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to areas of 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to areas of 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent-annual-chance floodplain, areas within the 0.2-percent-annual-chance floodplain, areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance flood by levees. No BFEs or depths are shown within this zone.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications. For flood insurance applications, the map designates flood insurance risk zones as described in Section 5.0 and, in the 1-percent-annual-chance floodplains that were studied by detailed methods, shows selected whole-foot BFEs or average depths. Insurance agents use the zones and BFEs in conjunction with information on structures and their contents to assign premium rates for flood insurance policies. For floodplain management applications, the map shows by tints, screens, and

symbols, the 1- and 0.2-percent-annual-chance floodplains, floodways, and the locations of selected cross sections used in the hydraulic analyses and floodway computations.

Within this jurisdiction there are one or more levees that have not been demonstrated by the community or levee owner to meet the requirements of 44CFR65.10 of the NFIP regulations as it relates to the levee's capacity to provide 1-percent-annual-chance flood protection. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information on how this may affect the FIRM.

The current FIRM presents flooding information for the entire geographic area of Cameron County. Previously, separate FHBMs and/or FIRMs were prepared for each incorporated community with identified flood hazard areas and the unincorporated areas of the county. This countywide FIRM also includes flood hazard information that was presented separately on Flood Boundary and Floodway Maps (FBFMs), where applicable. Historical data relating to the pre-countywide maps prepared for each community are presented in Table 9, "Community Map History."

7.0 OTHER STUDIES

Information pertaining to revised and unrevised flood hazards for each jurisdiction within Cameron County has been compiled into this FIS. Therefore, this FIS supersedes all previously printed FIS reports, and FIRMs for all of the incorporated and unincorporated jurisdictions within Cameron County.

This is a multi-volume FIS. Each volume may be revised separately, in which case it supersedes the previously printed volume. Users should refer to the Table of Contents in Volume 1 for the current effective date of each volume; volumes bearing these dates contain the most up-to-date flood hazard data.

FIRMs for the adjacent county of Willacy are concurrently being prepared and will include wave heights. The Willacy County study will be in agreement with this study.

FEMA has conducted updated hydrologic and hydraulic analyses for North Main Ditch, Paredes Track Drainage Ditch, Resaca De La Palma, Resaca Los Cuates, Resaca Los Fresnos, Resaca Rancho Viejo, and San Benito Canal #2. Due to the presence of the non-accredited IBWC levees along the Arroyo Colorado, North Floodway and Rio Grande that have not been demonstrated by the community or levee owner to meet the requirements of 44CFR65.10 of the NFIP regulations as it relates to the levee's capacity to provide 1-percent-annual-chance flood protection, these studies are not shown on the FIRM. Please refer to the Notice to Flood Insurance Study Users page at the front of this FIS report for more information on how this may affect the FIRM.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting FEMA Region VI, Federal Regional and Mitigation Division, 800 North Loop 288, Denton, Texas 76209.

COMMUNITY NAME	INITIAL NFIP MAP DATE	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	INITIAL FIRM DATE	FIRM REVISIONS DATE
Bayview, Town of				
Brownsville, City of	May 24, 1974	July 9, 1976	December 1, 1978	
Cameron County (Unincorporated Areas)	June 15, 1979	None	June 15, 1979	March 9, 1999 May 4, 1992 March 18, 1991 September 15, 1983
Combes, Town of				
Harlingen, City of	June 23, 1972	June 23, 1972	June 23, 1972	August 3, 1981 October 17, 1975 July 1, 1974 July 13, 1972
Indian Lake, Town of*	June 15, 1979	None	June 15, 1979	March 18, 1991 September 15, 1983
La Feria, City of				
Laguna Vista, Town of	July 21, 1972	None	July 21, 1972	September 15, 1983 June 11, 1976 July 11, 1975 July 1, 1974
Los Fresnos, City of	June 7, 1974	March 26, 1976	August 19, 1986	

* All Dates taken from the Unincorporated Areas of Cameron County

TABLE 9

FEDERAL EMERGENCY MANAGEMENT AGENCY

CAMERON COUNTY, TX
AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

COMMUNITY NAME	INITIAL NFIP MAP DATE	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	INITIAL FIRM DATE	FIRM REVISIONS DATE
Los Indios, City of*	June 15, 1979	None	June 15, 1979	September 15, 1983
Palm Valley, City of*	June 15, 1979	None	June 15, 1979	September 15, 1983
Port Isabel, City of	January 16, 1974	None	October 6, 1976	June 1, 1983
Primera, Town of				
Rancho Viejo, Town of*	June 15, 1979	None	June 15, 1979	September 15, 1983
Rangerville, Town of	June 15, 1979	None	June 15, 1979	September 15, 1983
Rio Hondo, City of	May 10, 1974	April 9, 1976	June 1, 1981	
San Benito, City of	November 5, 1976	None	May 5, 1981	January 19, 1982
Santa Rosa, City of	May 17, 1974	April 2, 1976	May 5, 1981	
South Padre Island, City of	June 7, 1974	None	September 15, 1983	March 9, 1999 May 4, 1992 May 2,1991

* All Dates taken from the Unincorporated Areas of Cameron County

TABLE 9

FEDERAL EMERGENCY MANAGEMENT AGENCY

CAMERON COUNTY, TX
AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

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