HMTAP Task Order 18

Mississippi Coastal Analysis Project

Detailed Wave Analysis and Mapping Report (Task 5)

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FEMA

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Task Order 18

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ADCIRC	Advanced Circulation Model for Coastal Ocean Hydrodynamics
AS	Above Surge
BFE	Base Flood Elevations
BU	Building
CHAMP	Coastal Hazard Analysis Modeling Program
DEM	Digital Elevation Model
ET	End of Transect
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
IE	Initial Elevation
IF	Inland Fetch
ITR	Independent Technical Review
JPM	Joint Probability Method
LiDAR	Light Detection and Ranging
LiMWA	Limit of Moderate Wave Action
NAVD88	North American Vertical Datum of 1988
NGLI	Northern Gulf Littoral Initiative
NOAA	National Oceanic and Atmospheric Administration
OF	Open Fetch
PFD	Primary Frontal Dunes
QA/QC	quality assurance/quality control
SWAN	Simulating Waves Nearshore
SWEL	stillwater elevations
TAW	Technical Advisory Committee for Water Retaining Structures
TIN	Triangular Irregular Network
TSDN	Technical Support Data Notebook
WHAFIS	Wave Height Analysis for Flood Insurance Studies
WISE	Watershed Information System

Among the data generated during Task 4 storm surge modeling are 1 percent- and 0.2 percent-annual-chance (100-year and 500-year) stillwater elevations (SWEL) including the effects of wave setup. While these data can be used immediately to delineate 100- and 500-year floodplain boundaries, additional overland wave modeling using the 100-year SWELs is necessary to determine the Base Flood Elevations (BFE) and flood hazard zones (VE and AE) that are depicted on Digital Flood Insurance Rate Maps. A separate analysis of the wave effects for the 500-year SWEL was conducted for this study and prepared as wave profiles for the Flood Insurance Study appendix. However, none of the wave effects for the 500-year SWEL were included in the hazard mapping; only the limit of the 500-year SWEL was used as the standard boundary for the shaded Zone X floodplain.

This report describes the input data, models, analysis methods, and other procedures used to develop digital mapping of flood hazard zones and BFEs for Hancock, Harrison, and Jackson counties. In addition, this report presents any key assumptions or specialized procedures employed during Task 5 that are not expressly covered in the Federal Emergency Management Agency's (FEMA) coastal guidelines. As described herein, additional information is provided in the specified appendices or will be furnished in the Technical Support Data Notebook (TSDN) for the flood study submitted under separate cover.

2.1 GUIDANCE FOR TRADITIONAL COASTAL FLOOD STUDY DELIVERABLES

At the initiation of Task Order 18 in February 2006, the document that governed the requirements and procedures for overland wave modeling and floodplain mapping along the Gulf of Mexico coast was Appendix D of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners,* dated April 2003. In February 2007, FEMA published the *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update* (herein called the *Atlantic/Gulf Guidelines*), which effectively superseded the guidance provided in Appendix D. The update to FEMA's guidelines did not require any alteration of the methods employed in Task 5; in fact, the *Atlantic/Gulf Guidelines* provided important new guidance that aided in completion of the assigned work. The guidance will be described in subsequent subsections of this document.

Like its predecessor, the *Atlantic/Gulf Guidelines* establishes an overall process for overland wave modeling and mapping, including requirements for intermediate data submissions that document the basis and results of coastal flooding analyses during the course of the flood study. For Task 5, this includes the following submissions discussed in Section D.2.12 of the *Atlantic/Gulf Guidelines*:

- Intermediate Submission No. 2 – Offshore Water Levels and Waves, which includes a Proposed Wave Transect Location Map that depicts the location and orientation of transects to be used in the subsequent wave elevation determination analyses. The transect location map(s) should be at a suitable scale and should show transects of sufficient length to account for modeling of all coastal flooding conditions.
- Intermediate Submission No. 3 – Nearshore Hydraulics, which includes erosion, wave runup and overtopping, and overland wave height modeling.
- Intermediate Submission No. 4 – Draft Flood Hazard Mapping, including documentation of the methods used to convert the results of the detailed hydraulic analyses into flood insurance risk zones.

To fulfill FEMA's *Atlantic/Gulf Guidelines* intermediate submission requirements, each product or dataset described above was submitted to the Senior Review Team for review and approval prior to initiation of the next project phase. Sections 3.9 and 4.5 provide further information on the Senior Review process during Task 5.

While the *Atlantic/Gulf Guidelines* provides current guidance concerning modeling procedures and coastal study documentation requirements, Appendix M of FEMA's 2003 *Guidelines and Specifications* still governs the TSDN and Coastal Notebook Requirements. As referenced throughout this report, supplemental data and forms that relate to the Task 5 analyses will be provided in the TSDN and Coastal Notebook. These include the final Wave Height Analysis for Flood Insurance Studies (WHAFIS) model input and output, runup analyses, and all quality assurance/quality control (QA/QC) forms.

2.2 GUIDANCE FOR NON-TRADITIONAL COASTAL FLOOD STUDY DELIVERABLES

In September 2007, FEMA released a Procedure Memorandum (No. 47) to describe the methods and analyses needed for determination of 500-year flood elevations (including wave effects), and

provided interim guidance on mapping of the Limit of Moderate Wave Action (LiMWA, also known as the "Coastal A Zone"). Both of these tasks were included in the scope for Task Order 18. The relevant FEMA guidance governing these non-traditional deliverables is outlined below.

On September 6, 2007, FEMA published its final guidance on procedures for determining 500-year wave crest elevations in Procedure Memorandum No. 47, "Guidance for the Determination of the 0.2-Percent-Annual-Chance Wave Envelope along the Atlantic Ocean and Gulf of Mexico Coasts," and its accompanying Technical Memorandum. FEMA also issued a revised version of its WHAFIS model, WHAFIS 4.0, which incorporates a new module with user-entered wind speeds for 500-year analyses. FEMA's Coastal Hazard Analysis Modeling Program (CHAMP) software was also updated to include the determination methodology for the 500-year wave analysis and the new WHAFIS 4.0. The URS Team, as part of the Task 5 effort, completed the 500-year wave height modeling and generation of wave envelope profiles in accordance with FEMA's Procedure Memorandum No. 47 guidance and used both the WHAFIS 4.0 program and updated CHAMP software tools.

At the time of this report, FEMA had not yet issued a final Procedure Memorandum and Technical Memorandum concerning the LiMWA. To complete the LiMWA mapping for Task 5, the URS Team applied the March 2007 draft guidance for identification of this feature based on the results of wave height and wave runup modeling. See Section 4.3 for more information on LiMWA mapping.

The URS Team's general approach to completing Task 5 was to adapt the published FEMA *Atlantic/Gulf Guidelines* and applicable procedure memoranda to completion of wave modeling and flood hazard mapping for the Mississippi Gulf Coast. As described in the sections that follow, the technical work was very typical for a FEMA coastal flood study. The only factors that triggered the need for atypical procedures or study-specific considerations were the highly compressed project schedule and the availability of SWEL data with wave setup already incorporated.

To meet the accelerated schedule for a study of this geographic magnitude, the coastal reach had to be subdivided into segments, with multiple teams of engineers working simultaneously to complete the modeling, mapping, and QA/QC. The division of labor among the peer teams is listed in Table 1 below.

Table 1: Modeling and QA/QC work assignments under Task 5

URS (Lead: M. Honeycutt, Ph.D., CFM)	**Watershed Concepts** (Lead: C. Johnson, PE, CFM)	**Dewberry** (Lead: J. Gangai, CFM)
Jackson County modeling and mapping for transects 10-23 Jackson County Detailed QC for transects 1-9 and 24-55 Harrison County Detailed QC Independent Technical Review (ITR) of all data (completed by D. Hatheway, CFM)	Jackson County modeling and mapping for transects 1-9 Jackson County Detailed QC for transects 10-23 Harrison County modeling and mapping Hancock County modeling and mapping	Jackson County modeling and mapping for transects 24-55 Hancock County Detailed QC
Senior Technical Review: D. Divoky (Watershed Concepts) and D. Hatheway (URS)		

Ensuring adherence to FEMA's guidelines and technical consistency across the Mississippi Gulf Coast was a primary concern of the Task 5 management team. In May 2006, the entire Task 5 team attended a three-day workshop at the URS Gaithersburg office to review the field reconnaissance, wave modeling, mapping, QA/QC, and study documentation procedures that would be employed. Throughout the technical work, guidelines compliance and regional consistency were achieved through the checks built into the QA process and frequent communication among the leads of the peer teams.

Taking the 100- and 500-year SWELs generated in Task 4 and generating draft mapping of flood hazard zones and BFEs required multiple sub-tasks. The data sources and procedures used to complete theses sub-tasks, as well as any Mississippi-specific assumptions employed in the process, are described in the subsections that follow.

3.1 TRANSECT AND MODELING RESOURCES

Task 5 wave modeling and flood hazard mapping required multiple high-resolution geospatial datasets, including terrain (topography and bathymetry) and aerial imagery. The size of these datasets and schedule demands of the study required use of customized data handling software

and Geographic Information System (GIS) tools. The origin of each dataset or tool applied in the Mississippi coastal study is discussed below.

3.1.1 Terrain

The Task 3 *Geospatial Technology Task Report* describes the data sources of the terrain data used to support both Task 4 and Task 5. For topography, pre-Hurricane Katrina Light Detection and Ranging (LiDAR) data for the three counties, which were collected between 2003 and 2005 by the State of Mississippi and the National Oceanic and Atmospheric Administration (NOAA), were merged with post-Katrina (September-October 2005) LiDAR data collected along the coast by the U.S. Army Corps of Engineers.

The bathymetric data used in Task Order 18 were obtained from the Northern Gulf Littoral Initiative (NGLI), which reflects data gathered by multiple Federal and State agencies, universities, and private contractors. The NGLI data were augmented, where necessary, by NOAA navigation charts. The Task 5 team received the bathymetric data from URS-Tallahassee in the form of a grid.

As described in the Task 3 report, all terrain data were provided in the North American Vertical Datum of 1988 (NAVD88) for use in other tasks. For Task 5, the terrain data were used in the generation of wave transects and in flood hazard mapping. Processing of the terrain data to generate the transect profiles is discussed in further detail in Section 3.1.3. In addition to the terrain data, the Task 5 team also used the 1982-1983 composite NOAA shoreline (0-foot contour) in various aspects of the Task.

3.1.2 Aerial Imagery

Both pre-Katrina and post-Katrina high-resolution orthophotography were available to the Task 5 team. Because the wave modeling and mapping were to be based on the vegetation and development patterns in existence at the time of the study (rather than some assumed future condition following recovery), the post-Katrina imagery was utilized. This imagery, dated September 15, 2005, originated from the U.S. Department of Agriculture.

3.1.3 Modeling Tools

In recent years, a number of specialized data pre- and post-processing tools have been developed to automate various aspects of coastal flood modeling and mapping for FEMA studies. Most tools are designed to interface with FEMA's approved wave models (e.g., WHAFIS 3.0, WHAFIS 4.0, RUNUP 2.0) and CHAMP software. The Task 5 team utilized two such tools: the Watershed Information System (WISE) Coastal Module, developed by Watershed Concepts and used by the URS and Watershed Concepts engineering teams, and the GeoFIRM Coastal Tools, developed and used by Dewberry.

Both the WISE Coastal Module and GeoFIRM Coastal Tools operate in a GIS environment, enabling viewing and analysis of multiple geospatial datasets simultaneously. The functions and capabilities of these tools are similar, and are generally centered on pre-processing of data that are fed into the FEMA wave models and post-processing to plot model results and aid mapping of flood zones. The actual wave modeling computations are completed outside of the tools. The WISE Coastal Module has a storm-induced erosion function (based on the FEMA 540-square-

foot criterion), which has been reviewed and approved for use by FEMA. Since the post-Katrina terrain data utilized in this study have been assumed to reflect post-storm eroded conditions, this function was not applied in Task 5.

The most significant difference between the WISE Coastal Module and GeoFIRM Coastal Tools is the terrain processing method. In WISE, the terrain point data (LiDAR topography and bathymetric grid elevations) are used to generate a Triangular Irregular Network (TIN) on-the-fly; to minimize computational demands, the TIN is generated behind the scenes for only the area that the user is working in at the time. When both topographic and bathymetric data are available, the 0-foot elevation is typically interpolated based on the available data. In GeoFIRM, the terrain data are processed to form a Digital Elevation Model (DEM) grid of the study area. For Mississippi, the NOAA shoreline was used to burn in a 0-foot contour into the GeoFIRM DEM.

3.2 WAVE TRANSECT SELECTION

For the Mississippi coastal study, the initial transect layout was developed following the procedures outlined in FEMA's *Guidelines and Specifications*. Each transect is intended to be representative of a particular reach along the coast that has uniform physical characteristics. After consulting available aerial imagery and effective Flood Insurance Studies, transect sites were chosen to capture the variability in coast orientation and coastal topography, large-scale vegetation distribution, and development patterns. Care was taken to ensure that transects extended inland from the shoreline and crossed key secondary flooding sources inland of the coasts, such as inland bays, marshes, and tidal rivers.

In most coastal studies, transect layouts will also take into account spatial variations in the 100-year SWEL data and the extent of the 100-year floodplain. In the latter case, transects are typically adjusted laterally to ensure that each is roughly centered on its representative reach. The accelerated project schedule for Task Order 18 dictated that transect locations be established and field reconnaissance and preliminary modeling be completed long before the final 100-year SWELs would be available. For the purposes of establishing a floodplain extent to guide the initial transect layout, the team assumed a maximum SWEL of 25 feet (NAVD88) for all areas east of the Biloxi River and a SWEL of 35 feet to the west.

Although not frequently used, a few crossing transects were included in the initial layout to better resolve overland wave patterns over peninsulas. In East Biloxi (Harrison County) and Bay St. Louis (Hancock County), flooding and wave effects from both easterly and southern directions pose substantial hazards. As a result, crossing transects in these orientations were included. The initial wave transect layouts for each county were reviewed and approved by the Sr. Technical Review Team and FEMA National Service Provider.

Following initial review and approval, the proposed transect layouts were implemented in the draft modeling for the remainder of Task 5. Two minor adjustments were made to the transects after the modeling and mapping began in earnest. Once final SWELs became available, rather than following along the valley edge (in and out of the 100-year floodplain), Jackson transect 25 was moved slightly east so that it was representative of a flooded valley. During mapping of wave results, Harrison transect 10 was shortened based on URS team Independent Technical Review (ITR) and the reviewer's request to represent only the open coast flooding effects in Pass Christian associated with the Gulf of Mexico and the Mississippi Sound. The final layouts of the

coastal transects for Jackson, Hancock, and Harrison counties are shown in Figures 1-3 below. These 161 transects reflect an increase of 55 percent over the 104 transects modeled in the 1980s effective studies for the Mississippi coast.

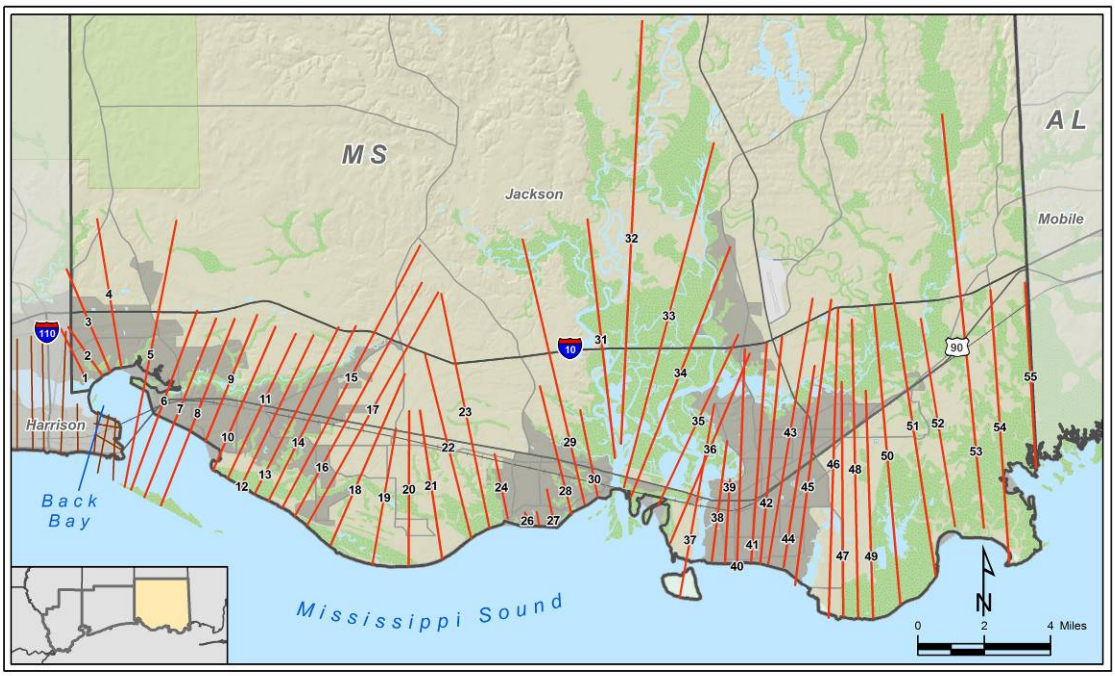


Figure 1 - Transect location map for Jackson County.

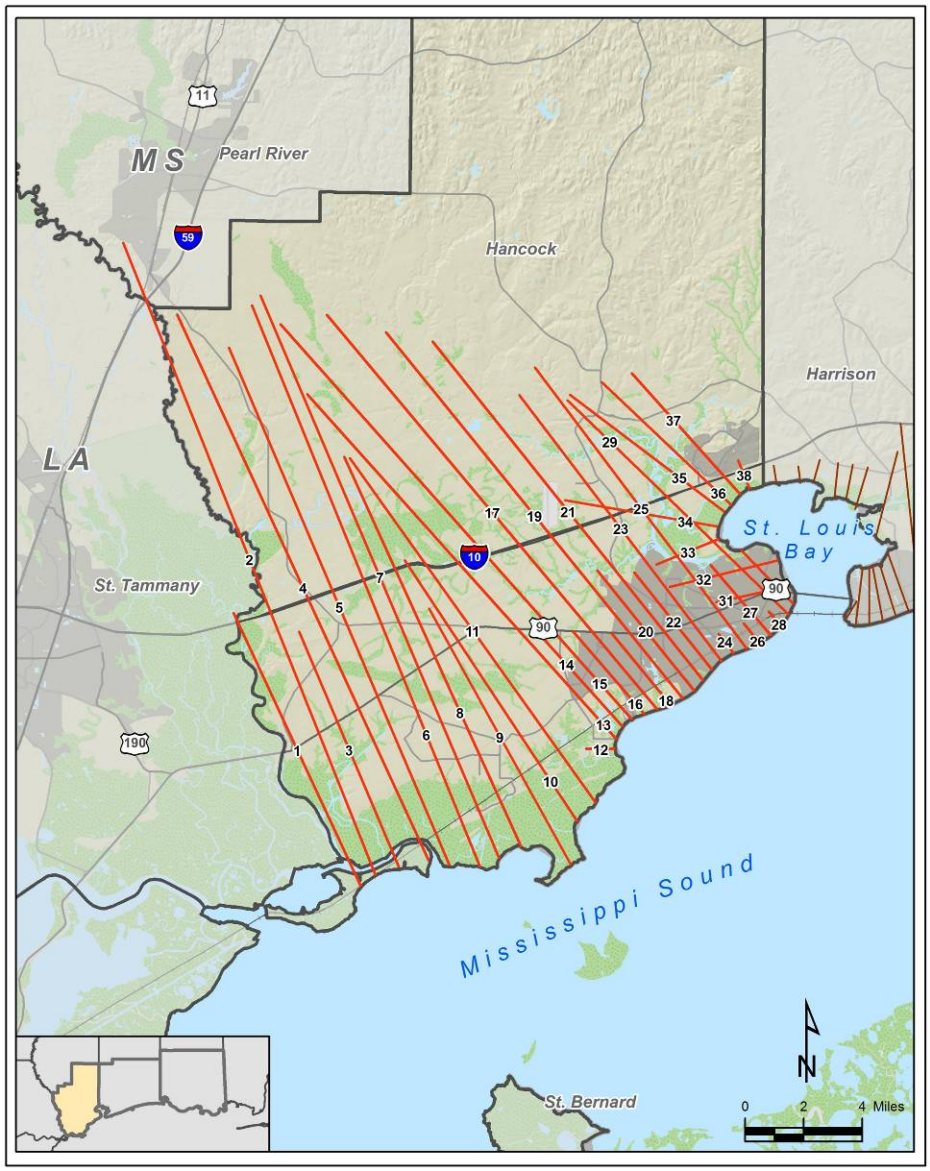


Figure 2 - Transect location map for Hancock County.

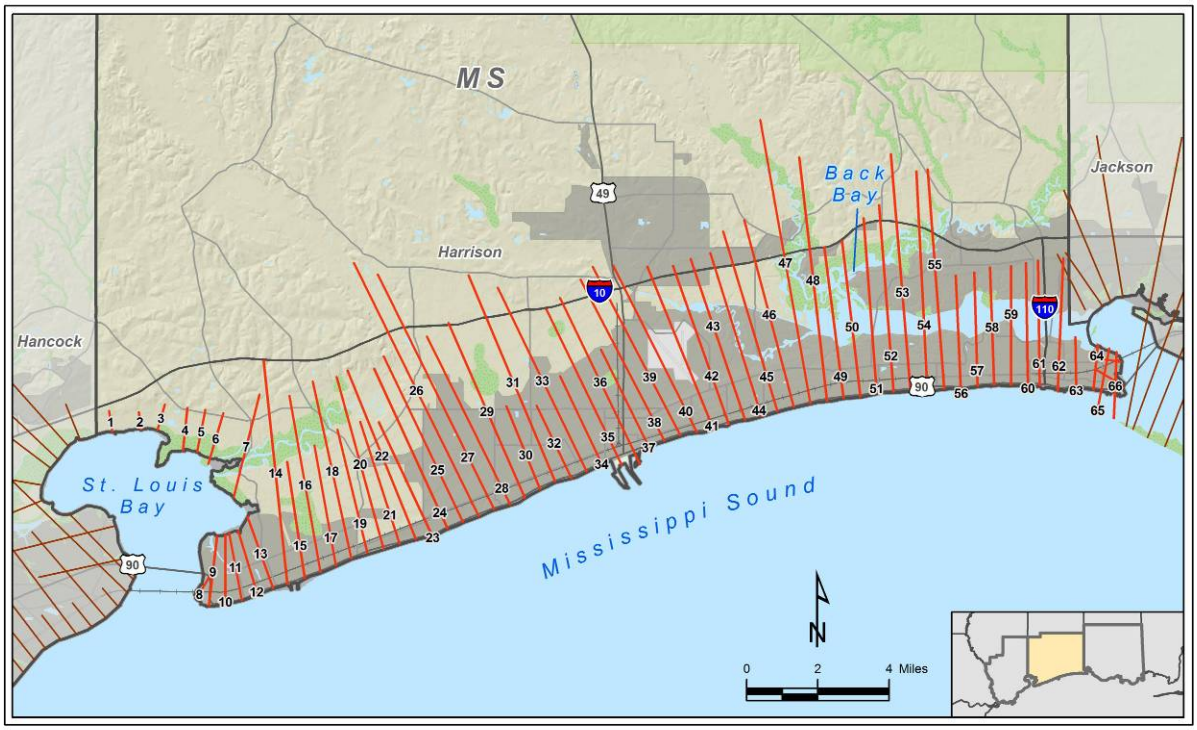


Figure 3 - Transect location map for Harrison County.

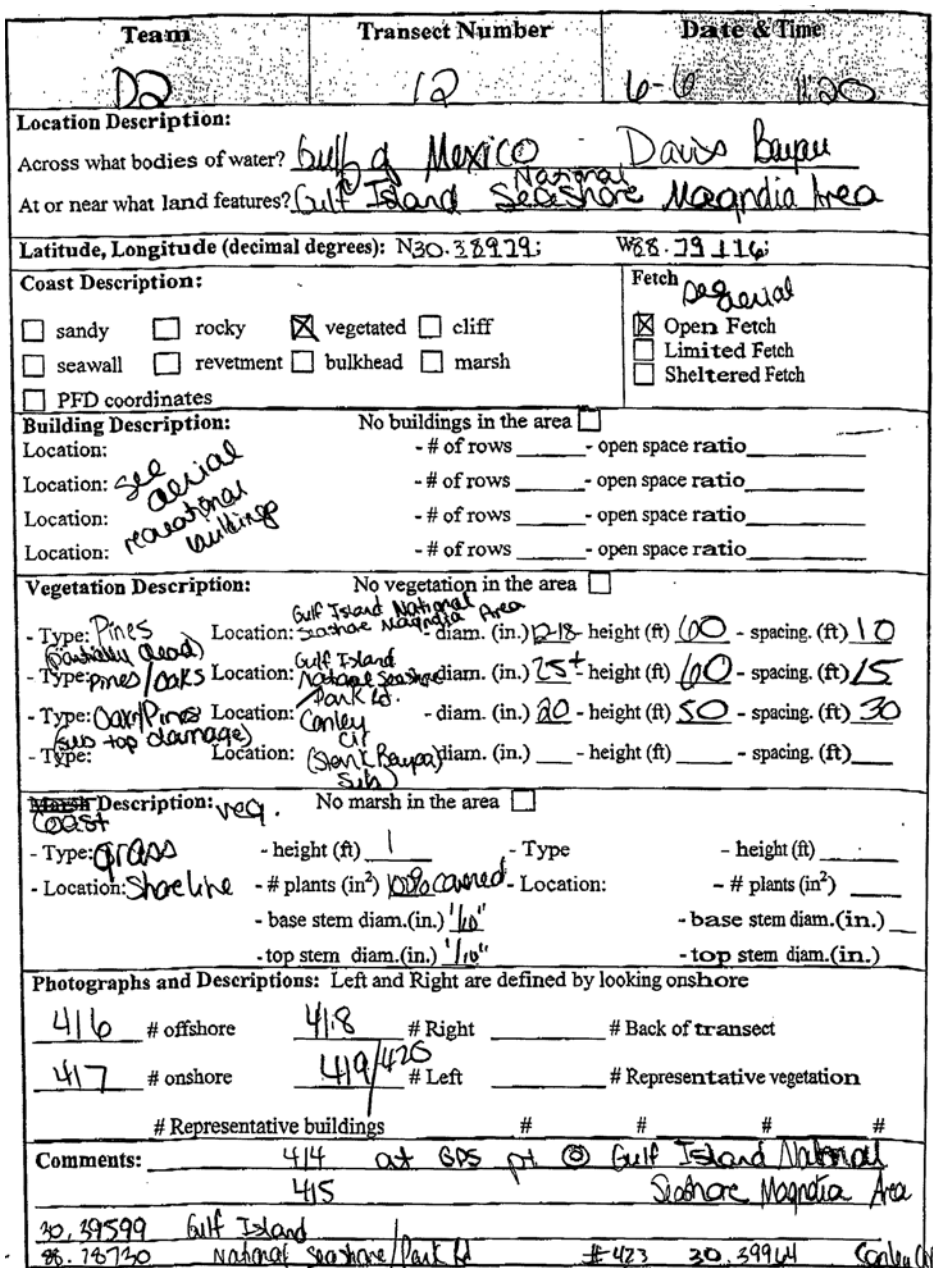
3.3 FIELD RECONNAISSANCE

Overland wave modeling using FEMA's WHAFIS model requires breaking transects into segments (defined by data "cards") that are assigned either a wave fetch or wave obstruction type. These cards are to be based on prevailing open-water, vegetation, or development conditions that exist over the reach represented by the transect. To properly assign a WHAFIS card and its attributes, and to later apply model results in mapping of flood zones, modelers must have detailed information concerning the conditions that exist along each transect. While much of this information can be gleaned from high-resolution aerial imagery, field reconnaissance is critical to documenting key features not visible on the imagery, such as building foundations (open pile-elevated versus enclosed slab-on-grade) and vegetation types (trees and marshes) and characteristics (e.g., size, density).

Once the initial transect layout was prepared, the Task 5 team planned and executed field reconnaissance along the Mississippi coast over a two-week period in early June 2006. Five two-person teams fanned out across the three-county area to document conditions at representative sites along the transects. While every attempt was made to collect data at a minimum of one station on each transect (including the open coast), road access and private property concerns occasionally prevented complete coverage. FEMA Transitional Recovery Office staff and State floodplain program officials aided the teams in gaining access to some restricted sites (e.g., military installations).

At each station, field teams recorded myriad data on standard data sheets (see Figure 4). This included approximate geographic location as provided by hand-held Global Positioning System

devices. Teams also recoded details concerning prevailing land use and related parameters. Identification of any Primary Frontal Dunes (PFD) is also a required element in the field reconnaissance; there were no PFD mapping sites with exception of one area along the coast in Jackson County, which was identified and mapped at transect 19. Photographs were also taken to illustrate conditions in all four directions surrounding the station (see Figure 5) and to document representative building stock or vegetation, as applicable. Notes were recorded by hand on the data sheets at each station, and basic data, such as stationing and geographic coordinates, were transferred to digital media each evening. Digital photographs were downloaded from cameras nightly.



Team	Transect Number	Date & Time
D2	12	6-6 1120

Location Description:
Across what bodies of water? Gulf of Mexico - Davis Bayou
At or near what land features? Gulf Island National Seashore Magnolia Area

Latitude, Longitude (decimal degrees): N30.38979; W88.79116;

Coast Description:
☐ sandy ☐ rocky ☒ vegetated ☐ cliff
☐ seawall ☐ revetment ☐ bulkhead ☐ marsh
☐ PFD coordinates

Fetch see aerial
☒ Open Fetch
☐ Limited Fetch
☐ Sheltered Fetch

Building Description: No buildings in the area ☐
Location: - # of rows ____ - open space ratio ____
Location: see aerial - # of rows ____ - open space ratio ____
Location: recreational buildings - # of rows ____ - open space ratio ____
Location: - # of rows ____ - open space ratio ____

Vegetation Description: No vegetation in the area ☐
- Type: Pines (partially dead) Location: Gulf Island National Seashore Magnolia Area - diam. (in.) 12-18 - height (ft) 60 - spacing. (ft) 10
- Type: pines/oaks Location: Gulf Island National Seashore Park Rd. - diam. (in.) 25+ - height (ft) 60 - spacing. (ft) 15
- Type: Oak/Pines (sub top damage) Location: Conley Cir - diam. (in.) 20 - height (ft) 50 - spacing. (ft) 30
- Type: Location: (Stark Bayou Sub) diam. (in.) ___ - height (ft) ___ - spacing. (ft) ___

~~Marsh~~ Coast **Description:** veg. No marsh in the area ☐
- Type: grass - height (ft) 1 - Type - height (ft) ___
- Location: Shoreline - # plants (in²) 100% covered - Location: - # plants (in²) ___
- base stem diam.(in.) 1/10" - base stem diam.(in.) ___
- top stem diam.(in.) 1/10" - top stem diam.(in.)

Photographs and Descriptions: Left and Right are defined by looking onshore
416 # offshore 418 # Right ____ # Back of transect
417 # onshore 419/420 # Left ____ # Representative vegetation
Representative buildings # # #

Comments: 414 at GPS pt @ Gulf Island National
415 Seashore Magnolia Area
30.39599 Gulf Island
88.78730 National Seashore/Park Rd #423 30.39964 Conley Cir

Figure 4 - Sample field reconnaissance form showing level of detail of information collected.

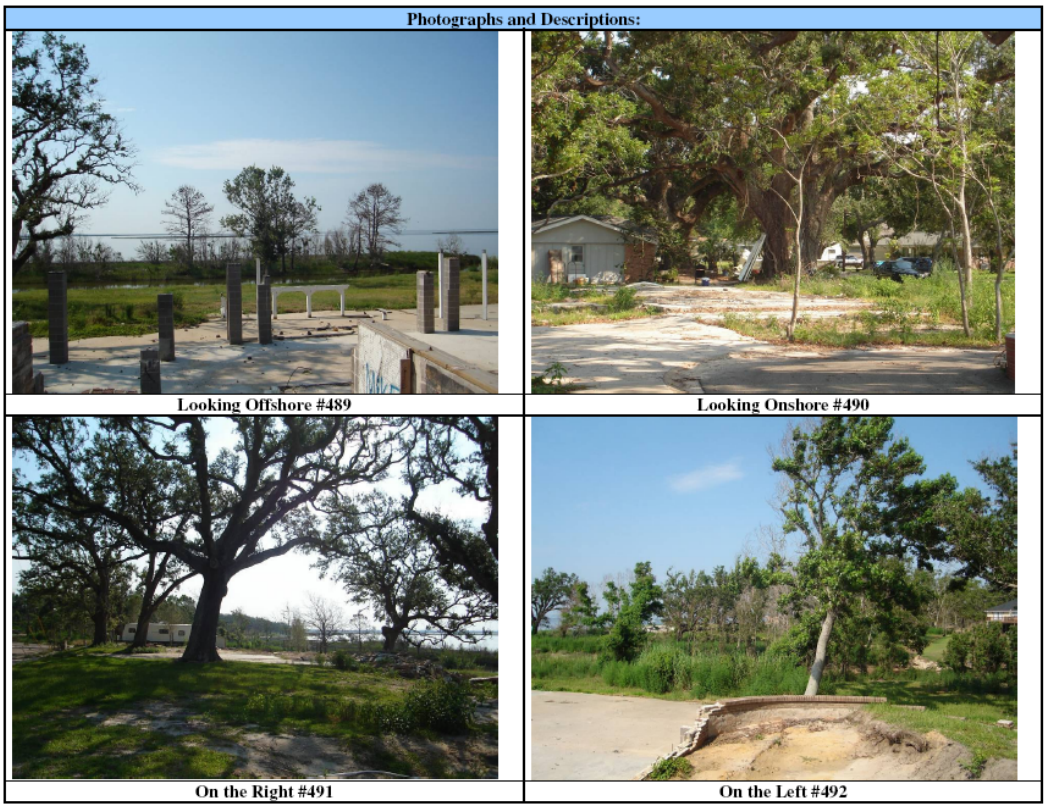


Figure 5 - Sample of digital photographs that accompany each field reconnaissance form.

Upon return to the office, field reconnaissance data were converted to a digital format (Adobe PDF) and subjected to quality reviews. The final reconnaissance dataset will be furnished as part of the TSDN and Coastal Notebook.

3.4 STILLWATER ELEVATIONS

On July 19, 2007, the combined FEMA and U.S. Army Corps of Engineers 100- and 500-year SWELs produced through the Task 4 Advanced Circulation Model for Coastal Ocean Hydrodynamics (ADCIRC) storm surge modeling and the Joint Probability Method (JPM) statistical analysis were provided to the Task 5 team as point data—i.e., final stillwater flood elevations (including wave setup) that correspond to a specific set of latitude and longitude coordinates. These point data were uploaded into the GIS-based modeling tools, the WISE Coastal Module and GeoFIRM Coastal Tools. While some JPM 100-year points may fall exactly on some coastal transects, interpolation of SWELs was necessary to determine elevations to the nearest tenth of a foot for most wave transect stations.

To facilitate the interpolation of SWELs and application of these data to the wave transect stations, both WISE and GeoFIRM applications develop three-dimensional SWEL surfaces. The applications then intersect the transect with the surface and assign SWELs (rounded to the nearest tenth of a foot) to each station. After this initial assignment, modelers then review the interpolated SWELs against the JPM point data to ensure there were no erroneous interpolations within the floodplain or extrapolations into above-surge areas at the floodplain boundary. As

there was insufficient time during SWEL surface generation to create breaklines to segregate JPM points among the various potential flooding sources, the modelers also had to examine flooding sources during evaluation of the interpolated data. Once satisfied that the SWELs populated in the coastal transects were valid, coastal hydraulic modeling commenced.

3.5 STORM-INDUCED EROSION

FEMA's coastal guidelines required modelers to consider adjusting transect ground profiles to account for storm-induced erosion of sand dunes and ridges, including PFDs. If the study site has recently experienced a significant storm surge event (equivalent to a 100-year or greater return period elevation) and has eroded the beach and dune system, FEMA accepts the current conditions as the eroded profile. As mentioned in Section 3.1.3, it was assumed that the ground elevations recorded in the post-Katrina LiDAR data reflected eroded conditions. Thus, no additional storm-induced erosion assessment was applied to any transect in the Mississippi study.

3.6 WAVE HEIGHT MODELING

The hydrodynamic forces associated with breaking waves pose a substantial additional hazard to buildings and other development beyond the hydrostatic effects of inundation during the base flood. While two-dimensional wave effects were integrated into the modeling of flood elevations in the offshore reaches of the Gulf of Mexico and Mississippi Sound during Task 4, a different suite of models are needed to examine the variation in wave heights as the base flood propagates over land. FEMA's accepted model list allows study contractors to select the numerical models that are best suited to the study area. For Mississippi, the effective flood studies in Hancock, Harrison, and Jackson Counties, completed between 1982 and 1985, used the WHAFIS model for overland wave propagation. Since the WHAFIS model is still a FEMA-accepted model for one-dimensional overland wave propagation modeling, the Mississippi coastal study team selected and received FEMA approval to use WHAFIS for all wave height modeling. The latest version of WHAFIS, WHAFIS 4.0, is capable of calculating the effects of open fetches and obstructions on the growth and attenuation, respectively, of wave heights on a detailed scale (i.e., large property or lot scale) for both the 100- and 500-year flood levels. The WHAFIS 4.0 model and its predecessor versions have been applied in FEMA coastal studies for more than 25 years, allowing for mature, well-defined methods and standard assumptions. The sections that follow outline the application of the WHAFIS 4.0 model to determine wave crest elevations along the Mississippi coast.

3.6.1 Input Preparation

A primary input to the WHAFIS 4.0 model is a profile consisting of station (distance in feet from 0-foot contour shoreline) and elevation (ground elevation in feet above NAVD88 datum) pairs that represent the bare-earth ground elevation along the transect, accompanied by the SWEL corresponding to each modeling station point. For each of the 161 coastal transects, detailed ground profiles were extracted from the high-resolution digital terrain surface (i.e., the TIN in the WISE Coastal Module and the DEM in the GeoFIRM Coastal Tools). As these ground profiles contain literally thousands of data points, the first step in the wave height modeling was to construct a profile, herein referred to as the WHAFIS profile, with appropriate resolution, eliminating redundancy and negligible variations.

The first and most critical point in the WHAFIS profile is the Initial Elevation, or IE station. To execute properly, the model should begin with an IE station (or "card") located at an elevation of zero. (Note: The FEMA *Atlantic/Gulf Guidelines* and original WHAFIS 3.0 model documentation [1988] recommend that the horizontal value of the IE card also be zero, but this is not required for the model to function correctly.) To enforce consistency, an initial station of zero and elevation of zero was adopted throughout this study.

The procedure for determining the IE station location varied slightly depending on which GIS-based modeling toolset was used for transect modeling. For transects modeled in the WISE Coastal Module, the TIN interpolated a 0-foot elevation from the LiDAR topographic data and bathymetric grid. WHAFIS profile IE stations were then placed where the ground data showed the elevation to be 0 feet (NAVD88). This elevation contour was found to deviate significantly (e.g., 10s to 100-200 feet or more) from the NOAA composite shoreline in some locations (see Figure 6). This lack of spatial coincidence is not unreasonable given the age of the NOAA dataset, which is 22-23 years older than the 2005 LiDAR data. Spot checks of the terrain data showed that most of the problem areas were located in Hancock County. The NOAA shoreline appeared consistent enough with current (2005) conditions in Jackson County to be burned into the GeoFIRM DEM as a 0-foot contour. As a result, the IE stations for all transects in this reach (Jackson 24-55) are aligned with the NOAA shoreline.

Figure 6 – NOAA composite shoreline (in red) fails to be a reliable proxy for the 0-foot contour when compared against current (2005) orthoimagery from Bay St. Louis (Hancock County).

Since the IE station for all 161 transects is based on the 0-foot elevation from the terrain models, the transect line's origin may not align with other features that are used formally or informally to mark the "shoreline," or water/land boundary. As discussed previously, IE stations for WISE-modeled transects may or may not align with the NOAA shoreline. For all transects, the IE stations may appear to lie landward or seaward of the wet/dry line visible on any orthoimagery

used as a base map since the line's location will be a function of the tide elevation and the wave climate at the time of collection.

The remaining stations in the WHAFIS profile were generated in a straightforward manner. The detailed ground profile data were used by modelers to select representative station-elevation pairs for the entire extent of the 100-year and 500-year floodplains. Generally, WHAFIS 4.0 results tend to be more sensitive to changes imposed by peaks or topographic highs present in the profile than narrow valleys or lows because of the fetch distance needed to regenerate waves. For this study, small valleys or depressions less than 100-200 feet in width were not always represented within the WHAFIS profile (i.e., no WHAFIS points to note the bottom or flanks of the valley).

WHAFIS stations were also placed wherever the 100-year or 500-year SWEL intersected the ground profile, including the start and end of any Above Surge (AS) segments located within a transect. Because many wave transects cut in and out of branches of the extensive drainage network, isolated below-surge transect segments that were located far from the primary coastal flooding source and less than 400 feet in width were typically omitted from the WHAFIS profile. This limited the generation of potentially spurious or unrealistic wave results far upstream, where coincidence of peak surge inundation and peak winds is unlikely.

3.6.2 WHAFIS Fetches and Obstructions

Following FEMA's *Atlantic/Gulf Guidelines*, each WHAFIS station (except IE, AS, and End of Transect [ET] stations) was assigned a fetch or obstruction card that corresponded to the prevalent land use for the transect segment immediately preceding the station. Modelers used the June field reconnaissance data and post-Katrina imagery in assigning cards and entering values for card-specific parameters, such as vegetation type or open-space percentage. The existing FEMA guidance was largely adequate to guide the WHAFIS profile carding. In the four settings described in Table 2 below, the Task 5 team developed a specific rule or procedure, had it approved by a Senior Technical Review Team member, and applied it consistently throughout the three-county study area.

Table 2: Study-Specific WHAFIS Modeling Practices

Fetch or Obstruction Carding Issue	Problem Description and Solution Implemented
Transition from Open Fetch (OF) to Inland Fetch (IF)	Problem Description: FEMA guidelines do not specify where to transition from higher wind speeds of OF cards to lower IF card speeds.
	Solution: Peak wind-speed distributions during Hurricane Katrina (provided by Ocean Weather for Task 4) were evaluated to determine a zone of significant decrease. In Harrison and Hancock, the zone occurred approximately near Interstate 10; in Jackson, the zone occurred closer to the shoreline, within a few miles of Highway 90. North of the transition zones noted, IF was used. South of the zones, OF was used unless the transect crossed a wide, high barrier (>20-25 feet NAVD88); in those areas, IF was considered more appropriate. Areas immediately adjacent to large inland bays, where fetch was adequate to permit wave growth (e.g., Biloxi Back Bay and St Louis Bay), were modeled as OF.

Fetch or Obstruction Carding Issue	Problem Description and Solution Implemented
Consideration of elevated versus non-elevated structures in use of Building (BU) cards	Problem Description: Many buildings elevated on open foundations in compliance with effective Flood Insurance Rate Map BFEs would be partially submerged by stillwater flooding. This could cause partial sheltering of wave heights. The BU card assumes buildings completely obstruct or prevent wave growth; there is no way to model partial sheltering by buildings in WHAFIS.
	Solution: It is beyond the scope of this regional study to model sheltering effects of the diverse building stock existing along the Mississippi coast. BU cards were used where the prevailing building type was slab-on-grade or solid-wall foundation (with flood vents). Elevated buildings were treated as OF or with a vegetation card, as appropriate. This includes large, elevated commercial structures and casino complexes.
Open space calculations for developed reaches oriented oblique to the transect	Problem Description: The number of building rows and open space percentages calculated by the modeler can be affected by the orientation of the transect relative to the layout of the roads and buildings in a subdivision. Under- or over-estimation of these modeling parameters would bias the WHAFIS results.
	Solution: The adopted approach was to count rows and calculate open space in the direction closest to perpendicular to the development. The actual orientation of the buildings was honored in the mapping of the WHAFIS results.

3.6.3 Incident Wave Conditions

As described in a separate two-dimensional wave modeling report, Dr. Don Slinn of the University of Florida used the two-dimensional, Simulating Waves Nearshore (SWAN) model to develop 100-year and 500-year significant wave heights and wave periods at the approximate location of the IE station (shoreline) for each of the 161 wave transects. Dr. Slinn's wave heights were converted to feet, and included as input to the WHAFIS 4.0 model. FEMA's CHAMP software automatically converts user-entered significant wave heights to controlling wave heights before WHAFIS 4.0 runs are executed. Prior to application to wave transects, an ITR and Senior Technical Review Team member conducted a quality review and approved all incident wave data prepared for use in the modeling.

3.6.4 WHAFIS Modeling

With WHAFIS station-elevation pairs generated, 100-year SWELs and all fetch and obstruction carding assigned, and incident wave height and period data entered in CHAMP, WHAFIS 4.0 runs were executed for all 161 wave transects. The resulting 100-year wave height profiles were automatically subdivided by WHAFIS 4.0 into flood hazard zones (VE and AE) and whole-foot BFEs to the limit of the 100-year floodplain. Application of these results for floodplain mapping is discussed in Section 4.0. Prior to application to hazard mapping, an ITR and Senior Technical Review Team member conducted a quality review and approved all wave modeling prepared for use in the mapping phase. The review focused on proper use of fetches and obstructions, application of SWELs, and overall consistency in modeling approaches.

3.6.5 500-year Wave Modeling

Once 100-year wave analyses and floodplain mapping (see Section 4.0) were completed for Jackson, Hancock, and Harrison counties, the Task 5 team commenced equivalent 500-year wave height modeling for the same 161 coastal transects. As mentioned above, WHAFIS profiles were extended where necessary to encompass the entire 500-year floodplain, and the station-elevation pairs were populated with 500-year SWELs derived from a surface generated from the corresponding JPM point data. The same field reconnaissance data and aerial imagery were used to card the new segments of the WHAFIS transects falling below the 500-year SWEL. (No changes were made to carding for areas previously modeled for the 100-year flood.) On August 22, 2007, Dr. Slinn provided 500-year significant wave heights and periods to support the analyses. Prior to application to wave transects, an ITR and Senior Technical Review Team member conducted a quality review and approved all incident wave data. Following that review and prior to application to 500-year wave envelope profile generation, an ITR and Senior Technical Review Team member conducted a quality review and approved all wave modeling prepared for use in the profiles. The review focused on new modeling for the 500-year analysis and on proper use of fetches and obstructions, application of SWELs, and overall consistency in modeling approaches.

3.7 WAVE RUNUP MODELING

FEMA's *Atlantic/Gulf Guidelines* requires consideration of both wave height and wave runup hazards where conditions are conducive to runup and/or overtopping processes. Final floodplain mapping must reflect the more conservative set of wave modeling results (assuming no PFD exists at the site). FEMA's RUNUP 2.0 model was traditionally used to determine the mean runup, and the current FEMA guidance requires calculation of the 2 percent-runup elevation (RUNUP results are easily converted to 2 percent-elevations). To clarify a point of possible confusion: the 2 percent-runup is the value exceeded by 2 percent of the successive waves occurring within the 1 percent- (or 100-year) event. During the 1 percent-flood, individual waves vary randomly over a broad range of heights. Whereas RUNUP 2.0 considers only the mean of these waves, the new FEMA guidance has specified the highest 2 percent as most appropriate for BFE determination.

On the Mississippi coastal transects, the Task 5 team examined ground slopes (both natural and manmade) at the intersections with the 100-year SWEL elevations. Any slopes steeper than 1-on-10 were designated for calculation of wave runup. The criterion triggered the need to calculate runup for 14 transects, or less than 10 percent of the total transects. Because the SWEL data generated under Task 4 incorporated wave setup, the RUNUP 2.0 model could not be used since it assumes a setup-free water level. A number of new runup methods and models were discussed in FEMA's new *Atlantic/Gulf Guidelines*. One of these, the Technical Advisory Committee for Water Retaining Structures (TAW) model, appeared to meet the needs for runup assessment in Mississippi. A separate Task 4 coastal documentation report on wave runup explains how the TAW runup model was adapted for use in Task Order 18.

Some of the sites where runup had to be evaluated fronted on plateaus, where the ground leveled off or rose at a much gentler rate than the steep slope where runup was calculated. For these transects, the plateau analysis described in Section D.2.8.1.7 of the *Atlantic/Gulf Guidelines* was applied to the computed TAW 2 percent-runup results to develop adjusted runup elevations,

where applicable. Prior to application to hazard mapping, an ITR and Senior Technical Review Team member conducted a quality review and approved all wave runup modeling prepared for use in the mapping phase. The review focused on incident wave data at toe of structure, structure or ground slope at the runup zone, conversion to the 2 percent-runup values, and overall consistency in modeling approach.

3.8 INTERNAL QA/QC

All modeling work completed under Task 5 was subject to a rigorous, multi-level, internal quality review process (see Figure 7), as outlined in the Task Order 18 QA Plan. By design, this process was intended to catch and resolve any modeling errors and omissions, and ensure that final results are consistent with the requirements published in FEMA's *Atlantic/Gulf Guidelines*. The purpose and scope of each step in the quality review process is described in the sections that follow.

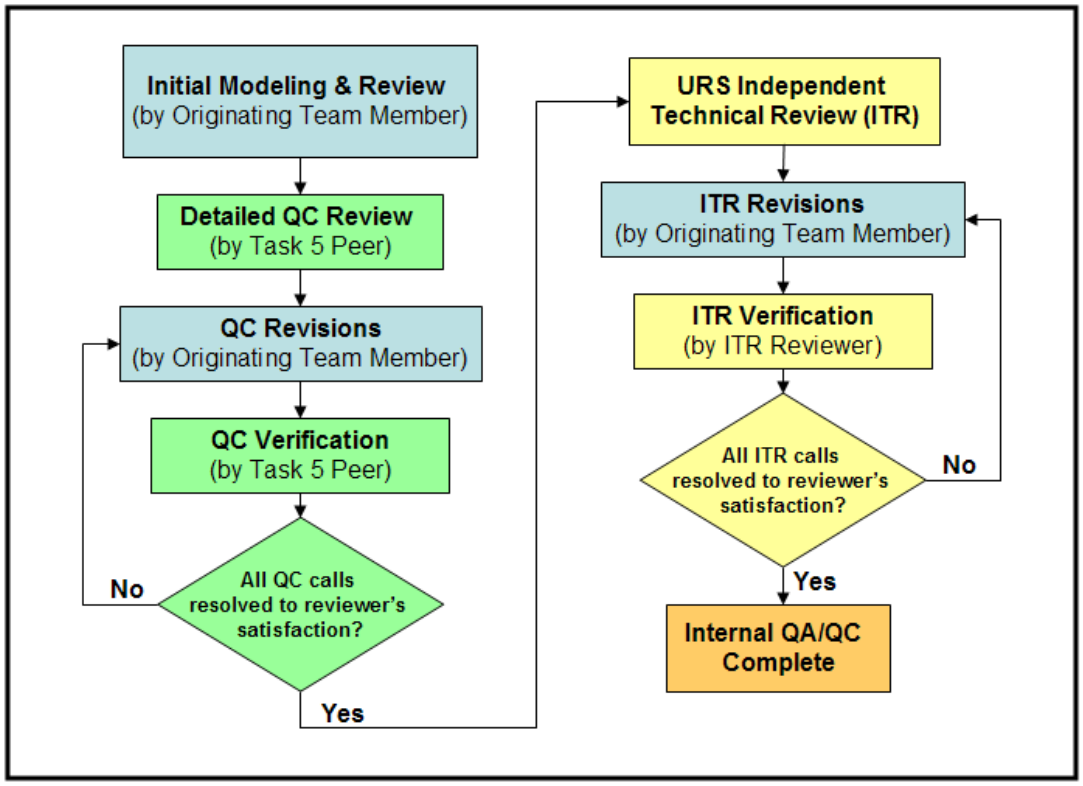


Figure 7 – Internal QA/QC process flowchart.

3.8.1 Initial Checking

Once initial WHAFIS transect carding was completed by the originating team member, an initial, internal (intra-team) quality review was performed before submission of the data to Detailed QC. This check focused on the degree to which the WHAFIS profile points honored the topographic data, the correctness of WHAFIS fetch and obstruction carding, and the use of correct input, such

as the incident wave conditions. Once modeling was reviewed and corrected, if necessary, the data were furnished to the peer team member assigned to complete the Detailed QC; see Table 1.

3.8.2 Detailed QC

Detailed QC, which was completed by a separate partner firm on the Task 5 team, looked at all the same issues as Initial Checking, but in much greater detail—every WHAFIS card, every non-default card parameter, all input, etc. This process helped ferret out inconsistencies in modeling approaches, and achieve a consistent product with the multiple teams.

Comments were provided in Detailed QC forms, which is typical of FEMA coastal studies. The forms went back to the originators, who would review the comments and begin revisions. It was incumbent upon the originator to immediately discuss any disagreements regarding requested changes with the reviewer and determine a solution acceptable to both parties. This final solution was documented in the QC form, which would then accompany revised modeling when it was resubmitted to the reviewer for QC verification review. Once all QC calls were resolved to the reviewer's satisfaction, the QC forms were finalized, and data could move on to the next review (the URS ITR).

3.8.3 ITR Process

The ITR is a URS-imposed requirement for all deliverables slated as ready for submission to the client. The ITR reviewer examines the Detailed QC history to ensure all issues were resolved, and then assesses whether the product is technically sound and meets the requirements set forth by the Statement of Work negotiated with the client. For Task 5 modeling, the ITR reviewer examined all Detailed QC forms and completed spot checks of the modeling itself to ensure the correct cards and parameters were used throughout. The reviewer also checked the modeling approaches against the requirements of FEMA's *Atlantic/Gulf Guidelines*, which was specified in the Task Order 18 Statement of Work. Once all outstanding issues were resolved to the ITR reviewer's satisfaction, the data were cleared for the next review phase, Senior Technical Review Team approval.

3.9 SENIOR REVIEW TEAM APPROVAL

As required by the QA Plan, all data are subject to Senior Review Team review prior to initiation of the next project phase or submission to FEMA, as appropriate. This review is intended to represent the review that FEMA or its designee would conduct for a deliverable, and includes checks to ensure that the methods employed are technically sound and follow FEMA guidelines or other requirements. Once the Task 5 wave modeling cleared the URS ITR phase, it was furnished to the designated Senior Technical Review Team reviewer. Any issues identified in this review were addressed to the reviewer's satisfaction before the data were finalized and cleared for floodplain mapping.

4.1 100-YEAR AND 500-YEAR FLOODPLAIN BOUNDARIES

The mapping completed under Task 5 commenced with delineation of the 100- and 500-year floodplain boundaries. Within the both the WISE Coastal Module and GeoFIRM Coastal Tools, standard GIS utilities were available to spatially analyze the available terrain and SWEL data and generate initial 100- and 500-year floodplain boundaries. This was done by intersecting each interpolated SWEL surface with the terrain model (TIN or DEM). This method produces a complex initial boundary with numerous unmappable fine scale irregularities, as well as many small, isolated areas that are inconsistent with the prevailing conditions in the area (e.g., minor dry islands within flooded areas, small ponds with no direct hydraulic connection to a coastal flooding source). With the initial mapping as a guide, the modelers manually drew the floodplain boundaries honoring the JPM point elevations and 1-foot topographic contours derived from the terrain model.

4.2 WAVE ANALYSIS RESULTS

The BFEs for the Zone VE and Zone AE special flood hazard areas were determined using the WHAFIS results in Part 6 of the output. After examining the WHAFIS results to determine what features were controlling (elevation, land-use, etc.), the zones were averaged to make sure all reaches had mappable widths that were at least within 0.2 tenths of the map scale or 100 feet in width (any reaches <100 feet were generally not included due to map scale limitations, but sometimes 40-50 feet widths were accommodated). Appendix 1 to this report includes a data disk with the final input and output files for the WHAFIS modeling. The disk also includes the CHAMP database, which includes all transects.

4.2.1 Interpolation Between Transects

The wave transects were selected to provide the best representation of the modeling reach, and generally had consistent transitional conditions between each transect. This means that between transects the SWEL and ground contours were uniform or gradually increasing/decreasing, and obstruction or fetch reaches were uniform or abruptly changing. This required interpolation and engineering judgment in the mapping of hazard zones and BFEs between transects. It was important to make sure that the mapping specialist followed the controlling feature (ground contour or obstruction) influencing the BFE decrease or hazard zone change. BFE increases are generally attributed to open, inland water fetches and did not require engineering judgment of the changes between transects. If WHAFIS 4.0 results were overruled based on engineering judgment or a crossing transect, the modeler was instructed to make a note for inclusion in the documentation layer that accompanied the gutters and other mapping features in the GIS project.

4.3 HAZARD ZONE AND BFE MAPPING

The guidance included in the February 2007 *Atlantic/Gulf Guidelines* was followed for all hazard zone and BFE mapping. In the case of the PFD criteria application to the Zone VE mapping, there was only one case documented along the coast of Jackson County (at transect 19). Prior to completion of the mapping deliverable to FEMA, an ITR and Senior Technical Review Team member conducted a quality review and approved all transect mapping and interpolation of

mapping transitions of hazard zone and BFE. In this case, due to the delivery schedule of the mapping products, the ITR and Senior Technical Review Team review and approval processes were conducted concurrently by the same team with the prior approval of FEMA.

4.4 MAPPING OF THE INLAND LIMIT OF MODERATE WAVE ACTION

Flood Insurance Rate Maps currently depict VE Zones, or the Coastal High Hazard Area, where high velocity flow due to wave action can cause structural damage to building foundations and other critical elements. Damages observed following numerous coastal storms over the last 15 years have shown a need to either lower the threshold for defining the VE Zone (wave height of 3 feet or greater) or to subdivide the AE Zone in such a way to show which areas have sufficient wave hazards to recommend more restrictive building practices.

Given the effort involved in modifying the Federal regulations concerning flood zone definitions, FEMA has elected in Mississippi to map an advisory line that marks the recommended subdivision of the AE Zone, which occurs at the 1.5-foot wave height. Post-storm engineering assessments have shown that the 3-foot runup depth criterion for VE Zone delineation is sufficiently conservative, and no further subdivision of the AE Zone is required in that case. In March 2007, FEMA developed draft guidance on the identification and mapping of the 1.5-foot wave height line, the LiMWA. Although the Procedure and Technical memoranda have not yet been finalized, the technical aspects of the guidance are considered final and have been followed in this work.

To map the LiMWA, the modelers analyzed the full WHAFIS 4.0 wave profile and plotted points along each transect where the wave height crossed 1.5 feet. Then, like a flood zone gutter, the LiMWA was connected via interpolation between transects. In runup-dominated areas, the LiMWA was placed immediately landward of the VE to AE zone gutter, per the current FEMA guidance, and tied-in with adjacent wave height-dominated zone mapping. To aid in the utility of this new flood map data layer, every effort was made to keep the line as a continuous feature throughout the study area, even when flood zones were at minimum mappable widths in the vicinity. The LiMWA was discontinued in instances when there were no mappable AE Zones (i.e., zones went directly from VE to X500). The LiMWA was truncated at the point where the last AE zone pinched out at the 100-year boundary.

4.5 INTERNAL QA/QC

4.5.1 Initial Checking

Consistent with previous modeling and mapping efforts, the initial review is completed within the originating modeling team. Each team checked the accuracy of mapping at flood zone breaks per the WHAFIS 4.0 output, and reasonableness of averaging of the LiMWA where applied and needed. The initial check also verified the degree to which zones follow controlling features and SWEL changes.

4.5.2 Detailed QC

The Detail QC considered similar modeling and mapping issues as noted in previous sections. Each reviewer examined and noted any justification for deviating from WHAFIS 4.0 or runup

results (where applicable). Detailed site-specific comments were provided in a GIS shapefile, with a simple QC form used to note global issues. Also, like standard wave modeling, originators revised and resubmitted mapping data, with responses provided in the QC form and shapefile. Once all issues were resolved to the reviewer's satisfaction, the data was considered to have passed Detailed QC and moved on to the next review (URS ITR).

4.5.3 ITR Process

The ITR process also followed the same requirements of the 100-year wave modeling and mapping. As noted previously, the ITR was performed concurrently with the Senior Technical Review Team review (with FEMA approval). Once all issues were resolved to the ITR reviewer's satisfaction (including any problems with the documentation provided in the Detailed QC forms), the data were considered complete and ready for submission to FEMA.

4.6 SENIOR REVIEW TEAM APPROVAL

As mentioned above, FEMA previously approved the use of a single team member to perform both the ITR and Senior Review Team quality review and approval. Each review followed the documentation requirements set forth in the February 2007 *Atlantic/Gulf Guidelines*. All the wave height and runup modeling input/output, field reconnaissance notes and photographs, and QA/QC documentation will be provided in the Coastal Data Notebook.

Appendix A

WHAFIS Input and Output Files

The WHAFIS files are provided on a separate CD

Appendix B

Wave Runup Calculations

FEMA TO-18 Wave Runup Results

County	Transect	SWEL (ft)	Hm0 (ft)	T_{m-1} (sec)	2 % Exceedence run-up elevation (ft)	DL/O	Overtopping case
Harrison	3	18.60	3.69	3.98	27.4	O	> 3 ft
Harrison	14	18.40	5.14	5.24	23.1	O	>3 ft
Jackson	21	14.70	4.88	4.74	18.8	O	< 3 ft
Jackson	27	14.54	4.61	3.55	16.6	O	< 3 ft
Hancock	28	18.00	7.36	5.15	20.8	O	No overtopping
Hancock	29	17.90	5.50	5.05	23.0	O	< 3 ft
Jackson	37	14.02	8.86	4.19	16.83	O	Adjusted from 17.2 for plateau behind low bluff
Jackson	45	13.59	4.57	4.12	17.1	O	No overtopping
Jackson	47	14.77	1.05	5.11	18.4	DL	No overtopping
Jackson	48	15.67	1.11	4.91	18.7	DL	No overtopping

FEMA TO-18 Wave Run-up Results

County	Transect	SWEL (ft)	Hm0 (ft)	T_{m-1} (sec)	2 % Exceedence run-up elevation (ft)	DL/O	Overtopping case
Harrison	15	18.00	4.63	5.35	20.30	O	Adjusted from 22.1 for plateau behind low bluff
Harrison	16	18.00	4.93	5.29	20.30	O	Adjusted from 23.1 for plateau behind low bluff
Harrison	17	18.00	5.09	5.49	20.60	O	Adjusted from 23.3 for plateau behind low bluff
Harrison	18	18.00	3.59	5.45	21.90	O	Adjusted from 23.2 for plateau behind low bluff
Harrison	19	18.00	6.81	5.45	20.80	O	Adjusted from 21.4 for plateau behind low bluff

Transect-ANY ft sec

$\tan\alpha =$ 0.11 SWEL= 17.9 H_{mo} = 5.50 T_{m-1}= 5.05

$\gamma_f =$ 1.0 $H_{1\%}$ = 8.80

$\gamma_b =$ 1.0

Top Layer	Mean	Significant	10% Exceedance	2%Exceedance	Maximum
Grass/Natural	20.2	21.6	22.6	23.0	24.5

Following Tables Contain Final Results

Done By: Bikash C Saha
Directed By: Alan Neodoroda
Checked By: Martin Brungard
Project: FEMA-Storm Surge Modeling(15707018.02000)

Transect-3,Harrison County, MS

$\tan\alpha =$ 0.29 SWEL= 18.6 Hmo = 3.69 Tm-1= 3.98

γ_f = **1.0** $H_{1\%}$ = **5.90**

γ_b = **1.0**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	22.5	24.9	26.6	**27.4**	29.9

Transect-14,Harrison County, MS

CASE-I

tanα = 0.1 **SWEL= 18.4** **Hmo = 5.17** **Tm-1= 5.24**

γ_f = **1.0** $H_{1\%}$ = **8.27**

γ_b = **1.0**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	20.5	21.8	22.7	**23.1**	24.5

CASE-II

tanα = 0.15 **SWEL= 18.4** **Hmo = 5.17** **Tm-1= 5.24**

γ_f = **1.00** $H_{1\%}$ = **8.27**

γ_b = **0.60**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	20.3	21.4	22.2	**22.6**	23.9

Transect-21, Jackson Conty, MS

tanα = 0.1 **SWEL= 14.70** **Hmo = 4.88** **Tm-1= 4.74**

γ_f = **1.0** $H_{1\%}$ = **7.80**

γ_b = **1.0**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	16.5	17.7	18.5	**18.8**	20.0

Transect-27, Jackson Conty, MS

CASE-I

tanα = 0.07 SWEL= 14.54 H_{mo} = 4.61 Tm-1= 3.55

γ_f = **1.0** **$H_{1\%}$ = 7.37**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	15.5	16.1	16.5	**16.6**	17.3

CASE-II

tanα = 0.12 SWEL= 14.54 H_{mo} = 1.19 Tm-1= 3.56

γ_f = **1.0** **$H_{1\%}$ = 1.91**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	15.4	15.9	16.2	**16.4**	16.9

Transect-28, Hancock Conty, MS

tanα = 0.05 SWEL= 18 Hmo = 7.36 Tm-1= 5.15

γ_f = **1.0** **$H_{1\%}$ = 11.78**

γ_b = **1.0**

Surface	Mean	Significant	10% Exceedance	**2%Exceedance Run-up Elevation**	Maximum
Grass/Natural	19.2	20.0	20.5	**20.8**	21.6

Transect-29, Hancock Conty, MS

tanα = 0.11 SWEL= 17.9 Hmo = 5.50 Tm-1= 5.05

γ_f = 1.0 $H_{1\%}$ = 8.80

γ_b = 1.0

Surface	Mean	Significant	10% Exceedance	**2%Exceedance Run-up Elevation**	Maximum
Grass/Natural	20.2	21.6	22.6	**23.0**	24.5

Transect-37, Jackson Conty, MS

tanα = 0.135 SWEL= 14.02 H_{mo} = 5.54 Tm-1= 4.19

γ_f = 1.0 $H_{1\%}$ = 8.86

γ_b = 0.62

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	15.5	16.4	17.0	**17.3**	18.2

Transect-45, Jackson Conty, MS
CASE-I

tanα = 0.1 SWEL= 13.59 H_{mo} = 4.57 Tm-1= 4.12

γ_f = 1.0 $H_{1\%}$ = 7.31

γ_b = 1.0

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	15.1	16.1	16.8	**17.1**	18.1

CASE-II

$\tan\alpha =$ **0.3** **SWEL= 13.59** H_{mo} **= 4.57** **Tm-1= 4.12**

$\gamma_f =$ **1.0** $H_{1\%}$ **= 7.31**

$\gamma_b =$ **0.68**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	16.8	18.7	20.0	**20.7**	22.7

Transect-47, Jackson Conty, MS

$\tan\alpha =$ **0.29** **SWEL= 14.77** H_{mo} **= 0.69** **Tm-1= 5.11**

$\gamma_f =$ **1.0** $H_{1\%}$ **= 1.10**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	15.8	16.5	17.0	**17.2**	17.9

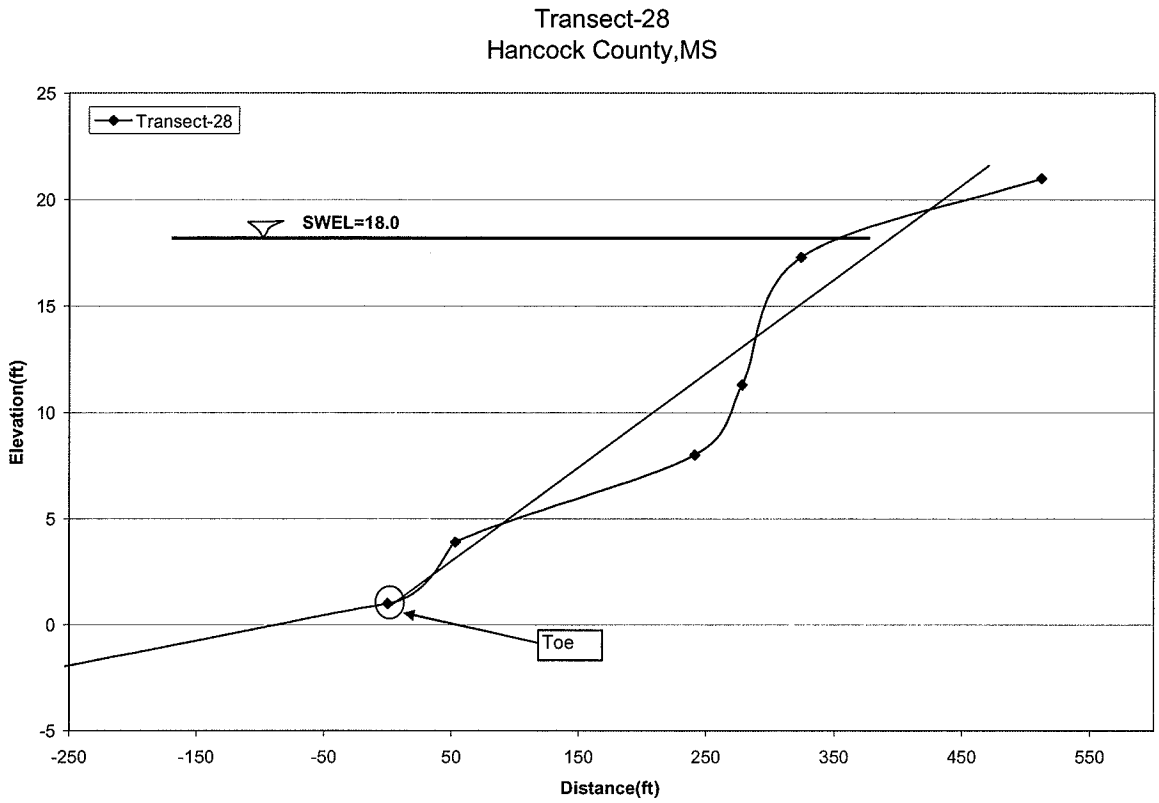
Transect-48, Jackson Conty, MS

$\tan\alpha =$ **0.15** **SWEL= 15.67** H_{mo} **= 0.69** **Tm-1= 4.91**

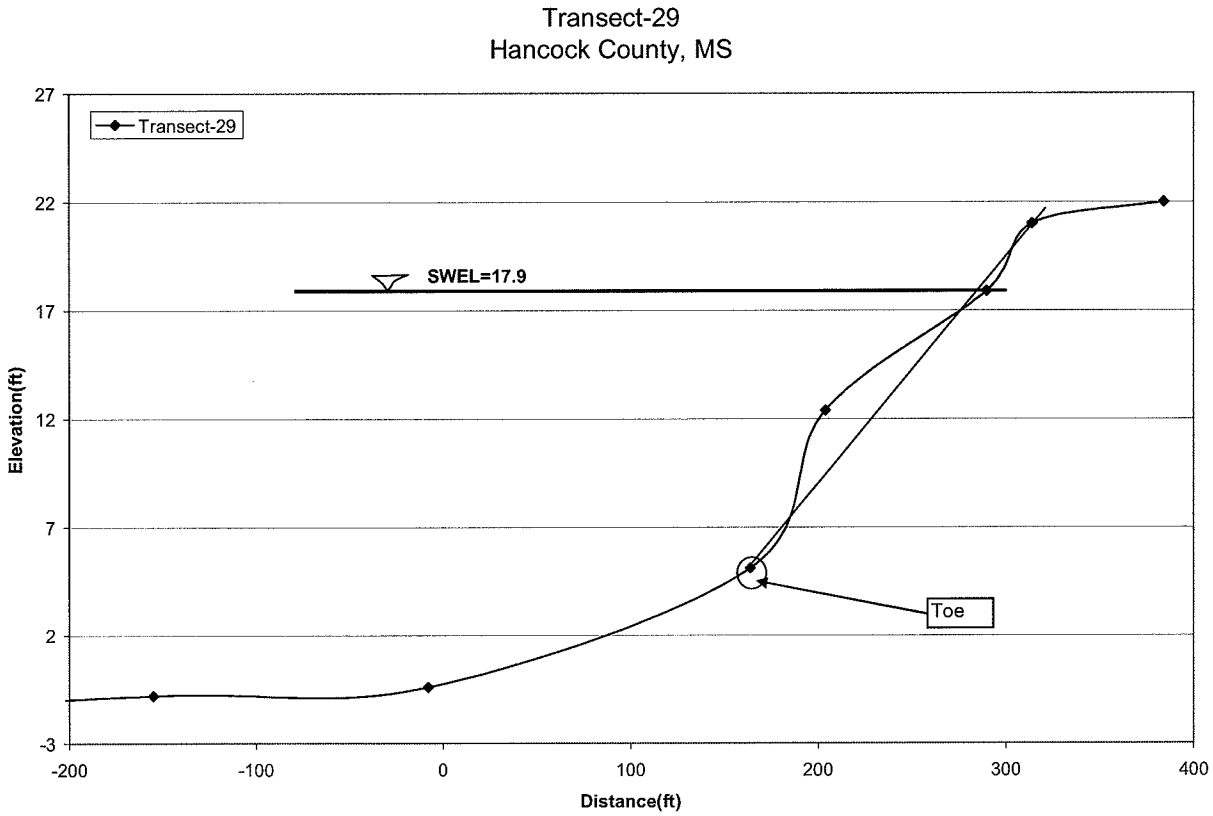
$\gamma_f =$ **1.0** $H_{1\%}$ **= 1.11**

Surface	Mean Run-up Elevation	Significant Run-up Elevation	10% Exceedance Run-up Elevation	**2%Exceedance Run-up Elevation**	Maximum Run-up Elevation
Grass/Natural	16.9	17.5	18.0	**18.2**	18.9

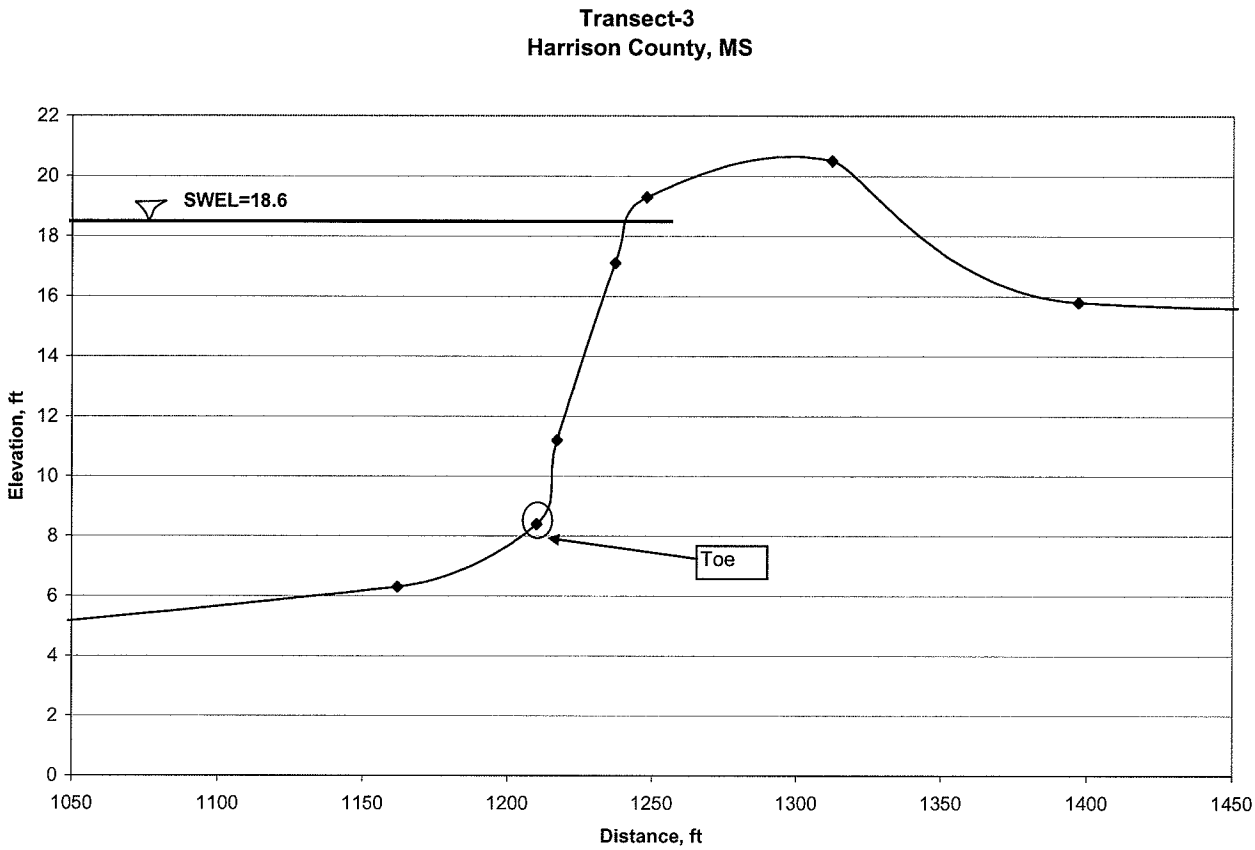
[All Elevations are in same unit as SWEL]



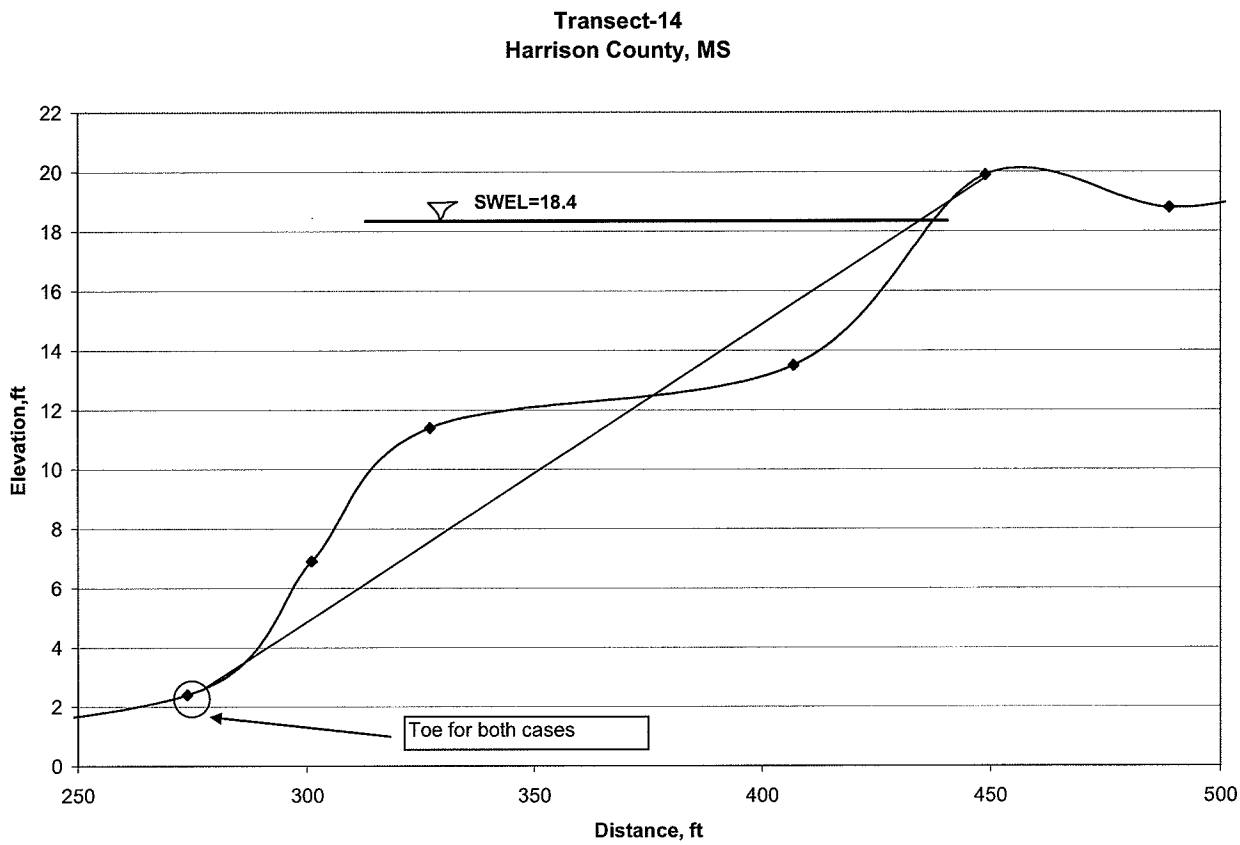
Transect-28: The location of controlling Wave Height and Peak Wave Period is at 0.0 [WHAFIS DATA]. The values are 11.78 and 5.67 respectively.



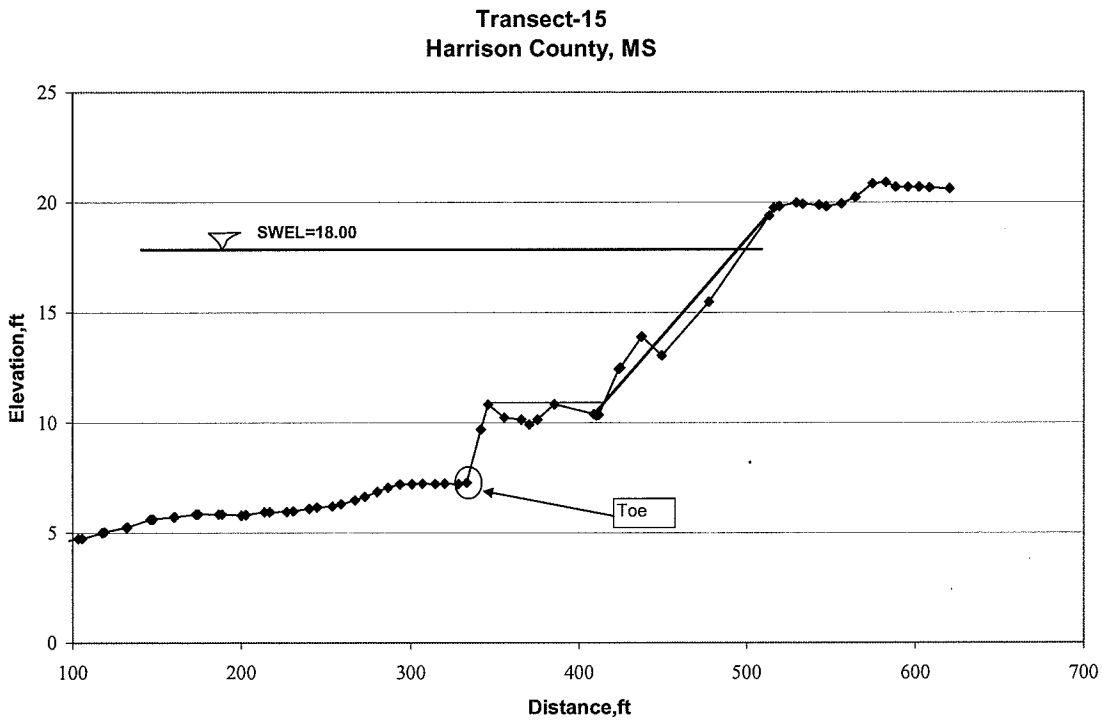
Transect-29: The location of controlling Wave Height and Peak Wave Period is at 164.0 [WHAFIS DATA]. The values are 8.80 and 5.55 respectively.



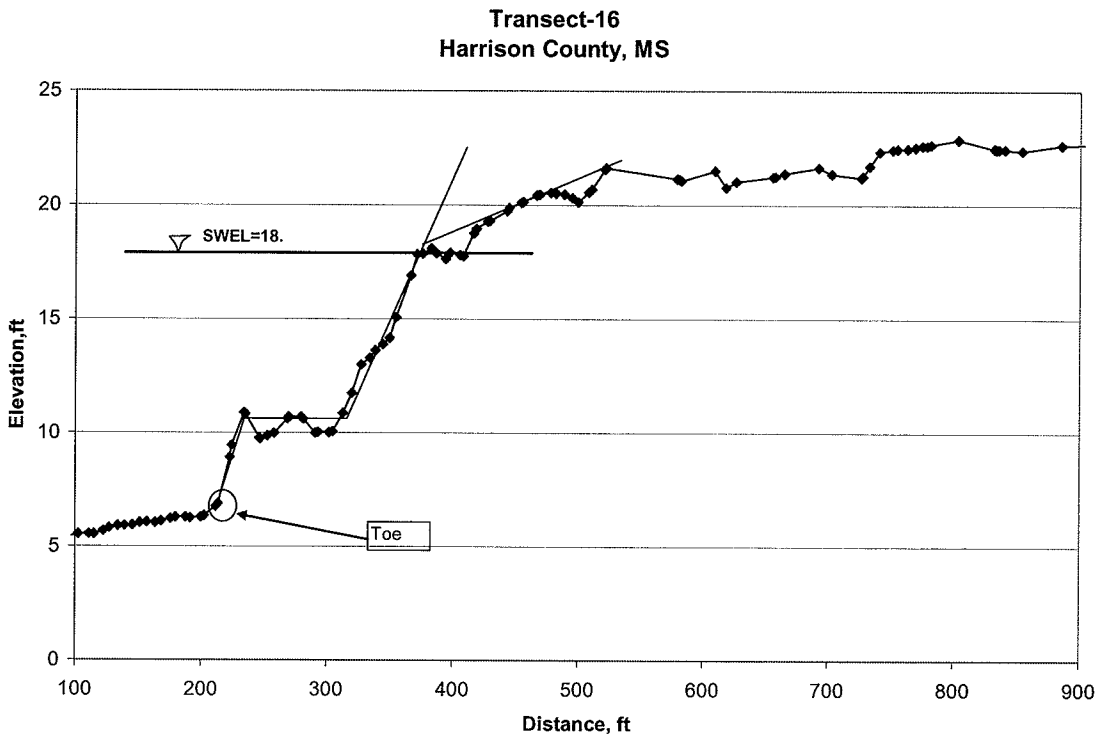
Transect-3: The location of controlling Wave Height and Peak Wave Period is at 1120 [WHAFIS DATA]. The values are 5.9 and 4.38 respectively.



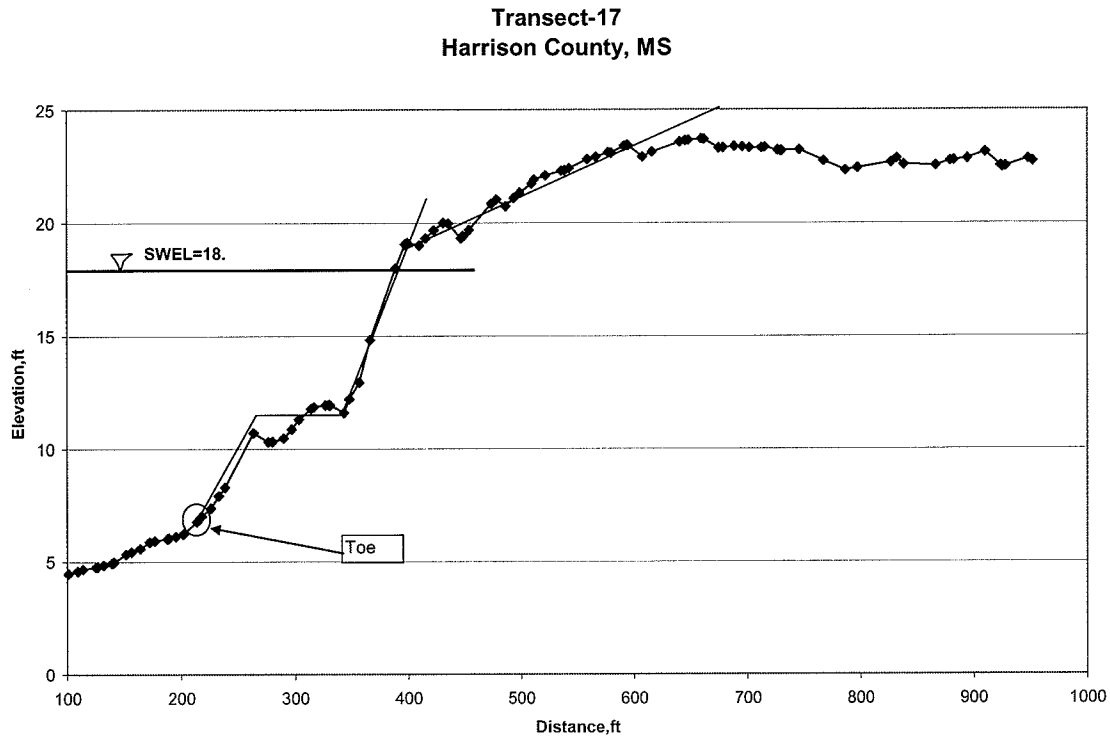
Transect-14: The location of controlling Wave Height and Peak Wave Period is at 276 [WHAFIS DATA]. The values are 8.27 and 5.76 respectively.



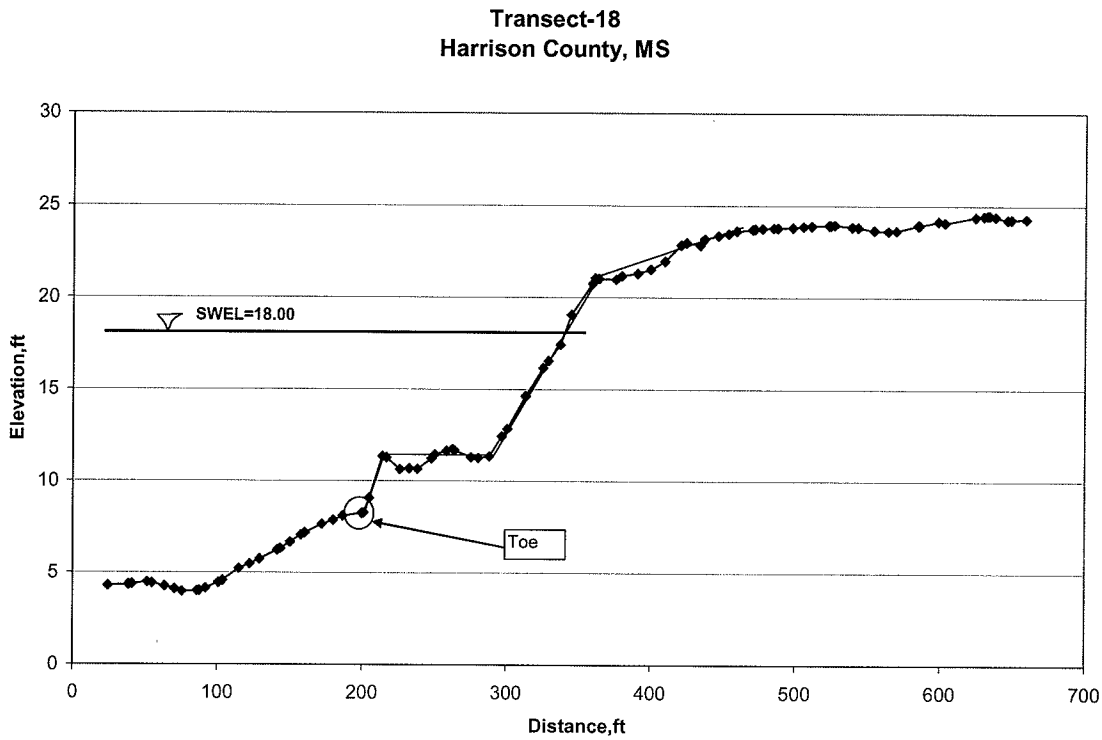
Transect-15: The location of controlling Wave Height and Peak Wave Period is at 333 [WHAFIS DATA].



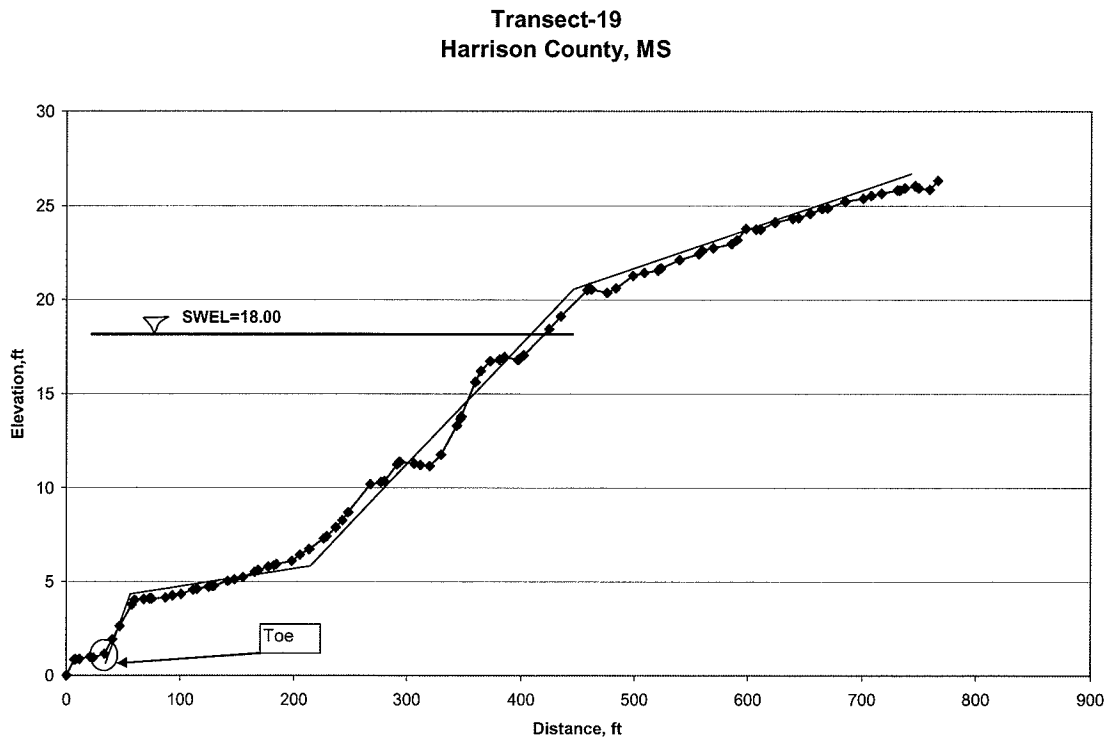
Transect-16: The location of controlling Wave Height and Peak Wave Period is at 213.7 [WHAFIS DATA].



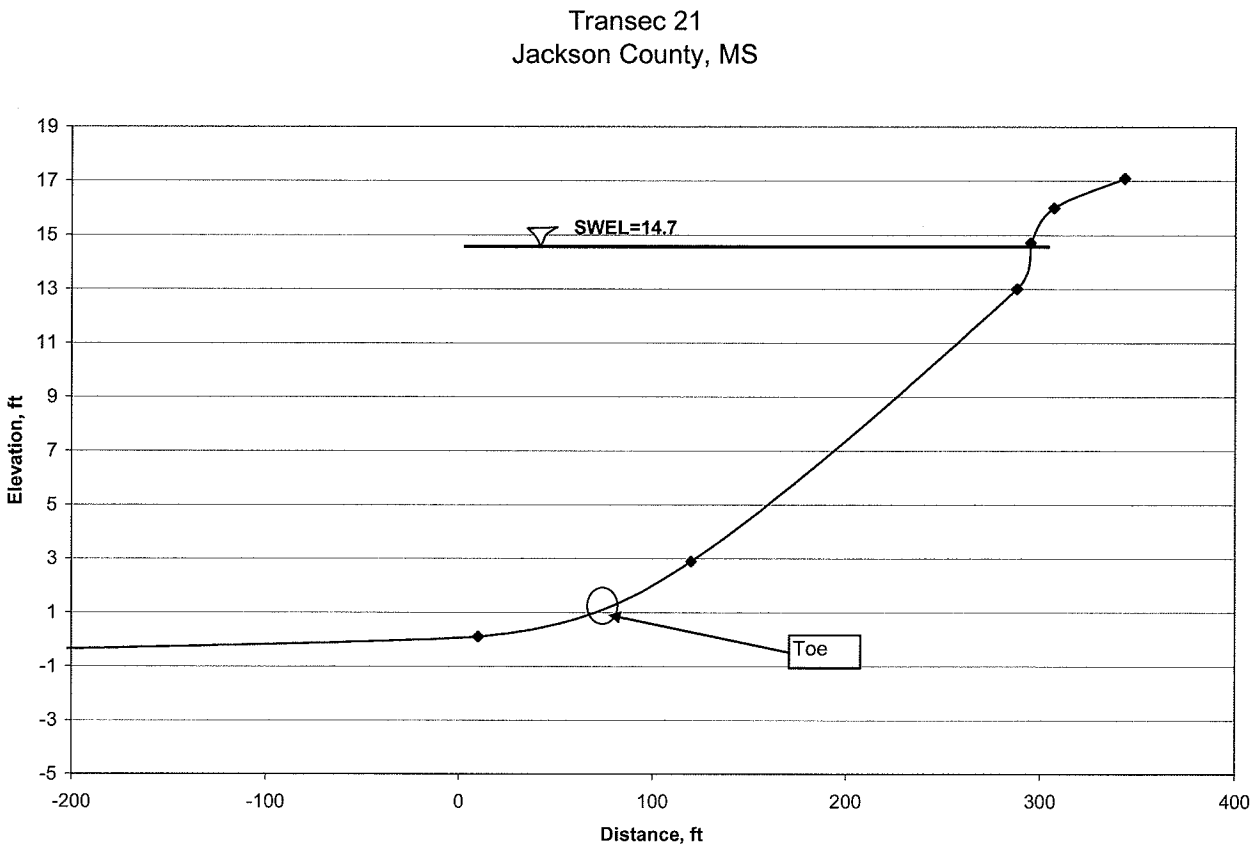
Transect-17: The location of controlling Wave Height and Peak Wave Period is at 203 [WHAFIS DATA].



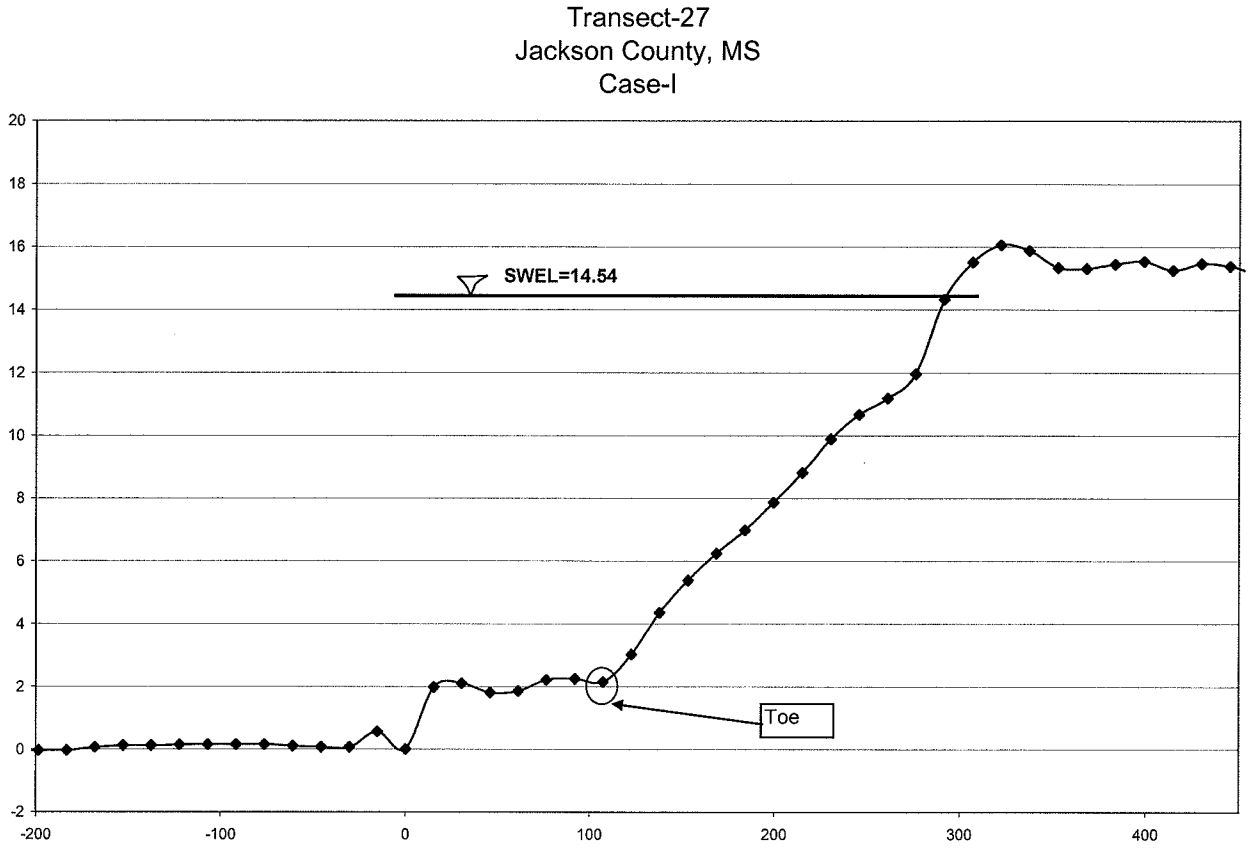
Transect-18: The location of controlling Wave Height and Peak Wave Period is at 201 [WHAFIS DATA].



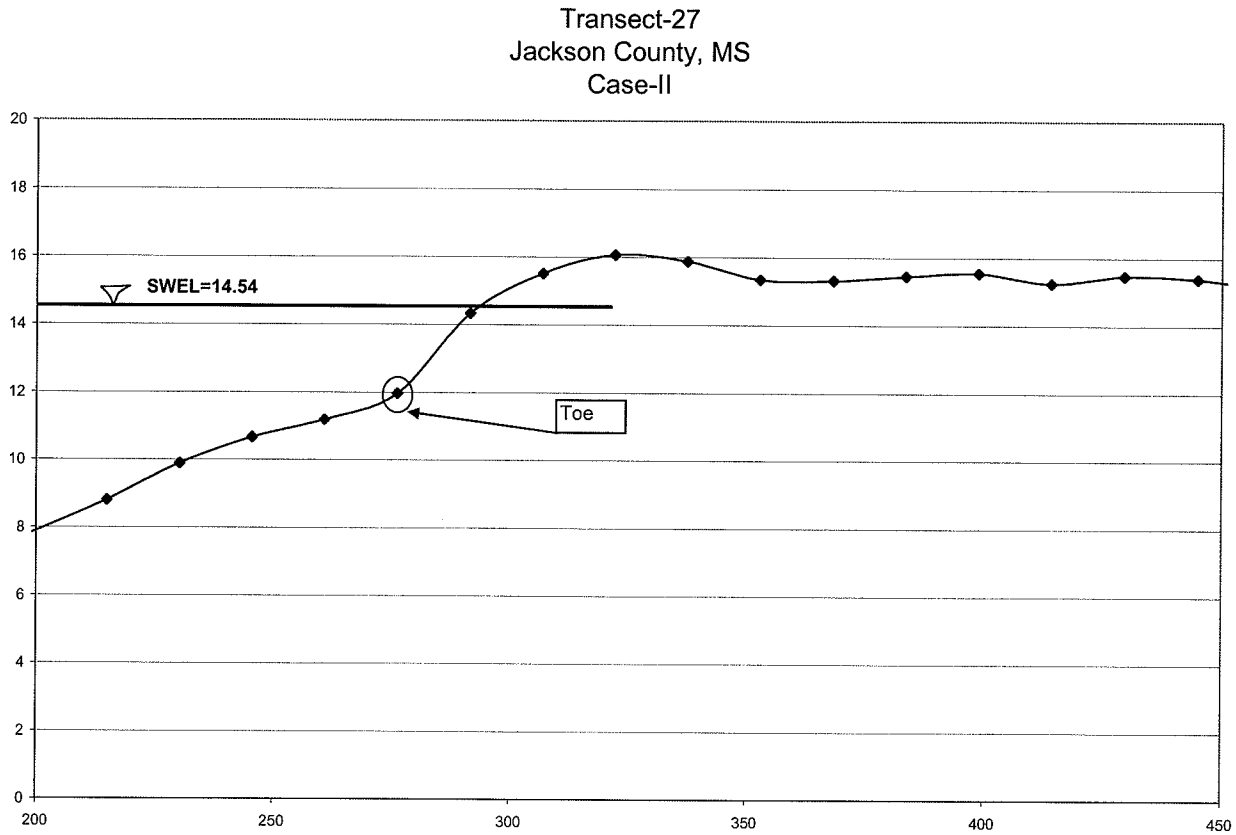
Transect-19: The location of controlling Wave Height and Peak Wave Period is at 33 [WHAFIS DATA].



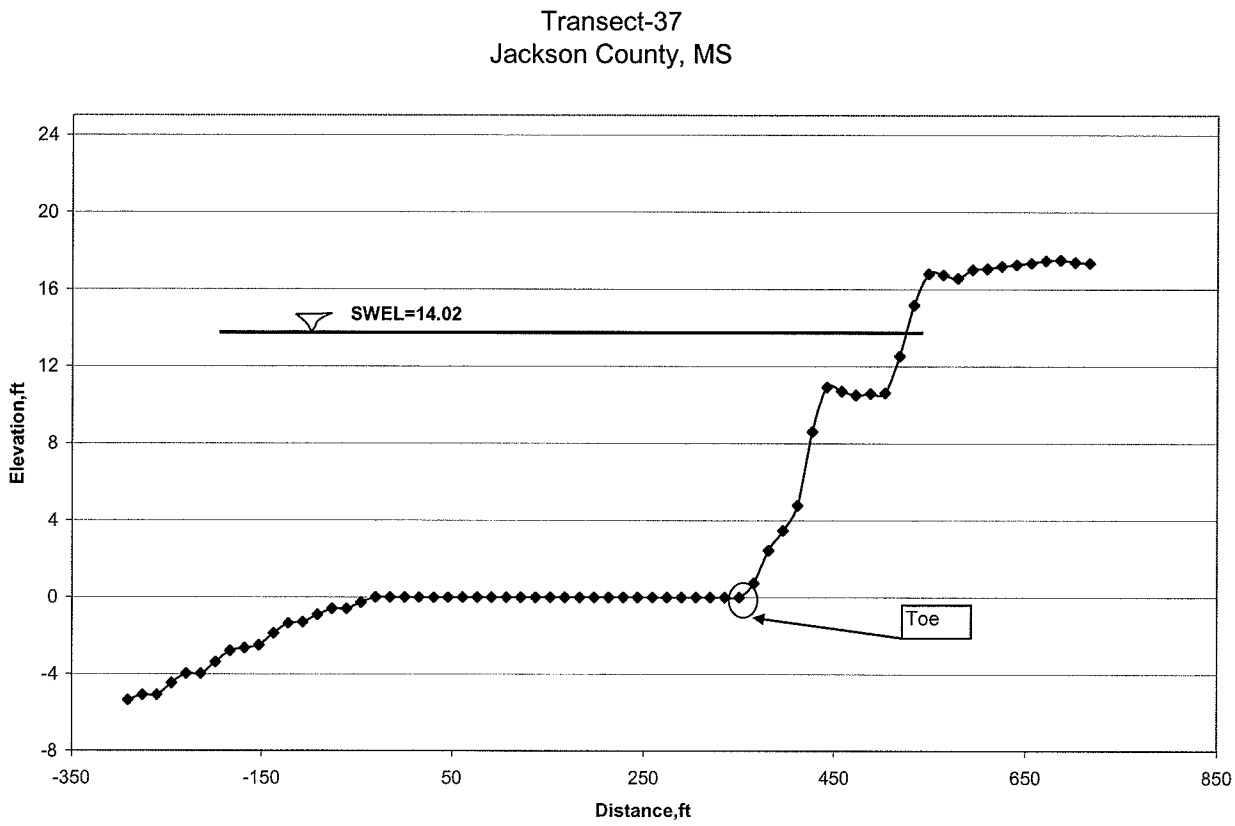
Transect-21: The location of controlling Wave Height and Peak Wave Period is at 0 [WHAFIS DATA]. The values are 7.8 and 5.20 respectively.



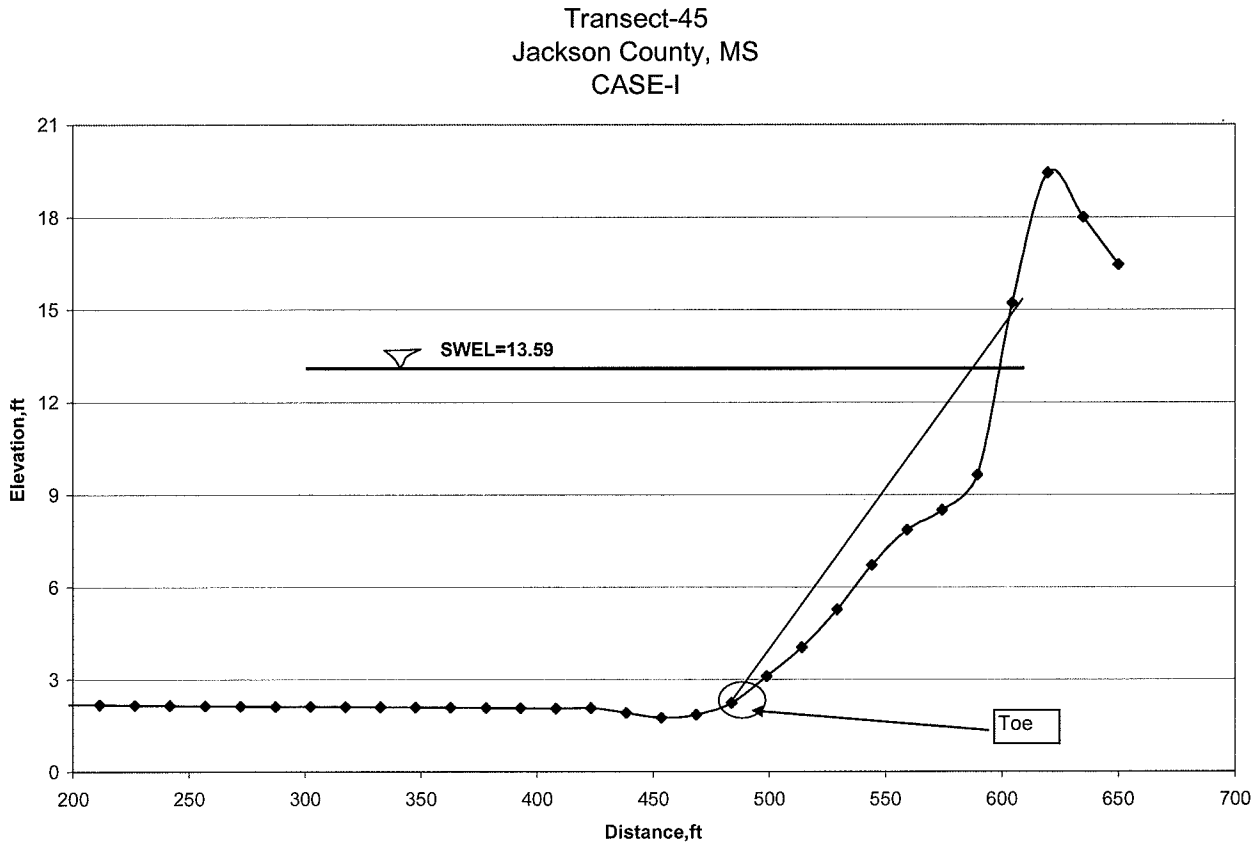
Transect-27(CASE-I): The location of controlling Wave Height and Peak Wave Period is at 107.40 [WHAFIS DATA]. The values are 7.37 and 3.91 respectively.



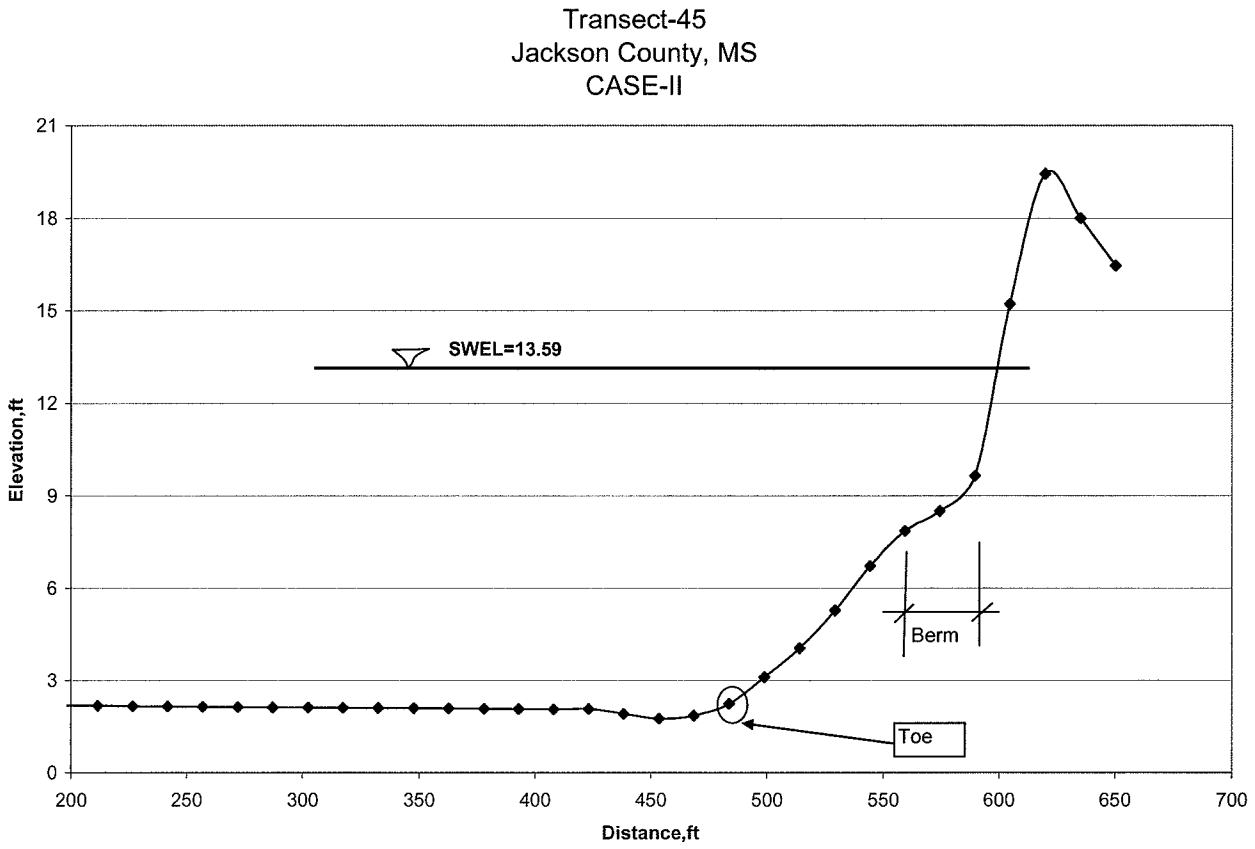
Transect-27(CASE-II): The location of controlling Wave Height and Peak Wave Period is at 276.20 [WHAFIS DATA]. The values are 1.91 and 3.92 respectively.



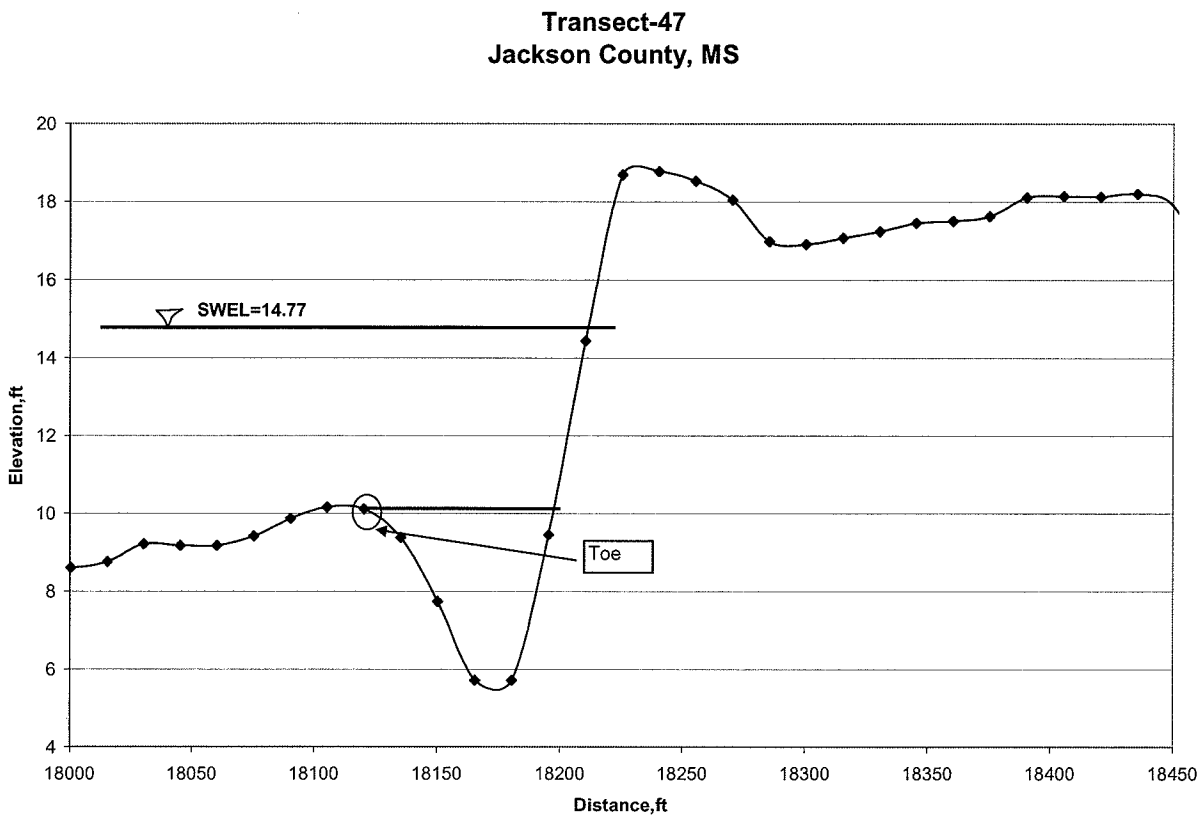
Transect-37: The location of controlling Wave Height and Peak Wave Period is at 245.28 [WHAFIS DATA]. The values are 8.86 and 4.61 respectively.



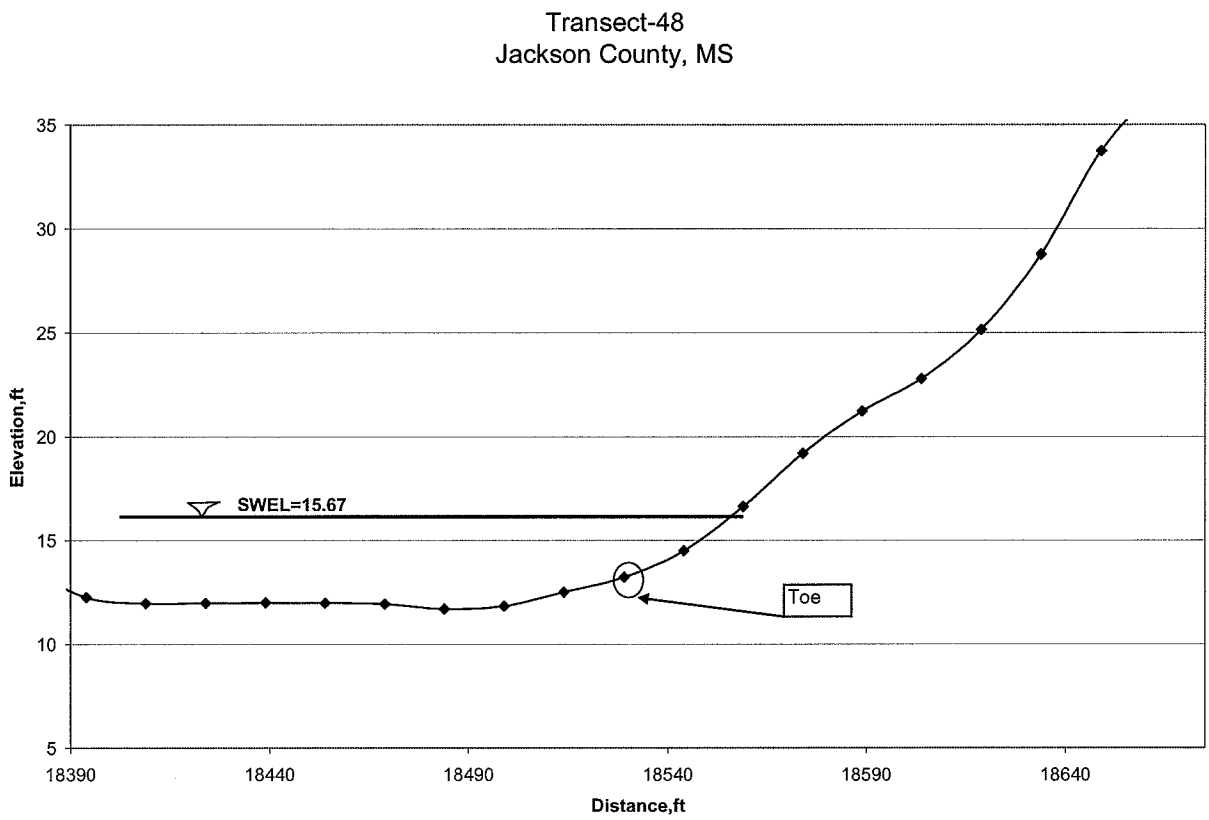
Transect-45(CASE-I): The location of controlling Wave Height and Peak Wave Period is at 483.70 [WHAFIS DATA]. The values are 7.31 and 4.53 respectively.



Transect-45(CASE-II): The location of controlling Wave Height and Peak Wave Period is at 483.70 [WHAFIS DATA]. The values are 7.31 and 4.53 respectively.



Transect-47: The location of controlling Wave Height and Peak Wave Period is at 18180.0 [WHAFIS DATA]. The values are 1.10 and 5.62 respectively.



Transect-48: The location of controlling Wave Height and Peak Wave Period is at 18498.0 [WHAFIS DATA]. The values are 1.11 and 5.40 respectively.

URS

Page 1 of 6

Job Wave Run-up Calculation | Project No. 15707018.02.000 | Sheet 1 of 4

Description Run-up calculation on Plateau above low Bluff | Computed by Bikash Saha | Date 8/27/07

Checked by M. Brungard | Date 8/24/07

Reference

Purpose: To calculate the adjustment of 2% wave run-up onto plateau above low bluff.

Procedure: if 2% wave Run-up Elevation = R

Bluff Crest Elevation = C

Then, $R' = (R - C)$ [Ref. Figure D.2.8-10 Attached]

From Figure D.2.8-11, X is computed for particular slope M.

Then Adjusted Run-up Elevation, $\boxed{R_a = C + MX}$

URS

Job: Wave Run-up Calculation
Description: Run-up Calculation on Plateau above low Bluff
Project No. 15707018.02000
Computed by: Bikash Saha
Checked by: M. Brungard
Page 2 of 6
Sheet 2 of 4
Date
Date 8/24/07
Reference

Calculation

Transect 15

Crest Elevation = 19.82'

2% wave Run-up level = 22.1'

$R' = 2.28'$, From Figure D. 2.8-11, $X = 28'$ for $M = 0.0187$

∴ Adjusted Run-up Elevation, Ra

$= 19.82 + 28 \times 0.0187$

$= 20.34' \approx \underline{20.30'}$

(Adjusted by Alan)

URS

Page 3 of 6

Job Wave Run up Calculation | Project No. 15707018.02000 | Sheet 3 of 4

Description Run up Calculation on plateau above low bluff | Computed by B. Kash Saha | Date

Checked by M. Brungard | Date 8/24/07

Reference

Transect 16

Crest Elevation = 18.40'

2% wave Run up Elevation = 23.10'

R' = 4.7', from figure D.2.8-11, X = 75'

for M = 0.0248

∴ Adjusted wave Run up Elevation Ra

= 18.40 + 75 × 0.0248

= 20.26' ≈ 20.30'

(by Alan)

Transect 17

Crest Elevation = 19.11'

2% Run up Elevation = 23.3'

R' = 4.19', from figure D.2.8-11, X = 67'

for M = 0.022

∴ Adjusted wave Run up elevation = 19.11 + 67 × 0.022

= 20.60'

URS

Job: Wave Run-up Calculations
Description: Run-up Calculation on Plateau above low Bluff
Project No. 15707018.02000
Computed by: Bilcash Saha
Checked by: M. Brungard
Page 4 of 6
Sheet 4 of 4
Date
Date 8/24/07
Reference

Transect 18

Crest Elevation = 21.02'

2% Wave Run-up elevation = 23.2'

R' = 2.18', from Figure D.2.8-11, X = 27'
for M = 0.032

∴ Adjusted Wave Run-up Elevation = 21.02' + 27×0.032
≈ 21.90'

Transect 19

Crest Elevation = 20.54'

2% Run-up Elevation: 21.40'

R' = 0.86', from Figure, X = 15'
for M = 0.0192

∴ Adjusted Run-up Elevation = 20.54 + 0.29×0.192
≈ 20.80'

A distinct type of overflow situation can occur at low bluffs or banks backed by a nearly level plateau, where calculated wave runup may appreciably exceed the top elevation of the steep barrier. A memorandum entitled *Special Computation Procedure Developed for Wave Runup Analysis for Casco Bay, FIS - Maine, 9700-153* provides a simple procedure to determine realistic runup elevations for such situations, as illustrated in Figure D.2.8-10 (French, 1982). An extension to the bluff face slope permits the computation of a hypothetical runup elevation for the barrier, with the imaginary portion given by the excess height R' = (R-C) between the calculated runup and the bluff crest. Using that height (R') and the plateau slope (m), Figure D.2.8-11 defines the inland limit to a wave runup (X) corresponding to the runup above the bluff crest (mX) or an adjusted runup elevation of R_a = (C + mX). This procedure is based on a Manning's "n" value of 0.04, with some simplifications in the energy grade line, and is meant for application only with positive slopes landward of the bluff crest. A different treatment of wave overflow onto a level plateau, for possible Flood Map Project use, is provided in *Overland Bore Propagation Due to an Overtopping Wave* (Cox and Machemehl, 1986).

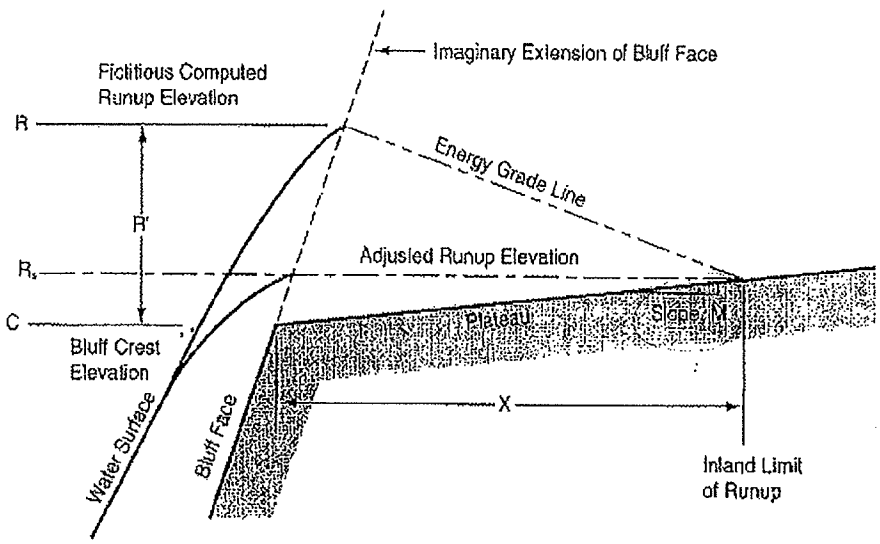


Figure D.2.8-10. Treatment of Runup onto Plateau above Low Bluff

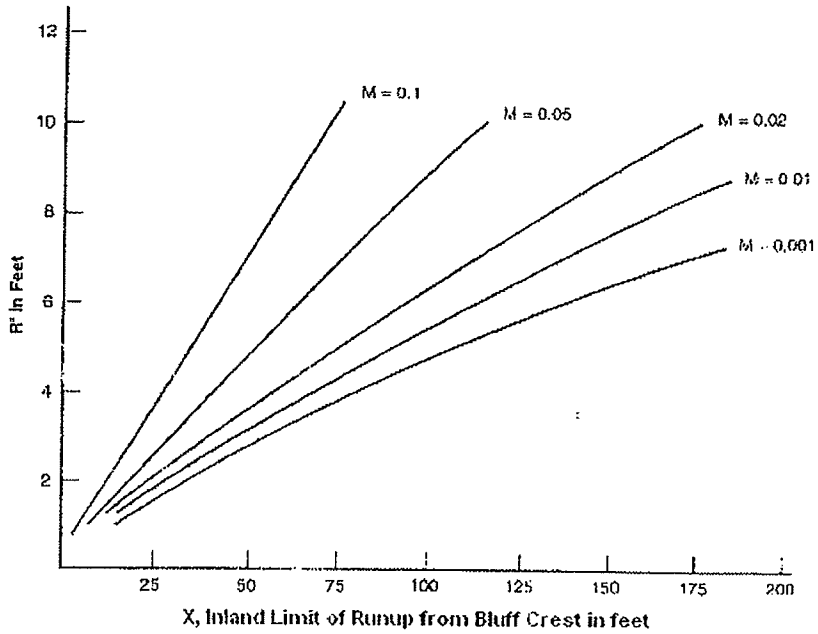


Figure D.2.8-11. Curves for Computation of Runup Inland of Low Bluffs

These runup assessment procedures are given for general guidance, but they may not be entirely applicable in certain situations. For example, runup elevations need to be fully consistent with the wave setup and wave overtopping assessments described in the subsubsections that follow. In problematic cases, the Mapping Partner shall use good judgment and rely on the historical data to reach a solution for the realistic flood hazards associated with a shore barrier. Subsection D.2.11 considers the integration of separately calculated wave effects into coherent hazard zones for the base flood. When a unique situation is encountered, the Mapping Partner shall prepare a Special Problem Report and discuss it with the FEMA Project Representative.

D.2.8.1.8 Advanced Wave Models

Wave models are becoming more sophisticated and able to account for the complexities of water waves. A rapidly developing class of these models is the Boussinesq group, which is both commercially and publicly available. The commercial models are generally more user friendly. In addition to wave setup, Boussinesq models can calculate wave runup. In conjunction with the development of these Guidelines and Specifications, 1-D Boussinesq models have been applied to calculate total wave runup, and the average and oscillating components were calculated separately. The comments below are based on an assessment of these Boussinesq results.

Compared to other methods, Boussinesq models yield generally realistic results. The main concern with Boussinesq modeling is the "learning curve" required to carry out these types of computations with confidence. Additionally, it was difficult to carry out calculations for deepwater waves with a small directional dependency. The reason for this difficulty lies in the associated substantial longshore wave lengths and the need for them to be represented by a 2-D