ATTACHMENTS A-F
(Updated 10/03/2011)
COASTAL MODELING AND DFIRM PRODUCTION
TECHNICAL APPROACH REPORT (TA)
FOR
COASTAL NORTHWEST FLORIDA

OCTOBER 08, 2009

INTRODUCTION

A new detailed coastal remapping study including storm surge analysis and overland wave height analysis is proposed to be performed by the Northwest Florida Water Management District (NWFWMD), in cooperation with Federal Emergency Management Agency (FEMA) and the Alabama Department of Economic and Community Affairs Office of Water Resources (OWR). This will include storm surge water elevation modeling analysis for Escambia, Santa Rosa, Okaloosa, Walton, Bay, and Gulf Counties in Florida and Baldwin and Mobile Counties in Alabama. This study will involve new and existing methodologies such as Light Detection And Ranging (LiDAR)-based topography, use of a digital terrain model (DTM), new aerial digital ortho-photos, planetary boundary layer (PBL) hurricane wind modeling, Simulating WAves Nearshore (SWAN) 2D wave modeling, Advanced CIRCulation model (ADCIRC) 2D hydrodynamic modeling and statistical analysis using a Joint Probability Method (JPM). This study would also include Wave Height Analysis for Flood Insurance Studies (WHAFIS) 1D overland wave modeling, coastal hazard mapping, and Digital Flood Insurance Rate Map (DFIRM) production. These analyses will be used to update the coastal hazard information and mapping depicted in FEMA's Flood Insurance Study (FIS)s and Flood Insurance Rate Map (FIRM)s for the counties identified above. The storm surge study will be performed for the coastline of eight (8) counties resulting in a single storm surge modeling effort. The overland wave height analysis will be subdivided by county or separate study reaches and performed by the respective state Cooperating Technical Partner (CTP)s or their contractors.

To complete the coastal study through to the mapping phase, it is estimated the work would take up to 36 months from the start of the initial data collection efforts and storm surge mesh development. The final objective following the TA at the end of the project study is to produce updated DFIRMs covering the coastal areas of Escambia, Santa Rosa, Okaloosa, Walton, Bay and Gulf Counties in Florida. The scope of this TA includes internal contractor Quality Assurance/Quality Control (QA/QC) procedures with reviews by the NWFWMD. If necessary, a panel of experts will be assembled by the

NWFWMD to provide external review on specific problem areas that may be identified related to coastal issues. The decision to form an expert panel will be at the discretion of the NWFWMD and will be based on their judgment of project progress as outlined herein. If special problem areas develop, they will also be documented in Special Problem Reports (SPRs) to FEMA. As new methods and procedures in Florida or other states in the Gulf of Mexico and Atlantic region are introduced, documented and accepted by FEMA, consideration to use them will be made. The new methods or procedures, with FEMA's approval, would be employed to produce DFIRMs at lower costs without sacrificing accuracy, and likely would be used to enhance map accuracy and detail. The study should take full advantage of current or modified draft versions of the FEMA guidelines and Procedure Memorandums for producing DFIRMs in the Atlantic and Gulf coasts, with the intent to reduce the project duration and costs. It should be understood going forward that all applicable FEMA guidelines and specifications, and procedure memorandums are included by reference in this TA. This includes new guidelines and procedure memorandums which have occurred after this study began when and where as applicable it is possible to apply the latest ones at no additional expense to the CTP. This study is also being conducted under the guise to maintain consistency with the FEMA coastal study methods to the west for Mississippi and to the east for the Florida Big Bend region. Therefore, these adjacent studies are included here by reference.

The work will be carried out by contractors currently certified and qualified to perform coastal mapping by the NWFWMD. Additional capabilities may include specialty teams recognized in the areas of statistics, hurricane meteorology, and hydrodynamic model development. Further specialized expertise will be obtained from several academic institutions involved in coastal hazards analysis, hydrodynamic modeling and model development. Thus, the "project team" will include continuing services contractors, recognized experts in the field of coastal modeling, university research expertise as well as NWFWMD hydrologists and engineers. Currently, the team members and principle contacts of each team member are:

1) NWFWMD - Ron Bartel, Project Management and Oversight
2) UCF - Scott Hagen, ADCIRC Surge Modeling, Digital Terrain Model Development
3) University of Florida (UF) - Don Slinn, SWAN Modeling
4) OceanWeather, Inc. - Andrew Cox, Wind Field Modeling
5) Risk Engineering - Gabriel Toro, Storm Characterization and Probability Analysis
6) URS – Chris Reed and Robert Johnston, QA/QC and Mapping
7) Dewberry - Jeff Gangai, Technical Oversight and Mapping
8) AECOM – David Divoky and Darryl Hatheway, Special Problems Technical Review

INTEGRATED WATERSHED MANAGEMENT

This study will apply an integrated watershed management approach as a general tactic for the development of flood hazard maps. Some of the benefits of this tactic are reduced study costs, enhancement of data sources, and increased longevity or continued use of study products by multiple parties. Such tactics include the use of recently developed models, data mining or leverage of existing water resources data from local sources, and obtaining in-kind support from the map user communities. Local level uses of the study data or its by-products add greater “buy in” to the program and, in turn, provide greater incentive for local governments as well as the NWFWMD to actively participate in the development of the program.

MODELING AND MAPPING ASSUMPTIONS

The project development team has examined a number of solutions to expedite the ADCIRC mesh development and to save computer run-time costs by carefully designing as well as eliminating unneeded mesh resolution. These savings should be applied to the study effort as it gets underway.

This TA also does not include a discussion of a 2D overland wave modeling approach because FEMA indicated it should not be included. The possible benefits in using this approach are currently being studied elsewhere by the NWFWMD. Currently, the 1D WHAFIS overland wave model is being used to estimate the overland wave conditions associated with the 1% annual chance mean water elevation. The final cost estimates, methods, and modeling assumptions as stated in this document form the basis of the TA for this study which was formally submitted to FEMA as a deliverable under a Cooperating Technical Agreement Mapping Activity Statement (MAS) and as an attachment to the TA presented to NWFWMD coastal communities for review.

Recent FEMA coastal flooding studies in Texas, Louisiana, and Mississippi have set many new precedents, which have changed study methods and procedures in many ways from what are defined in the current FEMA Guidance Document (Appendix D and 2007 update) and the draft *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update*. Any more recent advances when adopted or otherwise applied with a potential to change the study results will be subject to FEMA review for approval and included in updates of this TA. However, this does not preclude the NWFWMD as CTP from contributing or conducting its own independently funded study as part of this TA. Significant proposed changes to the TA will not be implemented until they are reviewed and approved by FEMA. This document and future updates will be published on the NWFWMD web site: http://NWFWMDfloodmaps.com.

Completion of this project requires several major tasks. Storm surge and wave model development, model production runs to simulate surge, wave set up and overland waves, and mapping and DFIRM production, as well as outreach, are the primary ones. The initial task of storm surge and wave set-up modeling covering the entire study area will be developed under a Florida MAS. Overland wave modeling, mapping, DFIRM production, and outreach will be carried out through separate MAS documents developed for each state. There are some potential cost savings which may be realized by slightly reducing the number of map panels and automated distribution or redistribution of coastal transects. There are, for example, coastal barriers which are in conservation in Okaloosa County and not inhabited as well as bay area where a high density of map panels are unnecessary where it will be possible to reduce production costs. The developed paneling scheme will also be more efficient because the flood maps will be developed and accessible through a Geographic Information System (GIS) environment. Also, the automated processes for transect development allow for a much higher density of transects and utilize LiDAR data. Any changes to the transect location and map panel distribution that deviate from the Guidelines and Specifications and Procedure Memoranda will be submitted to FEMA in a Special Problem Report (SPR) and will not be implemented until approved by FEMA.

1.0 STORM SURGE AND WAVE SETUP MODELS DEVELOPMENT

Detailed coastal study for FEMA flood hazard mapping requires development of a 2D surge model coupled with a wave model. The ADCIRC and SWAN models which have been selected for the modeling analysis are from FEMA's list of approved software for coastal floodplain analyses. Development of the models for this study will cover the entire Alabama coast in Mobile and Baldwin counties and the western panhandle of northwest Florida from Gulf County to Escambia County, Florida. There are five steps that are necessary for model development. The first involves the construction of a seamless digital terrain model (DTM), which will be built from LiDAR and the best available bathymetric data. A second step, done in conjunction with the DTM, is the development of a detailed ADCIRC model mesh. The mesh will be resolved on order of 40-300 meters, with small enough elements to describe the entire Gulf Intracoastal Waterway. The determination of geospatial friction coefficients comprises the third step, which will be based on the NOAA Coastal Change Analysis Program (C-CAP) land use and land cover data. The SWAN model will be validated as a fourth step. Finally, validation of the ADCIRC model for tides and storm surge will be completed.

Details of the ADCIRC model and mesh including mesh resolution of coastal features are generically or broadly defined in figures 1 and 2 below. However, more specific details of the model and its development including friction coefficients, bathymetry, and validation may only be provided in more detailed documents which will be produced as an outcome of this study.

Once the models are developed, they will then be used in a production mode to simulate approximately 300 synthetic storms (based on current estimates) needed to establish the surface water elevation statistics needed for mapping. The derivation of the final estimate of the number of synthetic storms is discussed below but it should be recognized this can only be determined after a significant amount of testing and trial and error procedures. Also, many more synthetic storms may be run as an intermediate step to test the model as well as derivation of final results. Hence every effort is made to economize and develop an efficient final storm set.

1.10 TERRAIN AND BATHYMETRIC DATA PROCESSING

LiDAR data has been collected for both states and is currently available as a seamless digital terrain model and at a standard datum (feet, NAVD 88) for all the coastal counties in the Florida Panhandle and Alabama (Figure 1, in feet, NAVD 88). As part of this TA, no new LiDAR data collection or processing is needed. Adequate offshore data is available from the National Oceanic and Atmospheric Administration (NOAA) bathymetric surveys and stored on the Geophysical Data System (GEODAS) database. Additional data sources, investigated, included the United States Army Corps of Engineers (USACE) shelf data acquired with LiDAR. The USACE also maintains a survey database of shoreline structures (e.g., jetties, groins, and revetments) around inlets and bridges. All of these identified datasets are evaluated by NWFWMD and its contractors and, as appropriate, are to be used in the development of a final digital terrain model covering the study area. The project team, as defined earlier also evaluates the terrain and bathymetric data and as necessary will correct them to build a seamless set tied to a standardized datum. The bathymetry and topographic datasets will be then merged together with the shoreline, to produce a separate seamless DTM for the entire study area. No other data collection is anticipated for DTM development. This task is completed before the mesh development task and is to be documented in a detailed report for review. Statistical characterization of storms will be performed concurrent with the DTM development and aid in understanding the upper limit and extent of the storm surge boundary. This effort will include but not be limited to the following tasks:

- Conduct field reconnaissance prior to final TA development to familiarize the study team with the varying coastal conditions and local topographic and structural features that will control flows.
- Conduct field reconnaissance to identify the type and nature of the vegetation and building obstructions, and document unique coastal features that need to be

considered in the surge modeling (seawalls, levees, bluffs, inlets, and river confluences).

- Conduct limited bathymetric surveys of the river mouth areas where depth data is sparse.
- Obtain available data from the USACE Mobile District office on ADCIRC surge modeling, LiDAR shore line and other data including authorized channel surveys. Obtain available data from State of Florida's Beaches and Shores Resource Center, community data, and other state agencies including the Florida Department of Transportation (FDOT) and Alabama Department of Transportation (ALDOT).
- Review digital elevation data from various sources (NOAA, NWFWMD, OWR, FEMA, State of Alabama, State of Florida, USACE, and United States Geological Survey (USGS)) which is available to enhance the DTM.

Most of the initial field reconnaissance task was completed during the scoping phase of this project. NWFWMD watercraft and land based vehicles were used for the field reconnaissance work covering the entire study area in detail. A primary purpose of the field work was to identify, describe and measure flow controlling structures including bridges, culverts, causeways, etc. and familiarize the project team with the entire study area. It will also be necessary to have information about the depths and cross-sections of most streams. For the purpose of this TA, adequate data was available from existing sources, such as existing river flood studies, DOT crossing surveys, and navigation/nautical charts. The available data was a significant amount of data which has been reviewed and no deficiencies have been identified requiring additional expense and schedule adjustments for collection of additional field data.

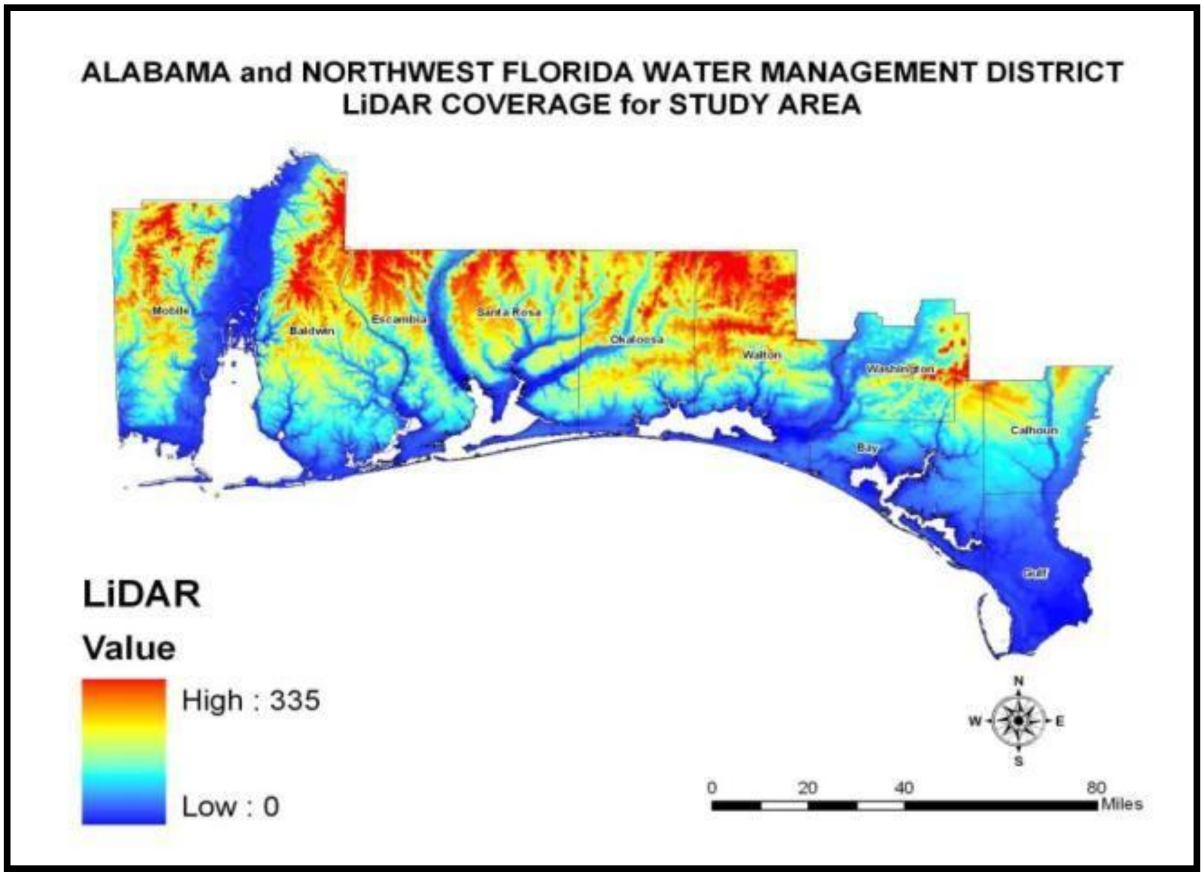


FIGURE 1. LiDAR Coverage Map
(*All Units are in Feet, North Atlantic Vertical Datum (NAVD) 88)*

1.20 MESH DEVELOPMENT

ADCIRC model mesh development which follows DTM development has begun and will include extraction of vertical features, identification of roadways, riverbanks and other poly-lines that are identified within the DTM and should be fixed within the mesh. All surface characteristics (including Manning's n, wind-reduction factors, and canopy assignments) will be based on the NOAA coastal Change Analysis Program (C-CAP) land use and land cover data. The surface characteristics are planned to be done as a part of a Model Testing and Validation tasks which are aligned with the developed model mesh. Thus, because the final set of surface characteristics are produced after the model mesh is developed and following model testing, some minor adjustments in the mesh may occur. Additional documentation on the sources and development of surface characteristics will be provided with the completion of this task.

Although many existing ADCIRC meshes have already been created for the northern Gulf of Mexico, only the most recent model developed by NOAA as a part of their V-Datum efforts (see http://vdatum.noaa.gov/) and highest resolution mesh developed prior to this FEMA study is discussed here(displayed in Figure 2).

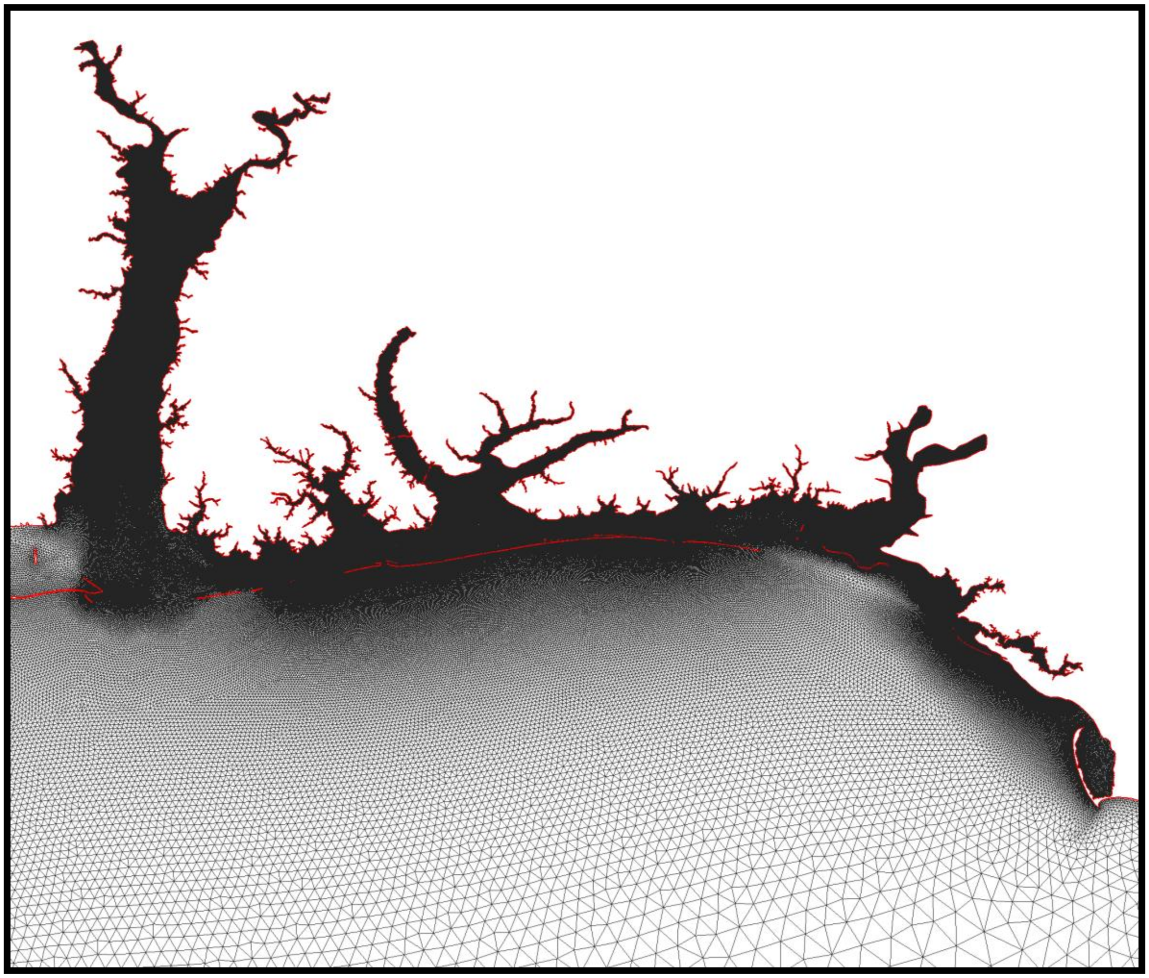


Figure 2. Overland Model Mesh Developed by NOAA Covering the Study Area.

This mesh extends overland up to the 15-meter contour and covers an area west to Mobile County, Alabama and east to Gulf County, Florida. The project team approach is to use the preexisting NOAA model to extract useful data and perform some initial sensitivity tests to understand the resolution requirements for the system to be modeled.

However, the University of Central Florida (UCF) has decided to develop a new ADCIRC model mesh for this study in order to take full advantage of a recently developed technique to extract vertical features. This technique proved invaluable in the development of a stable, accurate mesh for the storm surge model employed in Franklin, Wakulla and Jefferson counties, Florida. A newly developed software tool, called SMS 11, will also be applied to assist in the automated construction and design of a more rigorous mesh around these vertical features. As an objective, the model mesh will cover an area that covers the landward extent of surge defined by a Category 5 hurricane as delineated by Sea, Lake, Overland, Surge from Hurricanes (SLOSH) model maps and somewhat higher up to the 10 to 15 meter (32 to 48 feet) elevation (see attachment B).

On the west end, the mesh will coincide with the mesh developed for the FEMA sponsored Mississippi model study (western model). On the east end, the mesh will align with the Franklin, Wakulla and Jefferson Counties model developed for the NWFWMD's FEMA study (eastern model). This important step will help to ensure consistency between FEMA flood insurance rate maps adjacent to the subject area. However, the mesh resolution will be relaxed further east and west and coarser on either end of the model domain.

The contractors involved with model mesh development will address how consistency between the eastern and western models should be accomplished and checked using actual verification storm results. Statistical data sets previously accomplished will be used as a check and to assure that the model mesh will produce the same or similar mean water elevations. The NWFWMD and its contractors will also check the model results for consistency with the models previously applied adjacent to the study area.

It is now estimated that an initial detailed mesh for the entire study area will contain almost 2,500,000 mesh nodes. Nonetheless, since the model developed will also be used to perform the production runs, the project team ensures that the time to implement a single production run will be approximately four hours, which is reasonable and cost efficient in order to simulate several hundred production runs. The final mesh will meet QA/QC requirements with appropriate documentation to explain how the final mesh was developed.

The project team shall ensure that the mesh is accurately interpolated to the terrain and bathymetric data providing an accurate representation of the morphological features represented in the data set. The final mesh and mesh node size will be explicitly documented followed, by QA/QC reviews and officially submittal to FEMA for approval, along with the topographic and bathymetry data prior to production.

1.30 GEOSPATIAL FRICTION COEFFICIENTS

This task will begin with the determination of surface characteristics, including Manning's n (a bottom roughness parameter used in the calculation of bottom drag), wind-reduction factors (to modify the marine-based PBL winds to account for land features), and canopy assignments (to reduce wind stress when the vegetation canopy would restrict wind from reaching the water surface). Surface characteristics will be derived from land cover representations from the NOAA coastal Change Analysis Program (C-CAP) land use and land cover data. Other data sources may include the National Land Cover Database, GAP data and Florida Fish & Wildlife Conservation Commission (FFWCC) land cover data.

1.40 ADCIRC MODEL ASTRONOMIC TIDE AND STORM SURGE VALIDATION

The study team will perform astronomic tide simulations and a series of hurricane storm surge runs with tides, wave forces and wind/pressure forcing to validate the overall model. Simulated astronomic tides and hurricane storm surge shall be compared against verified tidal constituents maintained by NOAA, tidal elevation hydrographs and high water marks in order to ensure that the model is reasonably reproducing the hydrodynamic behavior of the study area. This effort will include, but not be limited to, the following tasks:

- Include and test the developed surface characteristics.
- Apply the ADCIRC model in astronomic tide simulations and validate with NOAA station data.
- Acquire the historical hurricane wind field datasets from OceanWeather, Inc. (OWI) (as necessary) and incorporate existing data (as appropriate) for the storm surge modeling effort.
- Test the ADCIRC model stability under conditions of hurricane storm surge.

- Apply the ADCIRC model in storm surge simulations for the entire coastal reach.

Several storms shall be run over the study areas in order to verify that the mesh and the models correctly represent water elevations and wave heights associated with the selected historical events. This task includes but is not limited to:

- Providing results that show comparisons between model simulated and observed high water mark data from past events.
- Providing results that show model data comparisons with observed tidal gage data which were collected during the storm as well as during non storm astronomic tidal periods.

1.41 TESTING OF MAJOR RIVER INFLOW EFFECTS FOR PRODUCTION

As part of the ADCIRC modeling process it is also important to understand and test the interaction between storm surge and the inflows of major rivers. While not necessarily explicitly modeled during production it is important to recognize the impact of river flows will have on water levels during surge events. For the purposes of this study riverine flood flows as a result of a hurricane are treated as mutually exclusive events and typically occur after the surge even has subsided, however "pre-storm" riverine inflows below storm induced flood levels could still impact surge elevations in the flood ways of major rivers. Model sensitivity tests will be limited to major rivers where river gage data exists for the validation storms. With and without river inflow simulated results will be quantified to demonstrate the possible impact of these pre-storm river flows on predicted surge heights. If the impact of river flows is significant, a decision will be made how to treat river inflows in the ADCIRC model production phase. This task includes but is not limited to:

- Provide ADCIRC model results with and without inflow estimates based on existing USGS gage data for selected validation storms.

1.50 VALIDATION STORM DATA ORGANIZATION AND SELECTION

As previously discussed, a set of storms were identified early in the study and pulled out from the NOAA database to be run for model testing and subsequent validation (computed versus measured result comparisons) for both surge and wave modeling. Thus, the named storms Hurricanes Katrina (2005), Opal (1995), Ivan (2004), and

Dennis (2005), and Georges (1998) will used for validation because they have the most recent and best meteorological records of wind, pressure, surge, and waves available. The five historic hurricane events, which are an unprecedented amount, will be used to validate the ADCIRC model as well as the SWAN model. Hurricanes Ivan, Katrina, Opal, Dennis, and Georges are also excellent candidates because of the amount of data available documenting them and they are relatively recent events which have impacted the "current" conditions of the coastline. In general, the validation storms selected are those that have impacted a large area of the coastline being studied as well as ones having an adequate amount of historic measured data to validate a model against. This task includes:

- Review available validation data sets connected with historic storms and provide a QA/QC review of these data.
- Provide a final list of historic storms and corresponding data sets for validating the models.
- Prepare a validation data set report to document the data to be used for validation and evaluations of the error associated with water level data collected.

1.60 SWAN MODEL DEVELOPMENT AND CALIBRATION

New state-of-the-art methods will be used for the determination of wave setup over the open water portions of the study area. A 2D wave model will be run concurrently with the surge model. By doing so, the amount of wave setup due to wave breaking can be determined and mean water levels (inclusive of wave setup) can be calculated. The approach outlined below utilizes a conventional approach as was developed recently for the State of Mississippi.

Wave setup modeling includes calculation of the wave setup and wave fields across the study area. This initial subtask involves model development and testing. Utilizing the present capabilities of ADCIRC, the project team will perform 2D wave modeling using the SWAN model developed by Delft Hydraulics. Offshore boundary conditions shall be developed to use as forcing for the nearshore wave modeling. The 2D wave modeling will determine radiation stresses that will be input into ADCIRC in order to provide mean water elevation accounting for wave setup. Results from the SWAN model will also be used to determine starting wave conditions for the transects modeled during the coastal hazard analyses.

Model development includes preliminary SWAN model grid development and layout, SWAN script development for nested grids and winds, calibration and testing with historical storms, inclusion of final topographic and bathymetric data sets, optimization and testing on portable computing platforms.

The ocean bathymetry and coastal topography are taken from multiple sources, the National Oceanographic and Atmospheric Administration (NOAA) - National Geophysical Data Center (NGDC), and from the NWFWMD ADCIRC Alabama-Florida Grid, which incorporates the high resolution LiDAR survey data reported on elsewhere. For consistency with the ADCIRC model, the same bathymetric data is used as in the ADCIRC model inland and for water depths less than 20 meters deep. In the coastal zone, the bathymetry in the wave models was interpolated from the ADCIRC two million node grid.

The SWAN model is currently planned to be implemented on a set of seven (7) nested grids, with resolutions of 10 km, 2.5 km and approximately 160 meters. This nesting system was designed to optimize grid resolution and simulation time. At the coarsest resolution, there was a basin grid that covered the entire Gulf of Mexico with a grid resolution of 0.1 degrees or approximately 10 km. Inset inside of this is the second grid level. This is referred to as the Alabama - Florida Region grid that has a grid resolution of 1.67 km (0.01667 degrees). The region domain was made to match exactly with the high resolution wind fields given from OceanWeather, Inc. In shallow water, the bathymetry becomes important and needs to be represented for wave modeling on a higher resolution grid. Thus, the final coastal resolution grids of approximately160 meters were used in the coastal domains. Previous FEMA FIRM studies (e.g., Louisiana and Mississippi, 2008) used either 200 meter (Louisiana) or 160 meter grid resolution (Mississippi, Florida) for the coastal waves. Tests were done for those studies, and are reported on in the respective URS and Arcadis final FEMA Engineering reports, to determine the sensitivity of the results to the grid refinement and these resolutions were found to be adequate and have been adopted in the ongoing Texas and Florida (Franklin, Wakulla, and Jefferson counties) FEMA FIRM studies. Five coastal grids are used that overlap along the coast with 160 meter grid spacing in the x direction, and 180 meter grid spacing in the y direction (both are 0.00166667 degrees at this latitude).

The high resolution grids have a combined total of 1,446,224 grid points at 160 meters grid resolution plus 76,328 grid points in the Basin and Region domains for a total of approximately 1.5 million wave computational points.

The basin grid does not need wave boundary conditions as it is forced by the OWI wind and pressure fields. Wave spectra on the boundary locations of the regional grid are obtained as a function of time from the basin grid simulation and saved as the boundary condition input fields for the regional grid simulation. Wave spectra on the coastal grids are obtained from the regional grid as a function of time and saved as input fields for the coastal grids.

A procedure that accounts for the generation of the boundary conditions, the runs of the 2D wave model, the validation of the results against historic data, and the coupling process between the wave and the storm surge models has been established. The coupled wave-surge modeling system implements a two-way coupling in an iterative manner. Storm surge water levels are calculated with the AdCIRC model and the wave fields are calculated on a high resolution (160 meter) grid along the Alabama-Florida coastline in the study area. The wave forces were then passed to the final high resolution ADCIRC (Advanced Circulation) model grid for the Florida Panhandle Flood Study.

SWAN model version 40.78 is used for this study. It is implemented with 36 directional bins (e.g., with 10 degree directional wave spectral bins) and with 26 frequency bins (from 0.0314 to 0.4177 Hz) covering wave periods between approximately 32 seconds down to 1 second (the last frequency bin for the highest frequency waves is nominally at 2.4 second periods, but represents waves and wave energy with periods from 0.0 to 2.4 seconds). The time step is 30 minutes and the model data is output every 30 minutes.

Five storms will comprise the model validation including Hurricanes Ivan (2004), Katrina (2005), Dennis (2005), Georges (1998), and Opal (1995). The validation data is primarily available from offshore buoys. The National Oceanographic and Atmospheric Administration (NOAA) maintains a number of wave buoys in the Gulf of Mexico and the data is available on line at the National Data Buoy Center web site (NDBC). Buoy 42039 and 42036 are of primary interest because they are located closest to our region of focus on the shelf of the Florida Panhandle in our study area. Buoys 42003 and 42004 are also near our domain. Model results will be compared against calibration data sets from the five validation storms. Model results will be presented and provided in an acceptable format to the project study team. All model data and model run data will be archived and stored as necessary.

2.0 MODEL PRODUCTION

To develop revised 10%, 2%, 1% and 0.2% annual chance mean water elevations for each study area; the project team will conduct hurricane and tropical storm surge modeling using ADCIRC (version 46.58), a 2-D hydrodynamic model commonly used for storm surge simulations. As discussed in more detail below, this study will rely on the PBL-generated wind and pressure field data, offshore wave data, SWAN 2-D wave modeling and a statistical analysis of the model results using the appropriate JPM. The coastal mean water elevations will then be used for the overland wave analysis and hazard mapping process described in the next section.

As discussed previously in Section 1.0, the ADCIRC model version 46.58 will be used by the project team in a production mode to conduct storm surge modeling and QA/QC the results. This modeling will require preliminary model setup time and daily concurrent execution of ADCIRC and SWAN model runs, followed by concurrent model preparations and starts. This TA calls for running the ADCIRC model once following a SWAN model run for each model production run. The current TA also calls for comparisons of the model results obtained previously for Mississippi and east of Gulf County, FL in order to maintain consistency between coastal reaches. The results of those studies will be used as guidance in conducting this study. Also, the results of this study will be compared to those at the shared boundaries to access consistency.

The model production run process involves an initial application of a coarse mesh ADCIRC model (58,000 element ADCIRC grid of the Gulf of Mexico, Weaver and Slinn, 2010 and Graber et al. 2006) run to obtain SWAN model input to produce SWAN wave modeling output. This coarse resolution ADCIRC model does not include overland surge, so the predicted surge at the coastline is extrapolated inland by assuming the inland surge is level with the elevation at the coastline. The sensitivity to this approximation was tested in previous studies on Hurricane Dennis by alternately running ADCIRC twice on the high resolution grid and it was found that the results for storm surge were nearly indistinguishable, within ~1 percent; therefore the 50 percent savings in efficiency with ADCIRC was worthwhile. A similar sensitivity test will be performed for this study area and results reported on prior to production. This SWAN model output is then used as input for subsequent ADCIRC modeling. This step is to be followed by post-processing for further use in subsequent ADCIRC with SWAN wave modeling/coupling runs.

The ADCIRC production runs is the most critical and most expensive component of the study because the model mesh size or number of nodal points developed is great, and will require several months of computer time during the production run phases. The storm surge study also includes a number of sub-tasks. All procedures and deliverables will be in compliance with the QA/QC section given later in this document. It is particularly important that the initial ADCIRC and SWAN models developed go through the QA/QC process prior to model production as well as afterwards during production. The actual number of model runs to be undertaken at any one time is dependent on length of shoreline and whether or not the storms maximums are adequately achieved to represent the 10%, 2%, 1% and 0.2% annual chance mean water elevations over the shoreline segment studied. It is estimated that for the eight county shoreline length, a sufficient level of accuracy will be achieved within 600 model production runs. If the study team is unable to achieve a sufficient level of accuracy within the 600 model production run limit and current budget limitations, it will consider alternate methods for estimating the 10% and 2% annual chance mean water levels.

2.10 DEVELOPMENT OF JOINT PROBABILITY METHOD STATISTICS AND SYNTHETIC TRACKS

In order to reduce the number of production runs needed in the JPM analysis, it is necessary to investigate the important storm parameters, combination of parameters and storm tracks that influence the return periods. The NWFWMD contractors will perform a JPM statistical analysis and develop a synthetic set of storms and tracks to be run for production.

This task includes definition of Coastline Capture Zone and Compilation of Data over a selected historic period. To define a Capture Zone for the collection of hurricane data and the calculation of hurricane parameters at a minimum the zone will extend no more than 400 km from either end of the area under investigation. This zone will be limited to the storms that originate in the Gulf of Mexico or enter the Gulf of Mexico from the Caribbean, and may also include storms that have crossed (east to west) the Florida peninsula and enter the Gulf of Mexico. Storms that only make landfall once on the Atlantic Ocean shorelines will not be used in this study. The exact dimensions of this capture zone are of little importance because distant storms will be given a low weight and will have a minimal effect on the calculations. The widely accepted Chouinard's kernel approach will be used for weighting storms and developing the storm statistics. This approach follows a statistically fitting procedure to account for the rate of occurrence and the spatial variation of the intensity of land falling storms along the Northwestern Gulf Coast.

The proprietary Tropical Parameter Database (TROP) or equivalent files provided by OWI, will be used to calculate the storm characteristics (ΔP , Rp, forward velocity Vf, heading, landfall coordinates, etc.) at landfall for each storm in this dataset during the period 1947-2005). The simplified coastline geometry developed by Dr. David Levinson's group at NOAA, or a similar coastline used in NWS38, will be utilized to define the coastal crossings and as the reference coastline for other tasks in this study.

Owing to well-documented limitations of the data prior to 1940, the Period of Record is defined as beginning in the 1940's, as has been done in most recent surge studies in the Gulf of Mexico. In addition a list of shore-crossing storm parameters (landfall date-time and coordinates, ΔP, Rp, forward velocity Vf, heading, etc.) at the shore crossings for individual historical storms that fall within the Capture Zone and Period of Record defined above will be developed.

The Statistical Analysis for Development of Probabilistic Model for hurricane occurrence and characteristics will include performing a statistical analysis to estimate the parameters of a probabilistic model of hurricane frequency and characteristics at landfall. This model consists of the following elements: annual rate of hurricanes with ΔP above a certain threshold, probability distribution of ΔP (given that it exceeds the threshold), and the conditional distributions of Rp, forward velocity Vf, heading, and Holland B, given ΔP. As in recent probabilistic surge studies, this work will focus on the conditions at landfall. This effort will include consideration of alternative probability distributions for ΔP. Adjustments to the approach may be necessary, to accommodate the shape of the NE Gulf of Mexico coast.

The statistical analysis also requires investigating the temporal variation of ΔP and other key storm parameters, considering storms that make landfall within the Capture Zone. Based on these comparisons, the temporal schemes used in the Mississippi or Louisiana studies may be adopted or modified. The appropriateness of adopting the schemes from Mississippi or Louisiana, an explanation of the data sources, methods and procedures used to establish the spatial extent of the Capture Zone as well as the Period of Record used will be documented in the detailed JPM report developed as part this study.

The Development and Validation of Synthetic Storms and Associated Rates will involve using the probabilistic model developed above to generate 1,000 to 2,000 combinations of storm parameters at landfall (and their associated rates) to properly represent the flooding from all possible combination of parameters. These storms will be used in a large series of Sea Lake Overland Hurricane (SLOSH) model runs to develop the Reference-JPM storm surge analysis.

The Quadrature Joint Probability Method – Optimal Sampling (JPM-OS) will be used to develop a more compact JPM-OS representation of the storm population, which consists of an initial estimate of 600 combinations of storm parameters. This will involve performing the SLOSH runs for these storms and comparing the resulting values to those obtained with the Reference-JPM set. The final number of storms or other elements of the formulation will be determined when the right combination of accuracy and efficiency is achieved. The goal for this project will be to achieve results for the 10%, 2%, 1% and 0.2% annual chance events with less than 600 synthetic storms.

Following the previous step, a set of approximately 300 (estimated) synthetic storms will be developed. In addition to the parameters at landfall, these synthetic storms will incorporate representative track geometries and temporal variations in key parameters. The synthetic tracks will be laid out in a uniform spacing across the study area and will be based on the parameters and landfalling locations of the historic storms.

2.20 SLOSH RUNS FOR JPM ANALYSIS

This section is to illustrate and describe the use of the SLOSH model to support the statistical analysis being performed as part of the JPM analysis in section 2.10. This is a separate task that was identified during scoping but it is performed more or less concurrently and in an iterative fashion during the development of the JPM storm data sets. It is, therefore, described separately rather than within Section 2.10. As previously discussed it is necessary to investigate the important storm parameters, combination of parameters and storm tracks that influence the return periods. Existing and the most recently available (SLOSH) models will be used to make up a large series of approximately 4,000 individual storm runs to determine the resulting effects on surge elevations. SLOSH is being used due to its ease of setup and ability to run each storm very quickly. The tracks will be laid out uniformly across the study area for the SLOSH runs. Model results will provide the initial JPM combination of storm parameters to run as well as the tracks for further analysis. Once the production set of synthetic storms is reduced to approximately 600 storms or less, SLOSH will be run again with these storms to compare back to the original set to assure the correct set of production storms has been selected for determining the surge elevation return periods.

Historical storms will be used to determine key statistical hurricane parameters that will be used to develop a suite of synthetic hurricane tracks whose spacing will be a function of the storm size (e.g. radius to maximum winds). Using the probabilistic model developed above 1,000 to 2,000 combinations of storm parameters at landfall (and their associated rates) will be generated to properly represent the flooding from all possible combination of parameters. These storms will be used in a large series of SLOSH model runs to develop the Reference-JPM storm surge analysis. The Quadrature JPM-OS method will be used to develop a more compact JPM-OS representation of the storm population, which will consist of up to 600 combinations of storm parameters. SLOSH runs will be performed for these storms and compare the resulting values to those obtained with the Reference-JPM set. The number of storms will be adjusted or other elements of the formulation adjusted until the right combination of accuracy and efficiency is achieved. Based on the parameter combinations obtained in the previous step, a set of synthetic storms will be developed. In addition to the parameters at landfall, these synthetic storms will incorporate representative track geometries and temporal variations in key parameters.

The effective FISs shall also be reviewed in order to identify the most destructive storms that had been part of the historic record at the time of those studies. These data will be updated to include all storms up to the most recent. To update the FIS, the study team will review the NOAA/NWS (National Weather Service) and North Atlantic hurricane database (HURDAT) that lists all the tropical events that have impacted the study area. The most significant historical storms that are characteristic of 10%, 2%, 1% and .2% annual chance will also be used to compare and test for reasonableness.

This effort will include, but not be limited to, the following tasks:

- Using the SLOSH model to validate the storm parameter selection.

- Develop probability distributions for all relevant storm parameters that will be applied in the ADCIRC model.
- Apply appropriate statistical modeling approaches and compare this to long-term tide records where available.

2.30 WIND/PRESSURE MODELING

Wind and pressure fields shall be developed for each synthetic track. Sensitivity studies of the key storm parameters shall be performed before the final generation of the synthetic wind and pressure fields in order to ensure that the data are suitable for a FEMA study. Wind and pressure fields will also be developed for the historic storms chosen to hindcast and validate the ADCIRC model. These synthetic storms will be used during production run to drive the SWAN 2D and ADCIRC models. The effort will use the previously developed detailed ADCIRC grid scheme, and the NWS HURDAT hurricane database wind field data modeled by OWI. Up to 300 simulations will be run and results statistically analyzed using an appropriate JPM (e.g. Optimum Sampling) in order to obtain mean water level return periods.

2.40 SWAN MODELING

The calibrated and verified wave setup model SWAN version 40.78 will be designed to provide wave forces for up to 600 synthetic storms (production runs) in addition to calculating the wave fields in the open ocean as well as open water (bay area behind the barrier islands). Prior to proceeding with production model tests will be performed on two calibration storms (Katrina and Ivan) to verify the difference between applying a coarse mesh and the ADCIRC mesh designed for production are as anticipated minor. The SWAN/ ADCIRC model tests and ADCIRC grids to be used will we documented in a pre-production technical memorandum. Wind fields will be produced by OWI in the same manner as previously developed for FEMA studies, will be used. The model, model data, and results will be archived in a format specified by the project study team and the necessary wave forces will be stored for passage to the ADCIRC model. A final report will be prepared to document the SWAN model results. All model results and reporting will be submitted to NWFWMD and FEMA as required.

2.50 ADCIRC MODELING

This effort assumes the use of a cluster high-speed parallel processor computer system and the ADCIRC 2DDI version 46.58. Wind fields produced by OWI, and previously utilized for FEMA studies, will be used and ADCIRC will be manually coupled with the SWAN model results. The open coast shoreline reach as well as back bay areas for the eight counties would be modeled all at once. This will require a significant total number of production runs. This will be resolved in more detail through the joint probability methodology task, but it is dictated by the storm meteorology for the region, optimum sampling techniques for statistical sensitivity, and nature of the probability results (storm direction, central pressure, Holland-B parameter, and radius of maximum winds) all of which can directly affect the number of storm paths needed for the synthetic storm population. However, it is assumed that a total synthetic storm population including pre and possible post production model tests will not exceed approximately 600 runs. It is currently estimated that approximately 300 synthetic storms will be needed for the production run phase(s) to cover the coastline of the eight-county area. The number of synthetic storms may be adjusted once the analysis of the storm parameters for the study area is made. The production runs will be performed as follows:

As outlined in Task 2.40 above the 2D SWAN wave model shall be run on grids covering the Florida panhandle and Alabama regions with water levels input from an existing low resolution mesh ADCIRC model for the set of storms selected for final production runs. The wave radiation stress gradients obtained through the SWAN model are then passed as input to the high resolution ADCIRC simulations to obtain a set of mean water Elevations (that include wave setup). As necessary, a separate independent team of experts will be assembled by the NWFWMD to evaluate results which may be deemed by NWFWMD to fall outside expected levels of accuracy or precision established by specific QA/QC standards.

Thus, the ADCIRC model will be run for the number of synthetic storms as determined above in order to provide SWELs that are inclusive of wave setup. As necessary, a separate independent team of experts may evaluate these results following specific QA/QC standards as well. Before releasing data to the next phase, these results will also be provided to FEMA and/or the National Service Provider (NSP) for review. For each synthetic storm, graphics will be generated which will be decided upon by the project study team and approved prior to conducting the production phase. The specific data review requirements will be determined prior to model production runs but will include review of wind and pressure fields and SWEL + waves as required for the study. Model data will be provided in a usable and acceptable format to the NWFWMD and FEMA which will be utilized for statistical analysis and final report preparation. If necessary, the project team shall also produce a lower resolution station grid layout where the results of the storm surge modeling may be extracted to perform the frequency analysis. All necessary model and run data will be copied onto a long-term storage device to be provided to FEMA in acceptable format as part of an Interim Data Submittal and at the end of the project. The results will also be archived with appropriate documentation as required by FEMA and NWFWMD. Tentative data formats are standard mesh files for the ADCIRC and SWAN grids, and the digital input created by OWI files for the wind fields. Simulated outputs will be provided in the raw fort.* file formats as generated by the ADCIRC model.

2.60 RETURN PERIOD ANALYSIS

The peak storm surge elevation generated by each storm at each station (or model node) will be analyzed using the appropriate JPM to determine return periods (i.e. 1, 10, 50, 100-year) for the 10%, 2%, 1%, and 0.2% annual chance mean water elevations. The standard deviations of the "error terms" associated with omitted storm parameters, limitations in the storm parameterization, lack of skill of the hydrodynamic model, tidal effects, etc. will be quantified. The tides will be integrated into the uncertainly term used in the frequency analysis. The frequency analysis will be performed on final ADCIRC production model results accounting for surge inclusive of wave setup. Results from the 2D wave model will also be extracted (using the same methodology as used in MS and in the Eastern Panhandle of Florida) at the starting location of each transect to obtain the 1% starting wave conditions for the overland wave height analyses. The summary of mean water results from the production runs as well as the results of the frequency analysis will be submitted to NWFWMD and FEMA for review.

This Phase will require but not be limited to the following tasks:

- Using results from ADCIRC and the appropriate statistical approach, determine the magnitude and extent of the coastal mean water elevation revisions necessary for the entire coastal shoreline.
- On the order of several hundred thousand output points will be distributed over the model mesh to support the joint probability method analysis. Calculated maximum water levels inclusive of surge plus wave setup, at this large number of locations on the grid will be stored for development of stage-frequency relationships.
- Calculate the 10%, 2%, 1% and 0.2% annual chance mean water elevations at numerous locations along the coast, bays, and inland areas for surge inclusive of wave setup datasets. The density and number of points will be sufficient to permit accurate delineation of the flood elevations. The points utilized will be the highest density possible. A practical limit of spacing between points will be considered. Stage frequency points will be dense where the elevations are changing rapidly and can be farther apart where the surge is gradually varying.

3.0 OVERLAND WAVE HEIGHT ANALYSIS AND MAPPING

The project team will perform overland wave height analysis, redelination and DFIRM production. This will entail updated detailed coastal flood analyses for each of the counties, including new storm-induced erosion assessments, updates to primary frontal dune determinations (as needed), 1-dimensional overland wave height modeling, and wave runup modeling (as needed), as well as mapping of the coastal flood hazard zones and base flood elevations. The following milestones will be accomplished in this process:

3.01 LAYOUT OF TRANSECT LOCATIONS

This task includes layout of published and mapping coastal analysis transect locations in each of the six Florida coastal counties. The transect layout for coastal hazards analysis and subsequent floodplain delineation is determined by physical factors such as changes in topography, bathymetry, shoreline orientation and land cover data, in addition to societal factors such as variations in development and density. The base map will be used to determine the appropriate placement for hazard modeling transects within each of the Florida counties.

First, the layout of the published transects will be made. These are the transects that will be the primary focus of the detailed modeling and will represent the major changing conditions along the coastline, such as topographic changes or land use changes. The published transect layout will be used in the field reconnaissance to verify placements and direct the coastal modeling team to focused areas. It is estimated that as many as 300 of these transects may be needed to adequately cover the coastal area being studied in northwest Florida. These initial transect layouts will also consider the comments collected at the scoping meetings to ensure adequate coverage of sensitive floodplain management areas. Knowledge gained from the storm surge field reconnaissance will also be used in determining suitable published transect locations.

Subsequent to field reconnaissance, the transect layout is finalized and the transect layout is submitted for FEMA review. The transect layout was initially submitted as a deliverable in the Communities' Scoping Report which is attached (Attachment F) to this TA below. In addition to the published mapping transects shown for review, unpublished transects are generated at a higher density in between the published transect locations. These denser set of transects support detailed hazard mapping by eliminating large areas of undefined hazard changes that typically involve interpolation of results. After the mapping transects are complete, elevation data are extracted from the topographic base and populated into the modeling.

Deliverables:

A. Published transect location map(s) covering the six Florida counties;
B. Published and mapping transect location GIS layers;

3.10 FIELD SURVEY AND RECONNAISSANCE

This task involves basic field data collection. The project team will conduct detailed field reconnaissance of the coastal areas for each of the counties to determine conditions along the floodplain(s) such as, types and numbers of hydraulic and/or flood control structures, apparent maintenance or condition of existing hydraulic structures, locations of transects to be evaluated for wave modeling (including fetch areas and obstruction areas, such as marsh, building, and vegetation information), and other parameters needed for the coastal storm surge and wave study. Interviews will be conducted with various federal, state and local officials regarding available storm and field measured data and records of past flooding events. Detailed LiDAR data sets, digital aerial photography, and available on the ground drive by video will also be reviewed as part of this reconnaissance task. All data collected and assembled for development of the overland wave modeling task will be digitally cataloged and recorded in an appropriate electronic file transfer format for later use as necessary and to document the study area current conditions.

3.20 WHAFIS ANALYSES AND SETUP

The contractor will follow Appendix D of FEMA's "Guidance for Coastal Flooding Analyses and Mapping" (2003) and the draft Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, February 2007, when performing the coastal analyses. Coastal modeling preprocessing tools, using a GIS environment, will be used to automate some of the modeling inputs such as identifying the transect layout, processing mean water elevations, performing dune erosions, and running WHAFIS 4.0 and RUNUP 2.0 models. The contractor will use the preliminary layout of coastal transects and areas requiring detailed overland wave analysis that will have been delineated earlier during the formal FEMA scoping process. While proceeding with WHAFIS, NWFWMD and its contractors have also considered implementation of a 2D overland wave hydraulic model SWAN. However prior to utilizing this approach for mapping the NWFWMD and FEMA would need to agree where this approach may be used for mapping in an acceptable manner. This approach is for example appropriate as outlined in FEMA guidance for "sheltered waters" (Guidance for Coastal Flood Hazard Analysis and Mapping in Sheltered Waters, February, 2008, http://www.fema.gov/library/viewRecord.do?id=3252). However, as currently planned, the coastal flood hazard analyses will be 1D and require an evaluation of erosion, computation of overland wave heights, and computation of wave runup as described in the following sections. A number of the 1D modeling tasks will be undertaken prior to the completion of the storm surge modeling for production and coastal hazard analyses.

Deliverables:

- A single seamless Topo/bathy Digital Elevation Model for each county;
- A summary document outlining the proposed erosion methods, identification of any structures that need special treatment, and proposed wave runup methods;
- A GIS polygon shapfile identifying the obstruction data to be used for input to WHAFIS;
- A CHAMP database along with associated WHAFIS input and output files of the preliminary model runs using effective stillwater elevations. A GIS point shapefile will also be included showing the resulting zone breaks along the transects;
- A GIS line shapefile identifying the landward toe of the primary frontal dunes where they exist; and
- GIS line shapefile identifying the location of the preliminary primary frontal dune landward toe.

3.21 SEAMLESS TOPOGRAPHY/BATHYMETRY SETUP

Under this task the topographic data and bathymetric data compiled and processed for the storm surge analysis will be used to build seamless Topo/Bathy Digital Elevation Model (DEM) for use with the Overland wave height analysis and coastal mapping. The topo and bathy will be combined to create a seamless data set tied to a common baseline, the shoreline. The shoreline is created by extracting the lowest, most continuous contour from the topographic LiDAR data and verified and/or corrected to the most recent aerial photographs. A seamless 10 foot DEM will be created from this process that integrates the zero foot shoreline, topography and bathymetric data sets

3.22 BEACH EROSION AND MODELING METHODOLOGY SELECTION

This task will focus on conducting a review of the area to ensure that FEMA standard methodologies and models are compatible and adequately represent processes in the study area. FEMA guidelines and specifications define a standard erosion methodology for dunes (i.e., the "540 rule"). A review of the geology and shoreline types will be made to determine the applicability of the standard method and determine if non-standard approaches are warranted. Final stillwater values are required for erosion application to the transects. Given this, preliminary erosion tasks will be limited to determining the best suited methodology for each transects. Any coastal structures such as seawalls, groins, or beach and dune nourishment projects will be identified and a determination made as to how to represent them in the modeling. Also each transect will be evaluated to determine the appropriate wave runup method to apply. If non-standard methodology or models is necessary, submission and interaction with FEMA regarding approval of methodologies will also be covered under this task.

3.23 OBSTRUCTION CARDING

The WHAFIS model requires land cover obstruction input, which will be completed in this task. The obstruction carding task serves to create a GIS obstruction coverage representing differing zones of land cover types or density from the aerial base map. Any existing digital land cover data, if available, will be used to help identify the areas of different obstruction types. Obstruction data collected during the field reconnaissance are used to correctly attribute each land cover zone for input to the wave modeling.

3.24 PRELIMINARY RUNS

On completion of the previously mentioned tasks, preparatory modeling runs will be commenced. These runs serve to verify extraction of topography and obstruction carding and allow for evaluation of model results. Model output, zone break locations, and base flood elevations are appraised to determine if modeling assumptions, base and input data are correct. The existing 1% stillwater elevations can be used in the preliminary runs to create a baseline to evaluate zone changes based on the updated 1% stillwater elevations once the surge study is complete. Results will be shared with NWFWMD to generate feedback.

3.25 PRELIMINARY DELINEATION OF PRIMARY FRONTAL DUNE

For areas with dune fields, the location of the Primary Frontal Dune (PFD) will be determined in this task. The PFD defines the landward limit of the coastal high-hazard zone. In addition, these areas are identified for erosion treatment per requirements of the FEMA guidelines and specifications. This task entails identifying location and extent of PFDs in the study area using a combination of aerial photography, topography, ground photography, and field GPS coordinates. The landward limit of the PFD is then digitized into the GIS project for later use during erosion and mapping tasks.

3.30 EROSION DETERMINATION

In accordance with National Flood Insurance Program (NFIP) regulations, an assessment of storm-induced beach and dune erosion will be performed using the 540 sq ft rule, as computed using FEMA's Coastal Hazard Analysis Modeling Program (CHAMP) via Dewberry's Coastal GeoFIRM™. The recent change in guidance and subsequent procedure memorandums to use the 1% total stillwater inclusive of wave setup will be used to evaluate the area criteria of dunes. Consideration and evaluation of the impact and magnitude of wave setup values will be made in determining the final approach.

Deliverables:

- Eroded transect profiles contained in the final CHAMP database along with the identified location of the peak and seaward toe of the dune where applicable.

3.40 OVERLAND WAVE HEIGHT ANALYSES

The contractor will perform the overland wave height analyses using Dewberry's GeoFIRM™, an Automated GIS Coastal Tool. The tool provides a spatial display of the modeling results, is comprised of the same modules included in the Coastal Hazard Analysis Modeling Program (CHAMP), and runs the models WHAFIS 4.0 and Runup 2.0. The coastal tools are also used in previous tasks for setting up the modeling data before the completion of the storm surge study. In addition, the mapping partner (NWFWMD) and their contractor will apply Guidance for Coastal Flood Hazard Analyses and Mapping in Sheltered Waters (FEMA Technical Memorandum, 2008) where necessary. A detailed description of each component of the analysis is included in the following paragraphs.

Deliverables:

- Digital total stillwater raster surfaces for the 10%, 2%, 1%, and 0.2% annual chance events;
- A CHAMP database along with associated WHAFIS input and output files of the mapping transect model runs using the new stillwater elevations for the 1% annual chance event. A GIS point shapefile will also be included showing the resulting zone breaks along the transects;

- A CHAMP database along with associated WHAFIS input and output files of the final published transect model runs using the new stillwater elevations for the 1% annual chance event; and
- A GIS point shapefile indicating the location of the 1.5 ft wave or LiMWA along each transect.

3.41 STILLWATER SURFACE CREATION

A 3D SWEL (Stillwater Elevation) surfaces for the 10-, 50-, 100-, and 500-year return periods will be created from the results of the stillwater analysis. These surfaces support erosion, WHAFIS, and run-up analyses in addition to allowing preliminary delineation of the floodplain and flood zones. Breaklines will be used, where appropriate, to guide the development of the surfaces. A detailed QA/QC of the surfaces will be performed to ensure that the final product correctly depicts the flooding mechanisms guided by the ground morphology.

3.42 WAVE SETUP CALCULATION

The 2D wave model implemented in the storm surge modeling suite will provide wave setup values for the study area. Wave setup values sourced from the storm surge modeling effort will be used directly in the wave hazard analysis. The results from the 2D wave model will also be used for providing the starting wave heights and periods.

3.43 WHAFIS SIMULATIONS

The WHAFIS model will be applied for each transect using the physical attributes (vegetation, profile, obstructions, etc.) identified during the field reconnaissance as input to the model. The 1% annual chance wave height and associated period will be extracted from the SWAN modeling results conducted for the surge modeling and applied at the offshore end of each transect as the initial conditions. The 1% wave height will be calculated using the same JPM definition as used for the storm surge analysis. The wave period will be extracted from an individual production storm result that matches the 1% wave height at the time the 1% wave height occurs. The WHAFIS model will simulate the propagation of the offshore wave onto and over the transect fetch, adjusting the wave height and period according to the wave energy equations, yielding a wave height profile along the transect. The simulated wave height will account for the characteristics along the transect.

WHAFIS 4.0 will be run using the final input data for all published and mapping transects to determine BFEs and zone break locations, using only the 100-year return periods. This data is also used to create attributed point shapefiles that are readily utilized within the GeoCoastal tools for hazard mapping. The 100-year WHAFIS results will also be used to determine the location of the 1.5 ft wave crest data that will enable the mapping of the Limit of Moderate Wave Action (LiMWA).

3.50 WAVE RUNUP 2%

The final draft Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, February 2007 and PM 37 (2005) establishes the need for higher waver runup elevations. The concept of the 2% wave runup (versus the mean wave runup previously calculated for FEMA studies) is introduced as the highest 2% of wave runups impacting the shoreline during the 100-year event. If high dunes or bluffs exist, their steeper profiles may cause wave runup to be greater than the calculated wave crest. The contractor will evaluate all published and mapping transects for the applicability of wave runup. As appropriate, one the following methods will be used to calculate runup: Runup 2.0, the Technical Advisory Workgroup (TAW) method, Automated Coastal Engineering System (ACES) and the Shore Protection Manual (SPM) method for vertical walls. Recent guidance for use of the 1% total stillwater only addresses its use with the TAW method. Each wave runup method selected will be evaluated for use with 1% total stillwater levels inclusive of wave setup and a determination made as to whether action is required to remove the effects of wave setup. There is also a new model being accepted by FEMA for wave runup calculation called CSHORE. The CSHORE model will be considered in the selection of runup methods. Runup elevations will then be compared to WHAFIS results to determine the dominant process and the appropriate mapping approach. Based on wave runup, wave overtopping will be computed as applicable following the FEMA (2007) Guidelines.

Deliverables:

- Depending on the wave runup calculation method employed one of the following will be provided for each transect where wave runup is applicable:
  - A CHAMP database along with associated RUNUP input and output files;
  - ACES input and output files;
  - Data sheet of TAW runup method calculations; or
  - Data sheet of runup on a vertical wall calculation.
  - If applicable a data sheet of overtopping analysis.

3.60 COASTAL FLOOD BOUNDARY AND HAZARD MAPPING

Using the latest digital aerial photography, most current LiDAR data, and results of the coastal hazard assessments for each transect, identify distinct special flood hazard boundaries for the Zone VE, Zone AE, Zone AO, Zone AH, and Zone X (shaded and unshaded) hazard areas and respective Base Flood Elevations (BFEs) or depth of flooding for each zone. The following tasks will be a part of this process.

- Interpolate flood hazard zone and BFE mapping using Dewberry's Coastal GeoFIRM™ GIS application between each transect based upon detailed topographic information, cultural features (vegetation and floodplain development), and effects of coastal flood protection structures with appropriate engineering certification and/or that meet the specific criteria from the 1989 USACE Coastal Engineering Research Center Technical Report No. 89-15 adopted by FEMA and included in the 2007 Guidelines. There are presently no known coastal structures that meet this criteria in the study area;
- Map the LiMWA based on the output of the WHAFIS model and the locations where the 1.5 foot wave occurs; and
- Provide a tie-in to riverine confluences of detailed flood studies at the limit of coastal flooding. Coastal and riverine 1% events will be treated as exclusively independent events and the dominate or higher flood elevation will be mapped, forming a boundary where the two 1% flood elevations from coastal and riverine intersect. If 1% riverine events are determined to influence the coastal 1% flooding, evaluations will be made of the combined coastal-riverine statistical analyses at the confluence of the coastal backwater flooding with detailed riverine analyses.

Deliverables:

- GIS line shapefile of the 1% and 0.2% annual chance floodplain boundaries;

- GIS line shapefiles of the zone brakes for both VE Zones and AE Zones;
- GIS point shapefile attributed with the Zone designation and base flood elevation for each zone mapped; and
- GIS line shapefile of the LiMWA.

3.70 PRELIMINARY DFIRM PRODUCTION

Utilizing the base map, topographic data, floodplain delineations, and results of the coastal wave analysis for each transect, the special flood hazard boundaries for the 100-year storm will be incorporated on DFIRM panels over a six (6) county coastal area (Escambia, Santa Rosa, Okaloosa, Walton, Bay and Gulf Counties). Initial estimates indicate there are 380 panels in Florida covering the coastal area in need of study. There are some potential cost saving measures that will be addressed during the scoping phase such as reduction of the number of map panels. Specifically, there are coastal barriers which are in conservation and not inhabited; in these areas the map scale could be reduced. The developed paneling scheme may also be more efficient because the flood maps will be developed and accessible through a GIS environment. Map production may also be staged over time to better accommodate the budget allocated for panel production.

3.80 POST PRELIMINARY DFIRM PRODUCTION

This effort assumes a preliminary map and report production for an estimated total of 380 coastal map panels, with Digital Orthophoto Quarter-Quadrangle **(**DOQQ) base maps and county-wide mapping schemes. Support includes submittal to FEMA and local governments for review through final adoption. Also, minimum post-prelim support has been provided by FEMA to NWFWMD for appeal resolution.

4.0 OUTREACH

An outreach plan has been developed and is being implemented. The plan is available at: http://www.nwfwmdfloodmaps.com/pdf/NWFWMD_Business_Plan_Revision.pdf. A key element of detailed coastal restudy outreach will be to take full advantage of the relationships the NWFWMD has with local communities and the fostering of those relationships through the most recent role the NWFWMD has had as the CTP for the

FEMA Map Modernization program. Continuation of the outreach program developed through Map Modernization will allow for a familiar face approach to be taken and allow for outreach to be tailored according to the voice and specific needs of the coastal communities involved in this study.

Outreach was discussed during the initial scoping meeting to determine community interests as well as identification of existing data, including publicly available bathymetry and topographic data, aerial photography, previous coastal studies, high water marks and historic flooding information, and other readily available documentation. The efforts of local governments who want to directly participate in this activity will be used as leverage toward the outreach effort. Further discussions with each community to identify their level of participation and how they want to reach their public and stakeholders will continue throughout the coastal study. The two basic approaches that are desirable and supported thus far include outreach meetings and web based support.

4.10 OUTREACH MEETINGS

Where possible, the NWFWMD will leverage or enlist the support of local governments who wish to participate and be heavily involved in outreach activities. Local government offices within the coastal area will be leveraged as the meeting places for these meetings. The project team will discuss the interests in local communities to develop the meeting format and help decide how to best reach the public. Each community will be encouraged to develop their own outreach activities in addition to those afforded by the NWFWMD. Meeting materials, such as an agenda, maps, study area limit maps, and any other supporting materials or handouts, will be produced by the project team. Scheduling of meetings will include invitations to FEMA Regional staff, project team members, community representatives, and other stakeholders to discuss the proposed TA, available data, data requirements and general coordination requirements for the project. New specific points of contact, along with those already established, will be used to expedite communications during the project. Discussions on expectations of each agency and FEMA will be documented.

The project team will be available for all scheduled meetings and prepare meeting minutes after each meeting.

4.20 WEB BASED OUTREACH ACTIVITIES

During the study, the District will periodically update its web site NWFWMDfoodmaps.com to keep the general public informed on the overall coastal study progress. The internet is the single most effective outreach tool in northwest Florida for reaching and exposing the general public to flood hazard studies. The NWFWMD and its contractor have recommended a number of ways to enhance FEMA's and NWFWMD's internet outreach capabilities which include the design of a mapping portal anyone may use and online video education for viewing by the general public. Current activities that are ongoing for the development of these capabilities include organization and collection of data for the mapping portal, website layout and design.

At the completion of preliminary DFIRMs, the NWFWMD will advertise that they are available to the general public in an electronic format for the general public to review. The project team will also conduct or facilitate Preliminary DFIRM Community Coordination (PDCC) meetings. These will be tailored to provide detailed guidance to each of the communities regarding public review process, timeframes, commenting, and appeal of DFIRM deliverables. The District will also work with the communities beforehand and during the PDCC meetings to determine what they would like to see as an effort to reach the public on a community by community basis. The NWFWMD has also obtained additional RISK map funding from FEMA in order to fully support web based coastal outreach (see http://www.nwfwmdfloodmaps.com/pdf/FloodInfoWebAppSOW.pdf) capabilities to insure the general public is reached and to maximize the exposure or public access to the results of this study. A web based outreach program was identified during scoping meetings as the single most effective way to reach the general public from the outset of the study through final map adoption and beyond.

5.0 QUALITY ASSURANCE / QUALITY CONTROL AND TECHNICAL REPORTING

5.10 QA/QC Coastal Analysis and Mapping

The primary standards for quality assurance and quality control (QA/QC) which apply to this TA are described in the NWFWMD quality control plan which is developed and updated by the NWFWMD contractors. The QA/QC standards to be utilized are approved by the NWFWMD and are also outlined in the MASs under the CTP agreement the NWFWMD has with FEMA. The FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix D: Guidance for Coastal Flooding Analyses and Mapping, April 2003 as well as the Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update, February 2007, and applicable Procedure Memorandums identified will be used to guide the reviews. Any new updates will be addressed by this TA when they occur through agreement between NWFWMD and FEMA. If QA/QC procedures change during the course of this study from the published FEMA documents, internal QA/QC procedures will be adopted and documented before project work is submitted for final review and approval. FEMA will be given the opportunity and has the ultimate responsibility to identify and approve new QA/QC standards when they do deviate from the existing ones. The quality assurance plan for coastal studies by NWFWMD may be found online at NWFWMDfloodmaps.com.

The primary QA/QC process will be to establish independent QA/QC teams within the project team and to have the work reviewed according to current accepted engineering practice. The independent review team will be selected from URS staff. URS has a QA/QC oversight and project management role in the project but are not directly involved in the initial study efforts and therefore are independent. In the case that URS is directly involved in a technical analysis, then the QA/QC roles are reversed. The UCF contractor also functions as a study contractor and URS or Dewberry may function to perform independent reviews of their work. The NWFWMD also has access to other Coastal Engineers for specific independent reviews which include Watershed Concepts (AECOM) and Taylor Engineering as well as major Universities within and outside of Florida. NWFWMD will decide all issues, disputes or conflicts which arise from QA/QC reviews.

Dr. Chris Reed of URS will be the primary person implementing the QA/QC procedures. He will, as directed by the NWFWMD as necessary and when appropriate enlist others with URS and with FEMA Coastal Map Modernization experience. When necessary, the NWFWMD in coordination with FEMA reviews, will prescribe QA/QC reviewers or review panels with an appropriate technical background to perform QA/QC work. The following is a list of the activities for which NWFWMD will require QA/QC to be independently performed:

- Terrain and Bathymetric Data Processing
- Develop/Refine ADCIRC Mesh
- 2-Dimensional Wave Modeling
- Tidal Calibration
- Storm Selection
- Storms Hindcasts and Validation
- Wind and Pressure Field Determination
- SLOSH analysis used to support JPM analysis
- Production Runs
- Statistical Analysis including JPM analysis
- Erosion and PFD Determination
- Overland Wave Height Analysis
- Wave Runup 2%
- Floodplain Mapping
- DFIRM database and products

In addition to following FEMA QA/QC guidelines, each individual QA/QC task will be documented in a TA issued in a task order by the NWFWMD. The individual TA for each QA/QC task will be inserted into the TA as well. The final deliverable for each QA/QC task will be a final QA/QC report.

5.20 Coastal Flood Hazard Analysis Documentation Notebook

The documentation produced from this flood hazard mapping project will be appropriately organized into the TSDN. The contractor will maintain this TSDN throughout the life of the project and compile a comprehensive set of deliverables for each of the tasks performed. The storm surge analysis included in the TSDN will be developed in an electronic coastal documentation notebook for the entire storm surge study. This will include the digital data of terrain and bathymetry data, final refined meshes, selected storms and storm parameters selections, wind and pressure fields, tidal calibration results, ADCIRC model and 2-D wave model results, frequency analysis, final mean water elevations, and associated digital products. For the overland wave modeling and mapping, the digital data will include seamless Topo/Bathy DEM, field reconnaissance data, starting wave conditions, erosion methods, overland wave height analyses including WHAFIS input and output files and a CHAMP database, wave runup input and output files and/or overtopping analyses, unique model applications, and GIS line work of the hazard mapping files. The TSDN will also include all documentation of the QA/QC process. The TSDN developed with funding for the storm surge phase of this project will be made available to Alabama agencies so that they can include it within their TSDN for related projects involving their coastal counties.

All final documentation developed will also be uploaded to FEMA's Mapping Information Platform (MIP) following PM 62 and the new Appendix M of the FEMA G&S for Data Capture Standards.

There will also be a total of five (5) submittals to FEMA for review and approval following the Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update Final Draft dated February 2007 guidelines as follows:

Intermediate Submission No. 1 – Scoping and Data Review

Intermediate Submission No. 2 – Storm Surge Model Calibration and Storm Selection

Intermediate Submission No. 3 – Storm Surge Runs and Flood Frequency Analysis

Intermediate Submission No. 4 – Nearshore Hydraulics

Intermediate Submission No. 5 – Draft Flood Hazard Mapping

6.0 PROJECT MANAGEMENT, ADMINISTRATION, AND SCOPING

The project management task includes a scoping task which has been used to refine this TA and the project schedule. NWFWMD has completed most of the scoping task related to mapping the Florida Panhandle as well as the scoping task for modeling the entire coastal study area. OWR is responsible for development of the initial scoping task for the mapping part of the Alabama coast. NWFWMD has assembled a team of qualified contractors for ADCIRC and SWAN model development and model production runs required through the model development and production tasks and will be the lead for these project management tasks. Subsequent to the initial modeling work NWFWMD and OWR will be the lead project managers for completion of outreach tasks for the respective counties in each state's jurisdiction.

The specific project management activities by NWFWMD described in this task relate to all the project management, project coordination, and related activities necessary to carry out all the activities described in this TA. NWFWMD will contract some of the project management tasks to Dewberry who has been selected as the lead contractor from the URS/Dewberry team to perform coastal project management work as needed. Related project management tasks are described below:

6.10 PROJECT BUDGETING, PURCHASING, INVOICING, AND MANAGEMENT OF CONTRACTORS

This task is the primary responsibility of the NWFWMD and is based on the total funding available through FEMA grants as well as the NWFWMD. Total funding for the Coastal Restudy project will be dependent on completion of successful negotiations with NWFWMD continuing service contractors and university contractors for the tasks they would be requested to undertake. Each contractor, when requested, will be expected to complete detailed scoping documents along with a corresponding cost estimate and schedule subject to NWFWMD review and approval. When the details of the proposed TAs would substantively change this TA they will be submitted to FEMA for review and the TA would subsequently be modified.

It is estimated that the initial two phases (I, II) of funding required for ADCIRC modeling and SWAN wave setup modeling over the entire study area including Alabama to be completed by NWFWMD contractors would require $2,673,000 in funding. This includes initial data collection through model production runs as well as initial scoping, outreach and project management tasks. Note that there are no contingencies currently built into this estimate. The mapping and DFIRM production tasks and outreach and project management funding needed for the Florida portion is estimated at $2,147,000. As currently envisioned, the priority order for funding will be to complete the western-most panels of the study area first, although there are currently sufficient funds available to complete all of the coastal County map panels in NW Florida at about the same time.

6.20 COORDINATION, MEETING ATTENDANCE AND PREPARATION

NWFWMD with assistance from Dewberry will coordinate project activities on a regular basis. Conference calls may occur as often as on a weekly basis to discuss the status of the project and updates to NWFWMD. At a minimum five (5) project coordination meetings will be held.

6.30 PROJECT SCHEDULING AND UPDATES OF SCHEDULE

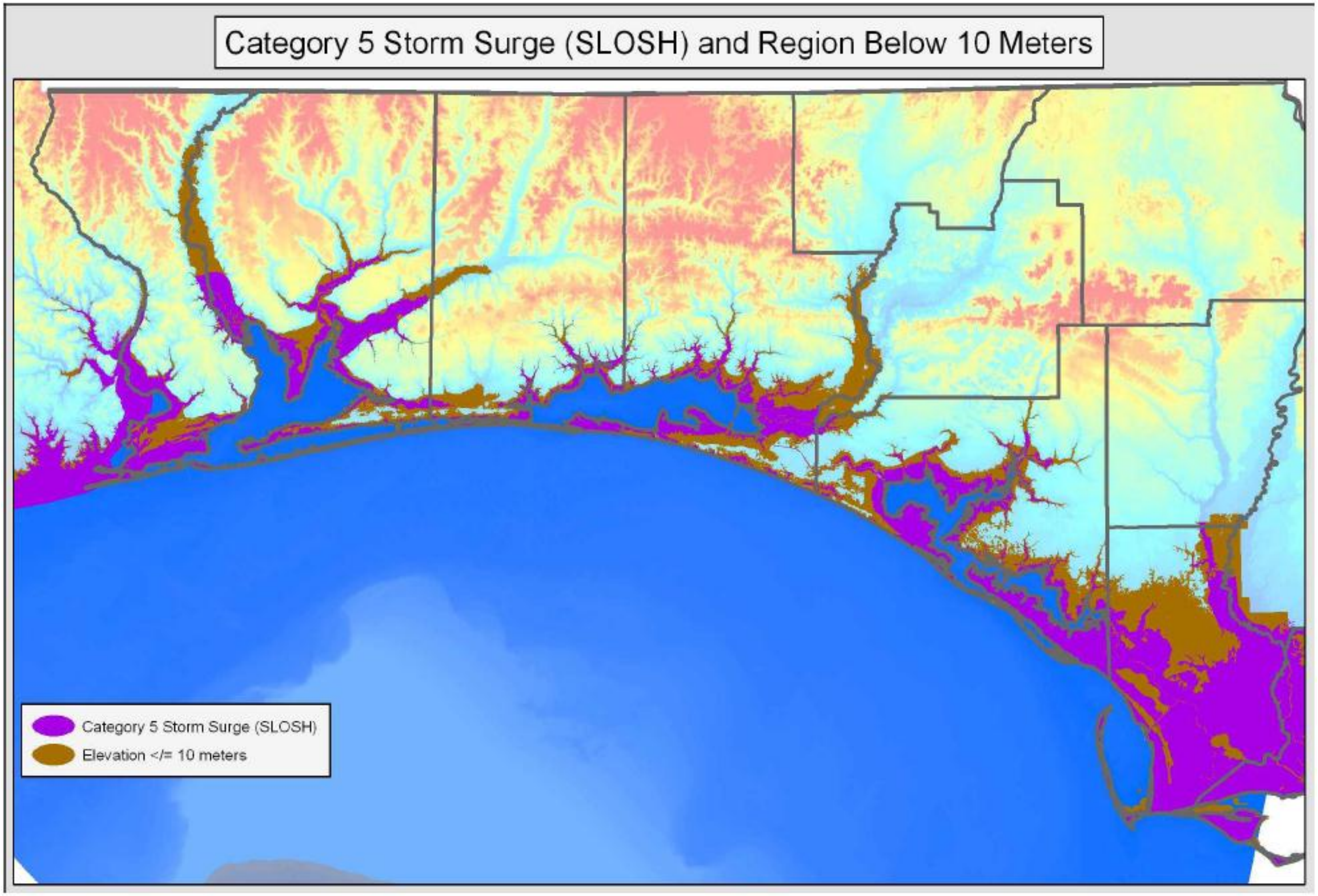
NWFWMD with assistance from Dewberry will develop scheduling tools. These tools will be utilized to initially plan the project schedule and then dynamically evaluate the work flow of the project as it occurs. NWFWMD recognizes that the project schedule is contingent on the results of the study as they occur and therefore there may be opportunities to finish some activities sooner than originally planned or unanticipated delays may occur. Periodic updates of schedule and adjustments will be made based on feedback from the project study team members. Periodic calls as needed among study team members will be made to discuss project progress and other task coordination issues. Project meetings will also be scheduled by the NWFWMD when needed and to make them as productive as possible. Overall project milestones and updates will be reported to NWFWMD in a table format which, following review by NWFWMD, will be reported to FEMA on a monthly basis and used to update the MIP as necessary.

The project schedule for this study as determined through negotiated contracts with consultants and universities indicates an estimated 36-month study duration. However, the duration of this study may need to be extended with 2-3 months of float because of uncertainties mentioned previously. It should be noted that several issues may also arise during the review of each phase that, depending upon the level of effort required to address reviews, can dramatically alter final schedules. These can include technical appeals which are not accounted for in this estimate.

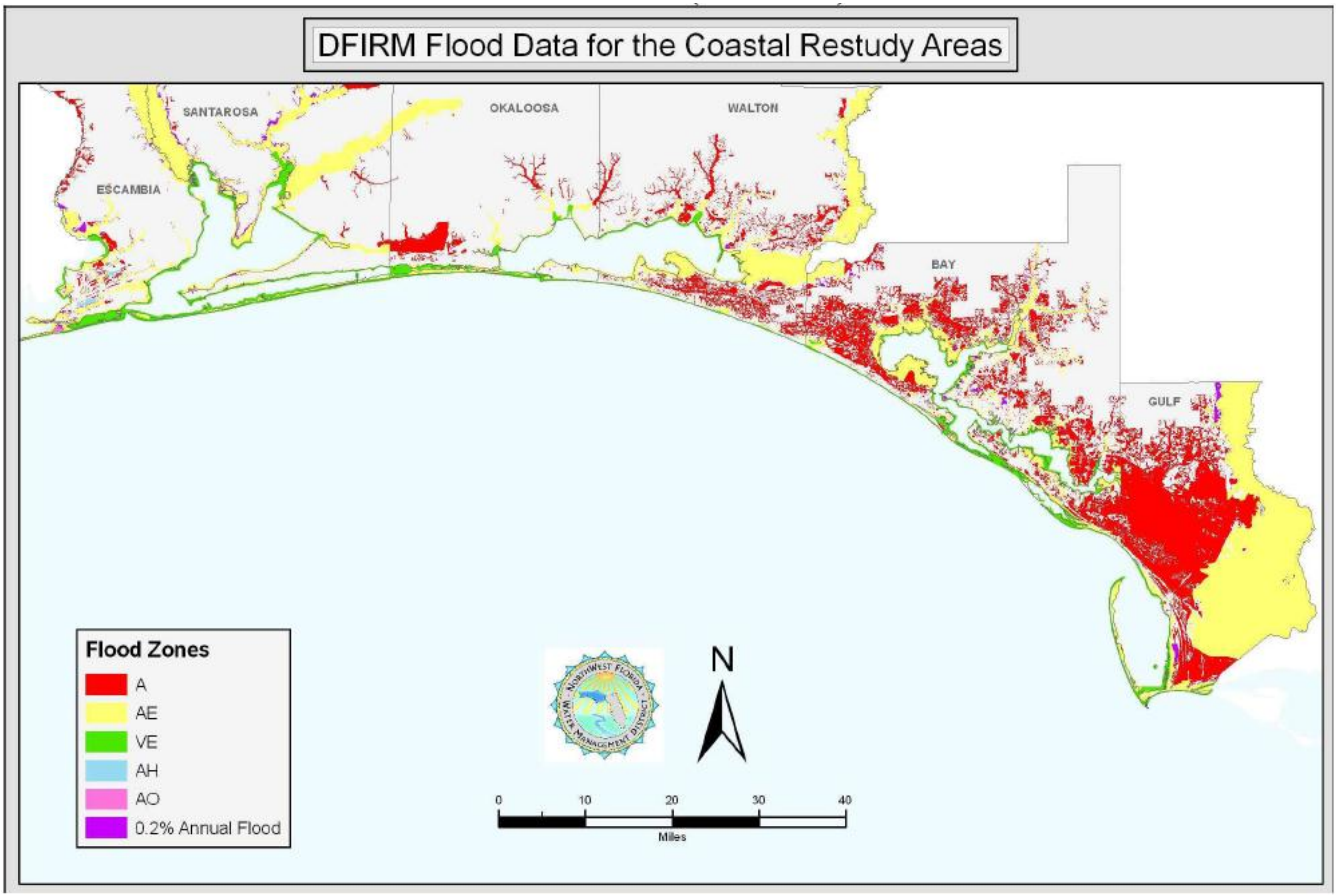
6.40 DATA MANAGEMENT AND WEB BASED SHARE POINT

NWFWMD and its contractors have developed and will continue to manage internal FTP and related web based sites necessary for exchange of draft and working data and documents among the project team. The web sites will be used and maintained throughout the study until complete. Formally reviewed approved final data and documentation will be uploaded to FEMA's MIP.

Attachment B



Attachment B (continued)



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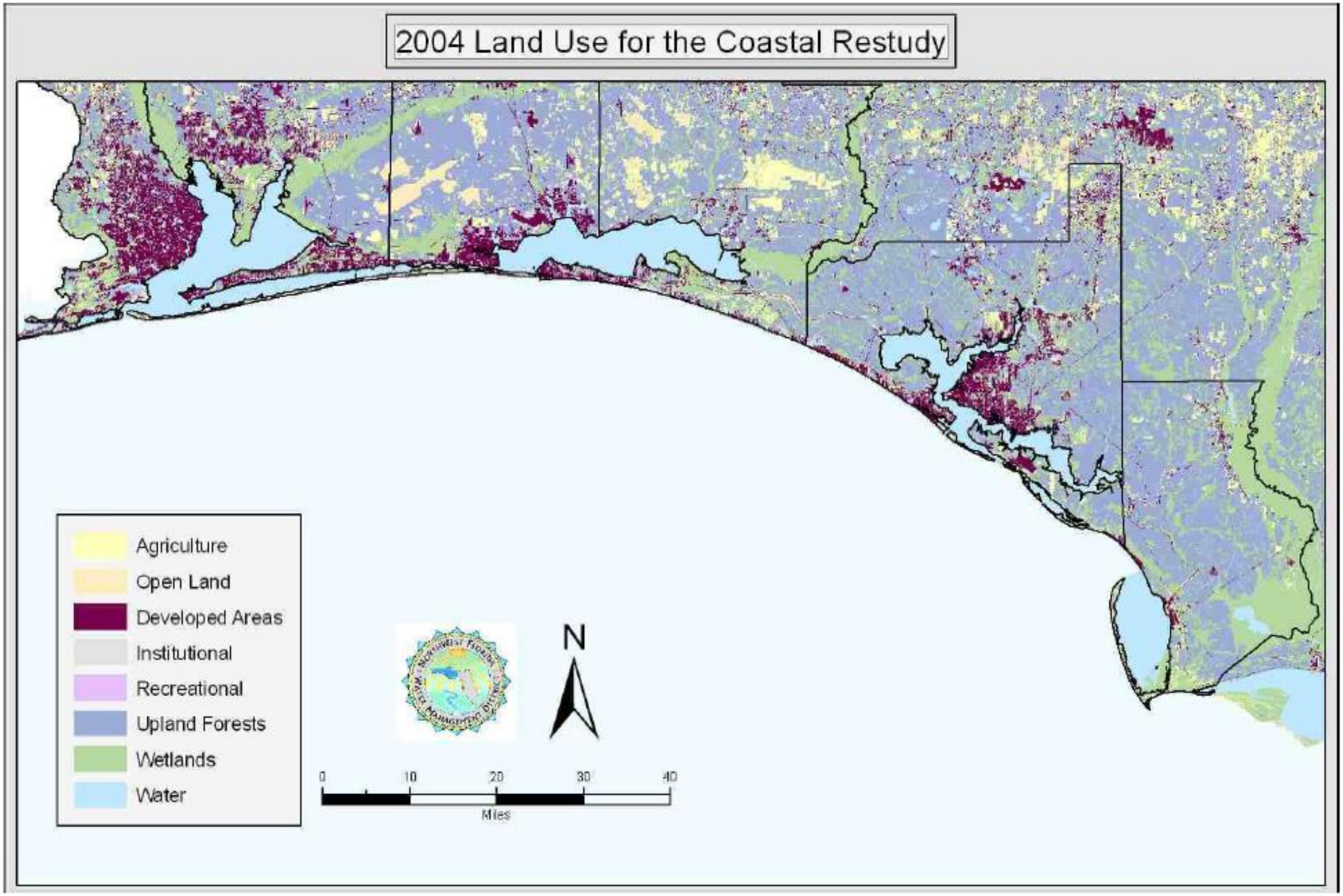

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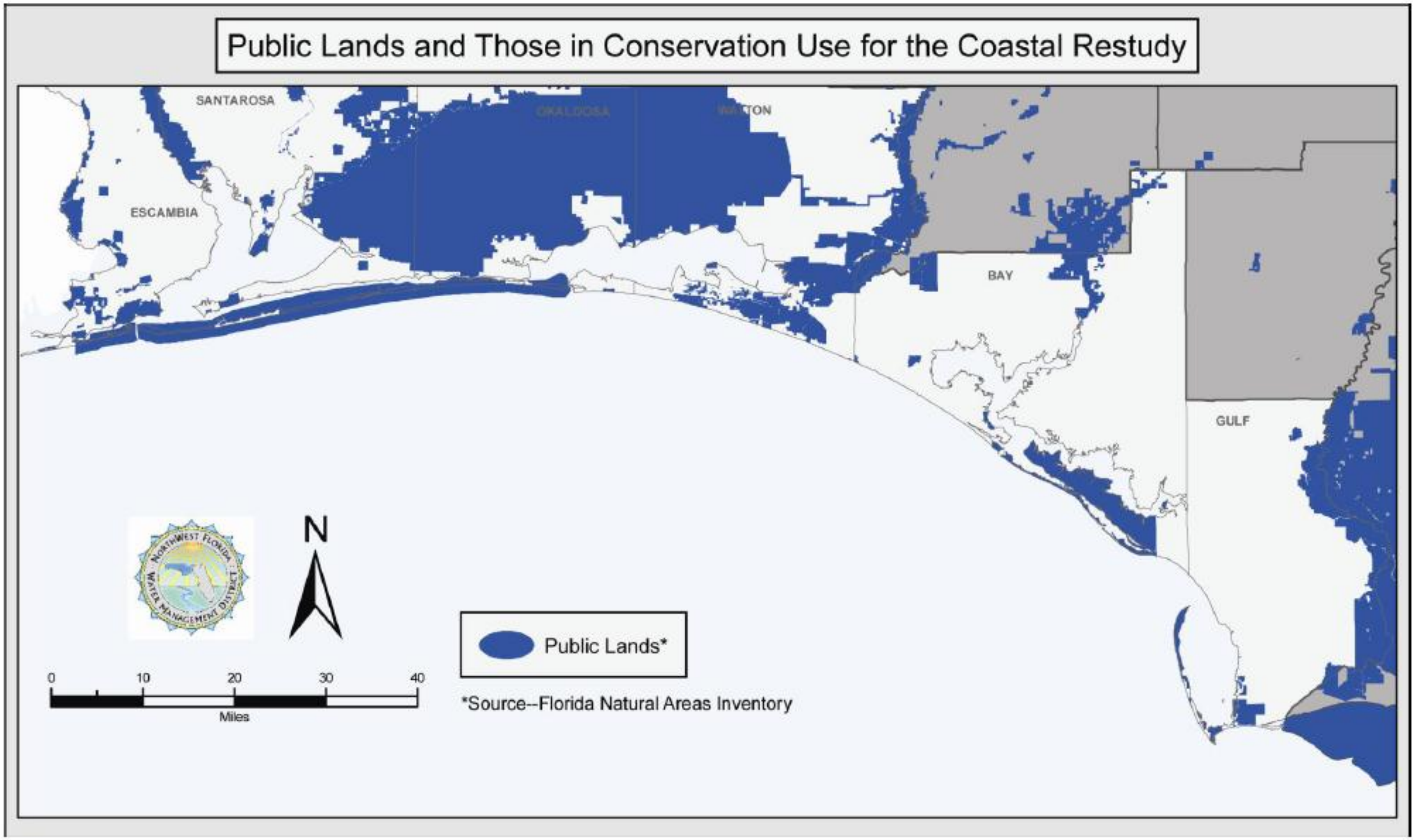

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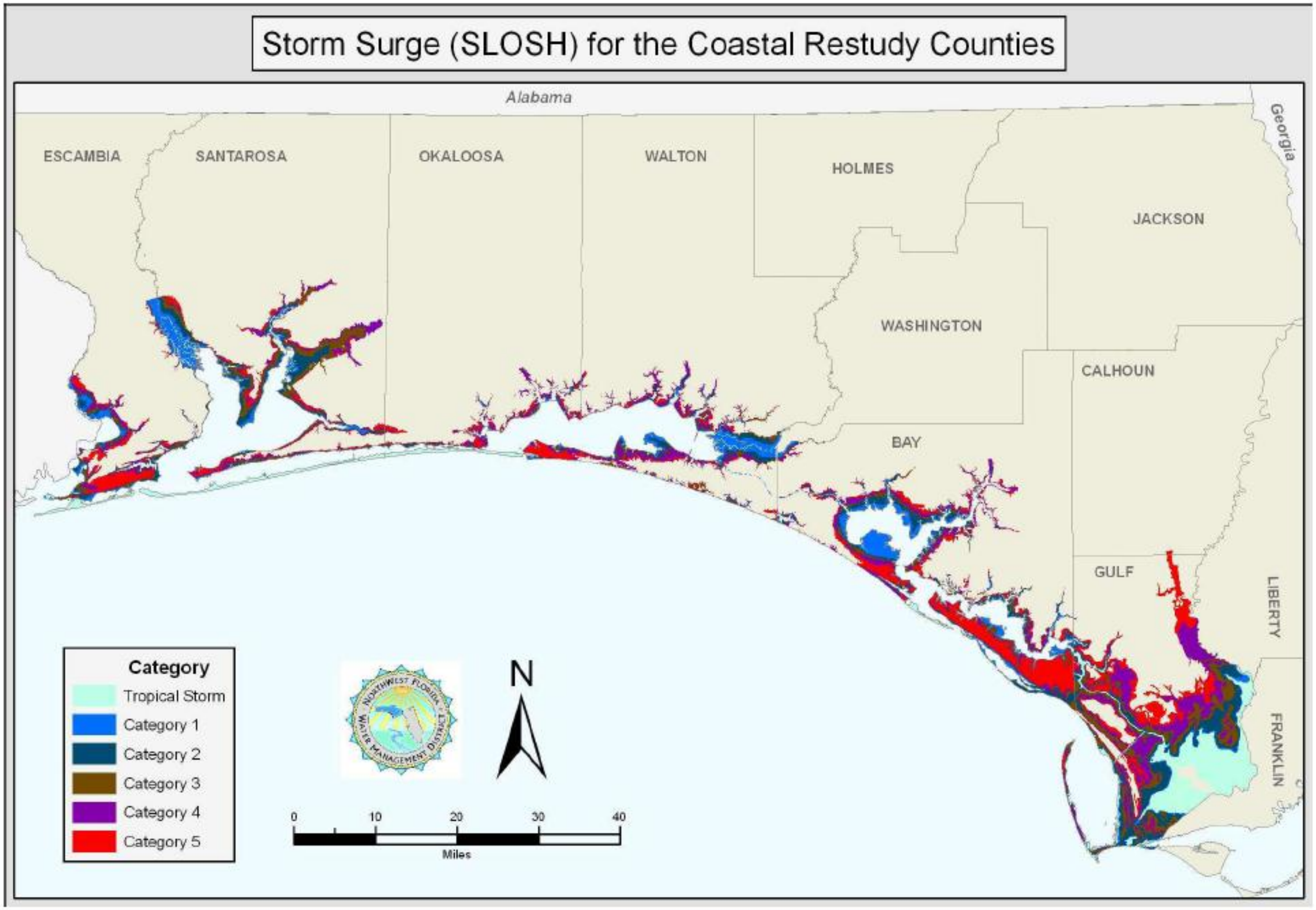
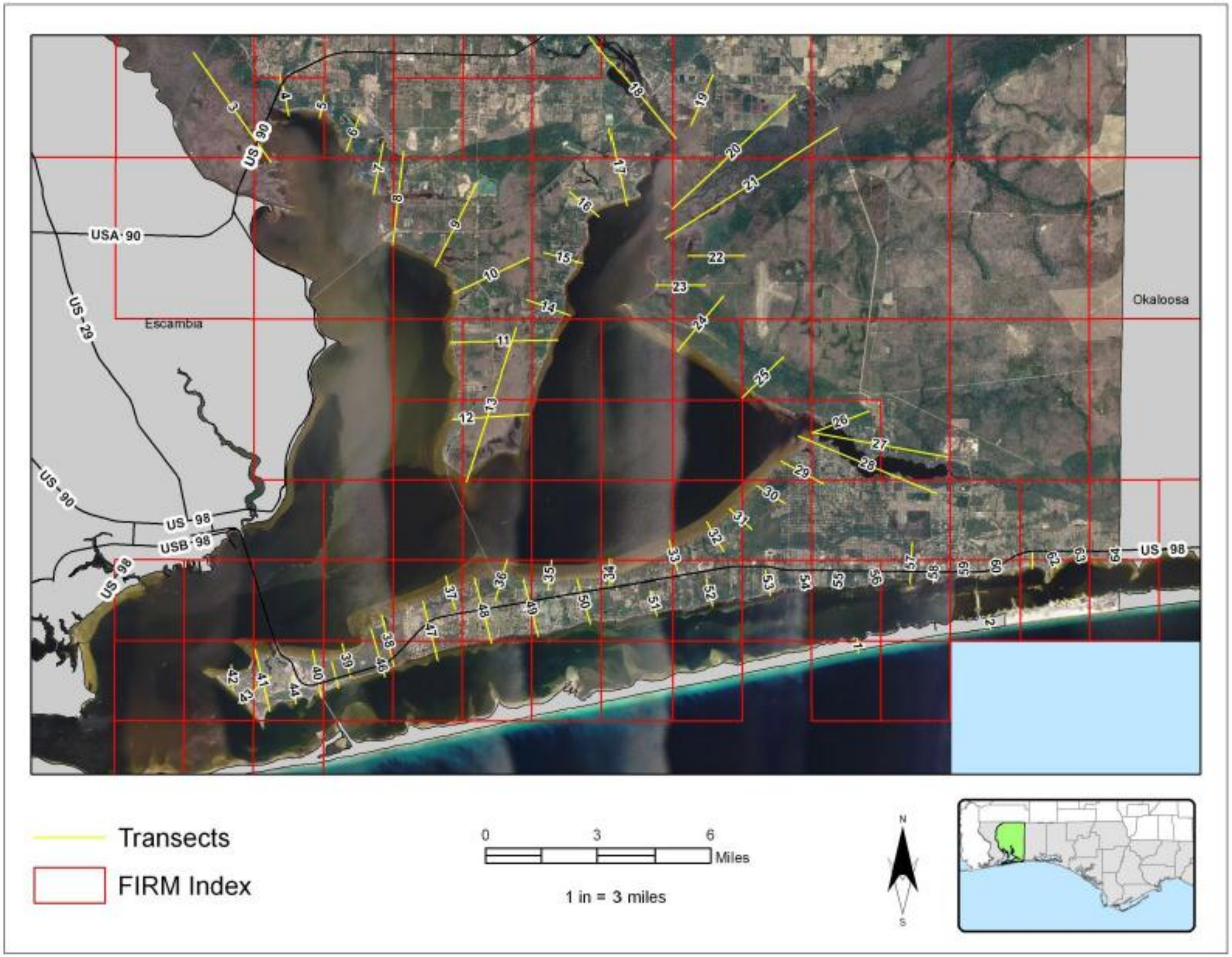
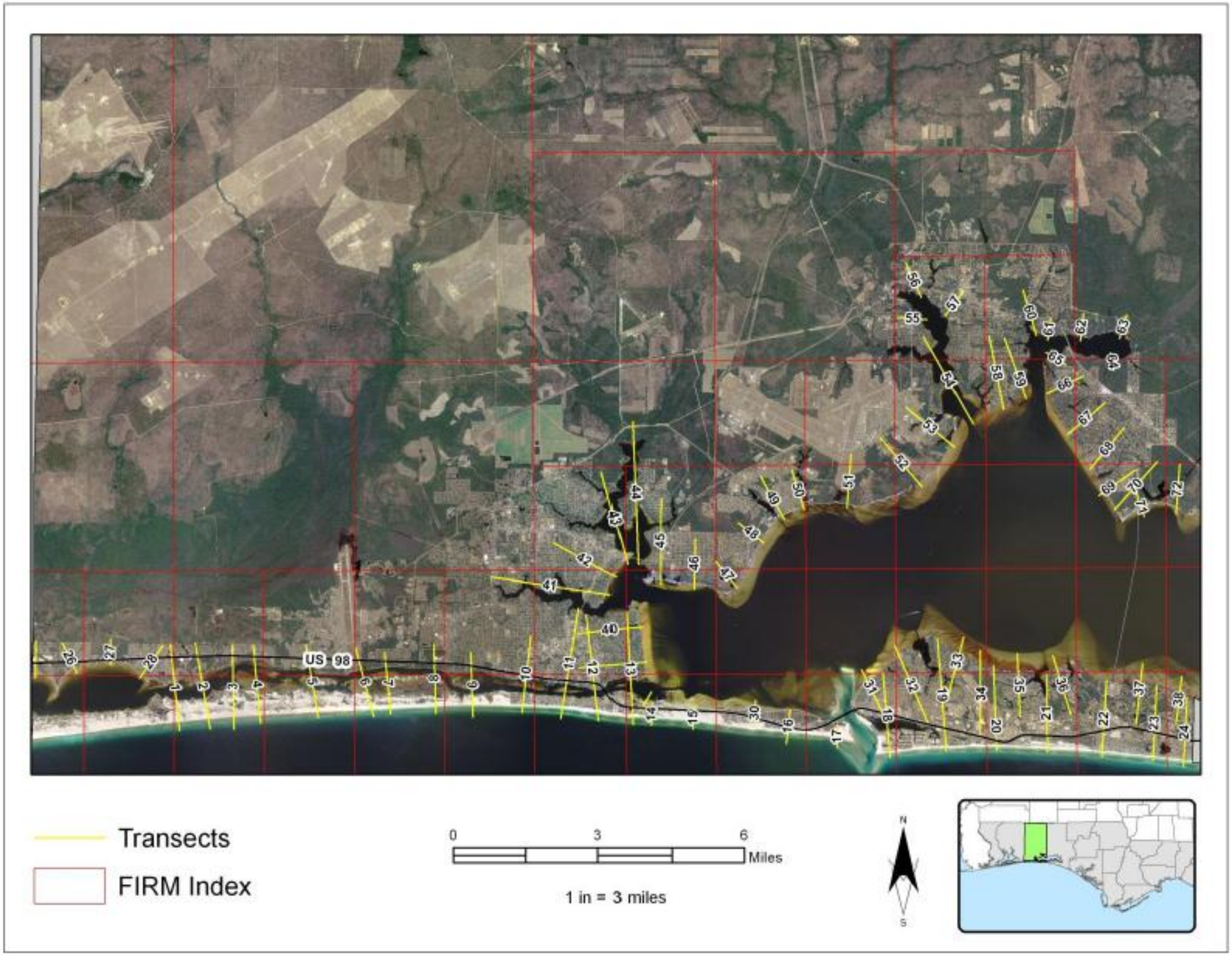


Attachment F – Coastal Study Area Draft Paneling Scheme & Transects Layout – Escambia County

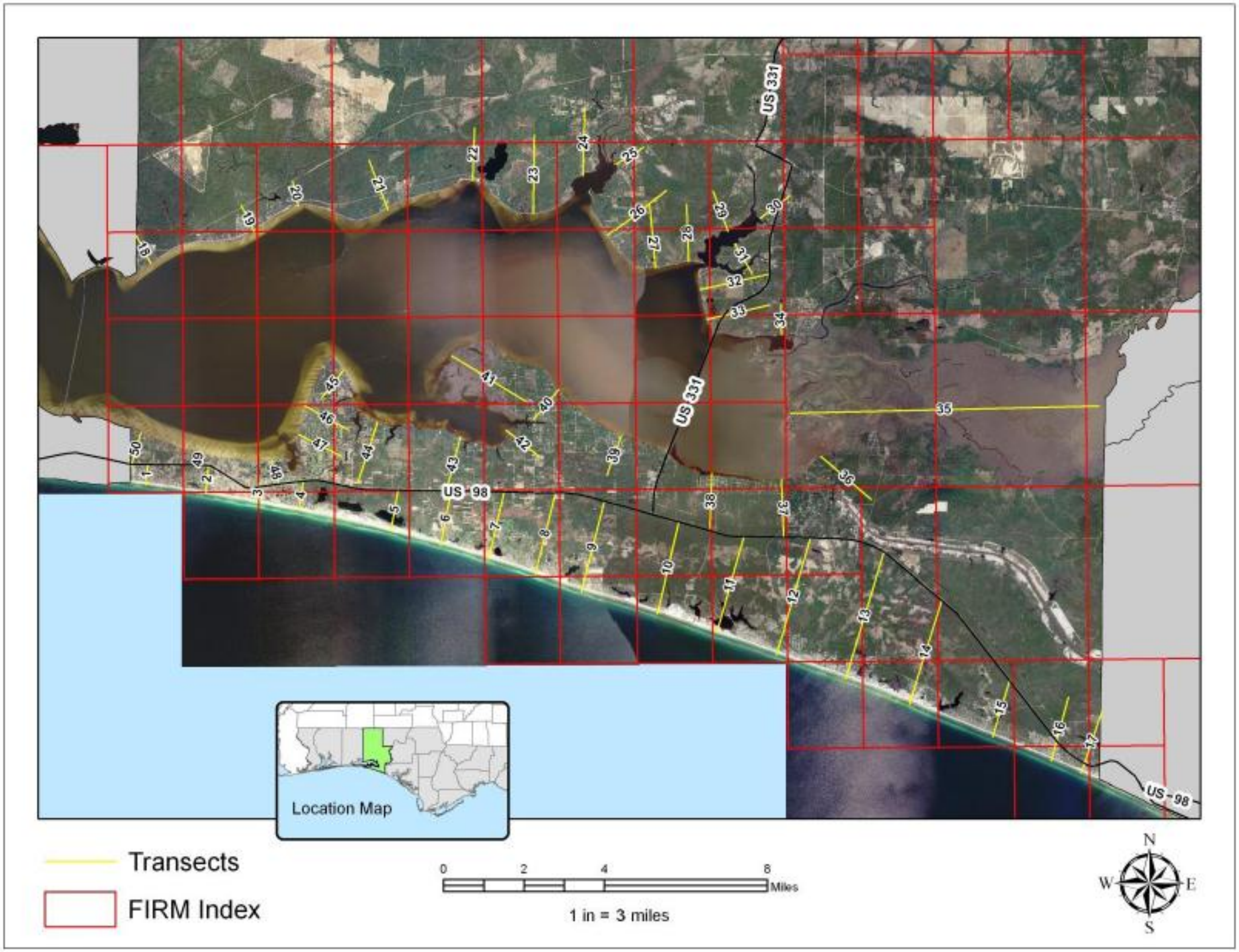
Attachment F – Coastal Study Area Draft Paneling Scheme & Transects Layout – Santa Rosa County



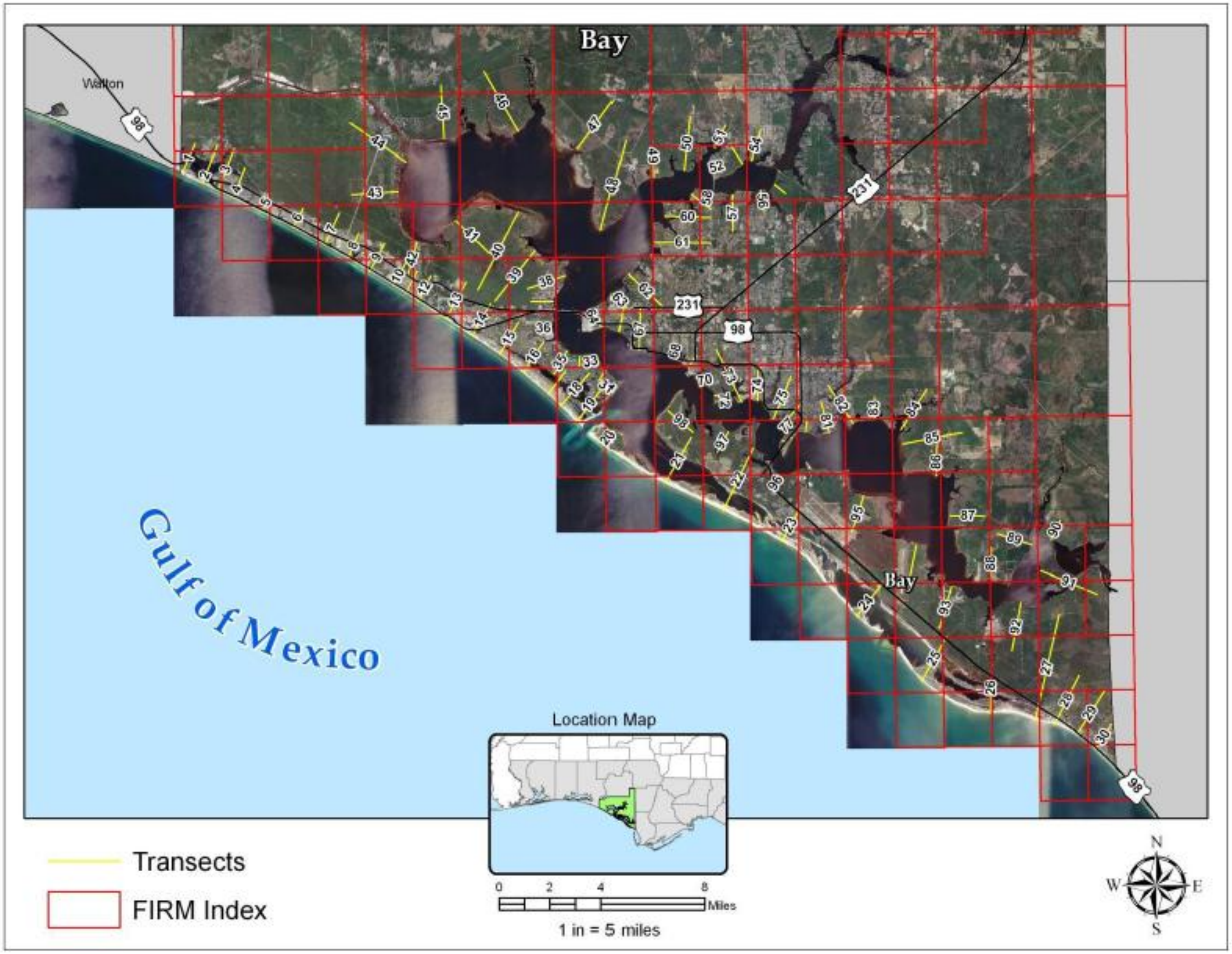
Attachment F – Coastal Study Area Draft Paneling Scheme & Transects Layout – Okaloosa County



Attachment F – Coastal Study Area Draft Paneling Scheme & Transects Layout – Walton County



Attachment F – Coastal Study Area Draft Paneling Scheme & Transects Layout – Bay County



Attachment F – Coastal Study Area Draft Paneling Scheme & Transects Layout – Gulf County