FINAL REPORT

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

NOAA Coastal Services Center
Storm Surge Social Science Project

April 2007

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Written under contract for the NOAA Coastal Services Center

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Submitted by Dr. Betty Hearn Morrow
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I. INTRODUCTION

Integral to its mission of providing support to coastal managers and other partners by facilitating access to and utilization of the most up-to-date technology, information and management strategies, one of the current focuses of the Coastal Services Center (CSC) is to identify strategies to assist in the appropriate use of storm surge data by managers, as well as the general public. To that end the general purpose of this project was to assist the CSC by providing social science data relevant to the effective packaging and dissemination of storm surge forecasts both within and outside of emergency and coastal management agencies.

The social sciences are able to make a unique contribution to the human dimensions involved in the use of technologies. In this case a sociological perspective provides insight into the processes by which various users receive, interpret and utilize storm surge data.

Specifically, the objectives of the project were to: 1) develop a database of relevant social science research and reports related to storm surge and 2) compile new data on information flows between management agencies, identifying areas where NOAA can support improved communication and understanding of storm surge data. Given the limited body of knowledge related to this topic, the project was exploratory in nature, striving to identify the issues and lay the groundwork for more systematic empirical research.

II. METHODOLOGY

To meet the project's objectives, the work plan evolved into several distinct tasks: 1) a review of the professional and lay literature related to the communication of storm surge information; 2) the collection of technical information about storm surge modeling and dissemination through field work and interviews with experts; 3) semi-formal interviews with key informants who were coastal managers or planners; 4) semi-formal interviews with key informants who were emergency managers on the Atlantic and Gulf coasts; and 5) the addition of several questions related to storm surge and hurricane forecasts to a National Science Foundation (NSF)-funded citizen survey.

The project began with face-to-face or telephone interviews with several experts to gain technical knowledge of the topic. I also attended a week-long Hurricane Preparedness course for emergency managers at the National Hurricane Center (NHC.)

Semi-formal, open-ended interviews were then conducted with coastal managers and planners, as well as emergency managers via telephone, recorded, transcribed and analyzed using the N-Vivo software package for analyzing qualitative data. Since this was a purposive sample designed to explore the topic, qualitative methodology was most appropriate. Instead of statistical analysis, the words of these respondents were coded into recurring themes. Examples of their comments are then presented under each theme as data supporting the findings. To protect the autonomy of the speakers they are identified by type and number (such as EM 1) when quoted. A complete list of interviewees is included in Appendix B. Interviews were completed with seven experts, 13 coastal managers or planners and 33 emergency managers, representing nearly one-third of all Atlantic and Gulf coastal counties. In all three cases I ceased interviewing when I was no longer gaining new information or insights.

In contrast the citizen survey was administered by the Institute for Public Opinion Research at Florida International University to a randomly chosen sample of households in Alabama, Mississippi and Louisiana. A total of 811 interviews were completed. The statistical analysis was completed using the SPSS statistical package.[1]

III. RESEARCH ACTIVITIES AND FINDINGS

A. Literature Review

An extensive search for academic and professional literature related to the dissemination and understanding of storm surge information, or related topics, revealed few sources. In addition to conducting a literature search of university libraries, I searched the library at the NHC, as well as various NOAA resources. The quest for educational information designed to educate the lay public was considerably more productive. There are many sources, particularly on the internet, designed to inform the general public about storm surge. They vary in complexity and intended audiences, but also in their content, sometimes offering confusing or conflicting information about storm surge. For example, the definition of storm surge is not consistent across different NOAA websites.

An annotated bibliography was submitted to the contract managers in October 2006 and appears in Appendix A with some additions.

B. Technical Information

In order to better understand the issues related to the dissemination and use of storm surge information, I interviewed several experts, including the leader of the NHC storm surge team, NHC administrators, FEMA hurricane specialists, state emergency management officials, experts from private industry, academic researchers, and meteorologists from the National Weather Service (NWS) and broadcast media.

[1] Dr. Hugh Gladwin was the principal investigator on the NSF project.

Additionally, I profited immensely from attendance at the NHC workshop where a considerable portion of the time was devoted to storm surge instruction.

The technical information gained from these experts guided the design and execution of the remaining tasks of the project. Several key points emerged to be considered when completing the project's tasks.

1) Storm surge is difficult to calculate and surge forecasts should be considered rough estimates.

According to the surge experts interviewed, storm surge forecasting is complex and the science is insufficient to provide precise estimates at this time. Storm surge is determined by the wind, the size of the storm (radius of maximum winds), the local topography and bathymetry, as well as the angle at which the storm approaches the shore. Therefore, the models are highly dependent upon the accuracy of the storm forecast, as well as the accuracy of local maps. Several models have been developed to estimate surge, but none is able to provide real-time forecasts with sufficient accuracy and timeliness to guide officials in calling evacuations. According to a post-Katrina assessment, 95% of the time the SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model 6-hour forecasts were within 20% of the observations from high water marks[2]. Six hours before landfall is too late to be of much benefit to decision makers.

2) The National Hurricane Center now issues 24-hour operational SLOSH runs as a storm approaches landfall.

FEMA has requested these estimates to guide in the pre-positioning of resources. However, there is some concern that these operational runs may be misused. For example, they might cause the delay of evacuations until it is too late to safely clear a coastal area. This issue was explored in the emergency management interviews.

3) There are other surge models, such as ADCIRC.

ADCIRC Coastal Circulation and Storm Surge Model was developed for the U.S. Army Corps of Engineers. It works at a higher resolution but takes longer to run. It is often used to make forensic runs after a storm. Researchers at several universities are developing additional surge modeling software.

4) Improvements in computing have made it possible to run SLOSH at a higher resolution within a reasonable time frame.

The time factor is very important in running the multitude of hypotheticals necessary to establish the Maximum of Maximum surge heights (MOMs) for each basin. Stephen Baig, NHC Storm Surge Team Leader estimates that it would take about 1.8 million

[2] Interview with Dr. Stephen Baig, Storm Surge Team Leader, National Hurricane Center, September 11, 2006.

theoretical runs (between 10,000 and 20,000 per basin) to establish the total potential storm surge risk for all U. S. basins. They are now able to run SLOSH for higher resolutions, however, without being time prohibitive. The state of Florida is in the process of remapping its entire coastline using LIDAR. The NHC expectsto determine the MOMs for all Florida basins using the new maps in 3-4 months after receiving the data.

5) The results of SLOSH runs in specific locations are intended to be used for hypothetical or planning purposes.

Emergency managers are given the software to run the SLOSH models developed for various hypothetical conditions. The results illustrate the worse case scenarios under various conditions and are intended to be used for hazard mitigation and evacuation planning.

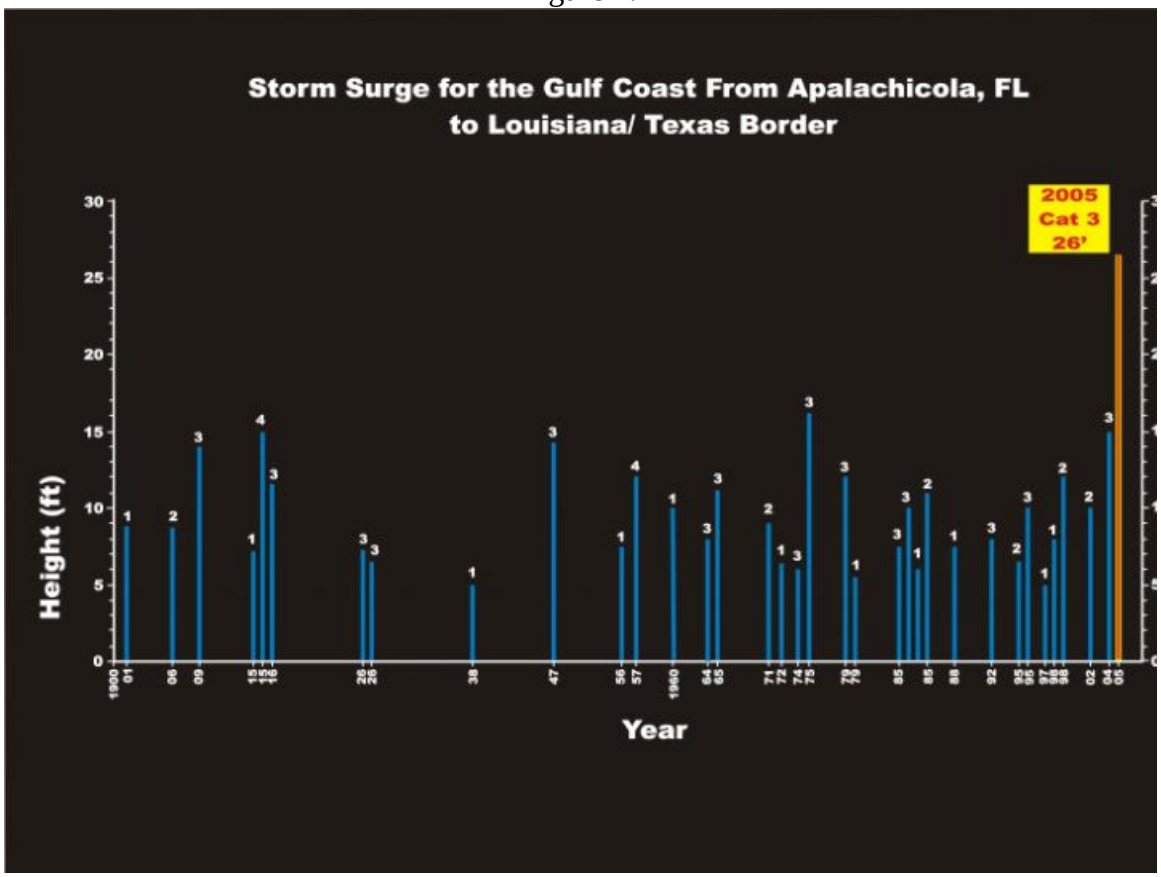
6) Surge estimates do not include the astronomical tide and wave action.

Surge forecasts should not be considered high water marks. It is important to know to what extent the public understands this.

7) Surge levels do not correlate well with the category of storm. (See Figure l.)

The NHC no longer includes surge forecasts as part of the forecast associated with the category of storm. They now use a modified Saffir-Simpson scale that does not include expected surge levels. These are provided separately. Figure 1 provides the surge and category data for past Gulf Coast storms, revealing the weak correlation between surge and storm category.

Figure 1.



Source: National Hurricane Center's Hurricane Preparedness Course, June 2007

8) There is confusion between SLOSH surge maps and FEMA flood insurance rate maps (FIRMS) that use different surge models.

The FIRM zones include a Velocity (V) zone denoting surge areas, also referred to as coastal high hazard areas. Other surge models, such as ADCIRC with higher resolution than SLOSH, are used for insurance mapping purposes.

9) Sea level rise needs to be taken into consideration when modeling surge.

It is estimated that there has been about a 10" rise in sea level in Florida in the last century. Sea level rise is being factored into the base elevation data (NVDATUM) in the coastal remapping currently underway for Florida.

The above technical information guided the development of topics to be explored in subsequent user interviews.

C. Interviews with Coastal Managers and Planners

One project task was to collect information on how coastal managers such as directors of National Estuary Programs (NEPs), Coastal Zone Management Programs and coastal planners such as those associated with Regional Planning Councils (RPCs) might use surge information in their work. For purposes of this project I interviewed several managers across these agencies to ascertain how they received and used storm surge data, such as that produced by SLOSH models. I interviewed the leadership in seven NEPs (Coastal Bends, Barataria-Terrebonne, Indian River Lagoon, Mobile Bay, Tampa Bay, Sarasota Bay and Charlotte Harbor), four RPCs (South Alabama, South Florida, Southwest Florida, and Tampa Bay), and one coastal zone manager (Alabama). After 13 interviews I was no longer gaining sufficient new information to continue.

An open-ended interview schedule was used which covered these topics:

- Mission
- Organization and staff
- Use of NWS water level products
- Use of SLOSH surge data
    - Hazard mitigation
    - Evacuation planning
    - Land use planning
- Opinion about citizen knowledge of storm surge
- Products or tools that could assist them related to surge

All interviews were taped (with their permission), transcribed and analyzed.

1. Organization and Staff

States, regions and counties vary considerably in the way they organize to protect their coastlines. The U. S. Environmental Protection Agency's 28 NEPs are located in key "estuaries of national significance" to document their environmental conditions and formulate plans for restoration and protection. These federal-state partnerships bring together private and public agencies and experts to attain and maintain water quality, protect the ecological environment, and guide the use of these estuaries. Similarly, the CZM Programs are federal-state partnerships set up to deal with coastal growth issues by balancing competing land and water issues with the protection of coastal resources. Several states have RPCs that are designed to coordinate local multi-jurisdiction planning and to provide a forum for dealing with issues such as economical development, environmental protection, transportation, and housing. In coastal areas these regional planners may also coordinate coastal zone management and regional planning for hurricane mitigation, evacuation, response and recovery.[3]

[3] Additional entities dealing with water-related issues include regional water management districts and state and local flood plain managers.

Remembering that this is only an exploratory snapshot of a few cases, there appears to be considerable variation in the structure, mission and activities of these agencies even within the same national program. One task they share is to respond to local issues and provide guidance to managers and elected officials in matters dealing with local environmental resources. The NEPs typically have a small staff and are partnered with or hosted by a larger agency. Much of the work is done by volunteers from the public and private sector who share their interests in protecting the estuarine resources. The regional planning councils (RPCs)tend to have larger staff and more formalized responsibilities. Their mission is to coordinate the various regional issues, such as transportation, among several counties. The directors of these agencies answer to governing boards consisting of volunteers from various agencies and jurisdictions, as well as local citizens.

2. Use of SLOSH

According to these informants, there is limited use of NWS water level products in general, and surge information in particular, by these environmental agencies. They tend to focus on water quality and environmental protection and restoration. The regional planning agencies are more likely to be using SLOSH. Following are some comments grouped according to the way in which water level products were used.

a) For Hazard Mitigation, Evacuation and Response

According to the informants from RPCs, those that have planning responsiblities related to hazard mitigation, evacuation and response make extensive use of SLOSH models. It is used in planning for mitigation projects, such as flood control, and for hurricane response decisions, such as where to place shelters and supplies. They are used extensively in evacuation planning.

> "We used the SLOSH maps for our last evacuation study. We produced the different quads county by county. We printed those maps and distributed them."
>
> CM 8

> "We have typically relied on the work at the county EOC to identify the areas that are subject to surge and the policies the county put in place to deal with the surge threat. . . We're about to be involved in a statewide effort ... to take advantage of the new SLOSH models being developed. Those are going to generate new evacuation zones in many counties."
>
> CM 1

> "We've actually defined the SLOSH boundary line as evacuation boundary line in some cases." CM 3

> "There are some different methodologies that counties use. Usually we'll do runs for them. They look at the SLOSH runs and match that up with their parcel data to develop their evacuation models." CM 10

The Southwest Florida Regional Planning Council has developed an impressive web-based atlas of the surge model runs for various basins and hypothetical type storms (landfalling, parallel, etc.).

b) For Land Use Planning

Since surge models are designed to show potential risk for a given coastal area, it is logical to assume that they play an important role in land use planning. To some extent this is true. From these examples it appears that they are considered in development and zoning requests, and may be used to scale back a project, or to require mitigation, rather than to prevent development in surge zones. Mitigation includes such things as raising the elevation of a structure, moving it to a different place on the site, and putting in sand dunes. SLOSH models have also been used in determining areas for acquisition in habitat restoration planning.

> "It [SLOSH data] has been used to change how development occurs. . . Yes, there have been cases where development was not necessarily denied, but evaluated related to whether it was in a high hazard area. . . It's been used in _____ to rigorously to maintain the current densities. The problem is new legislation is in place that allows development to mitigate its way out of the requirements." CM3

> "I don't know of any cases [where surge information stopped development]. I'm trying to remember if hurricane evacuation issues were a part of any of the land use amendments that we've reviewed. I don't recall any." CM 1

> "The Department of Environmental Management does our permitting and monitor enforcement. They use the EDUNE model to do an erosion model which has surge built into it in their permitting process for large developments." CM 8

> "The only time I've seen a building permit refused is actually if the buildings are in the water. If the water is lapping up on the base of the property, I've seen it condemned." CM 12

> "I have used them for restoration planning. When we're looking for areas for acquisition. Those areas are apt to be flooded during tropical storms. They have a higher level of need." CM 2

> "We've used SLOSH to transmit to the public the difference between the coast now and the coasts we had in the past. To show the benefits, the storm surge mitigation benefits, of coastal landscaple features." CM 7

There was concern about how the FEMA flood maps related to the SLOSH maps.

> "There's a flood insurance program run by FEMA that produces maps that tell you how high you're supposed to elevate your house because you're in this 100-year flood plain. Then you have SLOSH models that are used to try to save lives, where the flood maps try to save property… I think there needs to be a connection between the flood insurance program and the SLOSH maps at some level." PL 3

One NEP knew that NOAA had used information from the NWS to forecast red tide movement. A couple of problems with SLOSH data were mentioned:

> "The [SLOSH maps] are not used because they lack regulatory basis. We use the flood insurance maps in the planning process." CM 6

> "They [the SLOSH models] seem a little too conservative to me... It develops a 'super surge.' So the modeling makes it look a lot worse then it ever is. I think the result is in people mistrusting it." CM 2

3. Public Understanding of Surge

I asked these coastal managers for their opinions on the extent to which those they work with, as well as the general public, understand surge, including whether they thought surge forecasts included tide and wave action.

> "No. I would say they would be more likely to think of surge as having both already included. The destructive force of it as a wave as opposed to just water, that distinction is not made when we talk about surge." CM 1

> "I don't think most people in the planning field know that either." CM 10

> "I think right now they do, but memories are short. . . I think it took Katrina to reinforce the part about the waves." CM 8

> "I think they understand it but they under-estimate the potential for our area. I think there's a general feeling that it's not going to happen to us here. . . I think everybody is underestimating surge. I really do." CM 12

4. Education and Public Outreach

Storm surge information is sometimes used for educational purposes by these agencies.

> "I have downloaded the predicted storm surge and the actual storm surge for comparison ... to show the impact of storm surge." CM 2

> "We've used SLOSH in the past to transmit to the public the difference between the coast now and the coast in the past. To show the benefits, the storm surge

mitigation benefits, of coastal landscape features... We actually have animations that were built using SLOSH model output." CM 7

"One of the things our agency is known for is developing the hurricane guide. . . We use different partners to build and distribute it to the newspapers and TV." CM 10

"I think now might be a good time to get the public's attention. Quite frankly, an explanatory description of surge in the context of why your insurance rates are going up, I think that is an opportunity missed if we don't build on it."CM 1

5. Needs Related to Surge

I asked these middle managers what tools the CSC might develop related to storm surge that might help them with their work. Several coastal managers mentioned the need for educational aids.

"Obviously, pictures can be helpful." CM 1

"We need some sort of consumer education product." CM 6

"It's got to be portable, easy to access if it's on line. Really I think the best outlet to get information out is the local communities. . . I don't even know if it has to be high tech. A three-page stock handout is a great tool." CM 8

Another issue that came up sever al times was the confusion between FEMA flood maps and SLOSH surge maps.

"They get confused between the flood insurance rate maps and the surge maps. There's a real confusion there. We could do a better job of explaining what each is used for." CM 6

"We feel that someone, maybe CSC, should look at how the flood maps should be tied to SLOSH." CM 3

C. Interviews with Emergency Managers

In order to better understand the use of surge information by emergency managers (EMs), 33 telephone interviews were conducted with a purposive sample representing about one-third of the emergency managers of coastal counties or parishes from North Carolina to Texas.

An open-ended interview schedule was used which covered these topics:

- Organization of emergency services
- Size of staff

- Personnel turnover
- Training related to hurricanes and GIS
- Use of NWS water level products
- Use of private weather services or products
- Understanding of water level products
- Use of SLOSH, both hypothetical and operational runs
- Evacuation zone determination and labeling
- Any use of surge information in land use planning
- Opinion of citizen knowledge of surge
- Products or tools that could assist them related to surge

All interviews were taped (with their permission), transcribed and analyzed.

1. Organization and Staff

Emergency services are organized in a variety of ways. The most common county[4] model appears to be a small office or department located under a larger entity such as Public Safety or Fire Services. Since 9/11 many counties have added a Department of Homeland Security and placed emergency management within it or under it. In some instances the Director of Emergency Management reports directly to an official, such as the county manager or mayor, but more often there is at least one layer of bureaucracy in-between. In many cases there are municipalities within the county that also have emergency management staff. Typically they have cooperative agreements with the county and are given a seat in the county Emergency Operations Center (EOC) during activations.

The number of staff assigned to emergency management responsibilities varies with the size of the county, its bureaucratic and political organization, and the organization of the state emergency management operation. For example, in Texas many county emergency managers have the title of Texas Coastal Advisory Team Representative. The size of the emergency management unit varied from one to 20 people. In smaller counties there is often only one or two professional emergency managers. It is common for other county employees to be trained to move into the EOC to supplement the professional staff during activations.

One concern of the NHC was the degree of turnover in emergency management directors. For example, several of the county or parish emergency managers were relatively new at the time of Hurricane Katrina and had not gone through the NHC training program. If the purposive sample interviewed for this project is representative, this is not a serious problem. Only one director out of these 33 had been in his job for a short time (one year); most were veterans with at least eight years experience.

Significant to the topic of this project, all but one of these emergency managers had taken the NHC's Hurricane Preparedness course. In nearly half of the cases other staff had also been through the training, as many as five or six in a few instances. In one case a county

[4] For purposes of this report the term county will refer to both counties and parishes.

manager had taken the course. In some areas the county or state had provided a similar course locally. There was consensus that the training received at NHC was excellent and several lamented that it was difficult to get their staff into the class because of space limitations.

Given the movement toward the spatial presentation and analysis of data using Geographical Information Systems (GIS), I asked if any emergency management staff had GIS expertise. Only a handful said they or their staff had GIS skills. In most cases they relied upon other county departments to provide GIS maps and other products for their use. In one case the emergency management department partnered with a private utility company, as well as other agencies, to produce Community Vulnerability Assessments and other GIS-based products. Most had GIS capabilities in their EOCs during activations.

2. Use of Water-Level Products

It became clear early on in the project that most emergency managers did not understand questions about water level datums. Typically the only water level products they mentioned were the SLOSH surge maps used for planning. The relationship between the SLOSH surge maps and flood plain maps (FIRMs) was not clear to many of these emergency managers. They were unsure about the extent to which these were related. In fact most were unclear as to whether they were ever used together to provide inundation forecast maps.

a) For Evacuation Planning

All but one of these emergency managers used the SLOSH models to some degree in planning for emergencies, usually in determining evacuation zones. One coastal county had only one zone, i.e. if there was a mandatory evacuation it included the entire county. Most had 3, 4 or 5 zones, typically tied to the storm categories with the first zone being at highest risk and usually involving the evacuation of barrier islands, beaches and mobile homes and the last zone extending to some inland low lying areas.

Some counties followed the maps determined by the SLOSH models exactly in establishing zone boundaries, but most modified them according to their knowledge of local conditions.

> "If you look at the SLOSH maps in a Cat 1 storm there are parts of our barrier islands … that are not included in the inundation maps… According to the inundation maps you wouldn't need to evacuate barrier islands and that's crazy."
>
> EM 4

> "There's just no way you can define a Cat 1 surge zone just by looking at SLOSH. There's nothing for wave runup." EM 1

> "… the SLOSH maps show the inland flooding ending exactly at the county line… Like a magic line. We know that's not right." EM 9

Most defined the boundaries at known landmarks, such as a river or road. While the zones were usually labeled with numbers, there appears to be movement toward using letters. A few used neither, but relied on landmarks completely. One did not have pre-identified zones, but used landmarks, such as "everything below I-12."

> "We have an itinerate population here that we think it's best just to pick major arteries for boundaries." EM 19

> "Most everybody knows where they live in relation to these roads. But our problem with that is we have flood areas that run through the middle of these boundaries. We have to modify that by saying things like 'storm surge and flood plain areas as well as the island." EM 19

Several emergency managers said they err on the side of caution, bumping a high Cat 2 storm up and calling a Zone 3 evacuation, or always assuming mean high tide at landfall, as examples. Others are concerned that the use of the SLOSH maps alone can lead to over-evacuation and so they have made adjustments based on local knowledge.

> "I always regard storm surge modeling and the inundation atlas that SLOSH produces as technical data…on which to make objective decisions with some subjectivity instilled into it as to who is at most risk from surge. In that way we try to curtain the problem of over-evacuation from surge." EM 4

> "We try to base our evacuations on surge. The state's are surge and wind and quite frankly I think they're a little over conservative…We look at surge and then after that it's a case by case situation. You determine the integrity of your own structure." EM 29

While a few counties made this distinction, basing their zones on surge estimates, not storm category, it is important to note that most of these EMs were not aware that the NHC no longer gave surge estimates as part of the categories. When I explained this, the reactions were mixed.

> "Well that is super. So are they going to put that into a new scale?" EM 19

> "It's going to be difficult. Everything is tied to categories right now. You can't separate them. They can try. They may be able to separate them for us as professionals who can interpret them. However, from the public it's problematic." EM 14

> "I don't think that's a good idea to separate surge from the categories." EM 8

> "That's the first I heard of it. I don't know how I feel about that, to be honest with you. I typically try to make it understandable by the categories. I tell people that the categories are defined by the wind and storm surge." EM 20

Several who now used a number system remarked that they would need to change to letters to separate the zones from storm categories.

There were complaints that the SLOSH maps were out-dated. In fact many areas, including all of coastal Florida, are remapping their beaches and low lying areas using LIDAR. New SLOSH models will then be created and the evacuation zones adjusted accordingly.

It was not clear that several emergency managers understood how to interpret the SLOSH surge maps. Sometimes they thought they were high water marks, and many were not clear about how they related to the FIRMs, if at all.

b) For Land Use Planning

When questioned about the extent to which SLOSH surge maps were a factor in land use planning in their area, the most common response was a laugh. In only one of these counties was the emergency manager involved in the approval of land use applications. Aside from defining high hazard zones, SLOSH maps are rarely a factor in approving development of the coastal areas.

> "They may be taken into consideration but it doesn't go very far. Our county is growing so rapidly that everything gets approved." EM 3

> "They tend to steer clear of us. They don't like what we have to say." EM 25

> "We have attempted in the past but they always caved in. We have scars when we attempted to do the right thing but when everything is said and done, growth drives the train."
>
> EM 10

> "While we advise against it, I don't know of any that were turned down based on our recommendation."
>
> EM 12

> "We are not given the plats ahead of time to sign off on…There's a big disconnect between the planners and emergency management."
>
> EM 19

> "I'm not sure the state pays much attention to it either. They changed their procedures for the coastal high hazard area and that's bothersome, but there's nothing I can do about it. Nobody asked me." EM 8

Flood plain managers are more likely to be involved in land use decisions. Mitigation plans must be filed in order to qualify for national flood insurance. However, there appeared to be a disconnect between flood plain management and emergency management. (This complaint echoed that heard from a coastal manager.)

> "FEMA came out with flood maps A, B, C and then the Corps came out with surge maps A, B, C. A lot of people are confused. They're apples and oranges. The whole flood plain management system is totally off base. They're basing everything on 100-year and 500-year events. These are based on more inland riverine flooding they have nothing to do with surge…They keep wanting to apply flood plain to surge and they're not the same thing. I can't get anybody to listen… They aren't mitigating against what will actually cause the problem."
>
> EM 21

The bottom line is that the rapid growth of coastal areas, including development in surge zones, is increasing the size of the at-risk population at alarming rates. In a few counties surge maps do affect the building codes. Structures built in identified surge zones must be on stilts or above a base flood elevation.

c) During Emergencies

In flood-related emergencies most of these emergency managers relied on the forecasts from their local Weather Forecast Offices, particularly the Hurricane Local Statement (HLS). When a tropical storm threatened their area they looked to the NHC conference calls and forecasts to get the big picture. However, they often said the HLS was their most important tool.

> "The most significant product, the one that we're always going to rely on first, most, is the HLS from the National Weather Service. In addition they send us a synopsis via email of the detailed conditions we should expect… They extract from the HLS that particular page of information. It cuts out all the verbage and gives us just the facts. What we can expect. How much surge… What the peak winds will be, what will be the length of time the winds will be at different forces." EM13

These emergency managers were in direct contact with the local WFO. In most cases they referred to the WFO staff by name and had high praise for the level of service they received. Typical comments:

> "We have an excellent local weather office in …. They are excellent. We see them a couple times a month at meetings, etc. They are very familiar with our county. They can call me and tell me a neighborhood. They are very connected with us."
>
> EM 25

"They're absolutely phenomenal. The most supportive people you'll ever want to meet. They're down here every time we have an exercise or meeting. They come visit my EOC. I go up there. I know them all by their first names." EM 17

"They have been great about us picking up the phone and asking questions about what they're seeing. I could not be more pleased with our local weather guys. They've spent a lot of quality time over here. They're top drawer." EM18

In at least two of these counties the NHC had provided hypothetical SLOSH runs for use during training exercises.

Most of these emergency managers were not aware that the NHC now runs real-time SLOSH models 24 hours before expected landfall. This is probably because they have not been under a hurricane threat since this policy began. A concern expressed at the NHC is that emergency managers and officials might delay some evacuation actions until this real-time surge forecast. Based on this sample, this does not appear to be a serious danger. It was generally considered to be a good idea because it gave them more information about what to expect, both at landfall and afterwards.

"We use that [real-time runs] for search and rescue, post-event type of things. Obviously, evacuation decisions have to be made before then." EM 1

"Other than just for my own personal information, I certainly wouldn't base evacuation on it." EM 4

"Those run models are helpful in two ways: 1) it validates or allows for corrections in decisions made in the previous 6 to 12 hours, and 2) it gives a little window left to correct key action points." EM 18

"It's not an exact science … I would not utilize that operational SLOSH information in a briefing…I'm afraid that would set us up for failure." EM 26

These emergency managers understood the difficulty of predicting surge. They were hopeful that SLOSH or some other model would be able to improve future forecasts. They complained about the format of many NWS products, including the lack of graphics.

"I use the graphics from HURRVAC. I do the modeling with them. When I sell this to the Board of Commissioners, we do it in an open public forum because I want everybody to understand why we're making this decision." EM 14

"When we have to take these products to decisionmakers, the cleaner, the simpler the product, the better. I remember the old weather wire stuff and actually the products haven't been polished since then. It still looks like it came off the wire."

EM 18

Only two of these emergency managers used private weather services. They both said they rely totally on the NWS information to make their decisions, but consider the private sources a good backup. A major reason for purchasing these services, however, was the way they presented the information.

> "I will tell you that some of the graphics from the third party service, some of the early predictive graphics, are better. And some of the narratives are a little more polished, rather than just the typical weather statement. They read better… Some of those products are emailed to us and they print better for handing to an elected official…I get something that has captured the information in layman's terms and I can hand it to the boss and say this is where we are today, this is where we might be three days from now based on this model." EM 18

Most of the EOCs in these jurisdictions use other software aids such as HURRVAC to help with decision points and briefings as a storm approaches. One county purchased HURRTRACK and uses it with Google Earth maps. Several said they did their own real-time SLOSH runs, plugging in updated forecasts from the NWS emergency management website. One large county emergency management department had developed its own decision software with an automated checklist. They also run their own SLOSH models as the dynamics of the storm change.

When asked if they had used any other modeling programs, most knew there were some being developed, but for now they were sticking with SLOSH.

> "We understand there are other private models out there, but frankly the people that manage them are not real forthcoming in telling you how they did it so it's difficult to use it." EM 2

> "I look forward to seeing a new generation of SLOSH or some other model. I know a number of researchers are developing these. I don't believe any have been verified as being more accurate than SLOSH." EM 4

North Carolina has purchased WebEOC and several EMs were enthusiastic about its ability to link together local, state, regional, and national data and personnel, including politicians.

3. Public Understanding of Storm Surge

One of the most important topics covered in the interviews with EMs was their opinion of the degree to which their citizens understood storm surge. Only two expressed the belief that the people in their communities understood surge. (Incidentally, one of these EMs did not know how high the surge was predicted to go in his county.) There were some misunderstandings, even on the part of emergency managers. For example, one said that it was just the wind that caused surge. A few gave a qualified answer, such as some do

and some don't, but the vast majority felt their citizens did not fully understand surge. Some comments:

> "No I don't. I think a great example of that is what happened on the Mississippi coast with Katrina. For anyone to think that staying near the Gulf is a good idea even after Camille, I can't believe people understood the threat." EM 4

> "I don't think they know that it doesn't include tide and wave action. The big sensation to the public is the wind threat which you can protect yourself from. But if you're on the water, you can't protect yourself …" EM 6

> "I don't think they understand how bad it can be." EM 21

> "I don't think they really understand the actual surge that comes in off the ocean. The misconception we have here is that the majority of water will come from rainfall ... I don't think they realize how the water could come inland." EM 25

Some gave a qualified answer.

> "I think those that live on the coast understand it, especially those that might have experienced it in the past…Back from the coast I don't think they understand that water can come that far and that high." EM 14

The citizen survey discussed later in this report validates the opinions of most EMs that the public is not as knowledgeable about storm surge as it needs to be.

4. Education and Public Outreach

An important part of the job of emergency managers is public outreach. Most coastal EMs spend a great deal of time, particularly when in the non-hurricane months, giving public talks, designing brochures and leaflets, preparing websites, and participating in various public education campaigns. An important part of this is providing information to citizens about the elevation of their home and/or its evacuation zone. Some methods mentioned included:

- A Hurricane Expo where you can put your address in a computer and it will tell your evacuation zone;
- Putting an evacuation zone map in the phone book;
- A Know Your Zone website where citizens can put in their address and get their zone[5];
- Putting evacuation zones in distributed literature, such as an annual Hurricane Guide, often produced with community partners;

[5] In two counties the Coastal Services Center was credited with assisting in this effort.

- Putting flyers in utility bills;
- Mapping zipcodes and using them in the notification process;
- Distributing graphics and maps to local media.

Some communities have permanent signs that give the evacuation zone for that area. A clever method used with mixed success in several communities was to mark the hypothetical surge levels on telephone poles.

> "We've had brave souls who put up high water makers at certain geographical locations for reference and impact. The commercial folks are quick to point out that this is a scare tactic and not conducive to business." EM 15

> "We got the Corps of Engineers and our local Roads and Bridges people and went out with a transom and marked a palm tree in the median with FEMA colors for different surge levels. Within a week we were asked to take them down. Several realtors did not like it being there." EM 25

The state of Texas has initiated a program to post storm surge signage in visible areas. They're using color codes to show the different levels. Several cities have rejected the signs. The state is encouraging communities to have volunteer agencies install the signs to take the attention away from the emergency managers.

Many EMs use their local SLOSH maps as visuals, usually printing the various maps for distribution. Videos of SLOSH runs are sometimes presented on web sites, in presentations, and on Cable Access television channels.

The rapidly increasing coastline population was often mentioned as a problem presenting a continuous batch of new residents to be educated about hurricanes.

5. Needs Related to Surge

The focus of this project was not just to find out the extent to which storm surge is understood, but also to explore what the Coastal Services Center might provide in the way of tools and methodologies to help coastal and emergency managers to disseminate and use surge information. To that end informants were asked what might help them with their education and outreach activities.

The most common answer was to assist with visuals. Most used maps, charts and pictures, but wished they had something more dramatic. A few had been successful in getting surge videos from sources such as FEMA, the Corps of Engineers, hurritrack.com, and the University of South Alabama.

Several mentioned that they look forward to the day when there will be 3-D simulations of storm surge in actual geographical locations.

The literature review that began this project revealed numerous educational illustrations and definitions of surge on internet websites, but they varied considerably in content and clarity. Assistance with more standardized websites could be useful.

One idea that evolved in these interviews was to have a short (5-7 minute) visual of actual surge that illustrated its violence, as well as its potential height. Some said they would show it alone, others would include it in a Powerpoint presentation. Most felt they had failed to adequately demonstrate in their educational programs the terrible force of storm surge. While they appreciated the models, a video clip of actual surge would be more dramatic.

The second most requested assistance was to have tools to assist in explaining SLOSH models to the public.

> "They need to understand how the information is derived and how it will be applied, but it has to be kept basic" EM 7

> "Any kind of models or videos would help us make people understand." EM 8

It would also make sense to develop the methodology that would allow all counties to have Know Your Zone websites such as the one the CSC helped develop in some areas.

Another suggestion was not for tools, but for a practice change. The current NHC practice is to report only surge, stating that it doesn't include tide and wave action. The public isn't interested in what part is surge, tide and wave action. "They just want to know how high the water might get at their location" (EM 6). This is an important issue worthy of consideration and research.

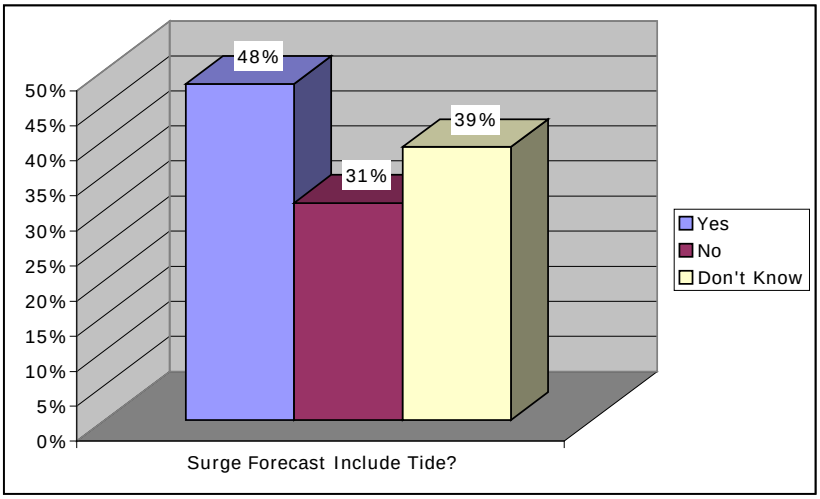
Finally, there appears to be considerable confusion and differing ideas about how surge maps and flood plain maps relate to each other. This concern was expressed by both emergency managers and coastal managers. There are major projects underway to update both types of maps. Perhaps this is the ideal time to develop methodologies that would result in new inundation maps that cover both coastal and inland flooding. At the least this appears to be a matter requiring clarification for these coastal decisionmakers.

E. CITIZEN SURVEY

I was able to add a few questions related to this project to the telephone survey conducted by the Institute for Public Opinion Research at Florida International University with funding from the National Science Foundation. The sample for this Post-Katrina Behavioral Study was a randomly chosen panel of citizens living in the coastal areas of Alabama, Mississippi and Louisiana. A total of 811 interviews were conducted. Four questions were designed to measure the public's understanding of surge forecasts.

When these residents of coastal Alabama, Mississippi and Louisiana were asked if surge forecasts accounted for tide, only about 31% knew that it did not. (See Figure 2.) Or, stated a more alarming way, 48% thought it did. There were no significant differences related to state, education, income or gender.

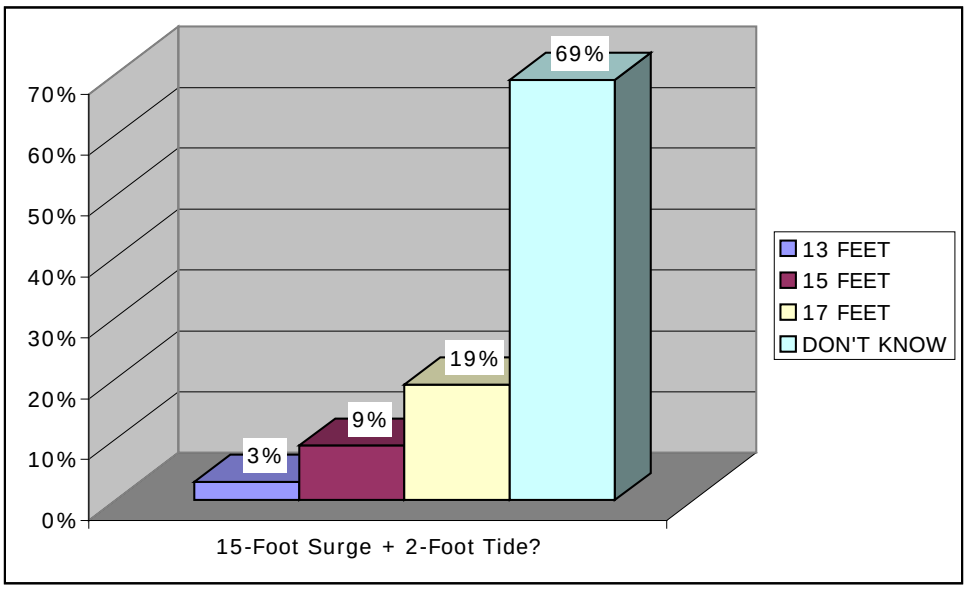
Figure 2



Source: FIU Post-Katrina Behavioral Survey

Respondents were then asked to use that information. They were asked what the expected sea level would be if a 15-feet surge occurs at the time of a 2-foot tide – 13 feet, 15 feet or 17 feet. The results are depicted in Figure 3. Perhaps the idea of a math problem threw them, but only 19% gave the correct answer of 17 feet, and 69% said they didn't know or weren't sure. There were no important differences associated with state, education or income. However, women were significantly more likely to give the correct answer ($p<.001$).

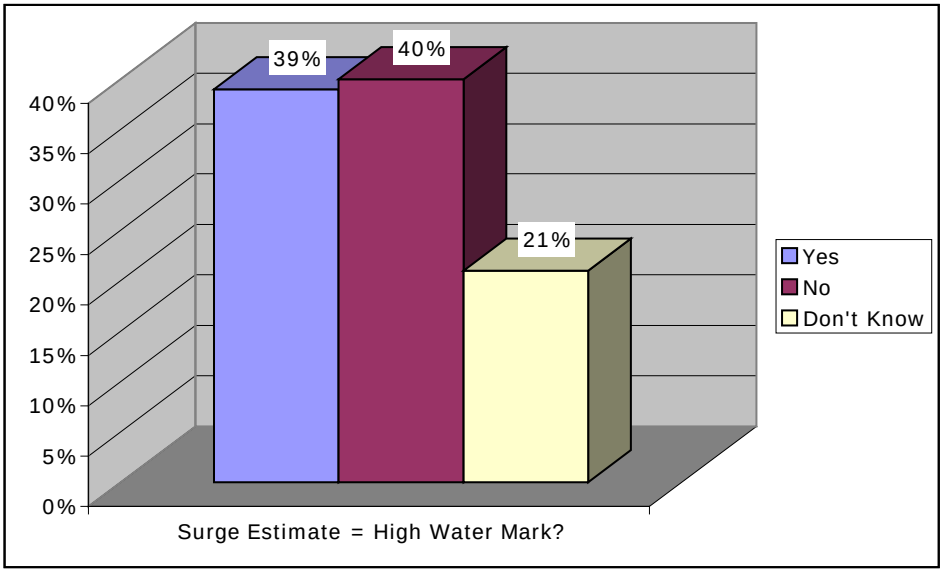
Figure 3.



Source: FIU Post-Katrina Behavioral Survey

The next questions asked "When a 12-14 storm surge is forecast, is this the expected high water mark?" (See Figure 4.) The most common answer was the right one; about 40% answered correctly. However, it is important to note that most people either thought it was the high water mark, or did not know the answer. There were no important differences related to state, income or education. While women were more likely to give the correct answer, the gender difference was insignificant.

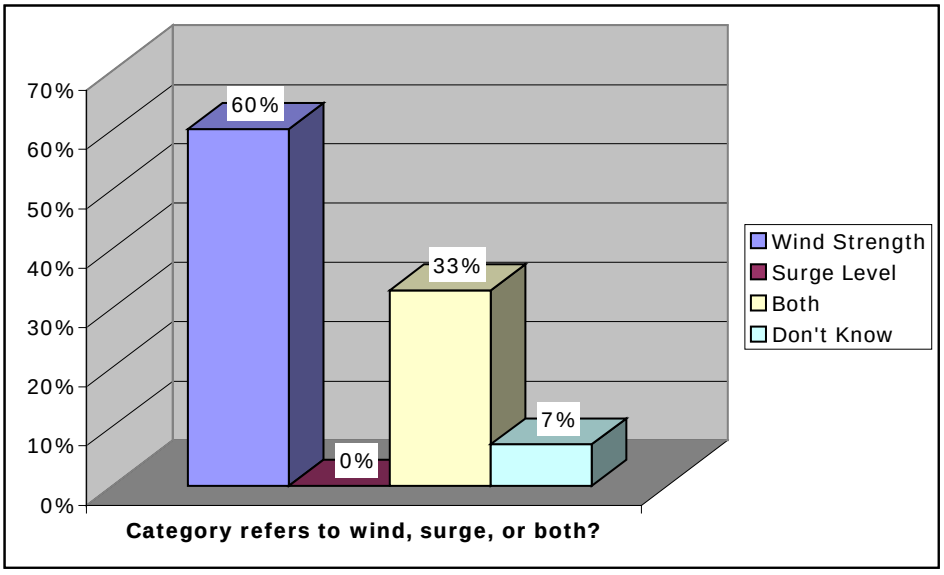
Figure 4



Source: FIU Post-Katrina Behavioral Survey

The last question related to surge asked if the National Hurricane Center's categories of storm referred to a storm's wind strength, surge level or both. Most gave the correct answer that it was based on wind, no one thought it was only based on surge, but about one-third thought it was based on both. College graduates, those with incomes over $50,000, and men were significantly more likely to give the correct answer ($p<.001$).

Figure 5



Source: FIU Post-Katrina Behavioral Survey

IV. SUMMARY

The topics addressed in this study emerged from a cross-NOAA effort to identify strategic areas where NOAA could support state and local managers in addressing the threats of coastal flooding from storm surge. This "storm surge action plan" identified a need for social science data related to how these managers receive, understand and use storm surge data. Added to this was an interest in better understanding how the public interpreted surge forecasts.

A. The Work

The Scope of Work identified the objectives for this sociological study as three-fold: 1) developing a database of relevant professional and lay literature; 2) compiling new data on how surge information is received and used by coastal management agencies, as well as the general public; and 3) identifying ways in which NOAA in general, and the CSC in particular, can support improved communication and understanding of surge.

Several tasks were laid out as intermediate steps toward reaching the objectives. As with any exploratory work, some of these tasks proved to be unreachable or irrelevant to the objectives. The project evolved as it progressed. Early on it became clear that there were no definitive channels for the dissemination of NWS surge information. For example, while the data for SLOSH models originated at the NHC, they were received and used in a variety of ways, even by the same category of users. Sometimes the models resulting from the NHC hypothetical runs were received directly from the NHC, sometimes from other agencies, sometimes from the internet. Sometimes only the printed maps resulting from the runs were used. The lay public might get it's information directly from the NHC, via the media, from a website, from emergency managers, or through some other method of outreach.

There is a great deal of variation among the coastal and emergency management agencies in terms of organization, mission and staff, and this was reflected in the manner and extent to which they used surge data. The bottom line was that there was insufficient consistency to allow the development of organizational charts for these agencies, to identify patterns of inter-organization networks, to develop a single typology of users, or to diagram their channels of communication. Instead, this project explored some of the ways in which these things occurred with the intention of highlighting the "possibilities" rather than documenting the extent to which each issue existed. This is the unique contribution of exploratory qualitative research – identifying issues that can then be studied in depth by more traditional research methods.

B. The Issues

The major findings from this project can be grouped into several categories.

1. Organization

- Coastal and emergency operations vary among agencies and across jurisdictions in organization, size and responsibilities.
- Coastal managers, coastal planners and emergency managers have some degree of access to GIS technology
- Turnover does not appear to be a significant problem among emergency managers and most agencies have at least one person trained at the NHC.

2. Understanding of Surge

- Some coastal managers do not know how to interpret surge models or forecasts.
- Emergency managers have more training and knowledge of storm surge, but some do not fully understand the meaning of forecasts.
- Most of the managers participating in this study did not believe the public understood the threat of storm surge.
- The survey questions included in the Post-Katrina Behavioral Study confirmed that most of the lay public in the Gulf coastal areas do not understand storm surge forecasts.

3. Use of Surge Information

- Coastal managers do not appear to use SLOSH surge models to any extent in their work.
- While surge data may be considered in land use planning, it has seldom resulted in the denial of permits, even in high coastal hazard areas.
- Regional planners are more likely to be involved in hazard mitigation and evacuation studies and to use SLOSH models.

- Emergency managers use surge information, usually SLOSH models, in their planning, including the establishment of evacuation zones.
- Since they are based on MOMs, the SLOSH models present worse case scenarios . and some managers feel this is too conservative to be useful in planning.
- An interesting suggestion was that SLOSH be used to compare the surge in hypothetical models before and after various features were added or subtracted from the coastline to see the effects of different mitigation ideas.

4. Surge Maps and Flood Maps

- The relationship between FEMA flood maps and surge models is not clear.

5. Use of Storm Categories to Define Evacuation Zones

- There is a great deal of variation in how jurisdictions define and label evacuation zones.
- Evacuation zones tend to be tied to storm categories and this needs to be reexamined given the NHC emphasis that surge forecasts do not correlate well with storm categories.

6. Need for Graphics and Other Educational Materials

- The NWS is not meeting these emergency managers' needs for graphics to use with their officials, as well as the general public. Some are using private services because they provide clearer messages and graphics that can be inserted into a Word document or PowerPoint easily.
- These managers were anxious for help in their educational and outreach activities related to storm surge. In particular, they would like visuals that highlight its destructive force, but any tools to assist with outreach would be welcomed.
- One idea was that the CSC set up a website for emergency managers using WebEOC where materials and other aids could be posted and communication between emergency managers and CSC facilitated.

7. High Water Mark

- The suggestion that something like a "high water mark" be included in a forecast that allows for surge, tides and waves is worthy of further exploration.

In my opinion storm surge is a very serious issue, requiring extensive educational and outreach activities. Many, if not most, coastal residents do not understand the surge forecasts or adequately recognize the threat. While Hurricane Katrina should have been a wakeup call, the tragic events in New Orleans over-shadowed the surge disaster that occurred in Mississippi. Given the unusual geography of New Orleans, other coastal residents did not personalize the tragedy.

Residents of surge areas need to understand how powerless they will be if they do not evacuate and their area is impacted by storm surge. Even a small surge can result in high water if it occurs at high tide and/or has considerable wave action. Clearly, the people who stayed on the Mississippi coast and lost their lives to Katrina did not fully understand the risk. I can think of no more important goal of the CSC than addressing this problem. Several issues identified in this study merit examination, including empirical studies, as the next step in addressing storm surge threat to coastal populations.

APPENDIX A

LITERATURE REVIEW

RELEVANT SOCIAL AND ECONOMIC REFERENCES RELATED TO COMMUNICATION, UNDERSTANDING AND USE OF COASTAL SURGE INFORMATION

EDUCATIONAL MATERIALS

American Meteorological Society. *Glossary of Meteorology*. Available at: http://amsglossary.allenpress.com/glossary/search?p=1+quiry=storm+surge

> "Storm surge – (also called storm tide, storm wave, hurricane tide.) A rise and onshore surge of seawater as the result primarily of the winds of a storm, and secondarily of the surface pressure drop near the storm center. The magnitude of the surge depends on the size, intensity, and movement of the storm; the shape of the coastline; nearshore underwater topography; and the state of the astronomical tides. The storm surge is responsible for most loss of life in tropical cyclones worldwide."

Atlantic Oceanographic and Meteorological Laboratory. n.d. *Storm Fury*. Available at: www.aoml.noaa.gov/general/lib/stormf.html.

> Describes storm surge as "a large dome of water often 50 to 100 miles wide that sweeps across the coastline near where a hurricane makes landfall."

Australian Institute of Marine Science. 2000. *Cyclone Survival: Understand Storm Surge*. Available at: www.aims.gov.au/pages/reflib/cyclones/pages/cs-06.html.

> Describes a storm surge as "a raised dome of seawater typically 60km to 80km across and two metres to five metres above normal sea level."

Dorst. N. Atlantic Oceanographic and Meteorological Laboratory. n.d. *What is storm surge and how is it different from tidal surge? Frequently Asked Questions*. Available at: www.aoml.noaa.gov/hrd/tcfaq/A8.html.

> Describes storm surge as "the onshore rush of sea or lake water caused by the high winds associated with a landfalling cyclone and secondarily by the low pressure of the storm."

Helgeson, B. 2006. *Making sense of storm surge.* Tampa Bay Online. www.tbo.com

> Describes vulnerability of Tampa Bay area and explains how South Pasadena city workers have bolted signs on a flagpole to mark how high storm surge would be for all five hurricane categories.

Landsea, C. n.d. Doesn't the low pressure in the tropical storm cause the storm surge? *Frequently Asked Questions.* Atlantic Oceanographic and Meteorological Laboratory. Available at: www.aoml.noaa.gov/hrd/tcfaq/C1.html.

Louisiana Homeland Security and Emergency Preparedness. 2006. *Storm Surges.* Available at: http://www.loep.state.la.us/factsheets/StormSurges.htm.

> "Howling winds around the hurricane's eye push water along, tending to pile it up. In the deep ocean, this dome of water sinks and harmlessly flows away. But as

a storm nears land, the rising sea floor blocks the building water pile's escape and it comes ashore as deadly storm surge. An intense hurricane can send a dome of water more than 18 feet deep ashore as the storm hits land."

Louisiana Homeland Security and Emergency Preparedness. 2006. *Storm Surge Information Sheet.* Available at: http://www.loep.state.la.us/factsheets/StormSurgeinfo.htm.

"Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with the normal tides to create the hurricane storm tide, which can increase the mean water level 15 feet or more. In addition, wind waves are superimposed on the storm tide."

Mandia, S. A. n.d. *The Long Island Express. Long Island South Shore Hurricane Storm Surge Maps*. Available at: www2.sunysuffolk.edu/mandias/38hurricane/storm_surge_maps.html.

Provides HURREVAC surge maps for various regions of Long Island for various category hurricanes, including animation.

Media General News Service. 2005. *What is Storm Surge?* Available at: http://hurricane.weathercenter.com/MGBTX03FX8E.html.

Describes storm surge as "an abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone."

National Hurricane Center. n.d. How is storm surge forecast*? Frequently Asked Questions*. Atlantic Oceanographic and Meteorological Laboratory. Available at: www.aoml.noaa.gov/hrd/tcfaq/F7.html.

N.O.A.A. 1991. *Storm Surge and Hurricane Safety*. (brochure) Washington: U. S. Government Printing Office.

"The storm surge is a great dome of water often 50 miles wide, that comes sweeping across the coastline near the area where the eye of the hurricane makes landfall. The surge, aided by the hammering effect of breaking waves, acts like a giant bulldozer sweeping everything in its path."

N.O.A.A. 2006. *Storm Surge: NOAA Hurricane Education Student Activities and Teacher Resources*. Available at: www.climate.noaa.gov/education/hurricanes/stormsurge.pdf#search=%22storm%20surge%20education%22. 22 pp.

"Storm surge, one of the most damaging components of a hurricane, is a massive dome of water often 50 miles wide that sweeps across the coast near the area where the eye of the hurricane makes landfall." Includes activities, illustrations, and other information about storm surge including how to protect yourself. Illustrates LIDAR mapping.

N.O.A.A. 2005. Jetstream: An Online School for Weather. *Tropical Cyclone Hazards*. Available at: www.srh.weather.gov/jetstream/tropics/tc_hazards.htm

"Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with the normal tide to create the hurricane storm tide, which can increase the average water level 15 feet (4.5m) or more. In addition, wind driven waves are superimposed on the storm tide."

National Hurricane Center. n.d. *Glossary of NHC/TPC Terms*. Available at: www.nhc.noaa.gov/aboutgloss.shtml.

"Storm Surge: An abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge is usually estimated by subtracting the normal or astronomic high tide from the observed storm tide."

National Hurricane Center. N.D. *Hurricane Preparedness: Storm Surge*. Available at: http://www.nhc.noaa.gov/HAW2/english/storm_surge.shtml.

"Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around the storm. This advancing surge combines with normal tides to create the hurricane storm tide, which can increase mean water level 15 feet or more. In addition, wind driven waves are superimposed on the storm tide."

NOAA. 2005. *Hurricane Basics*. Available at: http://hurricanes.noaa.gov/hurricanebook.pdf.

A booklet to educate the public about hurricanes. Defines storm surge as "a large dome of water, 50 to 100 miles wide that sweeps across the coastline near where a hurricane makes landfall. It can be more than 15 feet deep at its peak. The surge of high water topped by waves is devastating. Along the coast, storm surge is the greatest threat to life and property."

Norcross, B. 2006. Hurricane Almanac 2006. New York: St. Martin's Press.

Warns about storm surge as most dangerous part of a hurricane

Palm Beach Post. n.d. *Hurricane and Tropical Storm Glossary.* Available at: http://www.palmbeachpost.com/storm/content/storm/about/glossary.html#lq

STORM SURGE The high and forceful dome of wind-driven waters sweeping a long the coastline near where the eye makes landfall or passes close to the coast.

PC Weather Products. *StormInfo. Personal Storm Surge Analysis*. Available at: www.pcwp.com/storminfostormsurge.htm.

Private weather service that provides subscribers with detailed maps to illustrate maximum levels of flood to be expected in a given locale by different categories of tropical storms.

Rosenfeld, J. 1997. Storm surge! Hurricanes' most powerful and deadly force. *Weatherwise*. 50(3): 18-24.

Describes storm surge as a wholesale rise in sea level caused by wind and pressure effects on the ocean surface, and is evident when waters pile up against shore, especially at landfall.

Statesman.com. n.d. *Storm Warning Center: About Hurricanes*. Available at: www.statesman.com/news/content/shared/weather/storm/couldhappen.htm

USA Today. N.D. *Hurricanes: Creation of Dangerous Storm Surge.* Video. Available at: www.usatoday.com/weather/wsurge1.htm

U.S.G.S. 2005. *Hurricane Hazards – A National Threat*. 2-page leaflet available at: http://store.usgs.gov/sap/its/y_images/PDF/206453.pdf.

Provides information about hurricane impacts and federal efforts to deal with them. Defines storm surge as a dome of ocean water, can exceed 20 feet in height and extend along shore for 100 miles.

U.S.G.S. 2006. *Hurricane Rita Surge Data, Southwestern Louisiana and Southeastern Texas, September to November 2005*. Available at: http://pubs.usgs.gov/ds/2006/220/.

Waveland Fire Department. n.d. *Storm Surge Page*. www.wavelandfiredepartment.com/Flod/storm_surge_page.htm

Describes storm surge as "an abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone." Provides illustrations of surge in different categories of storms.

Williams, J. n.d. MEOWS help officials gauge surge danger. *USA Today*. Available at: http://www.srh.noaa.gov/ssd/nwpmodel/html/nhcmodel.htm

Describes MEOWS as Maximum Envelope of Water likely to be pushed ashore by a particular hurricane. Defines surge as a dome of water pushed ashore by a hurricane.

Weatherclassroom.com. *Surge*.

Defines as increase in sea water height from the level that would normally occur were there no storm.

PUBLICATIONS ON STORM SURGE MODELS

Collins, R. F. 1998. *Risk Visualization as a Means for Altering Hazard Cognition*. Columbia: University of South Carolina, Department of Geography. 140 pp.

This dissertation examined the use of animated 3-D risk visualization as a means for altering hazard cognition. The risk visualization model did increase risk cognition related to storm surge.

Graham, J. K. 1985. Utilization of the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model in hurricane evacuation studies. *Flood Hazard Management in Government and the Private Sector*. Boulder: University of Colorado, Institute of Behavioral Science, Natural Hazards Research and Applications Information Center. Special Publication No. 12. 333-336.

Describes how SLOSH works and its possible use in evacuation management.

International Hurricane Research Center. 2004. *Windstorm Simulation and Modeling Project: An Interactive 3D Hurricane Storm Surge Animation System*. Miami, FL: International Hurricane Research Center, Florida International University. 150 pp.

International Hurricane Research Center. 2004. *Windstorm Simulation and Modeling Project: Evaluation of Storm Surge Models for the Florida Coast*. Miami, FL: International Hurricane Research Center, Florida International University. Pp. 146.

International Hurricane Research Center. 2004.*Windstorm Simulation and Modeling Project: Executive Summary*. Miami, FL: International Hurricane Research Center, Florida International University. 11 pp.

Jarvinan, B. R. and M. B. Lawrence. 1985. An evaluation of the SLOSH storm-surge model. *Bulletin of the American Meteorological Society*. 66(11): 1408-1411.

Mercado, A. 1994. On the use of NOAA's storm surge model, SLOSH, in managing coastal hazards: The experience in Puerto Rico. *Natural Hazards*. 10(3): 235-246.

Meisner, B.N. 1995. *An Overview of NHC Prediction Models*. National Weather Service. Available at: www.srh.noaa.gov/ssd/nwpmodel/html/nhc.model.htm

Describes SLOSH model and provides examples.

National Hurricane Service. *Hurricane Preparedness: SLOSH Model*. Available at: www.nhc.noaa.gov/HAW2/english/surge/slosh_printer.shtml.

Describes what SLOSH does and states that it is generally accurate within plus or minus 20%. Also mentions that since model is dependent upon point of landfall SLOSH is most useful in identifying potential maximum surge for a location rather than forecasting for a specific storm.

National Ocean Service. N,O,A.A. 2003. *Enhanced resiliency of coastal communities to storm surge and flooding through improved data, models, tools, and methodologie*s. Available at: http://oceanservice.noaa.gov/

Describes the NOS Storm Surge Partnership to develop a prototype surge model for the greater Pensacola region.

National Weather Service. Evaluation Branch. *Hurricane Storm Surge Forecasting*. Available at: www.weather.gov/tdl/marine/hursurge.htm.

Describes SLOSH and provides animations to demonstrate.

National Weather Service Forecast Office, Melbourne, FL. 2006. *The Florida Hurricane Surge Atlas*. Available at: www.srh.noaa.gov/mlb/atlas.html.

Provides color maps of worst case storm surge inundation for the Space Coast of Florida. Gives storm tide delineations to reflect simulated conditions at high tide, but doesn't include effects of waves.

Proxix Solutions, Inc. 2006. Proxix Solutions unveils the next generation in storm surge modeling. *PR News Today*.

Announces its newest hazard risk model, Coastal Storm Surge and says it is the first to" incorporate offshore (wind speed, hurricane speed, storm track, barometric pr5ssure, tide and water depth) and onshore (human and natural barriers and elevation)variables into a model along with a range of storm heights derived from category 1-5 hurricanes."

Sheets, R. C. 1985. The National Weather Service hurricane probability program. *Bulletin of the American Meteorological Society*. 66(1): 4-13.

Discusses the fact that numerical storm surge model (SLOSH) simulations have shown that lead times much longer than the current 12 hours are required for preparation and evacuation.

U.S.G.S. *Hurricane Georges Storm Surge and Beach Erosion*. http://ms.water.usgs.gov/ms_proj/reports/georges/surge.html

"Hurricanes and extreme tropical storms cause elevated sea level near shorelines, know as storm surge…"

PUBLICATIONS FOR PROFESSIONALS

American Geophysical Union. 2006. Hurricanes and the U.S. Gulf Coast: Science and Sustainable Rebuilding. AGU Release No. 06-20. www.agu.org/sci_soc/prrl/prrl0620.html

The AGU brought together 20 earth and physical scientists to provide guidance to policymakers charged with rebuilding New Orleans. Seven areas were examined, including storm surge. The report states that accurate models of surge have been developed but better wind data, enhanced shoreline topography and better ways to assess flooding are needed if storm surge models are going to predict events and damage to levees and other structures. While the SLOSH model is still being used, new advances in numerical techniques that allow the use of computational grids that are triangles (rather than squares) will improve the representation of complex topographic features. Further, new models can better capture the effect of waves and hydrologic runoff on storm surge models. They make several research and technical recommendations to improve surge forecasting.

Bush, D. M., W. J. Neal, N. J. Longo, K. C. Lindeman, D. F. Pilkey, L. Slomp Esteves, J. D. Congleton and O. H. Pilkey. 2004. *Living with Florida's Atlantic Beaches: Coastal Hazards from Amelia Island to Key West*. Durham, NC: Duke University Press. 358 pp.

Provides overview of coastal hazards including storm surge.

Chesneau, L. S. 1987. The use of storm surge forecast models in improved flood management. Pp. 311-316 in *Realistic Approaches to Better Floodplain Management*. University of Colorado, Institute of Behavioral Science, Natural Hazards Research and Applications Information Center. 322 pp.

Coch, N. K. and M. P. Wolff. 1990. Probable effects of a storm like Hurricane Hugo on Long Island, New York. *Northeastern Environmental Science*. 9(1-2): 33-47.

The author predicts the damage to Long Island if Hurricane Hugo had made landfall there. Makes recommendations for mitigation against storm surge and wind.

Danard, M. B., S. K. Dube, G. Gonnert, A. Munroe, T. S. Murty, P. Chittibabu, A. D. Rao and P. C. Sinha. 2003. Storm surges from extra-tropical storms. *Natural Hazards*. 32(2): 177-190.

Examines possible influence of climate change on the tracks of extra-tropical storms as well as storm surges.

Danard, M., A. Munro and T. Murty. 2003. Storm surge hazard in Canada. *Natural Hazards*. 28(2-3):407-431.

Discusses the effects of climate change on storm surges in Canadian water bodies.

Edge, B. L., M. Aggarwal, and C. Maske. 2005. Hurricane surge at Johnson Space Center. Pp. 61-73 in *Solutions to Coastal Disasters 2005*. American Society of Civil Engineers.

Analysis of storm damage potential along the Texas coast.

Finkl, C. W. 1994. Coastal hazards: Perception, susceptibility and mitigation. *Journal of Coastal Research*. Special Issue No. 12. 375 pp.

34 authors from 10 countries give different perspectives on coastal hazards, including storm surge from tropical cyclones.

Flather, R. A. 2001. *Storm surges*. Encyclopedia of Ocean Sciences. 5(S):2882-2892.

“Storm surges are changes in water level generated by atmospheric forcing..”

Goudie, D. and D. King. Cyclone surge and community preparedness. *Australian Journal of Emergency Management.* 13(4): 54-60.

Gosselin M. S., D. M. Sheppard, and T. L. Glasser. 2005. Hurricane storm surge modeling for the Florida southeast coastline. Pp.96-105 in *Solutions to Coastal Disaster*s 2005. American Society of Civil Engineers.

Discusses the development of models to simulate storm surge inundation and discusses how they could be used to develop evacuation recommendations and in prioritizing bridge inspections during post-storm evaluations.

Harris, D. L. 1963. Characteristics of the hurricane storm surge. Washington: U.S. Weather Bureau.

This was an effort by the Storm Surge Research Project of the National Weather Service to collect all the quantitative data on storm surge from past storms. Begins with a discussion of what was known at the time about storm surge development. Storm surge is defined as "difference between the observed water level and that which would have been expected at the same place in the absence of the storm." Discusses the 5 effects that can alter water level as: 1) pressure effect, 2) direct wind effect, 3) Effect of earth's rotation, 4) effect of waves, and 5) effect of rainfall. Records of individual storms between 1926 and 1961 are provided.

Hovis, G. T. 2005. Analysis of storm surge measured at water level stations from Hurricanes Charley, Frances, Ivan & Jeanne. *Proceedings of Solutions to Coastal Disasters Conference*. Pp 33-41. Available at: http://www.pubs.asce.org/cedbsrch.html

In this analysis of surge levels for 2004 storms it is interesting that the storm surge levels are computed simply as the difference between the observed water level and the predicted tide level.

Kentang, L. 2000. An analysis of the recent severe storm surge disaster events in China. *Natural Hazards*. 21(2-3):215-223.

Documents greater economic loss from storm surge disasters than any other marine disasters. Discusses possible mitigation measures.

Lee, J. L., I. N. Kang, and S. D. Han. 2005. A storm-surge warning system for the use of emergency management officials. *Proceedings of Solutions to Coastal Disasters Conference*. Pp 33-41. Available at: http://www.pubs.asce.org/cedbsrch.html

Reports on a new warning system to forecast inland flooding associated with typhoon. One purpose would be allow coastal and emergency managers to anticipate the potential impact. The user is able to obtain real-time water level fluctation of specific points. However, the model results are sensitive to hurricane path and it is yet difficult to provide accurate information.

Lindell, M. K., W. G. Sanderson Jr., and S. N. Hwang. 2002. Local government agencies' use of hazard analysis information. *International Journal of Mass Emergencies and Disasters*. 20(1): 29-39.

This study of Texas government agencies' source of hazard information revealed that most emergency managers still relied on printed material. Land use planners were likely to make use of computers and hazards modeling applications.

Lindner, B. L., D. St. Jean, C. Cockcroft and S. Brueske. 2005. Predictions of storm surge flooding with the use of hurricane climatology. *AMS Conference on Applied Climatology*. Available at: http://ams.confex.com/ams/pdfpapers/90600.pdf.

Reports on a survey in Charleston, SC in which most respondents did not understand surge or the danger it poses, as well as other elements of forecasts. Misunderstandings were most prevalent among the poor, minorities and those

with less education. Authors have a project to tie visualizations of surge to local landmarks.

N.A. 1996. Emergency management and storm surge in Australia. *Australian Journal of Emergency Management*. 11(1): 25-27.

National Hurricane Center. 2006. *Experimental Storm Surge Products – 2006.* Available at: www.nhc.noaa.gov/surge_exp.shtml#awareness.
Announces that beginning in 2006 the NHC will generate experimental probabilistic hurricane storm surge forecasts when a hurricane is forecasted to make landfall within 24 hours.

N.O.A.A. 2005. *Storm Surge: A Report of the Assessment Performed by the NOAA Storm Surge Leadership Team in 2005. Executive Summary*. Available at: http://ekman.csc.noaa.gov/socialscience_2/execsummarystormsurge.pdg.

N.O.A.A. 2004. *Hurricane Isabel Service Assessment*. Available at: www.nws.noaa.gov/om/assessments/pdfs/isabel.pdf
The draft mentioned that people expressed confusion over exactly what storm surge forecasts meant, but this statement does not appear in the final version. However, 2 recommendations are relevant: "Future HLS issuances from WFOs should include specific information concerning localized effects from storm surge including forecast times of the maximum water level and potential effects." "Emergency managers, media and storm drainage personnel could use Storm Tide forecasts (a forecast of the total height of water expected) more effectively than storm surge and normal tide forecasts."

Safford, T., J. Thompson and P. Scholz. n.d. *Storm Surge Tools and Information: A User Needs Assessment.* Available at: http://ekman.csc.noaa.gov/socialscience_2/finalstormsurgereport.pdf.

Scholz, P. 2005. *NOAA Storm Surge Assessment*. PowerPoint presentation.

Siefert, W. and T. S. Murty. 1991. *Storm Surges, River Flow and Combined Effects*. German Federal In stitute of Hydrology and the International Hydrological Programme. IHP/OHP-Berichte, Sonderhelft 4. 151 pp.
Discusses problems in forecasting storm surges in estuaries and explores probabilities of combined storm surge and river flow effects.

Von Lieberman, N., S. Mai and C. Zimmerman. 2001, A storm surge management system for the German coast. In Phelps, D. and G. Sehike, Eds. *Bridging the Gap: Meeting the World's Water and Environmental Resources Challenges*. World Water Congress 2001. Orlando, FL. May 20-24.
Provides risk analysis of the coastline including economic costs of inundation.

Wiegel, R. L. 1993. Hurricane and coastal storm surge barriers in New England. *Shore & Beach*. 61 (2):30-49.

Windham, G. O., E. I. Posey, P. J. Ross, and B. G. Spencer. 1977. *Reactions to Storm Threat during Hurricane Eloise*. Mississippi State University, Social Science Research Center Report 51. 74 pp.

Reports on a survey taken one week after Hurricane Eloise. Among other findings people were more afraid of wind than storm surge.

APPENDIX B

KEY INFORMANTS

KEY INFORMANTS

Technical Interviews

Person	Entity	Position
Baig, Stephen	National Hurricane Center	Surge expert
Gladwin, Hugh	Florida Intl. University	Local LMS Member
Massey, Bill	Dewberry & Davis	Former Hurricane Liasion
Mayfield, Max	National Hurricane Center	Director
Nelson, Ben	State of FL EM	Meteorologist
Norcross, Bryan	CBS4	Broadcast Met
Odum, Patrick	FL Emergency Mgt	Hurricane Prog Mgr

Coastal Managers and Planners

Person	Entity	Position
Alderson, Mark	Sarasota Bay Estuary Program	Director
Allen, Ray	Coastal Bend Bays Estuary Prog	
Beever, Lisa	Charlotte Harbor NNEP	Director
Eckenrod, Richard	Tampa Bay NEP	Exec. Director
Ferraro, Carl	Alabama CZM	Coastal Zone Mgr
Johnson, Betty	Tampa Bay Reg. Pl. Council	
Miller, Greg	Tampa Bay Reg. Pl. Council	
Ogburn, Richard	S. FL Reg. Planning Coun.	
Rice, Troy	Indian River NEP	
Sanchez, Tina	So. AL Reg. Planning Com.	
St. Pe, Kerry	Barataria-Terrebonne NEP	Program Director
Trescott, Dan	SW FL Reg.Planning Council	Principal Planner
Yeager, David	Mobile Bay Natl Estuary Prog	Director

EMERGENCY MANAGERS

State	Person	Entity	Position
AL	Dickerson, Walt	Mobile County	EM Director
AL	Ryals, Leigh Ann	Baldwin County	EM Director
FL	Ashton, Ray	St. Johns County	EM Director
FL	Baker, Baker	Franklin County	EM Director
FL	Berman, Richard	Sarasota County	EM Oper. Chief
FL	Carper, Tony	Broward County	EM Director
FL	Gispert, Larry	Hillsborough County	EM Director
FL	Hahn, Daniel	Santa Rosa County	EM Planner
FL	Lay, Bob & Kirsten Scholl	Brevard County	EM Dir & Deputy
FL	Leto, Tom	Hernando County	EM Director
FL	Mock, Lorin & Don Hall	Duval County	Chief & EM Dir
FL	Peters, Kevin	Leon County	EM Coordinator
FL	Reddish, Frank	Miami Dade County	EM Coordinator
FL	Ryan, James	Volusia County	EM Director
FL	Sallade, Wayne	Charlotte County	EM Director
FL	Summers, Dan	Collier County	EM Director
FL	Wilson, John	Lee County	EM Director
FL	Wolf, Ken	Okaloosa County	EM Deputy Director
GA	Crews, Mark	Camden County	EM Director
GA	Webber, Phillip	Chatham County	EM Director
LA	Accardo, Dexter	St. Tammany Parish	EM Director
LA	St. Amant, Jesse	Placquemines Parish	EM Director
MS	Loper, Butch	Jackson County	EM Director
NC	Garner, Scot	Brunswick County	EM Deputy Dir
NC	Goodman, Mark	Onslow County	EM Director
NC	Sanderson. Sandy	Hyde County	EM Coordinator
NC	Smith, Allen	Carteret County	EM Director
SC	Haynes, Cathy	Charleston County	EM Director
SC	Winn, William	Beaufort County	EM Director
TX	Martinez, Aaron	Nueces	EM Planner
TX	Simpson, John	Galveston County	EM Director
TX	Watts, Bob	Matagorda	Coastal Adv Team