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A Study on the Integration of Multivariate MetOcean, Ocean Circulation, and Trajectory Modeling Data with Static Geographic Information Systems for Better Marine Resources Management and Protection During Coastal Oil Spill Response – A Case Study and Gap Analysis on Northeastern Gulf of Mexico Tidal Inlets

Richard Ray Knudsen

University of South Florida, rrknudse@mail.usf.edu

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A Study on the Integration of Multivariate MetOcean, Ocean Circulation, and Trajectory
Modeling Data with Static Geographic Information Systems for Better Marine Resources
Management and Protection During Coastal Oil Spill Response – A Case Study and Gap
Analysis on Northeastern Gulf of Mexico Tidal Inlets

Richard R. Knudsen

University of South Florida

College of Marine Science

Saint Petersburg, Florida

Thesis Advisory Committee

Dr. Mark Luther, PhD * (Major Professor)

Dr. Barnali Dixon, PhD** (Co-Major Professor)

Dr. Steven Murawski, PhD*

Dr Miles O. Hayes, PhD (Non-USF Advisor)***

*University of South Florida, College of Marine Science

**University of South Florida, College of Environmental Science, Policy, and Geography

***Principal, Research Planning, Inc.

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Integration of Multivariate MetOcean, Ocean Circulation, and Trajectory Modeling Data with
Static Geographic Information Systems for Better Marine Resources Management and
Protection During Coastal Oil Spill Response – A Case Study and Gap Analysis on
Northeastern Gulf of Mexico Tidal Inlets

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Dedication:

To the Coastal Fish, Wildlife, and Habitats of the State of Florida. I do the best I can to protect you from harm. And to my girls, Andrea and Isabella, thank you both for supporting me in this effort.

Personal Quote

“Standards foster innovation and solve problems.”

DECLARATION

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration, except where specifically indicated in the text. It has not been previously submitted, in part or whole, to any university or institution for any degree, diploma, or other qualification.

This thesis contains approximately 30,627 words, 38 figures, 2 tables, and 54 maps.

Signed:_____

Date:_____

Richard R. Knudsen

University of South Florida

SUMMARY / ABSTRACT

The Oil Pollution Act of 1990 requires the development of Regional and Area Contingency Plans. For more than 20 years, the State of Florida, under both the Department of Environmental Protection and the Florida Fish and Wildlife Commission, has worked closely with the U.S. Coast Guard and the National Oceanic and Atmospheric Administration to develop these plans for coastal and marine oil spill response. Current plans, developed with local, state and federal stakeholder input, use geographic information systems (GIS) data such as location and extent of sensitive ecological, wildlife, and human-use features (termed Environmental Sensitivity Index data), pre-defined protection priorities, and spatially explicit protection strategies to support decision-making by responders (termed Geographic Response Plans). However, they are long overdue for improvements that incorporate modern oceanographic modeling techniques and integrated data from coastal ocean observing systems. Better understanding of circulation in nearshore and estuarine waters, at a scale consistent with other spatial data, is especially lacking in Area Contingency Plans. This paper identifies the gaps in readily available information on the circulation-driven causes and effects missing in current oil spill contingency planning and describes a sample methodology whereby multiple coastal and ocean spatial science disciplines are used to answer questions that no single, non-integrated discipline can answer by itself. A path forward for further integration and development of more comprehensive plans to better support coastal protection in Florida is proposed. The advances made here are applicable to other coastal regions of the world.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACP – Area Contingency Plan

GRP- Geographic Response Plan

ESI – Environmental Sensitivity Index

TIPS – Tidal Inlet Protection Strategies

AOR – Area of Responsibility

COTP – Captain of the Port

OSRO - Oil Spill Response (or Removal) Organization

OSMO – Oil Spill Management Organization

POC – Point of Contact

SCAT – Shoreline Cleanup Assessment Technique

pGDB – Personal Geodatabase

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1 INTRODUCTION

1.1 Background and Oil Spill Response Frameworks

Response to oil spills is an inherently spatial problem. For this reason, a broad litany of geospatial technologies are used extensively in oil spill response. These include geographic information systems (GIS), satellite remote sensing, aerial orthoimagery, in situ sensor observations, radio tracking devices (AIS/GPS), radar tracking devices, airborne sensor technologies, oceanographic and meteorological modeling, aerial direct observation and mapping by trained observers, and numerous types of spatial data processing methodologies to render final products suited for decision-making (FIO-FWRI, 2014, 2015; NOAA OR&R, 2015; UNH, 2010; Faass, 2010; Beegle-Krause 2001, 2003; Gault 1997, 1996; ICCOPR 1997, 2015). While mostly geospatial in nature, the data and systems do not always “play well together” so to speak. This presents problems for decision-makers who often have to make challenging choices at fine mapping scales over short periods of time. Gault, Payton, Norris, and Friel (1996) recognized this problem following the 1993 Tampa Bay oil spill and subsequently published the “Digital Data Distribution Standard for NOAA Trajectory Analysis Information,” a reference document still actively used. The research presented here builds and expands on this work. When a spill occurs, eight basic oil spill response framework questions need to be answered as quickly as possible and three restoration framework questions need to be answered in an evolving manner.

The 8 Oil Spill Response Framework Questions:

1. What has spilled?
2. Where has it spilled?
3. Who is responsible for the spill?
4. How much has spilled?
5. Where is it going?
6. What is it going to hit?

7. How bad is it going to hurt?
8. What can we do about it?

The 3 Oil Spill Restoration Framework Questions:

1. What was damaged?
2. Who was damaged?
3. How can the damage be repaired or otherwise compensated for?

Rarely do responders have immediate access to answers to these questions. Thus, answering these questions becomes the realm of science and technology in coordination with response and restoration. Initially, only the most basic information is available: 1. What has spilled (what type of oil or chemical?); and 2. Where has it spilled? (the source location is a place name or bearing/distance reference to a place name, a geographic feature, or latitude and longitude). It is rare to immediately know how much has spilled until further information becomes available. In answering the “Where is it going?” question, predictive modeling becomes vitally important. The General NOAA Operational Modeling Environment (GNOME) is the principle tool NOAA uses to answer this question. It is important to note that GNOME is not a model itself, but rather a means to integrate multiple “movers” (physical processes) and oil fate “drivers” into an oil spill trajectory product (hence the “Modeling Environment” moniker). GNOME is very flexible and in concert with oil observing efforts can tap into multiple models and model mover data sources to serve the ultimate objective of answering the “Where is it going?” question quickly for responders. To answer the “What is it going to hit?” question, responders generally turn to specialized maps and geographic information systems and these are often vitally important in helping to answer both the “How bad is it going to hurt?” and “What can we do about it?” questions. Atlases on the Sensitivity of Coastal Habitats and Wildlife to Spilled Oil (also known as Environmental Sensitivity Index Atlases or ESI) and Geographic Response Plans (GRP) are generally the information that responders turn to in order to answer these questions for any given region and are the framework background of this paper. Both ESIs and GRPs are explained in depth in Appendix 1. It is important to understand what each represents and that

they both provide vital information for oil spill response nationwide. However, they do not always represent the entire picture and do have limitations.

The problems and framework question motivations

Prior to the Deepwater Horizon Oil Spill (DWHOS), the Coastal Area Contingency Plan, the plan for oil spill response under the Oil Pollution Act of 1990 (OPA 90), for the Northeastern Gulf of Mexico was under-funded, with less than \$100,000 invested in hard costs. Neither shoreline protection booming strategies nor Tidal Inlet Protection Strategies were developed. Thus, following the spill, shoreline protection measures were done “on the fly” with minimal scientific information on nearshore, inlet and estuarine circulation dynamics to guide efforts. This problem addresses the “What can we do about it?” response framework question which is at the core of any contingency plan.

Five years later, despite advances in GIS, numerical models and development of Coastal Ocean Observing Systems, there remains difficulty in integrating diverse data sets to rapidly determine surface current velocities and directional circulation information for most tidal inlets. Because these data are critical to making informed decisions for oil spill contingency planning and response, the work here was undertaken to make geospatial tools more interoperable for use in future planning, response and recovery efforts. This addresses response framework questions: 5. Where is it going?; 6. What is it going to hit?; 7. How bad is it going to hurt?; and 8. What can we do about it? It also potentially affects answers to restoration framework questions: 1. What was damaged?; 2. Who was damaged?; and 3. How can the damage be repaired or otherwise compensated for? These are problems that need to be addressed well beyond the scope of this paper.

A significant challenge to this work is that the majority of oil spill risk assessment, planning, and response information is conducted and distributed within a GIS (Marine Spatial Planning) framework while the majority of meteorological, oceanographic, watershed, and estuarine circulation studies are conducted in modeling environments. The approach to mesh this disparate information was to aggregate “averages” (climatologies) into an easily distributable, broadly understood, targeted GIS dataset for use in the development of Tidal

Inlet Protection Strategies for Oil Spill Response. Other challenges, less readily resolved without fiscal support, include significant gaps in the spatial coverage of operational coastal ocean observing systems, access to oceanographic models, and less laborious processing requirements to make these data GIS-consumable. An extension of this work should be a more streamlined means of accessing these types of scientific information within a geospatial framework. This addresses response framework questions: 2. Where has it spilled?; 5. Where is it going?; 6. What is it going to hit?; 7. How bad is it going to hurt?; and 8. What can we do about it?

There are gaps in the spatial coverage of operational coastal ocean observing systems and access to oceanographic model-derived data is often difficult, not well understood and rarely GIS-consumable without laborious processing. A more streamlined means of accessing these types of scientific information within a geospatial framework are needed. This addresses response framework questions: 2. Where has it spilled?; 5. Where is it going?; 6. What is it going to hit?; 7. How bad is it going to hurt?; and 8. What can we do about it?

These model-GIS interoperability challenges also exist in non-emergency response situations. For example, scientists and managers charged with understanding, managing and restoring dynamic watershed to coastal ecosystems, including those responsible for designing restoration plans for the Gulf of Mexico following the DWHOS, face the same interoperability issues. Thus, the challenges apply to many of the restoration framework questions. These challenges need to be addressed beyond the scope of this study.

Gault, Payton, Norris, and Friel (1996) recognized the GIS incompatibility problem following the 1993 Tampa Bay oil spill and subsequently published the “Digital Data Distribution Standard for NOAA Trajectory Analysis Information.” This digital data “open-standard” for sharing oil spill trajectory analysis information with static geographic information systems set the bar which is still in active use today and was the standard used for trajectory to GIS operations for the DWHOS. Yet, there may be better ways with newer open standards and technologies to accomplish the same goals and perhaps make model to GIS interoperability even easier and more commonplace. The research here builds and expands upon that interoperability work.

These technologies may not yet be ready for operational status so an interim solution was needed to satisfy the need for contingency planning: A GIS dataset (geodatabase) “container” to collate the required oceanographic and geomorphological information for developing Tidal Inlet Protection Strategies for Oil Spill Response in the Northeastern Gulf of Mexico.

1.1.1 Post-DWHOS Needs Derived from Review of Response Data Management and Tools

Following any major oil spill, including the DWHOS, the United States Coast Guard’s internal regulations call for an Incident Specific Performance Review (ISPR). In his prologue for the ISPR (dated March 18, 2011), Coast Guard Commandant Admiral R.J. Papp Jr. noted the DWHOS was the nation's first declared Spill of National Significance (SONS) and the first time in history where a National Incident Commander (NIC) was designated. Admiral Papp noted the reasoning for the ISPR:

“...to conduct a thorough examination of the Coast Guard’s preparedness process and to critically evaluate this process in conjunction with the implementation, integration, and effectiveness of national, regional, and local oil spill response plans. An ISPR provides an assessment of a major response along with recommendations for improvement. Over the years, ISPRs have provided one avenue, among several, for valuable assessments and recommendations that helped the Coast Guard and other oil spill response entities improve existing plans, response strategies, and coordination among government entities, responsible parties, and response organizations.”

Of most importance to this current research, he noted in Section 6 of his opening Memorandum, dated March 18, 2011:

*“Along with the President's Report by the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (available at: <http://www.gpo.gov/fdsys/pkg/GPO-OILCOMMISSION/pdf/GPO-OILCOMMISSION.pdf>) and several other Deepwater Horizon reports, the ISPR significantly adds to a body of important perspectives and opinions that the Coast Guard will take onboard and carefully evaluate to identify further opportunities for positive, effective preparedness improvements. I have already directed several actions to address areas where planning and preparedness will be improved, including directing Captains of the Port to review Oil Spill Response Plans for offshore facilities, requiring Area Committees to include Worst Case Discharge scenarios for offshore facilities in their respective Area Contingency Plans. Working with the National Response Team to review large volume and novel dispersant use, **reviewing response data management procedures and tools**, and establishing a Coast Guard, FEMA, and EPA workgroup to develop recommendations to harmonize the NCP and National Response Framework governance constructs. These are just a few of the actions the Coast Guard is pursuing. There is much more work to be done and we will work diligently with our government partners and industry to implement meaningful improvements for future oil spill planning, preparedness, organization, and response.”*

It was in the process of reviewing response data management procedures, geospatial data and tools that it became clear that this present research effort was needed to create information that was not readily available anywhere else. This was completely new information to be included within larger preparedness and response frameworks (the Florida Marine Spill Analysis System, Environmental Sensitivity Index, and Digital Area Contingency Plans, the background and descriptions of which can be found in APPENDIX 1). The data prepared by this research could also inform regions outside of Florida, including international response efforts.

1.1.2 What's Important to Protect on the Coast?

Coastal Area Contingency Plans for Florida and the regions around it state that **human health and safety** are always the highest priorities for protection in oil spill response. Through the contingency planning process, tidally-influenced inlets, passes, and creeks, the conveyance points to highly sensitive resources inside estuaries and bays, are the next highest priorities for protection. How do we protect them? How do we access information for decision-making and tactical operations? GIS and Modeling can help answer some of these questions.

1.1.3 A Disturbing Past Looks to a Brighter Future

According to the President's National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (pp. 85-86), prior to the DWHOS, the culture of safety and environmental stewardship that was the norm in most other areas of the country had eroded tremendously in the Gulf of Mexico and many laws and regulations passed to understand and protect marine resources were summarily ignored by both government and industry to maximize revenues from oil and gas extraction activities (United States. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011).

“The inescapable conclusion is striking, and profoundly unsettling. Notwithstanding statutory promises of layers of required environmental scrutiny—by NEPA, the Magnuson-Stevens Act, the Outer Continental Shelf Lands Act, and the Oil Pollution Act—and the potential application of some of the nation’s toughest environmental restrictions—the Endangered Species Act and Clean Water Act—none of these laws resulted in site-specific review of the drilling operations of the Macondo well. The agency in charge, MMS, lacked the resources and committed agency culture to do so, and none of the other federal agencies with relevant environmental expertise had adequate resources or sufficient statutory authority to make sure the resulting gap in attention to environmental protection concerns was filled.”

Federal oversight of oil and gas activities in the Gulf of Mexico—almost the only area where substantial amounts of drilling were taking place—took a generally minimalist approach in the years leading up to the Macondo explosion. The national government failed to exercise the full scope of its power, grounded both in its role as owner of the natural resources to be developed and in its role as sovereign and responsible for ensuring the safety of drilling operations. Many aspects of national environmental law were ignored, resulting in less oversight than would have applied in other areas of the country. In addition, MMS lacked the resources and technical expertise, beginning with its leadership, to require rigorous standards of safety in the risky deepwater and had fallen behind other countries in its ability to move beyond a prescription and inspection system to one that would be based on more sophisticated risk analysis.

In short, the safety risks had dramatically increased with the shift to the Gulf's deepwaters, but Presidents, members of Congress, and agency leadership had become preoccupied for decades with the enormous revenues generated by such drilling rather than focused on ensuring its safety. With the benefit of hindsight, the only question had become not whether an accident would happen, but when. On April 20, 2010, that question was answered."

Further narrative from that report to the President (dated January 2011) and subsequent reports illustrate this disturbing history (see APPENDIX 1 – Pertinent Background Information: Sections 1-3: 1. Excerpts from the "President's National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling; 2. Excerpts from the Deepwater Horizon Federal On-Scene Coordinator's Report; and 3. Summary on Findings of the Florida Commission on Oil Spill Response Coordination.) The well documented history of the DWHOS shows that a number of problems hampered spill response efforts, many of which were related to the management of information both pre-spill and during as noted above under the Problems and Framework Question Motivations section.

Following the largest oil spill in US history, IN the Gulf of Mexico, this is fortunately no longer the case. Efforts are under way throughout industry, government, and academia to

rectify this once poor state of affairs. The power of modern geospatial technologies, coastal ocean observing systems, and integrated modeling should now be used in a coordinated manner to ensure that natural resources and energy independence for the United States may coexist in peace and safety, if not harmony.

1.2 Statement of the problem: Lack of readily available information to support the development of Tidal Inlet Protection Strategies (TIPS) for Oil Spill Response – specifically currents

Tidal inlets and passes are found on barrier beaches and island chains worldwide and form a connection between the open ocean and environmentally vulnerable (from an oil spill perspective) sheltered bays, lagoons, marshes and tidal creeks. These inlets are complex, variable, and challenging environments for oil spill control. The importance of selecting protective strategies to match the physical characteristics of an inlet and the associated current patterns has been recognized for many years (e.g., Hayes and Montello 1995; NOAA 1994; Owens et al. 1985). There are 260 unique tidally-influenced inlets and passes along the approximately 24,700 miles of shorelines of the State of Florida and many are not well studied. This is a gap in federal, state, and local preparedness that this research proposes to fill (at least in part). In order to support the development of successful protective strategies for oil spill response in tidal inlets, there are three basic information requirements:

1. Understanding of the geomorphology and processes of a tidal inlet system.
2. Knowledge of specialized tactics and equipment (including limitations and operating requirements) for feasible operations in tidal environments.
3. Specific understanding of the circulation dynamics of individual inlets upon which to build the most effective protection strategies possible.

Tidal Inlet Protection Strategies (TIPS) are a specialized map and report product designed to be a comprehensive tactical and scientific solution to keep oil from an offshore (surface) oil spill from entering tidal inlets or passes, often the gateways to more sensitive resources

within an estuary. These inlets are also consistently identified as one of the highest priority areas for protection in the contingency planning process, always listed as an “A – Highest Priority for Protection.” These strategies take into account the scientific understanding of how circulation works in tidal inlet systems and then uses these physical forces in concert with oil spill response equipment such as deflection boom, protection boom, absorbent boom, skimmers, and various types of manual and mechanical collection equipment. Access and shoreline use parameters are also presented. In general, TIPS include the following elements: Background Science Writeups, Inlet Summary Sheets, an Aerial Photo Basemap (preferably at low tide), an Inlet Protection Strategy Sketch Map, Total Boom Length Required (by type, for inventory and resource ordering), Collection Point Summary Reports, Tidal Inlet Current Velocities (Average and Max Flood and Ebb, reported or observed), GIS Data, and a Map Service that is integrated with other GRP and Environmental Sensitivity Index (ESI) GIS data.

For additional reader reference into existing Peninsular Florida (the non-Panhandle part) Tidal Inlet Protection Strategies and other Geographic Response Plan GIS data, see the interactive web mapping application at: <http://ocean.floridamarine.org/ACPGRP/>.

Additionally, ArcGIS Server REST (Representational State Transfer protocol) endpoints allow for the integration of these spatial data layers with other sources of online map data service applications. GRP and TIPS REST Endpoints are available at:

http://ocean.floridamarine.org/arcgis/rest/services/Oil_Spill/ACPGRP/MapServer

TIPS are not a new concept in Florida. The first of these were produced by the Florida Department of Environmental Protection as early as 1994. Inlets have long been recognized as a high priority for protection when oil from offshore areas (e.g., from drilling or vessels) threatens shorelines and estuaries. The DWHOS and response showed clearly that determining flood and ebb currents through these inlets can be quite difficult. Five years after the Macondo incident, tidal inlet circulation dynamics data and information remain difficult to find. A short history of TIPS in Florida can be found in APPENDIX 1, Section 9. Tidal Inlet Protection Strategies – History in Florida. One problem this study addresses is the void in easily accessible circulation dynamics information on tidal inlets, specifically for the development of TIPS for Oil Spill Response. The proposed “data and information

compilation” format will be a Geographic Information System (GIS) product that collates “best available” information into one place (a GIS data set) for a targeted set of tidal inlets in the Northeastern Gulf of Mexico. The target region for analysis and data collection was the Florida Panhandle (Coastal Taylor County West to Escambia County in Florida, Baldwin and Mobile County in coastal Alabama, and the three coastal counties in Mississippi, Jackson, Hancock, and Harrison Counties). This target region has been chosen because these are the counties disproportionately impacted by the DWHOS (excluding Louisiana and Texas). Additionally, given the continued deepwater drilling activities in this region of the Outer Continental Shelf, these areas remain at risk from future spills. Finally, this region within Florida is the only region of the state that has NOT had TIPS for Oil Spill Response developed for the inlets within the area.

1.2.1 Tidal Inlet Protection Strategies in the “Real World”

As mentioned in Benggio et al. (2014), there is a disconnect between multivariate met-ocean observing and modeling systems and the geographic information systems that are widely used in the development of oil spill contingency plans. The current research effort is a bit of a “stop-gap” measure to address the shortfall until funding for further research becomes available. The authors documented a full scale TIPS boom deployment exercise at Bear Cut, Miami, FL, and mentioned several topics towards these disconnects. Within the conclusions were mentioned the following observations (most applicable in bold): A note on acronyms not previously mentioned: OSRO - Oil Spill Response Organization. POC – Point of Contact, AOR – Area of Responsibility.

1. Costs and protection realities - Managing expectations within the Area Committee (Planning) stakeholder groups is critical. Area Committees should talk about risks in their region and how operational strategies outlined within the Area Contingency Plan document (or Geographic Response Plan maps) aren't necessarily fully realistic given the finite amount of resources and time it takes to implement (and maintain) said strategies. This was one of the key lessons learned from this fully operational exercise.

2. *There is great value in exercising major components of the ACP.*
3. *There is great value in exercising with multiple OSROs and agencies.*
4. *The importance of Public Affairs and Outreach should not be underestimated.*
5. ***Current velocity and direction information were fairly vague for this inlet; it would have been beneficial to involve oceanographers with local knowledge.***
6. ***It would be beneficial to focus future study on updating tides and currents information specifically for inlets using spatial data, coastal models, and coastal ocean observing systems information given that all other Geographic Response Plan information is also spatial.***
7. *Each individual TIPS plan should account for flexibility, while at the same time more clearly define boom strategies, documenting actual currents in that area, listing potential alternatives to the booming strategy, etc.*
8. *Boom should be continually managed/maintained throughout the evolution, based on conditions.*
9. *Prioritization of strategies should be briefed to Area Committee for awareness (i.e. with limited time and resources for a large spill event, only primary areas/strategies may be put in place).*
10. *Would be beneficial to vet public information statement thru OSRO POC for accuracy.*
11. *Feasibility of pre-staging equipment not viable in this AOR (Miami).*
12. ***Reach out to academia – see if they have any ongoing research projects that could jointly benefit from a TIPS exercise.***
13. *After the fact ESI mapping revealed two aquaculture water intakes in the very near vicinity of Collection Point #3 (the West side of Bear Cut closest to the bridge). This underscored the need to support ESI mapping and maintenance of ESI GIS data and maps.*
14. *Planning for and actually carrying out a TIPS exercise is beneficial to bringing science, industry, the regulatory entities, and the community together for better awareness of local capabilities and restrictions, which in turn helps the*

Area Committees better quantify risk for assigning priorities and building more realistic strategies.

It was towards addressing observations #5 and #6 that the objectives of this research were developed to address the shortcomings of the larger contingency planning geospatial infrastructure previously mentioned.

1.3 Why is this research needed?

TIPS have been produced and are publically available for inlets on the East Coast of Florida, the Florida Keys, and the West Coast of Florida North to Hurricane Pass (Pinellas County) (<http://ocean.floridamarine.org/acp/tips>

(as PDF) and via a Web Mapping Application as GIS data layers,

<http://ocean.floridamarine.org/ACPGRP/>. However, there are no TIPS for the Big Bend and Panhandle areas of Florida. For this reason, the first research priority was to focus on inlets in those areas by researching to collate the average and maximum flood and ebb current velocities and directions, as well as average tidal ranges (tidal climatology). The second research priority was to focus on the tidal inlets in the coastal zone of Alabama and Mississippi because these areas comprise the balance of US Coast Guard Sector Mobile, the majority of which is Panhandle Florida (approximately two-thirds of the west-east extent of Sector Mobile is Panhandle Florida). The third research priority (beyond the scope of this work) is to validate the average and maximum flood and ebb current velocities and directions listed in the TIPS that have been completed for Peninsular Florida, referring to the updates that were produced in late 2012 in response to threats from deepwater drilling in Cuba. The listing of those inlets that have had TIPS developed are available in APPENDIX 1 – Pertinent Background Information: 9. Tidal Inlet Protection Strategies – History in Florida.

2 RESEARCH OBJECTIVES

This research defined two overall, broad research objectives: 1. Conduct an information gap analysis regarding the availability of information on tidally-driven surface currents at the inlet-specific level (center point of inlet throat; flood and ebb average velocity and direction); and 2. Demonstrate the risk to and value of inlets as conveyance points for spilled oil into sensitive bays and estuaries. Then using available technologies, evaluate the value of Model-GIS integration and coordination, document gaps in information between these two “systems” and describe the challenges encountered when conducted in a region of the study area.

2.1 Gap Analysis

A gap analysis is needed to identify tidal inlets where little to no information is available on tidally-driven surface currents to be used as source information for the development of TIPS for Oil Spill Response. The methodologies of that research are as follows:

2.1.1 Build Geodatabase “Container” Information Collector

Design and build a GIS data schema capable of containing all of the information pertinent to be collated for tidally-influenced inlets that would be needed to support the development of TIPS for Oil Spill Response.

2.1.2 Collate Best Available Data into Geodatabase Collector

Map Tidal Inlets; Using this geodatabase schema, each tidal inlet in the study area will be mapped as a single point location defined as the center point of the main inlet throat channel.

Collate “Best Available” information for each inlet; Data collection will focus on the target region as described above, and then systematically, each inlet will be researched and characterized. Required information collated from each source of data (where available and as appropriate). Sources:

1. Government data and publications
2. Scientific publications or data

3. Past or ongoing scientific research or data
4. Oceanographic model-derived data
5. Direct observation/measurement (GPS drifters, Acoustic Doppler Current Profiler (ADCP) studies)
6. Tidal constituent current interpolation
3. Private industry data (as available)
4. Private Citizen information (first hand observers, such a charter and private boat captains and any others that may be found in the process).

2.1.3 Conduct Gap Analysis

Conduct analysis on the availability of tidally-driven surface current velocity and direction information suitable for the production of an informative, intuitive, simple map product and map service to be used in the development of TIPSfor Oil Spill Response.

2.1.4 Make Conclusions on Areas for Further Research

Represent the availability of this information on a map to identify gaps in knowledge that can direct future research.

2.2 Oil Spill Scenario Study to Illustrate

2.2.1 Risk to Inlets

Generate an oil spill scenario using existing risk-based analysis geospatial data on the transport of petroleum products through the region offshore of the study area. Generate a plausible oil spill trajectory scenario with best available oceanographic model data for GNOME. Demonstrate risk of conveyance through an unprotected inlet.

2.2.2 Value of Inlets

Using maps, geospatial data, and the NOAA GNOME Operational Modeling Environment, illustrate the importance of tidal inlets as a pathway to highly oil-sensitive resources within estuaries and bays.

2.2.3 Value of GIS-Model “Integration/Coordination”

Conduct a demonstration of importing model-derived oil spill trajectory information into a specialized geographic information system, the Florida Marine Spill Analysis System (FMSAS), capable of “cookie-cutter, multi-theme drill-down, spatial analysis, and reporting”

thru multiple layers of information on coastal Florida's natural and socio-economic resources and summarizing those resources potentially impacted by the spill scenario trajectory (passing thru an unprotected inlet,). Note that the author wrote the design specification for this FMSAS application as a migration to ArcGIS 9.x and 10.x.

2.2.4 Document Difficulties Encountered

Document the process and challenges of conducting this sort of Model-GIS integration. Summarize conclusions and provide direction for future efforts.

2.3 Future Efforts

Investigate methodologies and technologies that may provide directions for future efforts.

2.4 Study Area for This Research

The boundaries of US Coast Guard Sector Mobile were chosen as the study area for this effort as they contain an area of Florida that does not currently have TIPS for oil spill response completed for the inlets in the region. As most, if not all, oil spill contingency planning efforts are conducted for the ultimate use of the US Coast Guard, who under US law are the principle federal officials in charge of coordinating response efforts, it was logical to organize the study area along the lines of their area of responsibility.

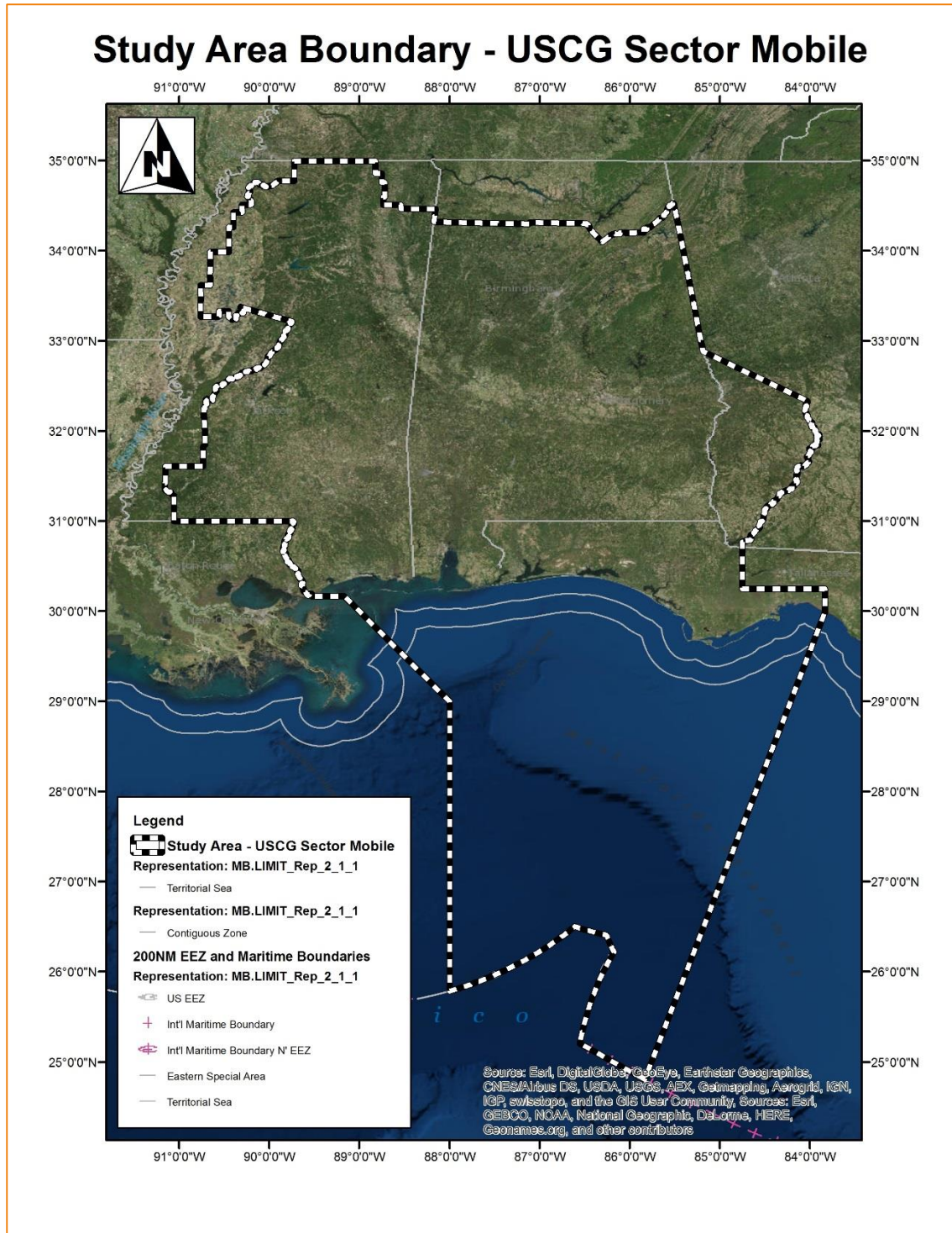


Figure 2-1. Study Area Boundary – US Coast Guard Sector Mobile

The following Tidal Inlets have been identified as the focus areas for the gap analysis objectives of this research (2.1). This region coincides with the boundaries of USCG Sector Mobile.

1. Panhandle Florida Inlets/& Proposed Priority Level (Counties included are: Escambia, Santa Rosa, Okaloosa, Walton, Bay, Gulf, Franklin, Wakulla, Jefferson, and Taylor)
 - a. Perdido Bay (1 inlet – Perdido Pass) - 1
 - b. Pensacola Bay (1 inlet – Pensacola Pass (Caucus Channel)) - 1
 - c. Choctawhatchee Bay (1 inlet – East (Destin) Pass) – 1
 - d. Coastal Dune Lakes (most can be closed with a sediment dike) – 3
 - i. Morris Lake Inlet
 - ii. Stalworth Lake Inlet
 - iii. Draper Lake Inlet
 - iv. Alligator Lake Inlet
 - v. Western Lake Inlet
 - vi. Eastern Lake Inlet
 - vii. Deer Lake Inlet
 - viii. Camp Creek Lake Inlet
 - ix. Phillips Inlet (Powell Lake)
 - e. Saint Andrew Bay (Panama City) (2 inlets)
 - i. St Andrew Bay Entrance – 1
 - ii. St Andrew Sound Entrance – 1
 - f. Salt Creek (Bay County)(Mexico Beach) - 2
 - g. St Joseph Bay (1 inlet St Joe Bay Entrance) - 1
 - h. Apalachicola Bay (up to as many as five inlets)
 - i. Indian Pass - 1

- ii. West Pass (Apalachicola Bay) - 1
 - iii. Government Cut (St George Island) - 1
 - iv. East Pass (St George Sound) - 1
 - v. St George Sound Entrance - 2
- i. Alligator Harbor Channel (Alligator Harbor Entrance) - 2
- j. Ochlocknee Bay Entrance – 2
- k. Apalachee Bay Estuary Entrances (Four Inlets) - 2
 - i. Dickson Bay Entrance
 - ii. Oyster Bay Entrance
 - iii. Goose Creek Bay Entrance
 - iv. St Marks River/East River Entrance
- l. East Apalachee Bay Rivers - 3
 - i. Pinhook River
 - ii. Sulphur Creek
 - iii. Aucilla River
 - iv. Econfinia River
- 2. Coastal Alabama (Counties included are: Mobile and Baldwin)
 - a. Mobile Bay Entrance - 1
 - b. Pelican Passage - 3
 - c. Pass aux Herons - 1
- 3. Coastal Mississippi (Counties included are: Jackson, Harrison, and Hancock)
 - a. Petit Bois Pass – 1
 - b. Pascagoula Harbor/River Entrance – 1
 - c. Biloxi Bay Entrance - 1
 - d. Horn Island Pass – 1
 - e. Little Dog Keys Pass – 1

- f. Loggerhead Shoal – 2
- g. Ship Island Pass – 1
- h. Bay St Louis Entrance - 1

3 METHODS

3.1 Creating the Geodatabase “Container”

3.1.1 API TIPS Manual as Template for Geodatabase Schema

In January of 2014, the American Petroleum Institute (API) published Technical Report 1153-1, titled “[Tidal Inlet Protection Strategies \(TIPS\) – Phase 1 – Final Report](#)” (copyright 2014 American Petroleum Institute) prepared by Polaris Applied Sciences, Inc., Owens Coastal Consultants, and RCE (30 April 2013). Within this Post-DWHOS document prepared by the API Shoreline Protection & Cleanup Technical Working Group, a detailed “cookbook” was provided on methodologies and approaches to develop TIPS for Oil Spill Response. Most relevant to this research was the presentation of a template data collection form to characterize tidal inlets. It was with this template data collection form that a geospatial database schema (framework) was created to serve as a “container geodatabase” for the systematic aggregation of applicable information.

ESRI ArcCatalog version 10.2.2 was the software used to create this geodatabase from scratch. The feature class was point (simple Lat/Long) for location information, but the intention was to collate as much pertinent information on each inlet as possible so that the “database” underlying the spatial feature could be used in data driven reporting, form generation, field data collection, map symbology representation, and a number of other uses yet to be determined. This methodology had been used in the past to generate thousands of custom reports on numerous other geographic features because fundamentally, a GIS is a “database” with a place and there is fundamental utility in managing and presenting information with a database. (See numerous references to (Knudsen, Druyor – Digital Area Contingency Plans for Oil Spill Response) as well as APPENDIX 1 – Digital Area Contingency Plans). The API Template to Summarize the Physical Character of a Tidal Inlet was a perfect place to start as a template to build such a geodatabase intended to do the very same thing, yet with the flexibility of being digital, spatial, maintainable, web-servable, and

easily integrated with other geospatial frameworks and data, including model-derived information as could be gleaned from further efforts. With the template form in mind and looking toward the future and other potential uses, the data schema was carefully built, field by field, and tested for usability in the intended purpose of collating available information.

Template to Summarize the Physical Character of a Tidal Inlet (2)

A. Inlet Name					
B. Tidal Range: <i>(from tidal predictions)</i>				Average Range	Spring Range
				m	m
Tidal Period: Diurnal Tide _____ Semidiurnal Tide _____ Mixed Diurnal/Semidiurnal Tide _____					
C. Location of Inlet Throat					
Latitude:			Longitude:		
D. Inlet Character <i>(circle as appropriate)</i>					
Straight beach	Offset	Overlap	Jetty/ies	Rip Rap Armor	Bridges
Current Data Available?		Y / N	Source:		
Operational Difficulty					
E. Inlet Components					
INLET THROAT	Width	m	Depth	m	
EBB-TIDAL DELTA SYSTEM			FLOOD-TIDAL DELTA SYSTEM		
1. Main Ebb Channel			1. Flood Ramp		
2. Marginal Flood Channels			2. Flood Channel(s)		
3. Swash Platform			3. Ebb Shield		
4. Terminal Lobe			4. Ebb Spit(s)		
5. Swash Bars			5. Spillover Lobes		
6. Channel Margin Linear Bars			6. Marginal Channels		

Figure 3-1. API Template Form to Summarize the Physical Character of a Tidal Inlet.

However, the form by itself did not fully facilitate the capture of information on currents, as can be seen by one line in the table layout of the form: “Current Data Available? Y/N” and “Sources”. This then posed the challenge of how to capture the most pertinent information on the tidal currents within the geodatabase. The diagram shown in Figure 3-2 summarizes the general types of information that can be contained within the geodatabase. The geodatabase data schema was created to collate specific information on the tidal inlet “average” surface current velocity and direction (at both flood and ebb), “average” tidal range, and geomorphological characteristics most pertinent to designing effective protective booming strategies. The author has termed this “Tidal Inlet Circulation Climatology” in reference to the practice of applying the term “climatology” to regional averages in meteorological and oceanographic sciences, but the “official” GIS layer name for the ISO metadata is “Tidal Inlet Locations, Characterizations, and Basic Circulation Dynamics for the Development of Tidal Inlet Protection Strategies for Oil Spill Response.” The metadata can be found in APPENDIX 2.

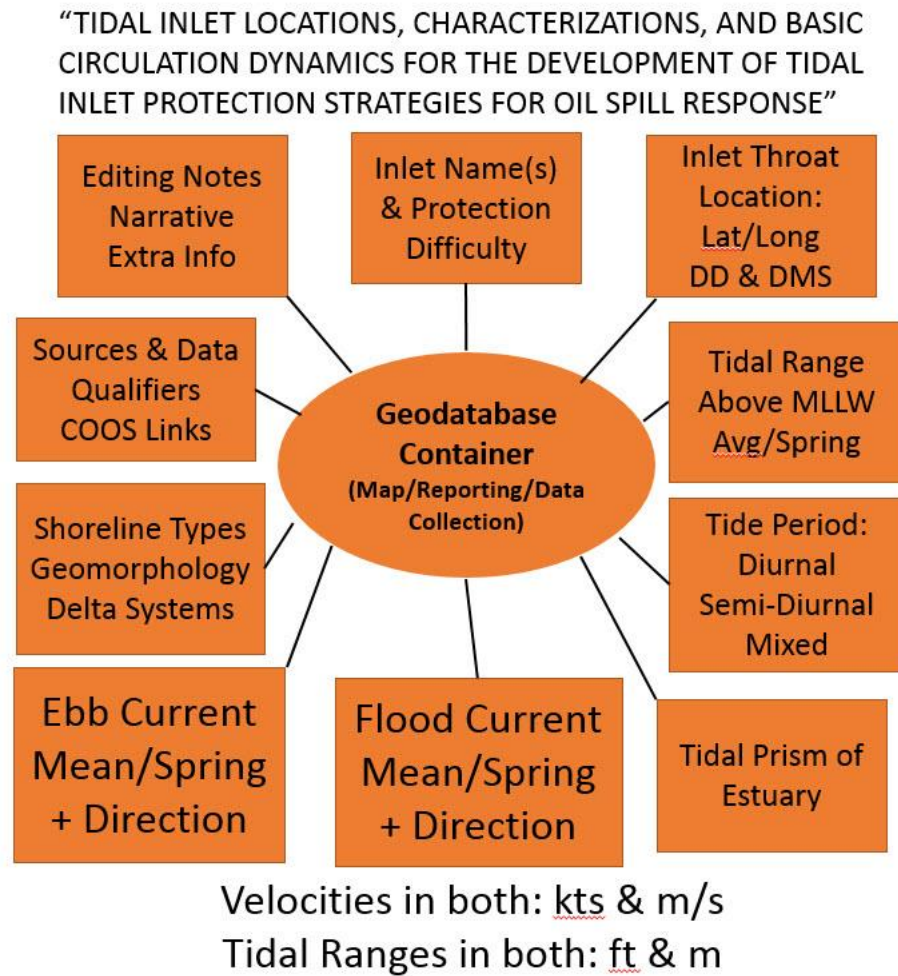


Figure 3-2: Tidal Inlet Characterization Geodatabase Elements Diagram

The entity attributes (database field names, field types, lengths and easily understood field “alias” names) that constitute the database dictionary for this dataset are described in Table 3-1. It should be noted that no fields in this geodatabase are larger than 254 characters in order to support the export to shapefile with no loss of information by truncation. Geodatabases can support field lengths significantly larger than 254 characters, but shapefiles are a more commonly used “open” spatial data format, so every effort was made to ensure support for this data format yet retain some higher-level geodatabase functions such as enterprise versioning and database reporting.

Table 3-1: Basic Geodatabase (or shapefile) Data Schema for Characterizing Inlets for the Development of Tidal Inlet Protection Strategies.

Name	Type	Length	Alias Name
OBJECTID	OID	4	OBJECTID
SHAPE	Geometry	0	SHAPE
GEONOTES1	String	254	GIS EDITING NOTES 1
GEONOTES2	String	254	GIS EDITING NOTES 2
NAME1	String	254	TIDAL INLET NAME 1
NAME2	String	254	ALTERNATE TIDAL INLET NAME
ABBREV	String	50	ABBREVIATED NAME FOR TIPS
CLASS	String	50	INLET PROTECTION OPERATIONAL DIFFICULTY CLASSIFICATION (A-D)
STATUS	String	50	INLET STATUS - OPEN OR CLOSED
TIDALRNGFT	String	20	AVERAGE TIDAL RANGE IN FEET
TIDALRNGM	String	20	AVERAGE TIDAL RANGE IN METERS
AVGFLDCURRKTS	String	20	AVERAGE FLOOD CURRENT IN KNOTS

AVGFLDCURRMS	String	20	AVERAGE FLOOD CURRENT IN M PER S
SPRNGFLDCURRKTS	String	20	SPRING FLOOD CURRENT IN KNOTS
SPRNGFLDCURRMS	String	20	SPRING FLOOD CURRENT IN METERS PER SECOND
RPTMAXFLDCURRKTS	String	20	REPORTED MAX FLOOD CURRENT IN KNOTS
RPTMAXFLDCURRMS	String	20	REPORTED MAX FLOOD CURRENT M PER S
FLDCURRDIRT	SmallInteger	2	FLOOD CURRENT DIRECTION DEGREES TRUE
AVGEBBCURRKTS	String	20	AVG EBB CURRENT KTS
AVGEBBCURRMS	String	20	AVG EBB CURRENT M PER S
SPRNGEBBCURRKTS	String	20	SPRING EBB CURRENT KTS
SPRNGEBBCURRMS	String	20	SPRING EBB CURRENTS IN M PER S
RPTMAXEBBCURRKTS	String	20	REPORTED MAX EBB CURRENT KTS
RPTMAXEBBCURRMS	String	20	REPORTED MAX EBB CURRENT M PER S

EBBCURDIRT	SmallInteger	2	EBB CURRENT DIRECTION DEGREES TRUE
LATDD	Double	8	LATITUDE DECIMAL DEGREES
LONGDD	Double	8	LONGITUDE DECIMAL DEGREES
LATDMSTXT	String	50	LATITUDE DMS TXT*
Name	Type	Length	Alias Name
LONGDMSTXT	String	50	LONGITUDE DMS TXT*
NARRATIVE1	String	254	INLET NARRATIVE 1
NARRATIVE2	String	254	INLET NARRATIVE 2
NARRATIVE3	String	5000	INLET NARRATIVE 3
GSOURCE	String	254	GEOGRAPHIC SOURCE
ASOURCE	String	254	ATTRIBUTE SOURCE
GRPMAP	String	50	GEOGRAPHIC RESPONSE PLAN MAP ID
GRPMAPNAME	String	254	GEOGRAPHIC RESPONSE PLAN MAP NAME
GRPMAPURL	String	254	GEOGRAPHIC RESPONSE PLAN MAP URL
ESIMAP	String	50	ENVIRONMENTAL SENSITIVITY INDEX MAP ID
ESIMAPNAME	String	254	ENVIRONMENTAL SENSITIVITY INDEX MAP

			NAME
ESIMAPURL	String	50	ENVIRONMENTAL SENSITIVITY INDEX MAP URL
TIPSMAP	String	50	TIDAL INLET PROTECTION STRATEGY MAP ID
TIPSMAPNAME	String	254	TIDAL INLET PROTECTION STRATEGY MAP NAME
TIPSMAPURL	String	254	TIDAL INLET PROTECTION STRATEGY MAP URL
SCATDIV	String	50	SHORELINE CLEANUP ASSESSMENT TECHNIQUE DIVISION ID
SCATDIVNAME	String	254	SHORELINE CLEANUP ASSESSMENT TECHNIQUE DIVISION NAME
SCATMAPURL	String	254	SHORELINE CLEANUP ASSESSMENT TECHNIQUE DIVISION MAP URL
COUNTY	String	100	COUNTY INLET IS WITHIN
STATE	String	50	STATE INLET IS WITHIN
SECTOR	String	100	USCG SECTOR INLET IS WITHIN
SECTORSUBDIV	String	100	USCG SECTOR SUBDIVISION

			INLET IS WITHIN
COLLATEDATE	Date	8	DATE CIRCULATION INFORMATION WAS COLLATED
TIPSCOMPLETEDATE	Date	8	DATE THAT TIDAL INLET PROTECTION STRATEGY WAS COMPLETED
TIPSUPDATEDATE	Date	8	DATE THAT TIDAL INLET PROTECTION STRATEGY WAS UPDATED
LOCQUALIFIER	String	254	LOCATION QUALIFIER
Name	Type	Length	Alias Name
OCEDATAQUALIFIER	String	254	OCEANOGRAPHY DATA QUALIFIER
OVERALLDATAQUALIFIER	SmallInteger	2	OVERALL INLET CHARACTERIZATION DATA QUALIFIER
COOSURL1	String	254	COASTAL OCEAN OBSERVING SYSTEM (COOS) URL 1
COOSURL1DESC	String	254	COASTAL OCEAN OBSERVING SYSTEM (COOS) 1 SOURCE DESCRIPTION

COOSURL2	String	254	COASTAL OCEAN OBSERVING SYSTEM (COOS) 2 URL
COOSURL2DESC	String	254	COASTAL OCEAN OBSERVING SYSTEM (COOS) 2 SOURCE DESCRIPTION
COOSURL3	String	254	COASTAL OCEAN OBSERVING SYSTEM (COOS) 3 URL
COOSURL3DESC	String	254	COASTAL OCEAN OBSERVING SYSTEM (COOS) 3 SOURCE DESCRIPTION
INLETCHARACTER	String	254	BRIEF DESCRIPTION OF INLET CHARACTER
STRAIGHTBEACH	String	50	STRAIGHT BEACH INLET (YES OR NO)
OFFSET	String	50	OFFSET INLET (YES OR NO)
OVERLAP	String	50	OVERLAP INLET (YES OR NO)
JETTIES	String	50	JETTIES PRESENT (YES OR NO)
RIPRAPARMOR	String	50	RIPRAP SHORELINE

			ARMORING PRESENT (YES OR NO)
BRIDGES	String	50	BRIDGES PRESENT (YES OR NO)
INLETTHROATWIDTHM	Single	4	INLET THROAT WIDTH IN METERS
INLETTHROATDEPTHM	Single	4	INLET THROAT DEPTH IN METERS
DIURNALTIDE	String	3	DIURNAL TIDE (YES OR NO)
SEMIDIURNALTIDE	String	3	SEMI-DIURNAL TIDE (YES OR NO)
MIXEDTIDE	String	3	MIXED DIURNAL/SEMI- DIURNAL TIDE (YES OR NO)
OSMAINEBBCHANNEL	String	3	OCEAN SIDE - MAIN EBB CHANNEL PRESENT (YES OR NO)
Name	Type	Length	Alias Name
OSMARGINALFLOODCHAN	String	3	OCEAN SIDE MARGINAL FLOOD CHANNELS PRESENT (YES OR NO)
OSSWASHPLATFORM	String	3	OCEAN SIDE SWASH PLATFORM PRESENT (YES OR NO)

OSTERMINALLOBE	String	3	OCEAN SIDE TERMINAL LOBE PRESENT (YES OR NO)
OSSWASHBARS	String	3	OCEAN SIDE SWASH BARS PRESENT (YES OR NO)
OSCHANMARGINBARS	String	3	OCEAN SIDE – CHANNEL MARGIN BARS PRESENT (YES OR NO)
BSFLOODRAMP	String	3	BAY SIDE - FLOOD RAMP PRESENT (YES OR NO)
BSFLOODCHANNELS	String	3	BAY SIDE – FLOOD CHANNELS PRESENT (YES OR NO)
BSEBBSHIELD	String	3	BAY SIDE EBB SHIELD PRESENT (YES OR NO)
BSEBBSPITS	String	3	BAY SIDE EBB SPIT PRESENT (YES OR NO)
BSSPILLOVERLOBES	String	3	BAY SIDE – SPILLOVER LOBES PRESENT (YES OR NO)
BSMARGINALCHANNELS	String	3	BAY SIDE – MARGINAL CHANNELS PRESENT (YES OR NO)
TIDALPRISM1	String	254	TIDAL PRISM DESCRIPTION 1

TIDALPRISM2	String	254	TIDA LPRISM DESCRIPTION 2
EXTRA1	String	254	ADDITIONAL INFORMATION 1
EXTRA2	String	254	ADDITIONAL INFORMATION 2
EXTRA3	String	254	ADDITIONAL INFORMATION 3
EXTRA4	String	254	ADDITIONAL INFORMATION 4
EXTRA5	String	254	ADDITIONAL INFORMATION 5
EXTRA6	String	254	ADDITIONAL INFORMATION 6
EXTRA7	String	254	ADDITIONAL INFORMATION 7
EXTRA8	String	254	ADDITIONAL INFORMATION 8
EXTRA9	String	254	ADDITIONAL INFORMATION 9
EXTRA10	String	254	ADDITIONAL INFORMATION 10

*Degrees, Minutes, and Seconds (Textual with special character symbols) (eg. 17° 58' 46.77" N) – for reporting purposes. Coordinates are calculated and stored in decimal degrees with 6 decimal place precision (sub-meter).

For further information on specific data fields, please see the metadata in APPENDIX 2.

3.2 First Gap Analysis

The inlets were then mapped (centered on the inlet throat) using Raster Nautical Charts, Shoreline Vector GIS Data, High-Resolution Aerial Orthophotography, Geographic Names Information System, and other reference GIS data from the Florida Marine Spill Analysis System and Digital Area Contingency Plan as well as FWRI's Marine Resources Geographic Information System (MRGIS), an enterprise-level GIS library. Source data included, but was not limited to, county boundaries mapped out to the state waters boundary, roads and bridges, polygon and line bathymetry, managed areas, and previously mapped inlet name and location spatial data, but of a different data schema.

The previously mapped inlet name and location spatial data were loaded into the new data schema and fields of different names but appropriate values were cross walked to the appropriate fields in the new schema. This is a data management process where database fields of different names but same field type (text, string, number) may be passed from one database to another. For instance, inlet name in one geodatabase may be called "NAM" and in the other geodatabase be called "INLET_NAME". In the cross walking process, it is a simple matter of specifying that values in the "NAM" field be loaded into the "INLET_NAME" field of the new geodatabase.

The process of mapping the physical locations of each tidal inlet in the broader area of responsibility for US Coast Guard grants took many years of intermittent effort by a team of colleagues and GIS specialists. The broader region includes the shorelines of (counter-clockwise from the Gulf of Mexico to the Atlantic and then Caribbean): Mississippi, Alabama, Florida, Georgia, South Carolina, Puerto Rico, and US Virgin Islands (St Thomas, St John, and St Croix).

Figure 3-3: First Information Gap Analysis – Mapping Tidal Inlet Locations – Where Are They? Within What Administrative Boundaries?



Figure 3-3. Tidal inlet locations in relation to USCG Sector Boundaries

(Counter-Clockwise from Gulf of Mexico to Atlantic and the Caribbean) for Sectors; Mobile, Saint Petersburg, Key West, Miami, Jacksonville, Savannah, Charleston, and San Juan. The fine scale outlines on this image denote local county boundaries or county administrative equivalents, termed “Parishes” in Louisiana and “Municipalities” in Puerto Rico and The US Virgin Islands. Using the geospatial analytical routine of “within”, each inlet location was calculated with the county or municipal entity it was inside of. The same routine was performed for USCG Sectors, State, and Coastal County Operational Division (for Shoreline Cleanup Assessment Technique) operations and reporting.

3.3 Collate into Collector/Analysis (2nd Gap Analysis)

Once the geodatabase “Collector” schema was complete, FGDC and ISO metadata with clearly described field values was written. With all inlets, tidal creeks, and passes identified and mapped and the study area defined, the framework was set to begin the effort. Over a period of approximately three years, the author searched for and identified spatial and aspatial information to populate the data schema from the sources described below.

3.3.1 Sources of Information Surveyed

1. Coastal Ocean Observing Systems: Gulf of Mexico Coastal Ocean Observing System (GCOOS); Southeast Coastal Ocean Observing Regional Association (SECOORA); and US Integrated Ocean Observing System (US IOOS).
2. Government Operational Oceanographic Data: (NOAA Center for Operational Oceanographic Products and Services (CO-OPS), NOAA National Centers for Environmental Information (NCEI) (formerly the National Coastal Data Development Center (NCDDC).
3. Government Publications: (US Army Corps of Engineers, US Geological Survey, United States Coast Guard, Minerals Management Service (now known as BOEM/BSEE (US Department of the Interior – Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement), NOAA Office of Response and Restoration, NOAA National Marine Fisheries Service, United State Fish and Wildlife Service, United States Congress, US Office of the President of the United States)
4. Scientific Publications: Ocean Modeling, Estuarine, Coastal, and Shelf Science, Continental Shelf Research, Estuaries and Coasts, Journal of Atmospheric and Oceanic Technology, Continental Shelf Research, Chemical Engineering, Coastal Response Research Center, SARSIA, Journal of the Brazilian Computer Society, Association for Computing Machinery, ICES Journal of Marine Science, Proceedings of the National Academies of Science (PNAS), Marine Pollution Bulletin, Journal of Computational Science, Canadian Journal of Remote Sensing, Physica D, American Geophysical Union – Water Resources Research, International Journal of Computational Fluid Dynamics, American Geophysical Union – Lagrangian Modeling of the Atmosphere, Deep Sea Research II, G7 Science Academies, American Institute of Biological Sciences, Geophysical Research Letters, The Florida Watershed Journal, Aquatic Microbial Ecology, PLOS One, Journal of Coastal Research, Ecological Restoration, Frontiers in Marine Science, Science, Journal of Fluid Mechanics, American Meteorological Society, IEEE Journal of Oceanic

Engineering, Photogrammetric Engineering and Remote Sensing, Optical Society of America, International Hydrographic Review, National Research Council, New Journal of Physics

5. Industry Publications: American Petroleum Institute (API), Publications of the International Oil Spill Conference, International Tanker Owners Pollution Federation (ITOPF)
6. Local Knowledge: Charter boat fishing captains, local fishing guides, SeaTow Captains, local coastal/marine resource managers.

Data types varied significantly but included the following:

1. Map services (ESRI REST)(Representational State Transfer)
2. Open Geospatial Consortium (OGC) map services
3. Integrated Ocean Observing Systems (IOOS) data portals
4. Government data portals
5. Geospatial data downloads
6. Internet searches
7. Internet geospatial data queries
8. Electronic tabular formats (HTML, spreadsheets) converted to geospatial data
9. Personal interviews (boat captains, oceanographers, researchers, data specialists, oceanographic modelers, watershed and estuary modelers, operational oceanographers, NOAA researchers, and others).

Despite all these sources, basic inlet-specific information was difficult to obtain. At an April 2014 oil spill science meeting, a noted oceanographer in the state of Florida summarized his experience during the DWHOS. When asked by the Coast Guard what the tidal currents were at a specific inlet to Apalachicola Bay, he said “I don’t know, no one really knows.” This was the first of many indications that this was indeed needed research.

3.3.2 Digital, Spatial Data

First endeavours at identifying information gaps was to examine historical and active physical measurement locations conducted for operational oceanography, namely thru the NOAA CO-OPS

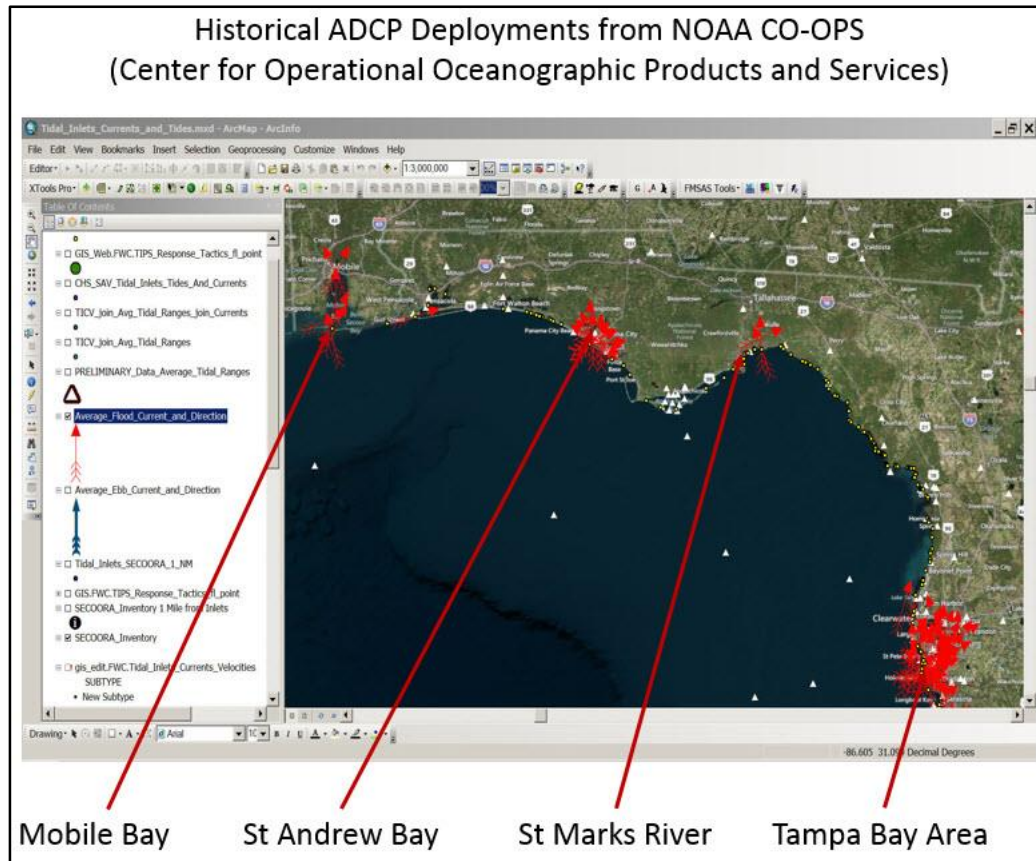


Figure 3-4: Historical ADCP Deployments from NOAA CO-OPS (Center for Operational Oceanographic Products and Services) depicted with average flood and ebb shallowest current velocity and direction (velocity vectors rotated on degrees true direction, centered on station location).

There were only three historical measurement locations in the study area that were available at the time of search and these were textual data that had to be manipulated digitally to render into a useable spatial product. This was an “aspatial” to “spatial” processing step. Figure 3-4 illustrates the areas covered by these insitu observations.

Active current measurement locations did not fare much better, with only four locations available, two of them at nearly the same location (Horn Island Pass), and one at the upper

end of Mobile Bay, which could not be considered a “tidal inlet” per se, but is certainly tidally-influenced (as can be clearly seen on the data pages for Mobile State Dock Pier E ([mb0301](#))). It should be recognized that Horn Island Pass, Pascagoula Bay, and Mobile Bay are all shipping fairways and that CO-OPS main mission is the support of safe vessel navigation and manoeuvring, not oil spill response or environmental monitoring. Acoustic Doppler Current Profilers are expensive to install and maintain and it would be a significant expense to physically measure all tidal inlets in the study area.

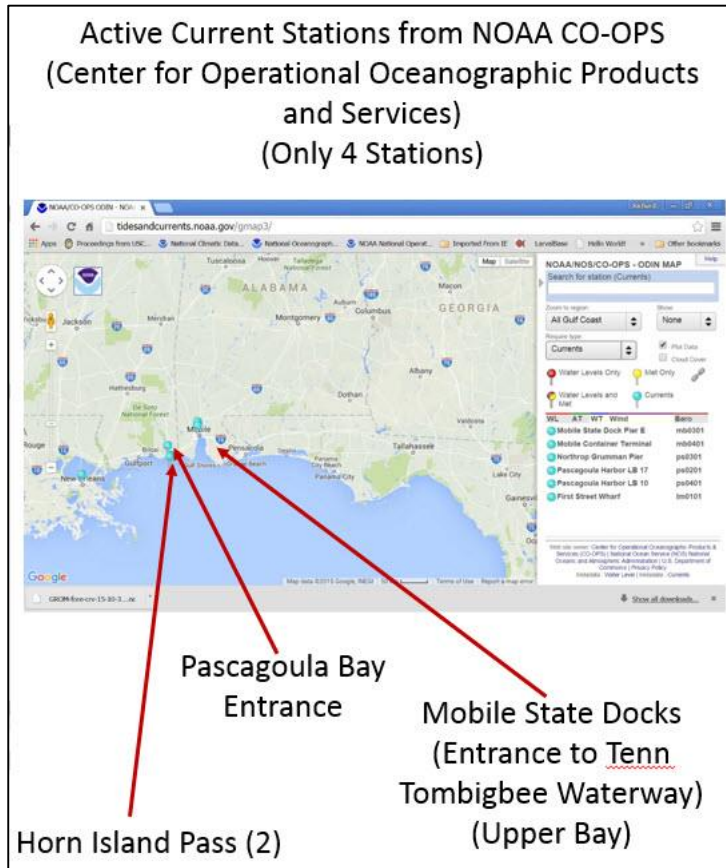


Figure 3-5: Active Current Stations in the Study Area (NOAA CO-OPS)

Of the historical current surveys, the surveys of the St Marks River Entrance are of interest. This inlet was listed as “Study Needed” because the historical measurement locations were not at the inlet throat specifically. Thus, the measurements could be considered provisional between 0.4 and 0.6 kts based upon measurements performed on the ocean side and then further up river, as can be seen in Figure 3-6. Note that the St Marks River is another region where active petroleum transport occurs to convey fuel to a power plant further up river. Further study would be needed to gain a better understanding on the inlet-specific circulation dynamics needed to develop TIPS for this area.

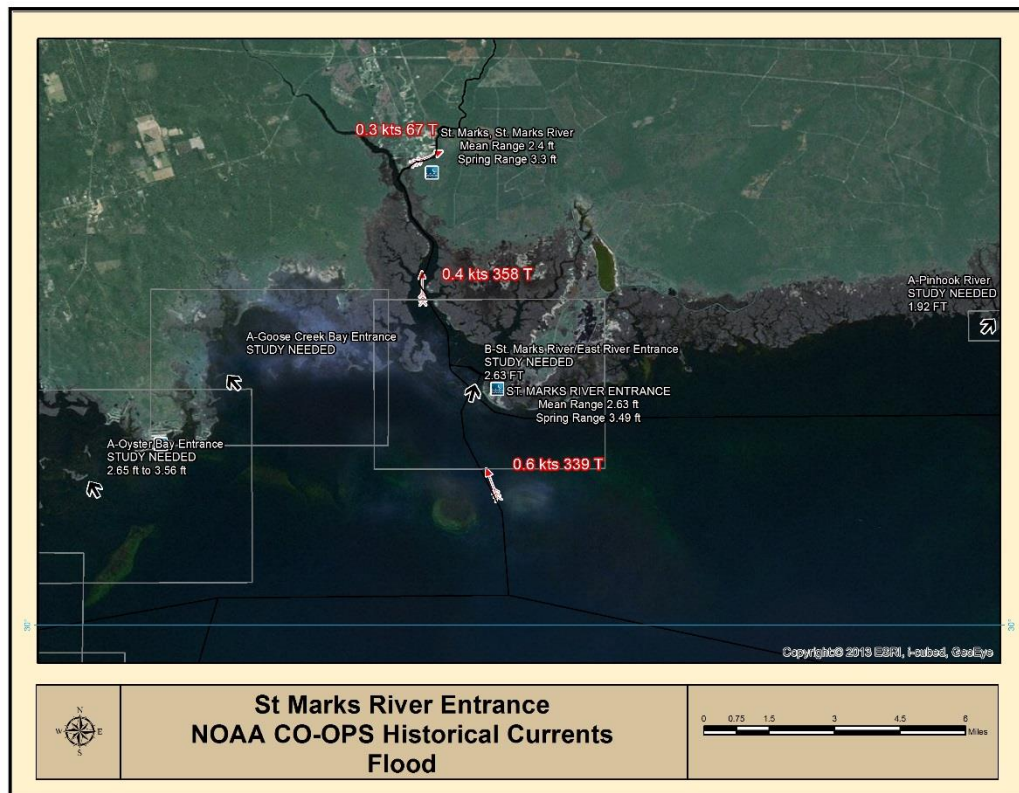


Figure 3-6: Map of St Marks River Historical ADCP Measurement Locations. See Figure 3-7 Map Legend Separate and Enlarged for Clarity.

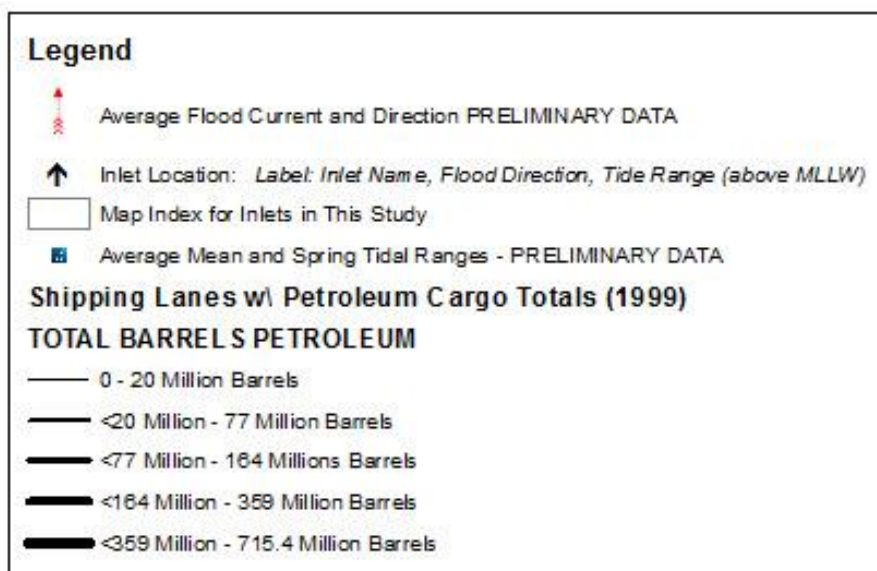


Figure 3-7: Map Legend for Figure 3-6 - Separate and Enlarged for Clarity

3.4 Summarizing Findings

A summary map of findings was needed for clearly conveying the survey information of this research, so a simple Green, Yellow, Red classification scheme was developed to show the survey status of information availability regarding tidal currents.

3.4.1 Tidal Inlets Assessment

A Green map color means there is reasonably actionable circulation information for the development of TIPS. Results indicated that 14 of 56 (25%) of the inlets satisfied this requirement. A color of Yellow means Inlet Closed or otherwise of little consequence for the development of TIPS. Results indicated 12 of 56 (21%) fell into this category. Red indicates Further Study Needed. More than half (30 of 56 or 53%), whether in-situ observations or model-derived determinations, fell into this category. Ideally, a high resolution tidal constituent derived nowcast-forecast system with a map-click interface would be the best solution for planning and operation products for TIPS, but that will be the focus of further research.

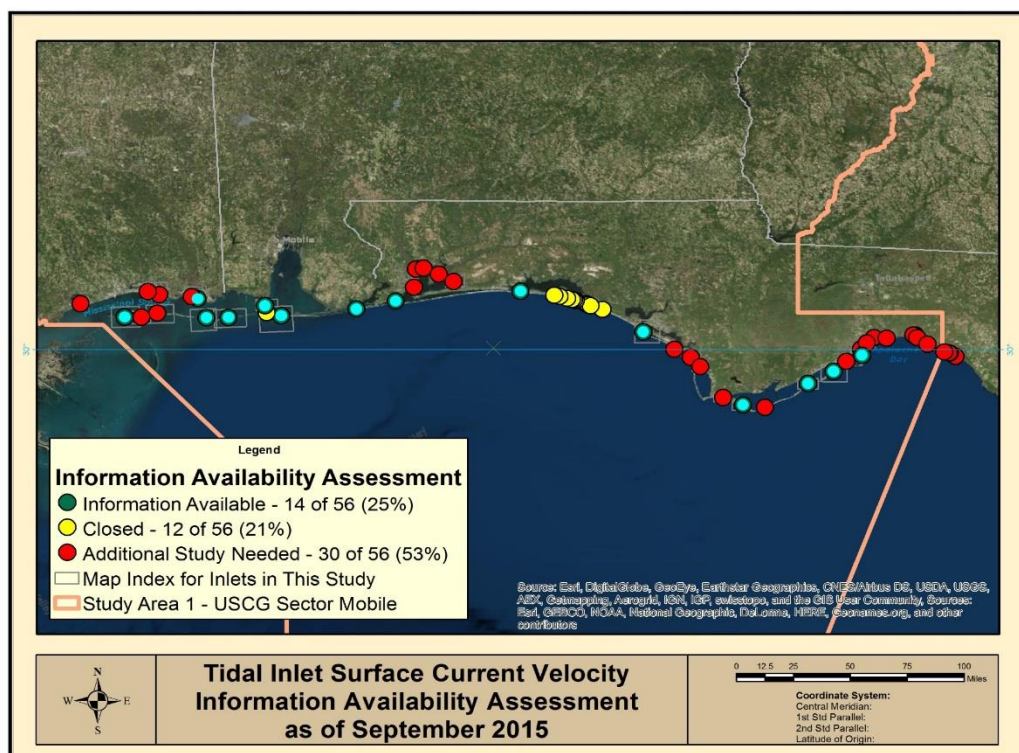


Figure 3-8: Summary Map of Inlet Locations and Assessment Results Regarding the Reasonable Availability of Information on Surface Current Velocity and Direction at the Inlet Throat.

3.4.2 Specific Inlet Findings

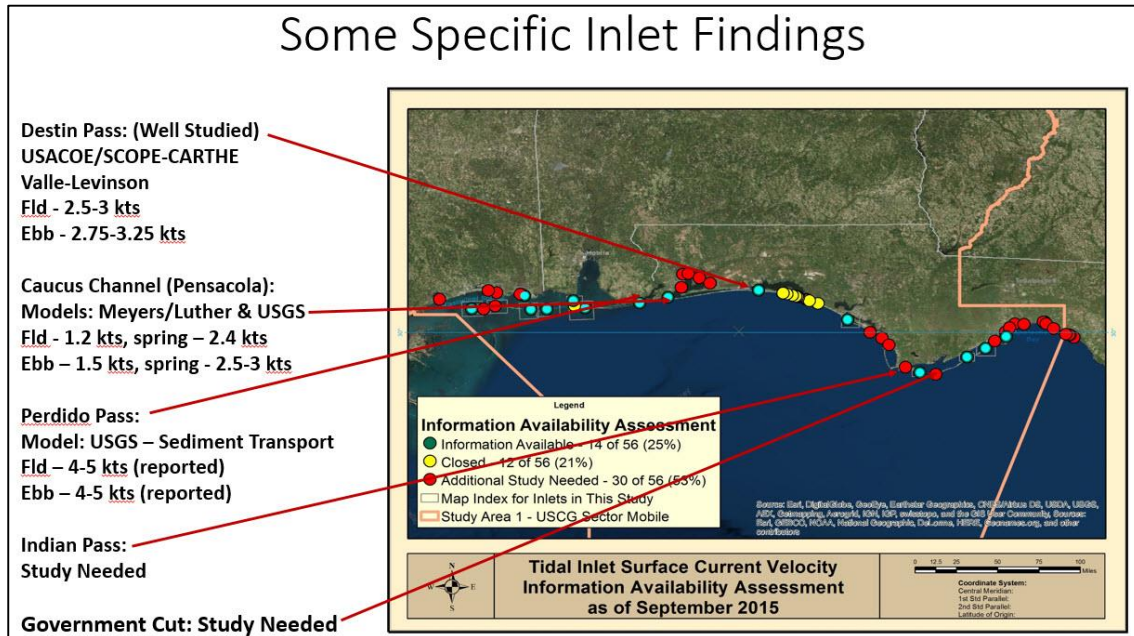


Figure 3-9: An Info-Graphic Pointing Out Some Specific Inlet Findings From This Research

Table 3-2 is a small sample of the results derived from the efforts of this study. These results have been extracted from a larger table that is behind each feature (inlet) of the larger dataset based upon the geodatabase schema described in Section 3.1. Fully Federal Geographic Data Committee (FGDC)- and ISO-compliant metadata have been produced and are available in Appendix 2. Table 3-2 has been trimmed down to show just the inlet name, inlet class (inlet protection operational difficulty), inlet status, average flood tide surface current velocity in knots, average current direction in degrees true, and average tidal range above MLLW. The full table contains significantly more information (see data schema Table 3-1).

Table 3-2 depicts these data sorted by State. There are 56 inlets total, 12 (21%) (shaded in yellow) are minor inlets along the Coastal Dune Lakes Region of Florida that can easily be

protected by a sediment dike. Inlet currents could be found for 14 of the inlets in the study area (25%) (shaded in green), and 30 (53%)(shaded in red) of which require additional study.

Table 3-2: Summary Table on the Availability of Information Specifically Regarding Average (Climatology)(Reported/Observed/Derived) Flood Tide Current Velocity and Direction.

INLET NAME	CLASS	STATUS	TIDAL RANGE GFT	AVERAGE FLOOD CURRENT VELOCITIES	DIRECTION	COUNTY	STATE
Ship Island Pass	A	Open	1.2 FT	0.3 kts (NOAA COOPS)	308	Mobile/Baldwin	Alabama
Petit Bois Pass	A	Open	1.2 FT	0.4 kts (NOAA COOPS)	349	Mobile/Baldwin	Alabama
Horn Island Pass	A	Open	1.2 FT	0.5 kts (NOAA COOPS)	23	Mobile/Baldwin	Alabama
Pass aux Herons	A	Open	1.2 FT	1.3 kts (Coast Pilot)	90	Mobile/Baldwin	Alabama
Mobile Bay Entrance (Main Ship Channel)	A	Open	1.2 FT	1.5 kts (NOAA COOPS)	14	Mobile/Baldwin	Alabama
Perdido Pass	A	Open	0.6 to 0.8 ft	4-5 KTS (Local)	20	Baldwin	Alabama
Pelican Passage	D	Closed	1.2 FT	STUDY NEEDED	90	Mobile/Baldwin	Alabama
Little Dog Keys Pass	A	Open	1.2 FT	STUDY NEEDED	0	Mobile/Baldwin	Alabama

Loggerhead Shoal	A	Open	1.2 FT	STUDY NEEDED	0	Mobile/Baldwin	Alabama
West Pass (Apalachicola Bay)	B	Open	1.2 ft to 2 ft	>1 kts	52	Franklin	Florida
Ochlocknee Bay Entrance	A	Open	2.6 FT	0.5 kts	26 0	Franklin	Florida
Caucus Channel (Pensacola Pass)	A	Open	1.1 to 1.3 ft	1.2 kts	35 6	Escambia	Florida
St. Andrew Bay Entrance	A	Open	1.2 ft	2 kts	45	Bay	Florida
East Pass (Destin Pass)	A	Open	0.6 ft	2.5 kts to 3 kts	31 0	Okaloosa	Florida
East Pass (St George Sound)	A	Open	1.9 ft to 2.74 ft	at least 1 kt	32 0	Franklin	Florida
St. George Sound Entrance	U	Open	1.9 to 2.8 ft	at least 1 kt	30 0	Franklin	Florida
Goose Creek	A	Open		STUDY NEEDED	32 0	Wakulla	Florida

Bay Entrance							
St. Marks River/East River Entrance	B	Open	2.63 FT	STUDY NEEDED	15	Wakulla	Florida
St. Andrew Sound Entrance	B	Open	1.2 ft	STUDY NEEDED	45	Bay	Florida
Salt Creek (Bay Co.)	C	Open	1.2 ft	STUDY NEEDED	325	Bay	Florida
Escambia River Inlet	B	Open	1.5 ft	STUDY NEEDED	290	Santa Rosa	Florida
Escambia River Inlet South	B	Open	1.5 ft	STUDY NEEDED	350	Escambia	Florida
Mullato Bayou Inlet	C	Open	1.5 ft	STUDY NEEDED		Santa Rosa	Florida
Blackwater Bayou Inlet	A	Open	1.6 ft	STUDY NEEDED	20	Santa Rosa	Florida
Philips Inlet	D	Closed		STUDY NEEDED	40	Bay	Florida
Eastern Lake Inlet	D	Closed	NA	STUDY NEEDED	40	Walton	Florida

Deer Lake Inlet	D	Closed	NA	STUDY NEEDED	15	Walton	Florida
Camp Creek Lake Inlet	D	Closed		STUDY NEEDED	65	Walton	Florida
Western Lake Inlet	D	Closed	NA	STUDY NEEDED	35 5	Walton	Florida
Alligator Lake Inlet	D	Closed	NA	STUDY NEEDED		Walton	Florida
Big Redfish Lake Inlet	D	Closed	NA	STUDY NEEDED	0	Walton	Florida
Little Redfish Lake Inlet	D	Closed	NA	STUDY NEEDED	35	Walton	Florida
Draper Lake Inlet	D	Closed	NA	STUDY NEEDED	15	Walton	Florida
Stalworth Lake Inlet	D	Closed	NA	STUDY NEEDED	0	Walton	Florida
Morris Lake Inlet	D	Closed	NA	STUDY NEEDED	0	Walton	Florida
Bayou Texar Inlet	C	Open	1.2 ft	STUDY NEEDED	32 0	Escambia	Florida
Dickson Bay Entrance	A	Open	2.65 ft to 3.56 ft	STUDY NEEDED	25 0	Wakulla	Florida

Oyster Bay Entrance	A	Open	2.65 ft to 3.56 ft	STUDY NEEDED	330	Wakulla	Florida
St. Joseph Bay	A	Open	1.1 ft to 1.6 ft	STUDY NEEDED	160	Gulf	Florida
Alligator Harbor Channel	C	Open	1.9 to 2.8 ft	STUDY NEEDED	120	Franklin	Florida
Indian Pass	B	Open	1.12 ft to 1.7 ft	STUDY NEEDED	62	Gulf/Franklin	Florida
Government Cut (St George Island)	B	Open	1.2 ft to 2 ft	STUDY NEEDED	335	Franklin	Florida
East Bay River Entrance	A	Open	1.6 ft	STUDY NEEDED	120	Santa Rosa	Florida
Sulfur Creek	A	Open	1.92 FT	STUDY NEEDED	35	Jefferson	Florida
Pinhook River	A	Open	1.92 FT	STUDY NEEDED	40	Jefferson	Florida
Aucilla River	A	Open	1.92 FT	STUDY NEEDED	45	Taylor	Florida
Econfina River	A	Open	1.92 FT	STUDY NEEDED	45	Taylor	Florida
Big Spring Creek	A	Open	2.4 FT	STUDY NEEDED	10	Taylor	Florida

Fenholloway River	A	Open	2.4 FT	STUDY NEEDED		Taylor	Florida
Regular Creek	A	Open	2.4 FT	STUDY NEEDED		Taylor	Florida
Pitts Creek	A	Open	2.4 FT	STUDY NEEDED		Taylor	Florida
Pascagoula Bay Entrance	A	Open	1.3 FT	0.6 kts (NOAA COOPS)	340	Jackson	Mississippi
Biloxi Bay Entrance	A	Open	1.6 FT	STUDY NEEDED	315	Harrison/Jackson	Mississippi
St. Louis Bay	B	Open	1.5 FT	STUDY NEEDED	15	Hancock/Harrison	Mississippi
Biloxi Channel	A	Open	1.6 FT	STUDY NEEDED	90	Harrison/Jackson	Mississippi
Pascagoula River Entrance	A	Open	1.3 FT	STUDY NEEDED	350	Jackson	Mississippi

3.4.3 Specific Inlet Discussions

The need to fill gaps in inlet circulation information was known and discussed during the DWHOS response. Five years later, little has changed. However, progress from this work is helping to brighten the picture. Every effort was made to progress using existing resources and overcome technology communication challenges. Because available resources were often not in useable geospatial data formats or map services, one of the following was needed: 1. Format conversions; 2. Requests to data providers to provide their data feeds in GIS-compliant services (OGC or ESRI REST); or 3. Research and create geodata or geodata services from scratch. This need resulted in an incomplete regional picture from what was

initially envisioned and was very much a marine spatial planning challenge. Progress was slower than desired, but will continue following thesis publication.

3.4.3.1 East Pass (Destin Pass)

This inlet has had fairly extensive study including a US Army Corps of Engineers report (Morang, 1992) and several research papers by authors from the CARTE consortium, including Valle-Levinson (2015) and the SCOPE (Surfzone Coastal Oil Pathways Experiment) projects focused on a slightly more offshore region seaward of Destin Pass. This inlet had fairly reliable information, (somewhat) available,. An operational model of the pass and Choctawhatchee Bay estuary for modeling protection strategies would certainly be useful. This may actually be possible, given proper fiscal support. Additionally, a model of Choctawhatchee Bay and Destin Pass may serve other water quality and fish and wildlife research purposes.

3.4.3.2 Caucus Channel (Pensacola Pass)

The only readily available information on the tidal current velocities for this inlet were found by reading the US Coast Pilot for the region and collating information from that source. However, Meyers and Luther (personal communication) had produced a circulation model for larval transport studies inside the estuary, but the model domain ended at the entrance (from seaward) to Pensacola Bay.

3.4.3.3 St. Andrew Bay Entrance

Inlet current velocity for this pass was derived from a NOAA CO-OPS ADCP deployments (30 days each) at three locations at the entrance. The inlet throat velocities and average directions were recorded. As ADCP measurements, these were not truly surface measurements, but rather for the shallowest measured depth.

3.4.3.4 Perdido Pass

Perdido Pass is a challenging inlet for oil spill control. During the DWHOS response, several million dollars was spent in devising and building a sheet piling diversion system, yet little

reliable information could be located on the flood and ebb surface current velocities. Wildly different numbers were proposed up to nine knots under certain conditions. Few publications could be located and no current velocities were mentioned in the US Coast Pilot. A modeling study on the surfzone transport of “tarballs” (termed Surface Residual Balls (SRBs)) was undertaken by the USGS (Plant, et al., 2011) under Operational Science Advisory Team Three (OSAT 3) of the DWHOS federal response, but this model was originally targeted for sediment transport objectives and subsequently modified in order to predict potential tarball settlement locations. The report mentioned that the model mesh resolution was not necessarily up to the task (250 m) and the inlet entrance did not take into account the jetty and groin infrastructure. It also did not specifically mention the average tidal current velocities of Perdido Pass, so local knowledge was relied upon to determine this (local SeaTow captains).

3.4.3.5 Government Cut (Franklin County)

Government Cut is a small, man-made cut on St. George Island, a barrier island of Apalachicola Bay. The author attempted to visit this inlet but found it to be enclosed within a gated beach community. No information was available on this particular inlet and in conducting some other professional activities (training others on Shoreline Cleanup Assessment Technique) it was discovered that a model whose domain included Apalachicola Bay did not resolve this inlet. It became a demonstration project on the “availability” of operational models for integration with coastal sensitivity GIS data to illustrate the value of having these two types of data work together in a “somewhat” effective manner. That effort is discussed in the Oil Spill Scenario Demonstration Project section of this paper.

3.5 Why are surface current velocities important for oil spill control in Tidal Inlets?

As documented in NOAA, 2001, [Mechanical Protection Guidelines](#), there is a direct relationship of boom angle to surface current velocity for maximum effectiveness. As can be seen in Figure 3-10, at approximately 1 knot of velocity, the angle of boom to the flow direction should be about 45 degrees and the angle should become more acute at increasing velocities. These angles result in an effective current velocity at the boom of less than 0.7 knots. A misplaced boom deployment will fail by allowing the passage of oil. These

observations play a significant role in the need for readily accessible information on surface current velocities in inlets.

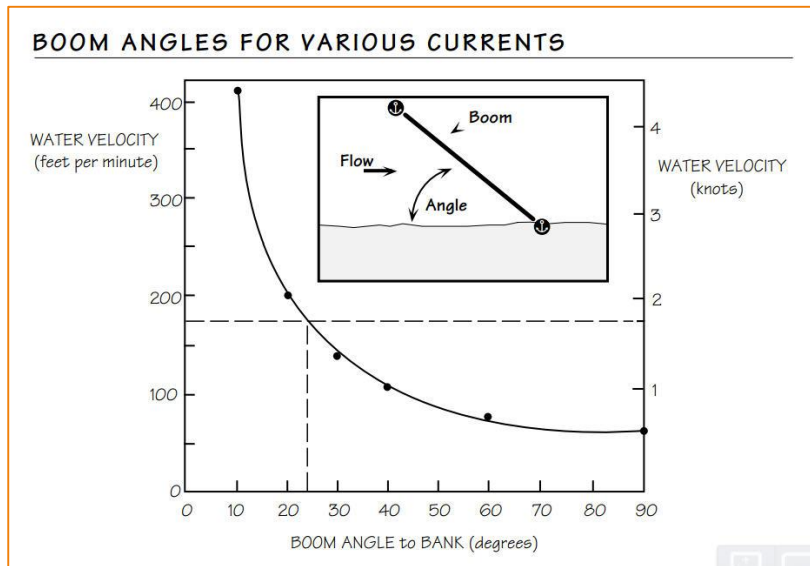


Figure 3-10: Boom Angles for Various Current Velocities

3.6 Inlet Map Series

A map series of 50 maps plus index maps have been produced that provide the basic information needed for planning future efforts. Each map contains the elements that every cartography student learns in their first class; a title, a primary data frame, a North arrow, a scale with appropriate units, and a locator map. Additionally, each map includes map projection details (for Florida's custom Albers Equal Area map projection), data-driven page designation as to which county the inlet is located within, data-driven attribute information on the "Inlet Protection Operational Difficulty" classification (CLASS field), and within the primary data frame, the inlet location is represented by an arrow that is rotated by the "FLOOD CURRENT DIRECTION DEGREES TRUE" value (FLDCURDIRT field) to cartographically represent flood tide current direction at the inlet throat. Each inlet location is labeled with a short script in ArcMap to display the inlet name, the average (best available) flood current velocity in knots (nautical miles per hour), and average tidal range above Mean Lower Low Water (MLLW)(in Ft) in a three line label. Standard US units (knots and feet) were chosen as the displayed units for the purposes of the intended audience, but the database schema is equipped for metric units for each value for more scientific applications down the line. Unit conversions were performed using a NOAA tool named NUCOS ([Number Unit](#)

[Converter for Oil Spills](#)), freely downloadable from the NOAA Office of Response and Restoration website (link provided).

The 50 map “atlas” of these identified inlets and their basic information is available in Appendix 2 of this paper. For illustrative purposes, a map/chart of Government Cut (St George Island) (Franklin County, FL) and Destin Pass (the official Geographic Names Information System (GNIS) Name of which is East Pass) (Okaloosa County, FL) are provided as Figures 3-11 and 3-12 because each inlet has additional implications to this research. Government Cut because this was the location chosen for a demonstration project on the integration of the USF West Florida Shelf Finite Volume Community Ocean Model (FVCOM) (Weisberg 2006) (Zheng 2012) (FIO-FWRI 2014) with GIS data via NOAA’s GNOME modeling environment as an intermediary for the conversion of a spill trajectory into useable GIS data for further spatial analysis using the Florida Marine Spill Analysis System on “Resources At Risk” within and around the Apalachicola Bay estuary. Discussed in Section 3.7.

Destin Pass and the Choctawhatchee Bay estuary hold special significance due to the efforts of the CARTHE Consortium (Consortium for Advanced Research on Transport of Hydrocarbon in the Environment) and Arnoldo Valle-Levinson’s (et al.) (2015) recent research on the tidal and non-tidal exchange of that particular inlet. Ideally, there would be a queryable oceanographic model at a comparable scale to other mapped static geodata on resources and management for every tidal inlet of reasonably significant size, particularly if it exchanges waters of a large estuary such as Choctawhatchee Bay that is so important to the broader overall health and sustainability of fish and wildlife species in the Gulf of Mexico (Collins 1994).. This one project is an attempt to demonstrate that potential.

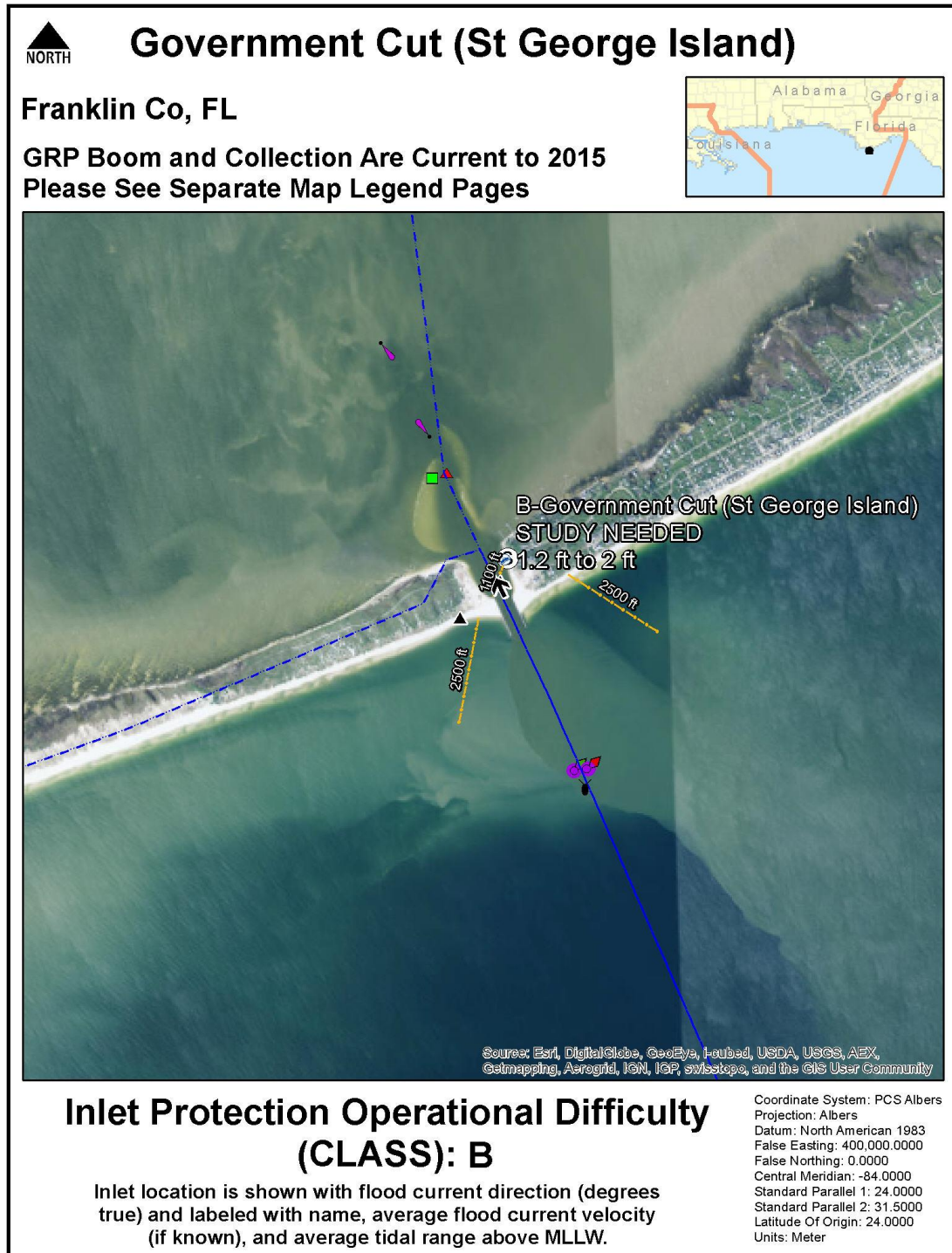


Figure 3-11: Government Cut (St George Island) TIPS Planning Map

Shown in Figure 3-11 are: Inlet location with average flood tide current direction, average flood tide current velocity is unknown (Study Needed), and tidal range above MLLW.

Additional map layers are present Geographic Response Plan boom placement with length in feet rounded to the nearest 50 feet (boom is typically available in 50 foot lengths). Oil

collection locations associated with booming strategies are shown as the small black triangle for a shoreline based collection point (manual or mechanical) and a skimmer is depicted further offshore to indicate surface skimming is part of the plan. As can be seen, there is a small segment of boom placed at an approximately 45 degree angle to the flood current which might only work if current velocities were below 1 knot (USCG Research and Development Center 2001). Surface current velocity thru this inlet remains unknown. It should also be noted that on a physical visit to this inlet, it is within a gated, secured community accessible only by permission. Access would be easiest by boat.



Figure 3-12: Destin Pass Map - Inlet Location, Average Flood Current Direction and Velocity, and Average Tidal Range Above MLLW

Destin Pass Inlet (East Pass) is classified as an A (most operationally difficult to protect) inlet because of swift tidal currents, complex geomorphology, large tidal prism, and complexity of staging and collection. This inlet might marginally be considered a B in terms of operational difficulty of protection.

3.6.1 “Intuitive” Representational Map Symbolology

The basic purpose of this research was to collate “really hard to find” information and make it easy to understand, distribute, and represent on a map. Toward that end, a representational means of showing this information on a map or map service to others was an objective. This was accomplished by using data field within the geodatabase to manipulate map symbology and labelling in a manner consistent with the end objective, showing surface current velocity and direction at flood tide when tidal inlets are most vulnerable to conveyance of spoiled oil and additionally showing operationally pertinent information like average tidal range (vessel operations). So, a methodology was developed to do this whereby an arrow centered on the tidal inlet throat is rotated by the prevailing advection direction in degrees true and then labeled with a script generated multi-line label that shows Inlet name, average flood current velocity, and average tidal range above Mean Lower Low Water. A sample of this map symbology is rendered in Figure 3-13.

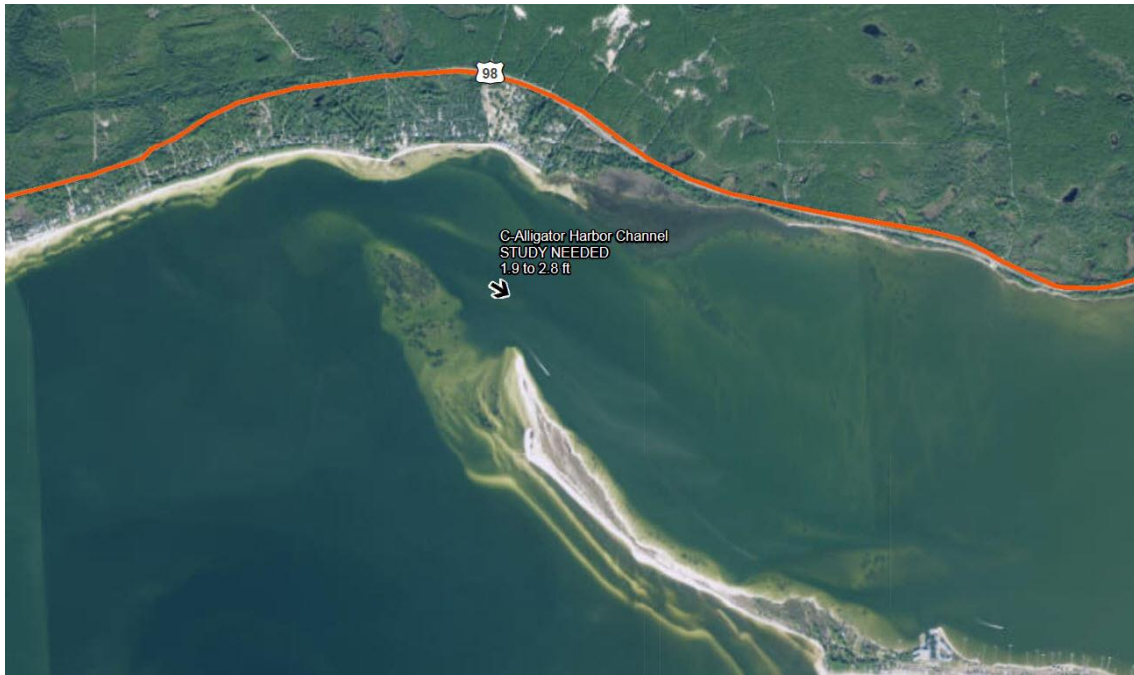


Figure 3-13: Intuitive Map Symbology Developed Through This Research

3.7 Oil Spill Scenario Study

The purpose of this project was three-fold. 1. Demonstrate “on-demand” oil spill trajectory modeling for a chosen region of the State of Florida (in this case, the demand driver was for a training class on Shoreline Cleanup Assessment Technique (SCAT) held at the Apalachicola National Estuarine Research Reserve). 2. Demonstrate interaction between oil spill trajectory modeling and the Florida Marine Spill Analysis System (FMSAS, a specialized Geographic Information System for oil spill contingency planning, response, and Natural Resources Damage Assessment maintained by the Fish and Wildlife Research Institute and used operationally by the Florida Department of Environmental Protection’s Office of Emergency Response). The FMSAS is extensible to import GNOME Trajectory output files by time step and then convert them to a GIS format (shapefiles). The user is able to customize the time step on export from GNOME and each time step then becomes a separate map layer as a

shapefile. Export as Lagrangian Elements (termed “splots”) is the only well documented function at this time. 3. Demonstrate the importance of methods to prevent the passage of oil products thru inlets that convey into much more sensitive habitats and wildlife areas as compared to barrier island beach.

3.8 Process Steps of GNOME Trajectory Model to GIS “Integration”

3.8.1 Setting Up GNOME for Trajectory Modeling

Step One: Downloaded and installed latest version of GNOME (v. 1.3.9) for Windows 7 Professional.

Step Two: Used the GOODS Shoreline Data Extractor to spatially query, extract, and download a BNA-format NOAA Medium Resolution Shoreline of the area of interest to be used as the “basemap” for GNOME.(Figure 3-14).

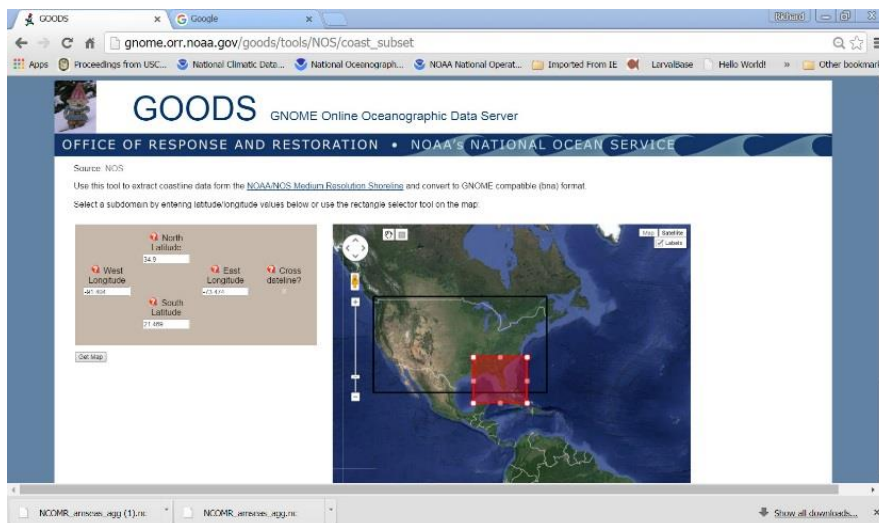


Figure 3-14: GOODS BNA Shoreline Extractor – Map interface to allow extraction of NOAA Medium Resolution Shoreline for any area of interest in a GNOME compatible data format

Step Three: Opened GNOME in “Diagnostic Mode”, the highest level of functionality and customizability for GNOME (Figure 3-15). Diagnostic Mode supports full modeling environment functionality and the ability to export in GIS-compatible formats, termed “MOSS” files.

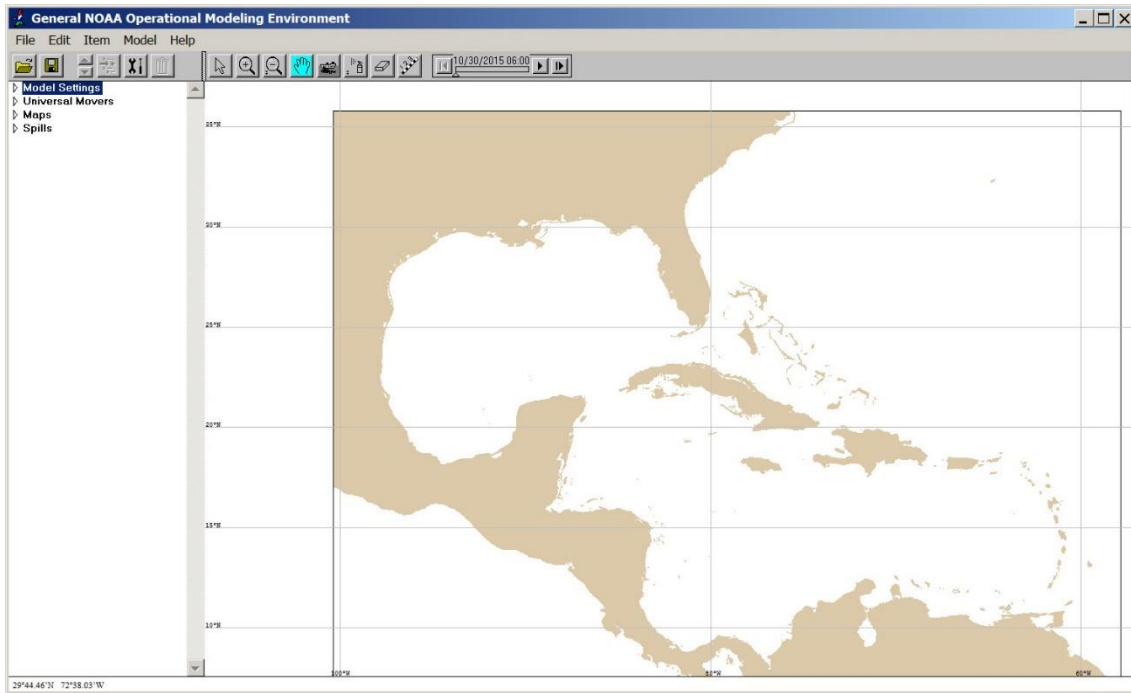


Figure 3-15: Extracted NOAA Medium Resolution Shoreline Shown in GNOME as a “basemap”. No model “movers” have been defined yet, so figure 3-14 is just the land/water interface.

Step Four: Searched for available “source oceanographic models” within the GNOME Online Oceanographic Data Server (GOODS) to supply currents as one of the “movers” in the modeling environment. This also allowed for visualization of the model mesh (model domain - the mapped physical space where model calculations occur) for visual comparison to the mapped shoreline, bathymetry, and other geospatial data for the region around Apalachicola Bay.

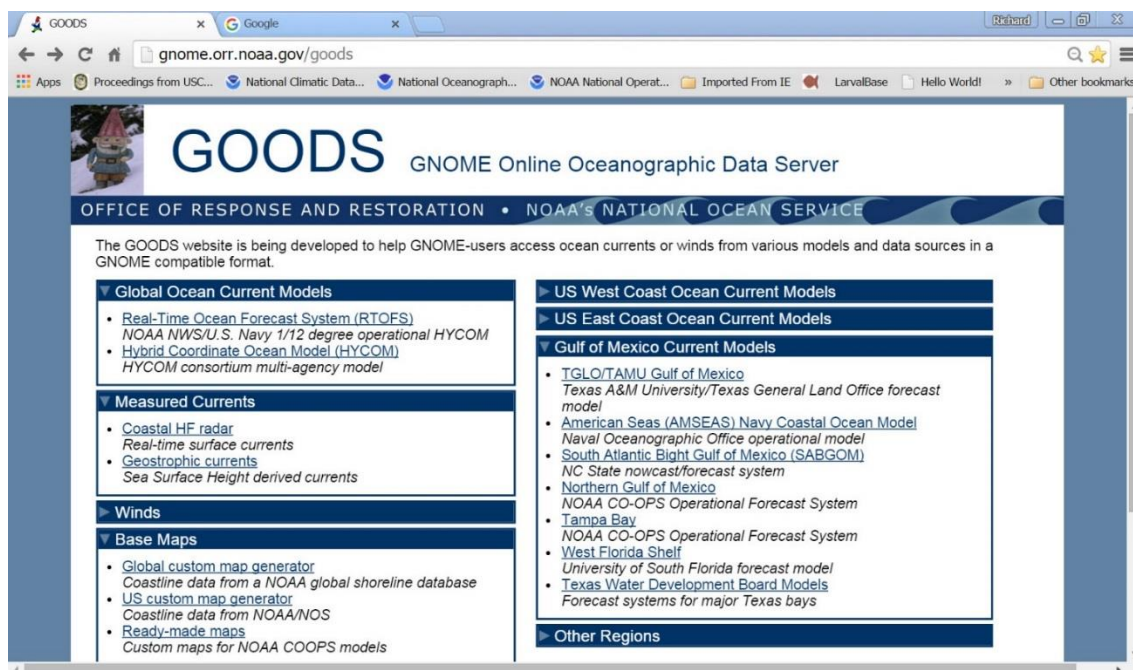


Figure 3-16: The NOAA GNOME Operation Oceanographic Data Server.

<http://gnome.orr.noaa.gov/goods>. Connects to THREDDS servers hosting GNOME compatible operational models available for use in GNOME.

3.8.2 Accessing GNOME “Available” Currents Derived From 3D Operational Oceanographic Models (GOODS)

Step Five: Compare Available Models - Three forecast models were available whose domain included the area of interest. (Figure 3-17).

- a. Navy NCOM (~3 KM Structured Grid that can be subset. Description: *The Naval Oceanographic Office operational ocean prediction system for the Gulf of Mexico and Caribbean is a ~3km resolution model based on the Navy Coastal Ocean Model. More information on the model can be found at the NOAA OceanNOMADS site.*
- b. Texas A&M University (TAMU) GOM (structured grid (can be subset)) (2 day hindcast, 3 day forecast). Description: *Gulf of Mexico Regional Ocean Modeling System (ROMS) model run by TGLO/TAMU.*
- c. USF WFS FVCOM (Finite Volume Community Ocean Model) (variable resolution. unstructured grid, cannot be subset) (triangles) - 4 day forecast. Description: *The College of Marine Science - USF, Ocean Circulation Group maintains a coordinated program of coastal ocean observing and modeling for the West Florida Continental Shelf (WFS).*

Their modeling efforts include a nowcast/forecast FVCOM implementation for the West Florida Shelf nested in the Gulf of Mexico HYCOM model. Access to the latest forecast from that model is available here for GNOME users. For model details and/or for access to archived nowcasts and model graphics visit the USF Ocean Circulation Group model page.

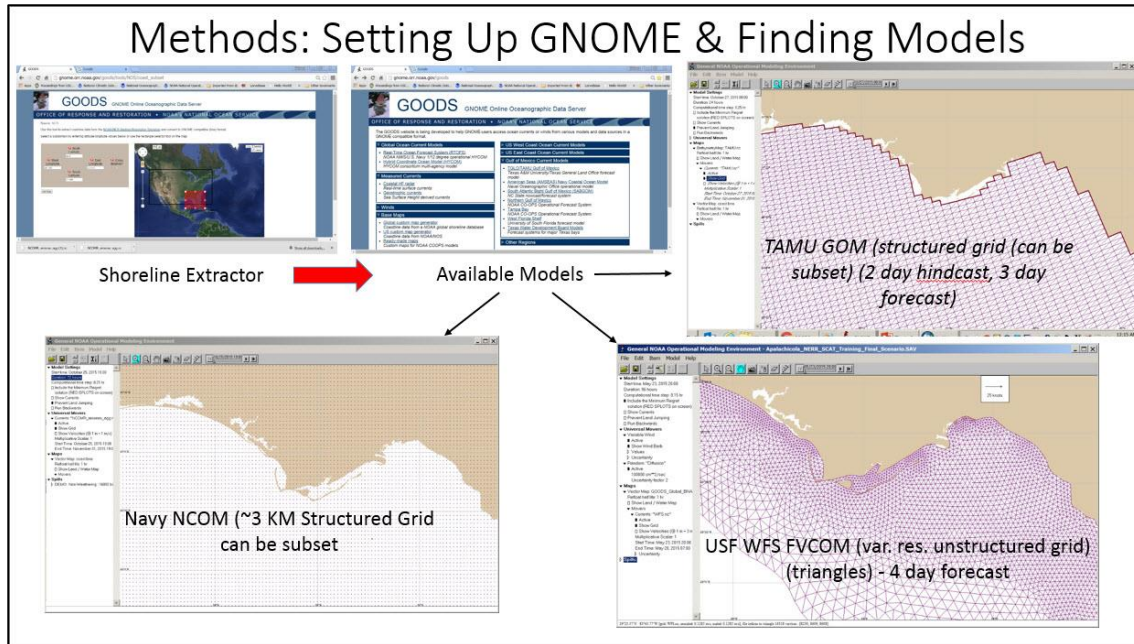


Figure 3-17: Available Models for GNOME with Domains somewhat suitable for the intended purpose.

Of the three available models, the USF WFS FVCOM had the most appropriate resolution for the shorelines of the area of interest. (Figure 3-17). Downloaded NetCDF file of 4 day WFS forecast containing the entire model domain. (Figure 3-17)

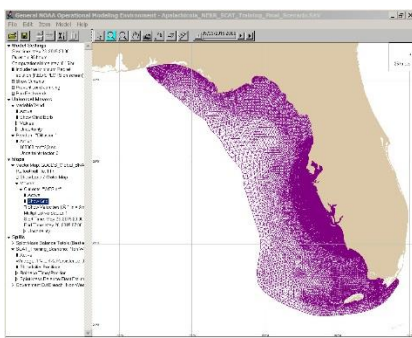


Figure 3-18: West Florida Shelf FVCOM Full Model Domain (Unstructured Grid, Cannot be subset for GNOME, so the full model domain must be used.)

Special Note: [GNOME Data Formats Technical Memorandum NOS OR&R 41 \(2012\)](#) is an excellent reference on using and formatting NetCDF (Network Common Data Format) data and modeled currents output for consumption in GNOME (and potentially other modeling environments). The academic and technical GIS communities are encouraged to reference and examine these technical specifications for any future research efforts that may support collaboration and data sharing of physical oceanographic information. The [GNOME Online Oceanographic Data Server](#) is one way to accomplish this collaboration, particularly if it relates to oil spill response. Newer technologies are however emerging as described by Dr. Rich Signell in describing “[A Distributed, Standards Based Framework for Searching, Accessing, Analyzing and Visualizing Met Ocean Data and Information](#)” at the 2015 Scientific Python Conference.

3.8.3 Observations on Model “Meshes” in relation to mapped (GIS) shorelines, tidal inlets, and other GIS data.

Making the model mesh visible and then with Zoom and Pan Functions in GNOME, it quickly became apparent that the target inlet (Government Cut (Franklin County)) was not resolved in the model mesh. For the purposes of demonstrating oil passage thru an inlet to impact sensitive estuarine resources within the bay for the training, a workaround was needed to mimic this passage thru the inlet, so a second spill scenario was modeled on the inside of the passage to mimic a 3 am breach of the passage with a staggered time step in relation to the initial offshore trajectory impact on the shoreline and inlet region. This was possible because the model mesh was of suitable resolution inside the estuary.

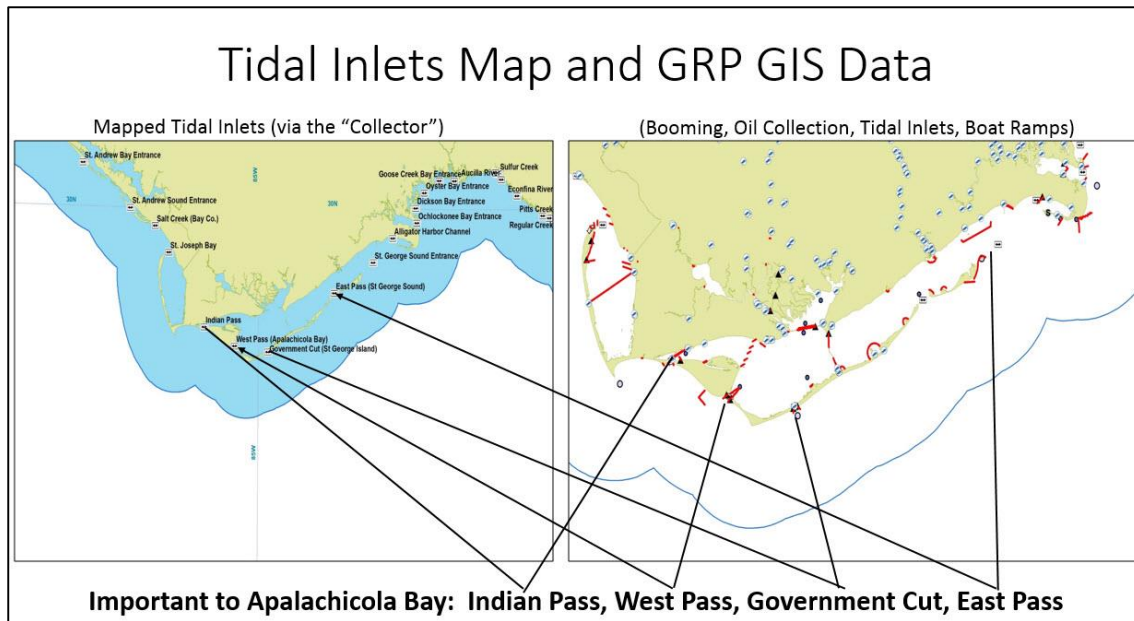


Figure 3-19: Tidal Inlets Mapped with Inlet Characterization Geodatabase and Other Contingency Planning and Response GIS Data Within the Region

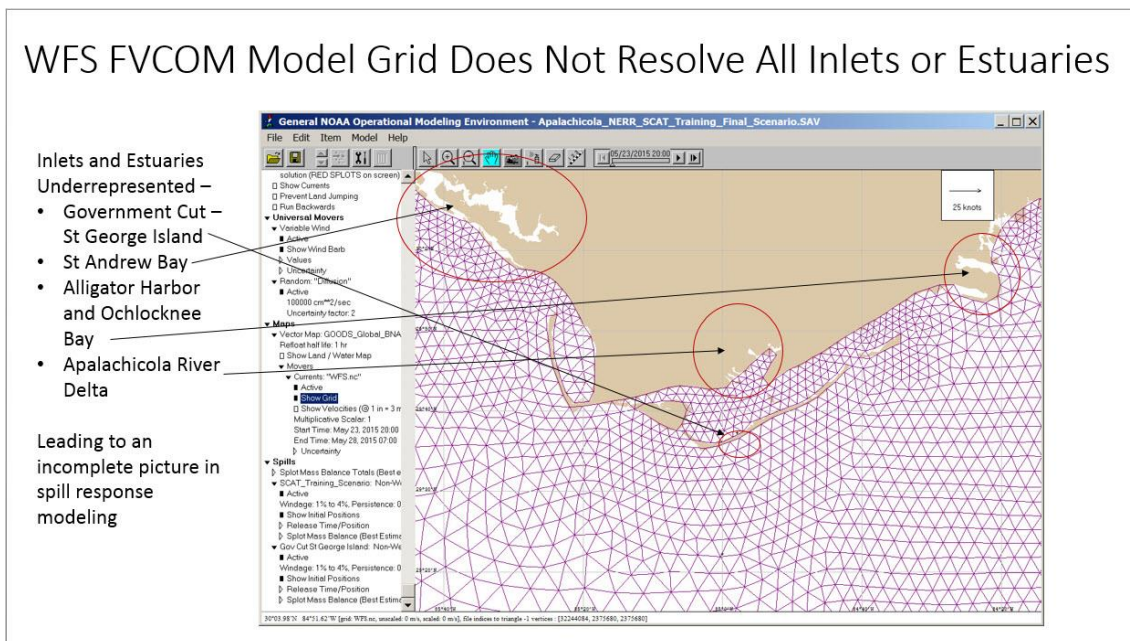
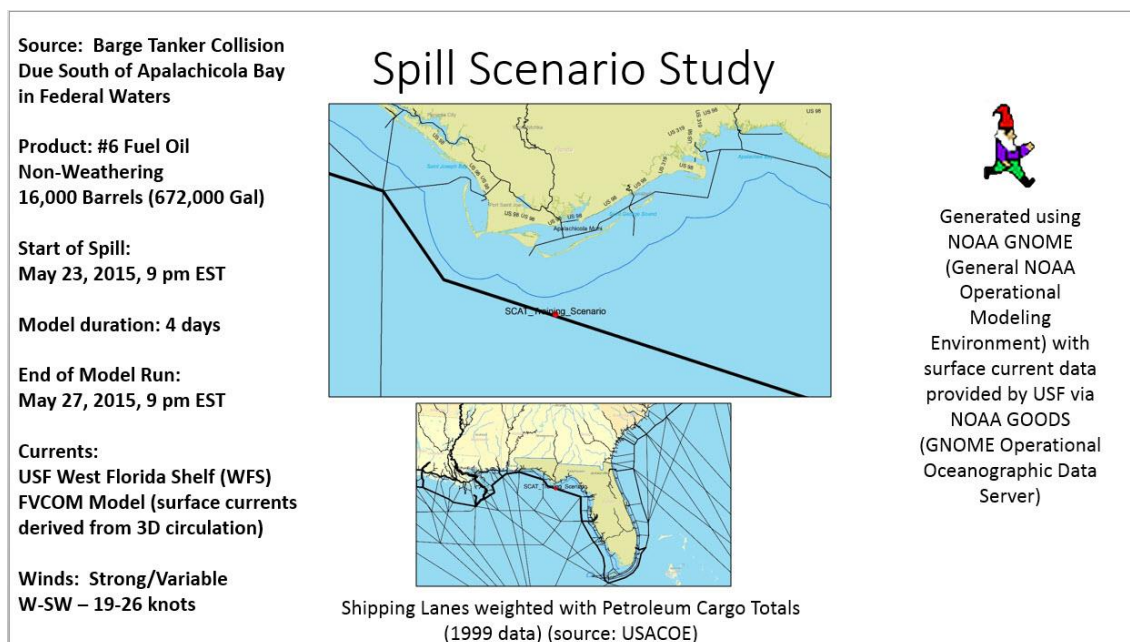


Figure 3-20: WFS FVCOM Model Mesh viewed in GNOME with specific observations on areas underrepresented in the mesh.

3.8.4 Developing Model Scenario

Using spatial data derived through other previous risk assessment efforts (Army Corps of Engineers – Navigation Data Center – Petroleum Cargo Transport Routes with Petroleum

Cargo Totals – 1999 data – created from aspatial tabular data joined to spatial shipping routes data by the author and colleagues in 2002), developed a “scenario” where a barge collision occurred in the federal waters offshore of Apalachicola Bay. The product spilled was #6 Fuel Oil, a heavy refined oil product used to power electric plants and large vessels that does transit this route regularly (so hence, plausible). This is a non-weathering (degrades slowly) oil that is very damaging to the environment and wildlife when spilled. A relatively standard barge volume of 16,000 Barrels (672,000 gallons) was chosen and for simplicity, an instantaneous release rate was used as if one barge cut the other in half on collision. The start of the “spill” was timed to be May 27, 2015 at 9 in the evening with a four day model duration. Coordinates of the source location of the spill were obtained from the GIS and entered into GNOME to mark the source location of the “spill”. For scenario generation purposes, strong and variable winds of 19-26 knots were used. This would indeed be blustery at sea.



3.8.5 Running the Trajectory Model

The oceanographic model without wind forcing carried the Lagrangian Elements of the spill trajectory to the West and then North up to the entrance of St Joe Bay, so in order to meet the mission of depicting impacts along the shoreline intended for the training and thence into Apalachicola Bay, significant wind forcing (19 to 26 kts) was applied to the trajectory to force it to the intended impact area. This is often done in drills and exercises to meet the objectives of the exercise, which is typically focused on organizing people and activities

within the Incident Command System (ICS) rather than accurately forecasting and tracking a real spill. These two types of activities, contingency planning and exercises and actual response, are significantly different and the distinction between them should be clear. Response forecasting is accompanied with regular direct aerial and remote sensing observations for trajectory validation and model re-initialization by a team of highly-trained specialists focused on “getting it right”. Contingency planning and exercise modeling are driven by the objectives of risk-based planning or specific exercise needs.

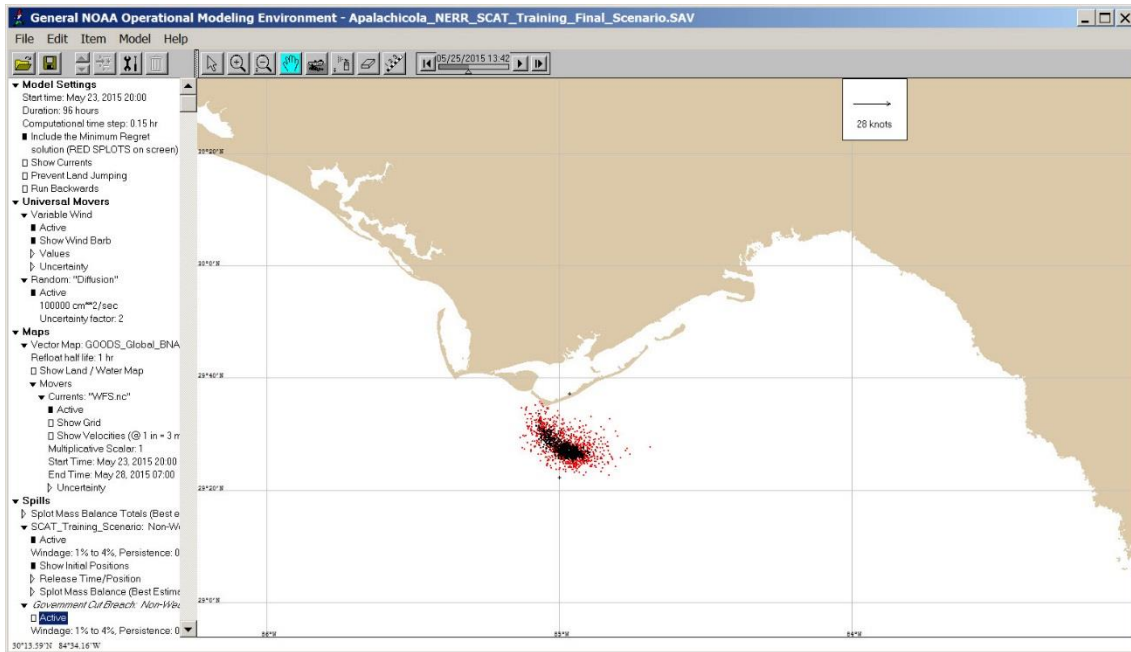


Figure 3-21: GNOME Trajectory Forecast – 2 days

Potential threats to several Apalachicola Bay Tidal Inlets and Apalachicola Bay itself.

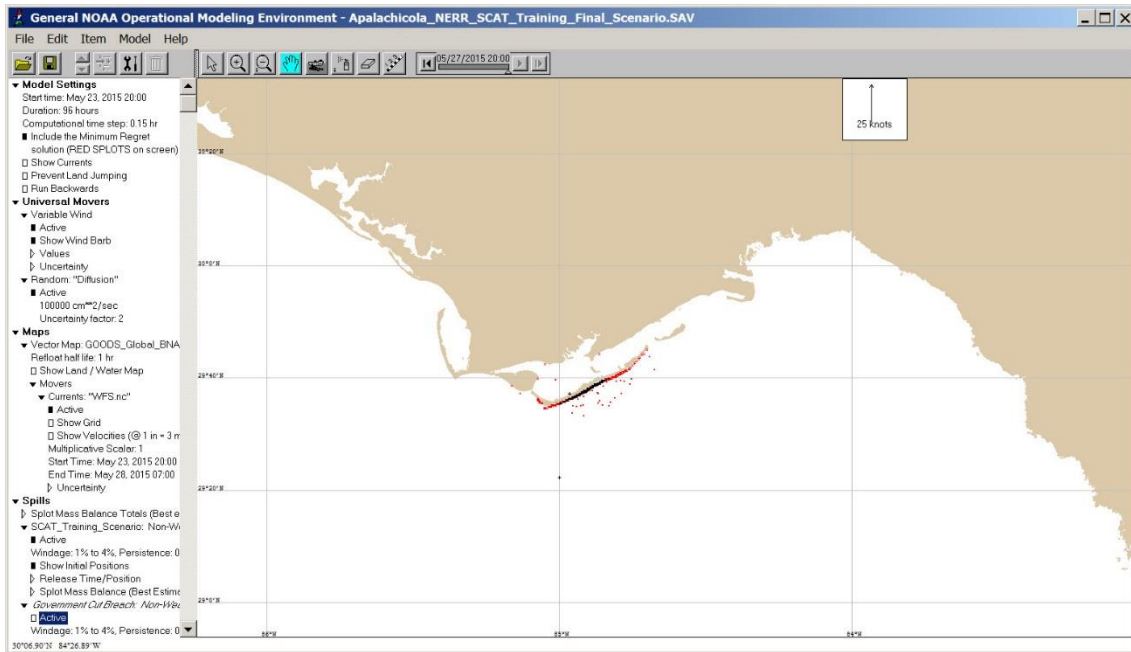


Figure 3-22: GNOME Trajectory Forecast – 4 days

Since Government Cut is not resolved in the model mesh, oil “spots” stop at the beach. This misses capturing potential impacts by passage of oil thru the inlet.

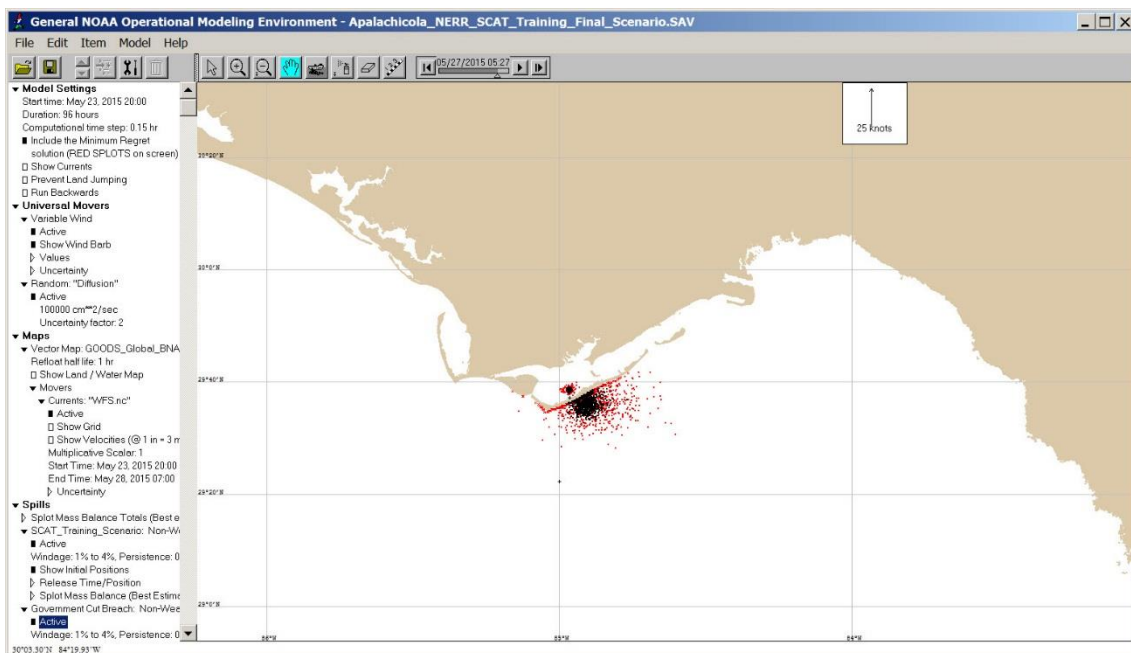


Figure 3-23: GNOME - Government Cut Breach at 3 AM, Model time 0527 hrs

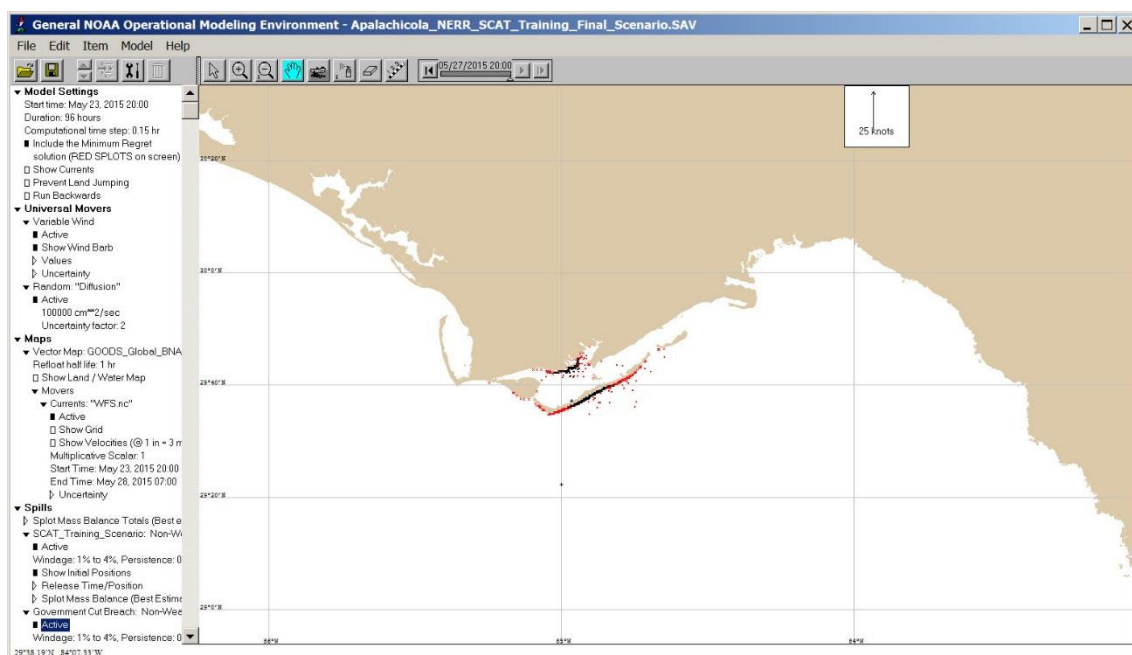


Figure 3-24: GNOME – Government Cut Breach – Full Model Duration – 4 days

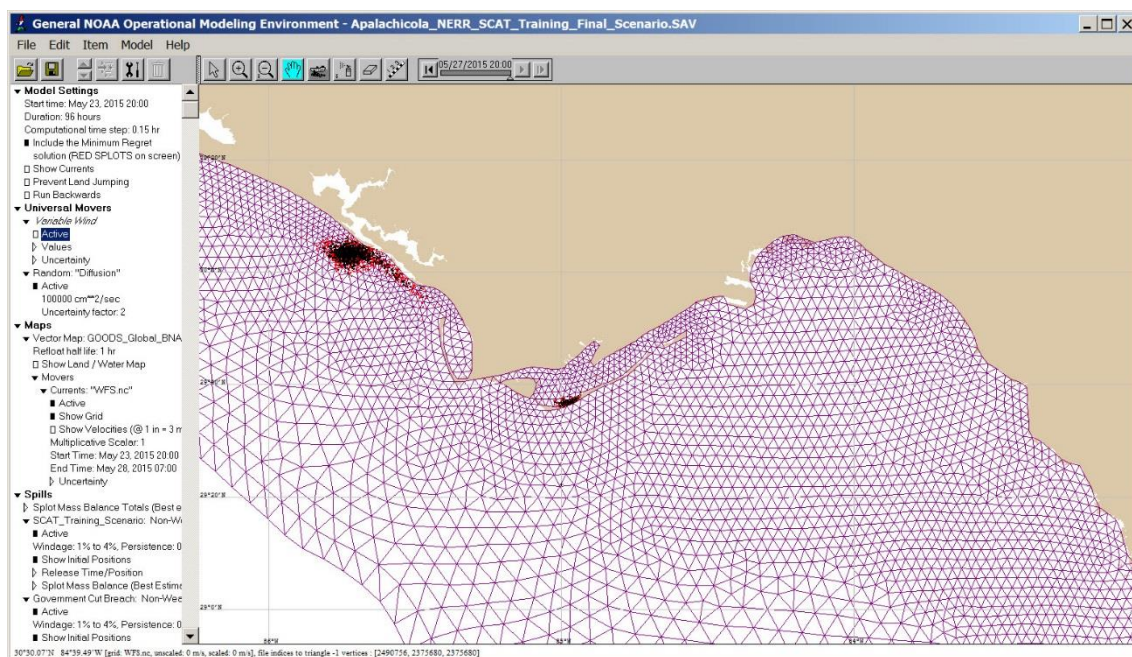


Figure 3-25: GNOME – No Wind Forcing, Model Grid On, Full Forecast Duration – 4 days*

*Note that in Figure 3-24, with no wind forcing, currents carry oil to the west to threaten St Joe Bay Entrance and St Andrew Bay Entrance. Model mesh does not include St Andrew Bay (Panama City, Florida). Leading to an incomplete picture of potential impacts.

3.8.6 Exporting Lagrangian Elements “Splots” (MOSS Format for GIS)

Once the trajectory modeling was completed and the desired outcomes for the purpose where complete, the trajectory “splot files” were exported in 12 hour time steps for a duration of 4 days for import into the GIS as “MOSS” files. This is not the only option available for exporting GIS compatible GNOME trajectory information but was the path taken in this example. (Figure 3-25). The entire model duration generated 46 separate files. As mentioned in the Special Note on Data Interoperability, this function is enabled by a data standard that allows for this to happen and that original data standard was developed following the 1993 Tampa Bay Oil Spill and was authored by two oceanographers with NOAA and two GIS professions with the Florida Marine Research Institute, now known as the Fish and Wildlife Research Institute.

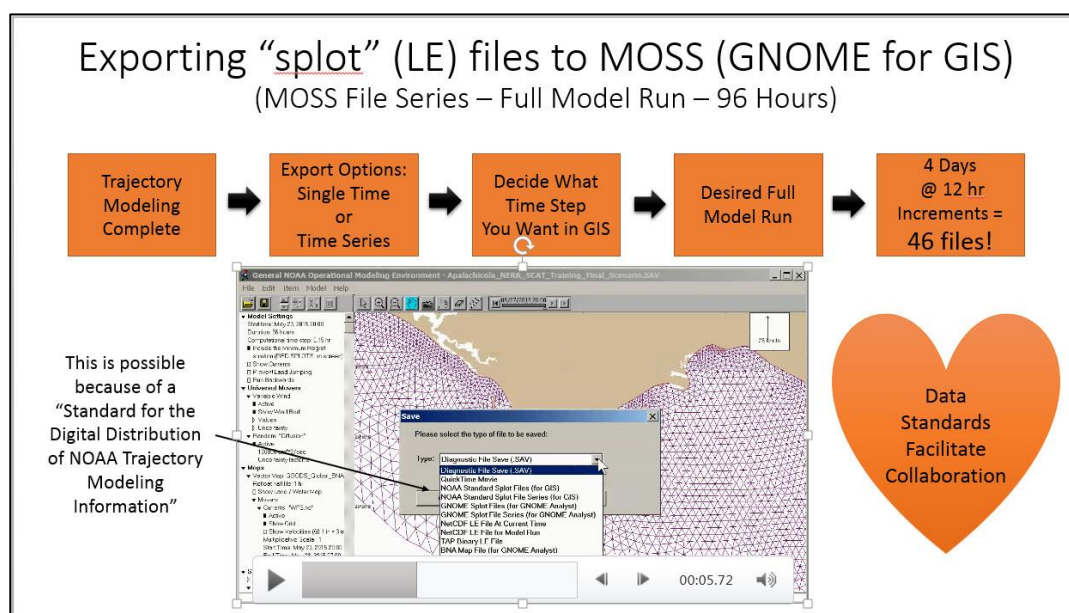


Figure 3-26: Decision-Diagram of Export Process for GNOME “splot” files to MOSS format (GNOME for GIS)

3.8.7 Importing MOSS files to ArcGIS Desktop 10.2.2

Using the “GIS-consumable” MOSS data format, imported the spill trajectory model results into GIS (the Florida Marine Spill Analysis System). This is a very tedious process so a process-steps diagram was drawn up in (Figure 3-26). An outline view of these process steps and key points is provided here. Requires GNOME Trajectory Import Tool (Free and Open Source Software) for ArcMap 10.x

- ii. ArcMap Data Frame must be in Geographic Decimal Degrees (Assumed Geographic)

- iii. Import First Time Step (Hour Zero) – This is the source location with no change or movement (delta) of Lagrangian Elements (splots).
- iv. Two layers of GIS data are generated per time step: “Forecast” and “Uncertainty”. Each time step has the default import name of either “Forecast” or “Uncertainty” and imports with no time designation in the layer name, but “age” is a field in the attribute table, so the end user can always reference there. It is a bit tricky because on import every layer looks the same with the default name and symbology, so the GIS user needs to pay close attention to the time step and order. This author chose to rename each layer by the time step to keep track of the layers.
- v. Within *each layer* of “Forecast” and “Uncertainty”, there are two default *CLASSIFICATIONS* that are used to generate map symbology. “INWATER” and “ONBEACH” which denote whether the “splot” has made it shore or not depending upon where it is in the model mesh.
- vi. On import of each time step (in this case, 12 hours), a new Personal Geodatabase (pGDB or rather file extension .mdb) is created. This corresponds with the MOSS file number.
- vii. The GIS User must keep careful track of layer names and time stamps in order to stay organized and this author found it useful to group layers of both “Forecast” and “Uncertainty” (4 separate classifications, Forecast-INWATER, Forecast-ONBEACH, Uncertainty-INWATER, Uncertainty-ONBEACH) into a GROUP LAYER per time step.
- viii. This 96 hour (4 day) trajectory generated 18 separate GIS layers (Zero hour + two 12 hour time steps per day over four days). The 18 layers were easiest to manage as a nested group layer. The overall process was painful, but worth documenting so that improvements could be made in the future.

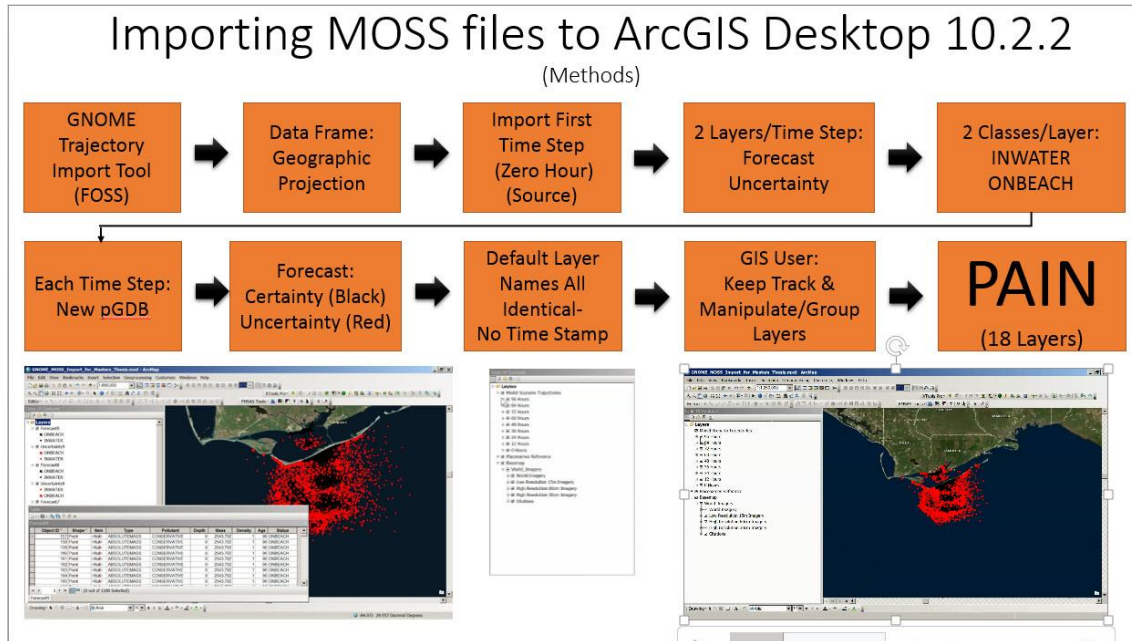


Figure 3-27: Process Diagram of Importing MOSS Files (NOAA Trajectory “spot” Files into a GIS.

3.8.8 Digitizing “Uncertainty Boundary” in FMSAS and RAR

Once the 18 layers of trajectory were imported into GIS, a polygonal representation of them needed to be created so that the polygon could be used for further spatial analysis on “Resources At Risk”. Figure 3.27 shows what this “contouring of the “Uncertainty Boundary” looks like when completed. The Complex Event Manager Tool of the FMSAS allows for rapid digitizing of oil spill response information, including booming strategies, collection and staging points, and multiple varied boundaries. Figure 3-27 shows this rapidly “hand-contoured” boundary. When a boundary is loaded into the FMSAS Complex Event Manager, it becomes available to use as the “cookie-cutter” polygon for drill-down spatial analysis.

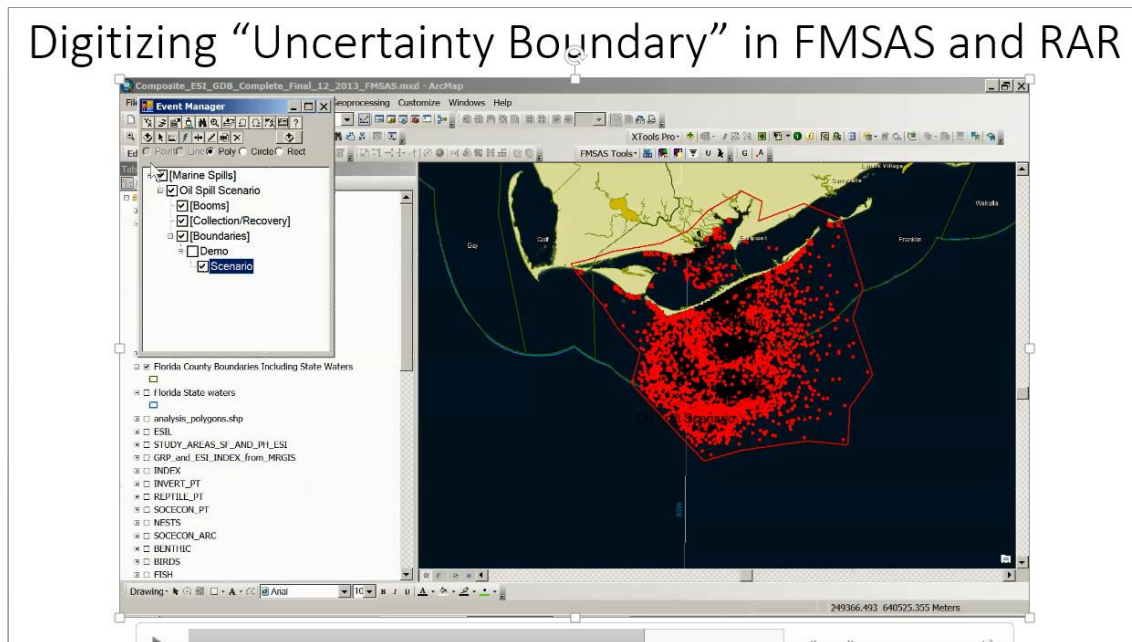


Figure 3-28: Digitizing “Uncertainty Boundary” in FMSAS for “Resources At Risk” drill-down spatial analysis.

The contoured polygon “Model Uncertainty Boundary” was then used to generate a listing of “Resources At Risk” that COULD be impacted by the given spill trajectory scenario. This is to answer the “What’s it going to hit?” question. The benefit of having the tidal inlets mapped and in GIS, is that they become available for this multi-theme, drill down, analysis and reporting as a listed “Resource At Risk”. A High Priority “Resource At Risk”

The hand contouring of the GNOME trajectory was done because a polygon “contoured” shapefile output is not readily available with well documented software tools from NOAA (these tools however, do exist and should be further developed, well documented, and included with other downloadable NOAA GNOME tools), the Lagrangian Elements “splots” had to be “hand contoured” by digitizing a polygon outline representing the outside uncertainty boundary of the trajectory model. This polygon thus represented the total (calculable) area that “could” be impacted by the spill and then became the polygon used for “cookie cutter, multi-layer, drill down spatial analysis and reporting” on the high resolution 2012-2013 Environmental Sensitivity Index (ESI) data for the region to generate a highly detailed “Resources At Risk” analysis and report.

ESI data is a very rich, high resolution, specialized relational geodatabase that can somewhat be termed a “model” of the shorelines, habitats, fish, wildlife, and soci-economic resources most sensitive to spilled oil for a region. The data structure (GIS schemas, tables, 1 to 1, 1 to many, many to 1, and many to many relationships) is designed to collate environmental and soci-economic information into maps and geospatial data so that it may be accessed quickly by oil spill responders tasked with rapid decision making in an actual oil spill situation.

3.8.9 Summary of “Resources At Risk” Analysis from Modeled Trajectory

This detailed report (with counts, lengths, and areas reported in a very detailed manner) was then used to generate “short lists” and maps of the resources potentially impacted by this spill scenario. A summary of this detailed report (Figure 3-28) are within the Discussion section of this paper.

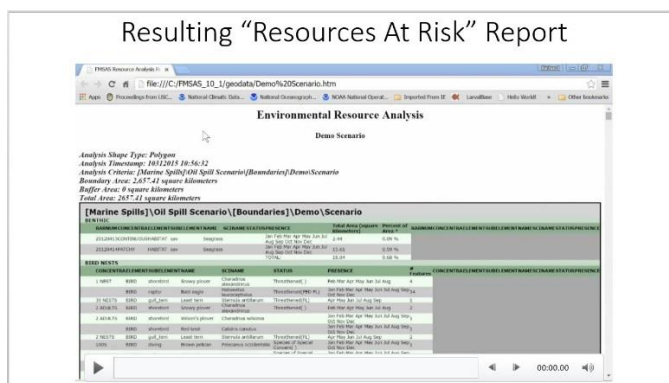


Figure 3-29: Detailed HTML “Resources At Risk” Report

4 DISCUSSION

4.1 Resources At Risk Analysis

With the use of the Florida Marine Spill Analysis System (FMSAS) (see APENDIX 1 for more information), a series of “drill-down” analysis routines were performed (using both the hand contoured polygon from the trajectory and broader envelope polygons covering wider and smaller regions respectively) to elucidate potential resources that could be impacted by this particular trajectory. Then a series of overview map “snapshots” were produced for visualization of these resources. The focus of this analysis was on the key information needed for defining response objectives. Primarily, sensitive shorelines and habitats, special managed areas, threatened and endangered species, fish and wildlife species, and socio-economic and cultural resources. The following series of figures and tables highlight these resources at risk.

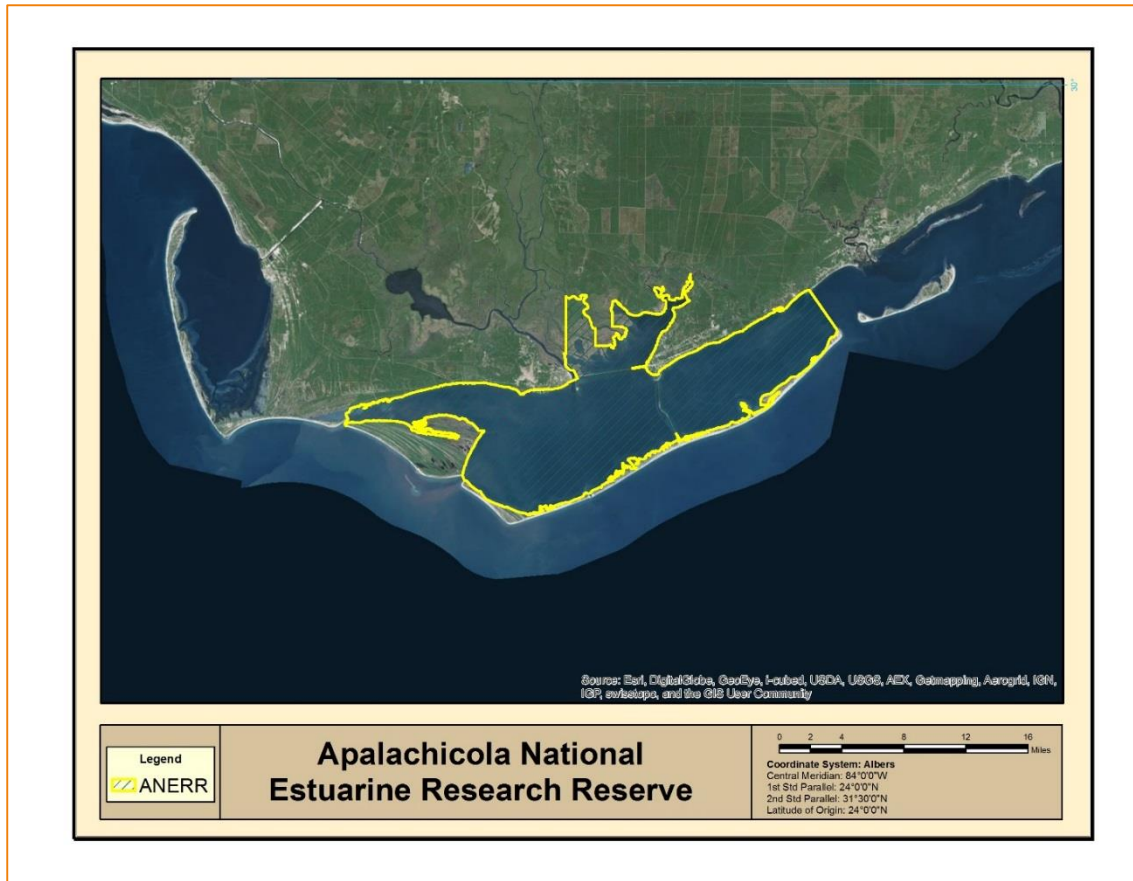


Figure 4-1: Boundaries of Apalachicola National Estuarine Research Reserve

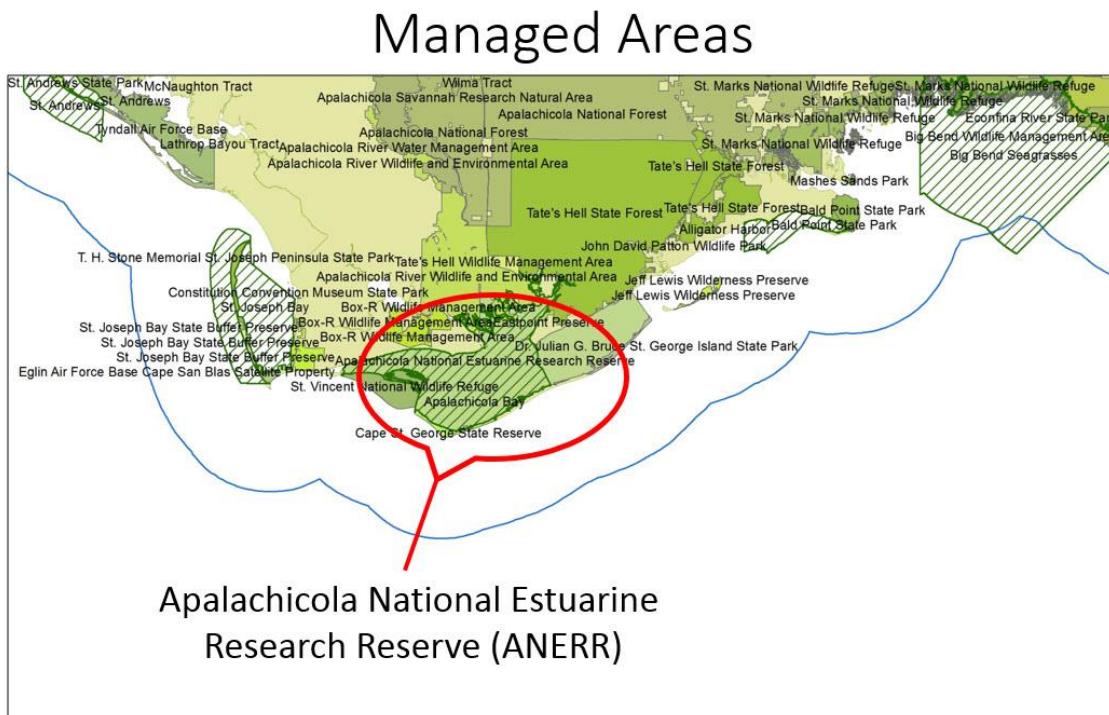


Figure 4-2: ANERR and Surrounding Special Managed Areas

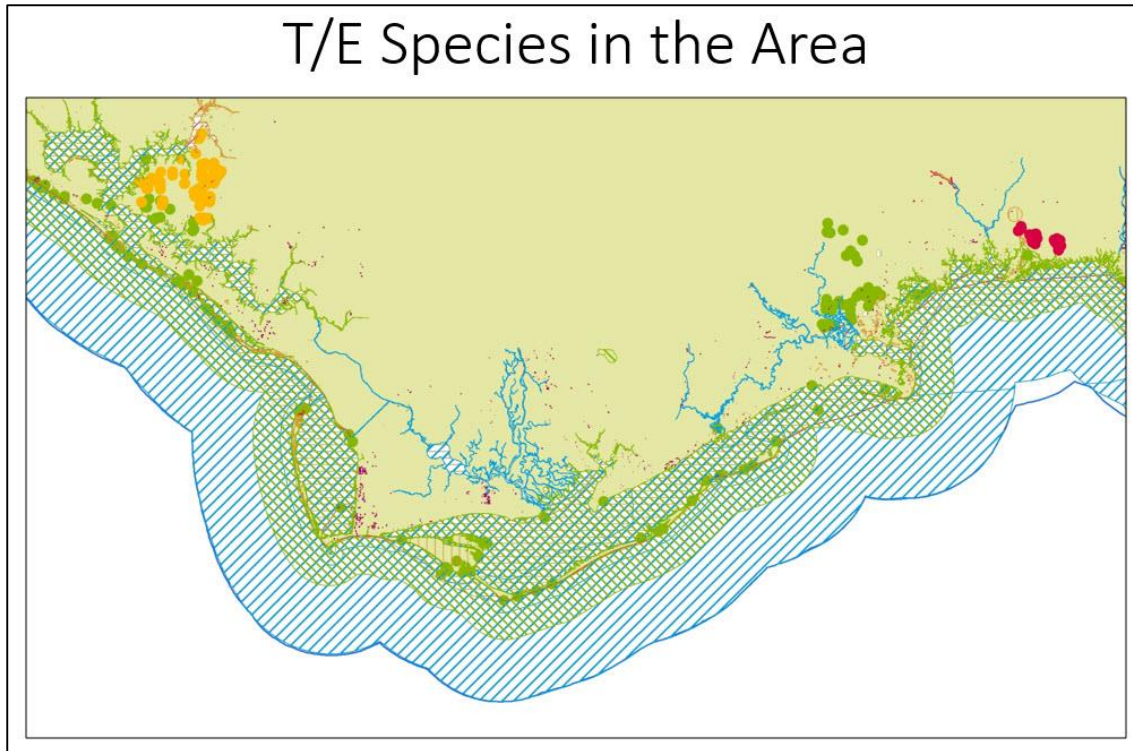


Figure 4-3: Threatened and Endangered Species in the Area of Trajectory Impact

T/E Species in the Area

<ul style="list-style-type: none">• Alabama Shad• American Oystercatcher• Black Skimmer• Bluefin Tuna• Brown Pelican• Gulf Sturgeon• Large Leaved <u>Jointweed</u>• Least Tern• Narrow Leaved <u>Phoebanthus</u>• Night Flowering Wild Petunia• Osprey	<ul style="list-style-type: none">• Pine Woods Aster• Piping Plover• Reddish Egret• Scare Weed• Scotts Seaside Sparrow• Small Flowered <u>Meadowberry</u>• <u>Smalltooth</u> Sawfish• Snowy Plover• <u>Telephus</u> Spurge• Thick Leaved Water Willow• Wild Birds In A Tree• White Top <u>Pitcherplant</u>
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Figure 4-4: Threatened and Endangered Species Listing

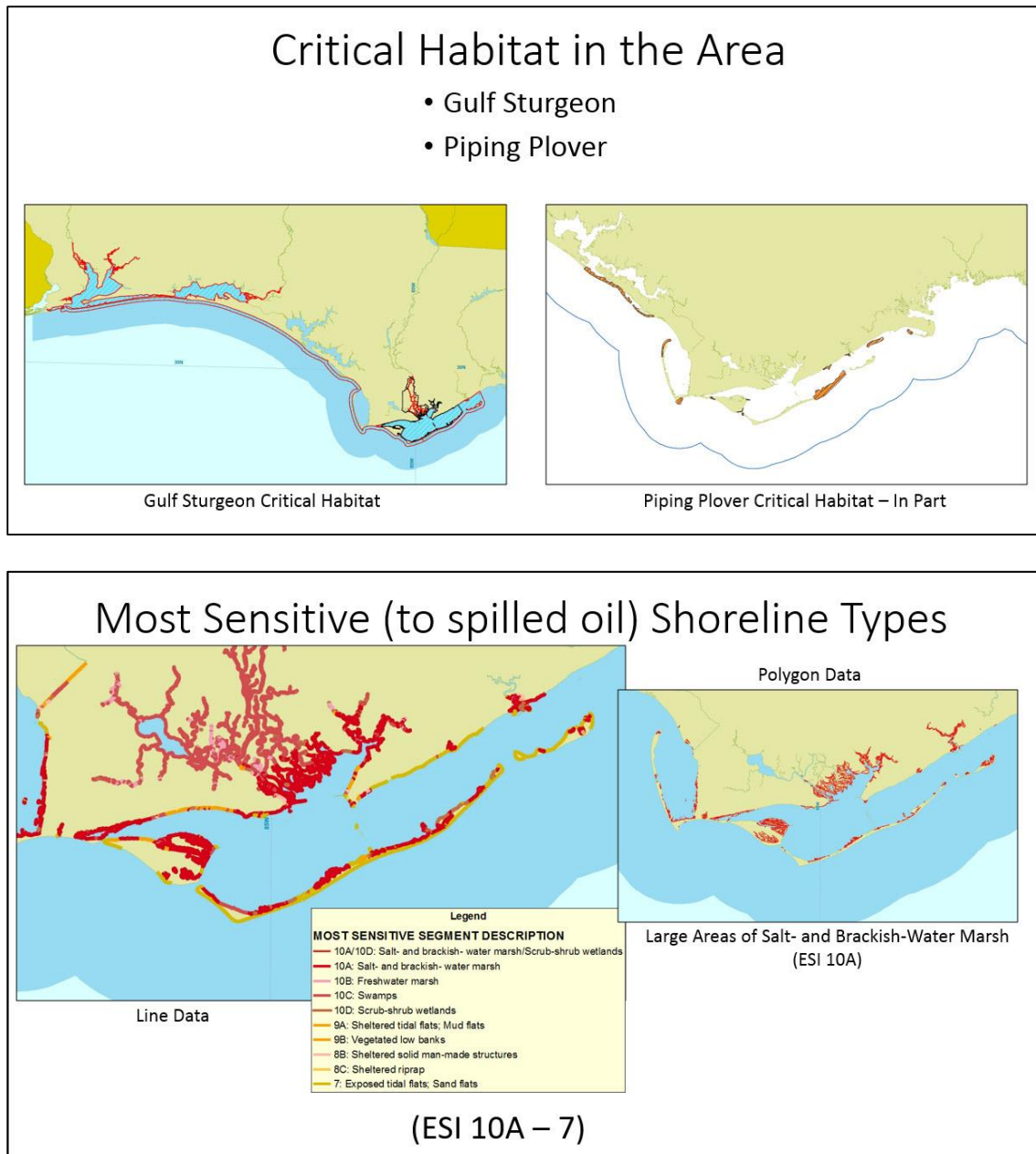


Figure 4-5: Most Sensitive (to spilled oil) Shoreline Types in the region of trajectory Impact

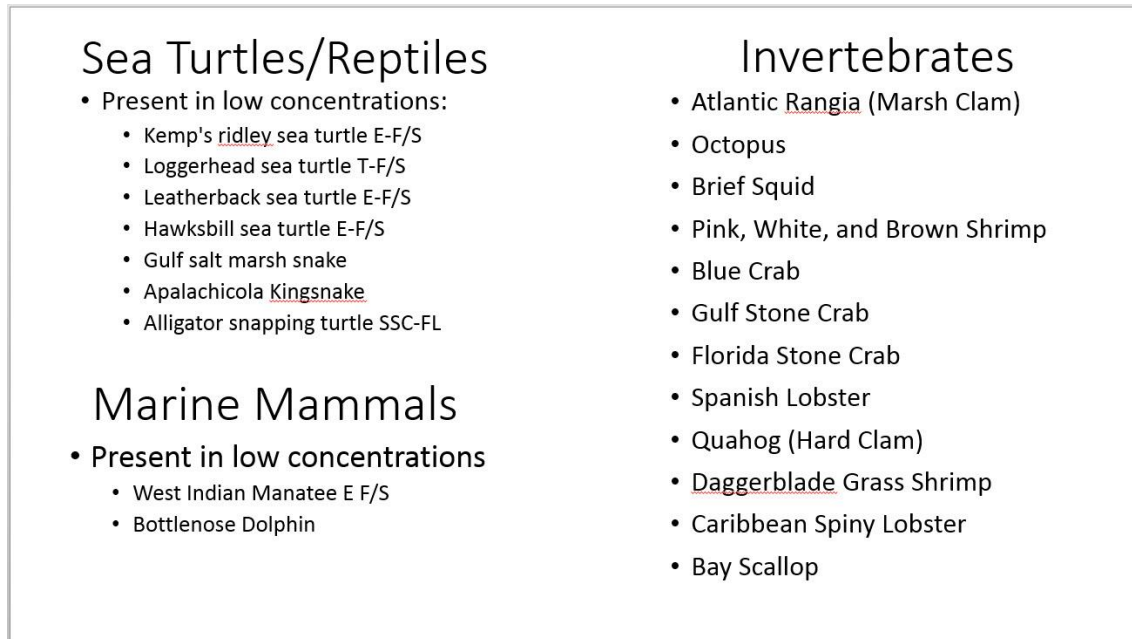


Figure 4-6: Sea Turtles, Marine Mammals, and Invertebrates within the region of trajectory Impact.



Figure 4-7: Fish Species Within the Region of Trajectory Impact

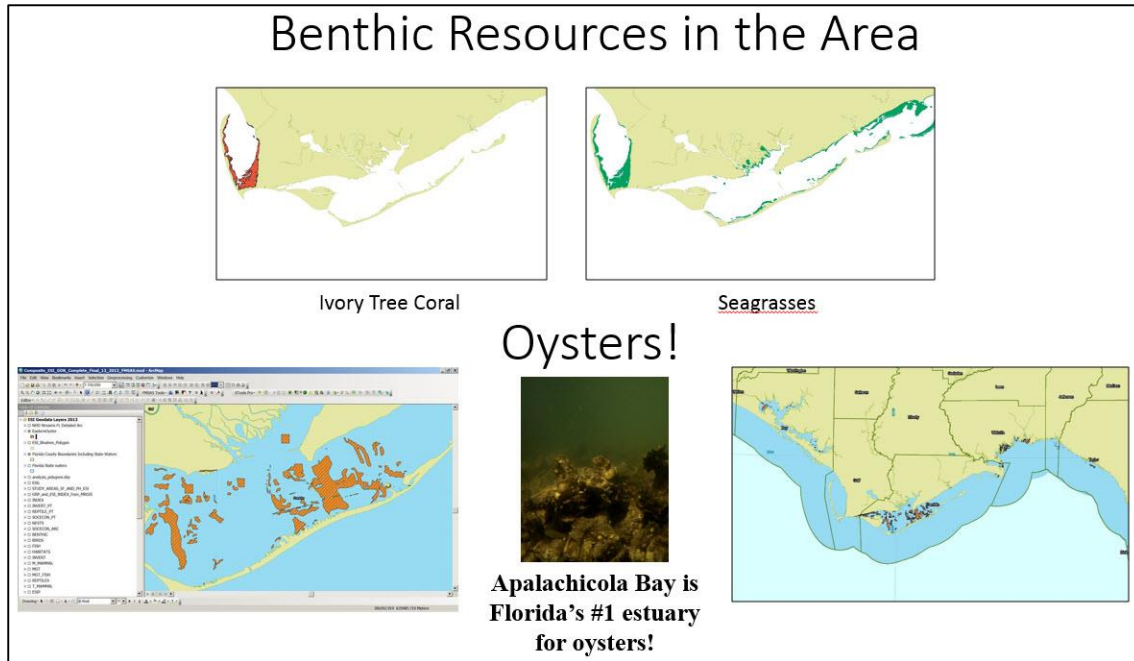


Figure 4-8: Benthic Resources Within the Region of Trajectory Impact

It is particularly important to note that Apalachicola Bay is Florida's number one estuary for the production of oysters, and an inlet breach such as described in this study would have significant impacts on the oyster industry in the region.

5 SUMMARY AND CONCLUSIONS

5.1 Gap Analysis Summary and Conclusions:

This gap analysis research effort has resulted in the creation of a specialized geodatabase for tidal inlet characterization and basic circulation dynamics that has many practical and research applications. This research has populated this geodatabase for the tidal inlets and estuaries behind them for US Coast Guard Sector Mobile, which includes coastal Mississippi, Alabama, and Panhandle Florida, regions impacted by the Deepwater Horizon Oil Spill and a reasonably significant part of the broader Gulf of Mexico. This research has created a new and never before seen “most needed information” aggregate inlet tidal climatology framework dataset for the development of Tidal Inlet Protection Strategies for Oil Spill Response in the Northeastern Gulf of Mexico and potentially other areas. These regions have never before had these before and they will serve as an additional layer of contingency planning protection for this coastline.

The Information Gap Analysis identified that there is a 53% GAP in information regarding readily available data on tidal inlet circulation dynamics - Only 25% are considered well represented. This requires further study to fill this gap. Models may be the answer.

This research developed an Intuitive Map Representation and Generated a 50 Map Atlas that clearly represents flood tide surface current and direction and average tidal range, all information needed in the development of TIPS.

5.2 Modeling to GIS Summary and Conclusions

The Modeling to GIS Integration Study Applied to Apalachicola Bay demonstrated the utility of GNOME in using community ocean models for practical applications like asking “What if?” questions like contingency planning does. This exercise also demonstrated the value of Model-GIS integration in gaining a better picture of the “What’s it going to hit?” question and the vulnerability of and value of protecting tidal inlets, the conveyance points to sensitive

estuaries. Overall, the final conclusion is that the full picture of a scenario becomes clearer when Modeling and GIS work together effectively.

6 APPLICATIONS OF THIS RESEARCH

6.1 Near-Term Applications

The geodatabase and data therein will be used for the development of Tidal Inlet Protection Strategies for Oil Spill Response for US Coast Guard Sector Mobile in their Marine Environmental Protection mission area.

This Geodatabase easily supports mobile device data collection thru a number of different applications (ESRI and other), so further in-situ observer information gathering is supported.

6.2 Broader Applications

This geodatabase CAN potentially serve government, academia, and industry worldwide in mapping and characterizing these dynamic coastal regions for protection. As a database design framework, it is a rather simple effort of technology transfer.

6.3 Future Work

6.3.1 US IOOS “Common Data Model” on THREDDS servers (Sci-WMS, UGRID & SGRID CF-Conventions)

With the fairly recent advent of Open Geospatial Consortium (OGC) standards for the flexible internet distribution of dynamic predictive met-ocean information consumable by modern geographic information systems, particularly web-based systems, a broader framework for the integration of these often disparate data sources with static information contained in geographic response and environmental sensitivity data begins to see the light of day. If organized and presented in meaningful ways, these resources begin to become a powerful and useful interface for contingency planning, response, restoration, and resiliency decision making in the future.

6.3.2 Potential Improved methodologies for model-GIS integration & discovery

It is hoped that the documented challenges in integrating Modeling and GIS will serve as inspiration for improving these methodologies into the future by the adoption and leveraging of the standards that make it possible.

6.3.3 Potential improvements in model resolution and coverage nearshore.

Awareness of models and the mysterious invisible grids that swirl particles around with math, are an intriguing topic for spatially-minded folk. This author believes that bringing awareness of these powerful grids to the GIS community in a cooperative “let’s figure it out together” manner will pay great dividends to both disciplines and more importantly, lead to much better informed management of our planet by increasingly improving resolution and facilitating connectedness in complex systems analysis ecosystem.

6.3.4 Broader Access to Models.

It is hoped that some of the documented challenges of this research may open avenues for new or emerging technologies that allow models and GIS to interact more seamlessly and fluidly, freeing up time for more “real world” problem solving rather than fighting with file types and code. Availability of oil spill trajectory modeling environmental “movers” (currents/tides/winds) is limited and needs to be expanded thru better coordination, funding, and standards-based data sharing systems. In this Scenario-Based Demonstration Project, the only appropriate available model (in a GNOME compatible NetCDF format) was the WFS FVCOM, yet there are grids with higher resolution “out there” but not readily “discoverable”.

6.4 Acknowledgements

The author of this work would like to thank his thesis advisory committee for the wise guidance and learning they have bestowed upon him through the many years of graduate study while employed full-time. Thank you.

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Dr. Barnali Dixon – USF – Co-Major Prof

Dr. Steven Murawski - USF

Dr. Miles O. Hayes – Research Planning Inc.

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Dr. Ed Mathieson

Ms. Beverly Sauls

Mr. George Henderson

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Dr. Richard Signell – USGS

Dr. Robert Weisberg – USF

Dr. Chris Barker – NOAA

Dr. Amy MacFadyen – NOAA

Mr. Vembu Subramanian – SEACOORA

Dr Glen “Bushy” Watabayashi – NOAA

Dr. Patricia “Soupy” Dalyander - USGS

Mr. Cameron Hunt – Metanomy.org

Dr. Ed Owens – Owens Coastal Consulting

Mr. Bradford Benggio – NOAA

Mr. Adam Davis - NOAA

Dr. Arnolfo Valle-Levinson - UF

Dr. Tamay Ozgokmen - UM

Dr. Brian Haus – UM

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1. Excerpts from “President's National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, pages 85 and 86.

“The inescapable conclusion is striking, and profoundly unsettling. Notwithstanding statutory promises of layers of required environmental scrutiny—by NEPA, the Magnuson-Stevens Act, the Outer Continental Shelf Lands Act, and the Oil Pollution Act—and the potential application of some of the nation’s toughest environmental restrictions—the Endangered Species Act and Clean Water Act—none of these laws resulted in site-specific review of the drilling operations of the Macondo well. The agency in charge, MMS, lacked the resources and committed agency culture to do so, and none of the other federal agencies with relevant environmental expertise had adequate resources or sufficient statutory authority to make sure the resulting gap in attention to environmental protection concerns was filled.”

Federal oversight of oil and gas activities in the Gulf of Mexico—almost the only area where substantial amounts of drilling were taking place—took a generally minimalist approach in the years leading up to the Macondo explosion. The national government failed to exercise the full scope of its power, grounded both in its role as owner of the natural resources to be developed and in its role as sovereign and responsible for ensuring the safety of drilling operations. Many aspects of national environmental law were ignored, resulting in less oversight than would have applied in other areas of the country. In addition, MMS lacked the resources and technical expertise, beginning with its leadership, to require rigorous standards of safety in the risky deepwater and had fallen behind other countries in its ability to move beyond a prescription and inspection system to one that would be based on more sophisticated risk analysis.

In short, the safety risks had dramatically increased with the shift to the Gulf’s deepwaters, but Presidents, members of Congress, and agency leadership had become preoccupied for decades with the enormous revenues generated by such drilling rather than focused on ensuring its safety. With the benefit of hindsight,

the only question had become not whether an accident would happen, but when. On April 20, 2010, that question was answered.”

Command and Control of “Boots on the Ground and Boats in the Water

At the outset of the response (April 29-May1, 2010) there was immediate conflict between an understanding of the law with regards to the National Contingency Plan as outlined by the Oil Pollution Act of 1990 and the Stafford Act, federal legislation designed to bring orderly federal assistance to state and local governments in carrying out their responsibilities to aid citizens. The following extract from the President’s report (pp. 138-139, Jan. 2011) highlights that conflict:

“State and local officials chafed under federal control of the response. Louisiana Governor Bobby Jindal’s advisors reportedly spent days trying to determine whether the Stafford Act or the National Contingency Plan applied.⁵⁷ On April 29, Governor Jindal declared a state of emergency in Louisiana, authorizing the director of the Governor’s Office of Homeland

Security and Emergency Preparedness to undertake any legal activities deemed necessary to respond and to begin coordinating state response efforts.⁵⁸ These efforts took place outside of the Unified Command framework. The Governors of Mississippi, Alabama, and Florida

followed suit, declaring states of emergency the next day.⁵⁹ At the outset of the spill, the pre-designated State On-Scene Coordinators for Louisiana, Alabama, and Mississippi participated in Unified Command.⁶⁰ These individuals were career oil-spill responders: familiar with the National Contingency Plan, experienced in responding to spills, and accustomed to working with the Coast Guard. Some had participated in the 2002 spill exercise run by Admiral Allen. They shared the Coast Guard’s view that the responsible party is an important ally, not an adversary, in responding to a spill. During this spill, however, the Governors and other state political officials participated in the response in unprecedented ways, taking decisions out of the hands of career oil-spill

responders. These high-level state officials were much less familiar with spill-response planning. In addition to the National Contingency Plan, each Coast Guard sector is an

“Area” with an Area Contingency Plan created by relevant state and federal agencies. When confronted with a contingency plan setting out how the federal and state governments were supposed to run an oil-spill response, one high-level state official told a Coast Guard responder that he never signed it. According to the Coast Guard officer, the state official

was not questioning whether his signature appeared on the document, but asserting that he had not substantively reviewed the plan.⁶¹ State and local officials largely rejected the pre-spill plans and began to create their own response structures. Because the majority of the oil would come ashore in Louisiana, these issues of control mattered most there. Louisiana declined to empower the officials that it sent to work with federal responders within Unified Command, instead requiring most decisions to go through the Governor’s office. For example, the Louisiana representative at Unified Area Command could not approve the daily agenda of response activities.⁶² Responders worked around this problem, but it complicated operations.

Local officials were even less familiar with oil-spill planning, though they had robust experience with other emergencies. Under Louisiana law, Parish Presidents exercise substantial authority—mirroring that of the Governor—during hurricanes and other natural disasters.⁶³ The parishes wanted to assert that same control during the spill, and many used money distributed by BP to purchase their own equipment and establish their own operating centers outside of Unified Command. Eventually, the Coast Guard assigned a liaison officer to each Parish President, who attempted to improve relationships with the parishes by providing information and reporting back to Unified Command on local needs.”

Despite the political conflicts, the core mission of the response was to stop the oil, remove it from the environment, and ensure protection of coastal resources, including shorelines and estuaries. Given the size and scope of the DWHOS, this is a simplistic assessment, however, it should be noted that this was a common goal of all parties to the response. Extensive efforts were made to ensure that protective measures were enlisted everywhere that was at risk, and in many cases, even in places that were not at risk for fear that they would be. This was particularly true in the deployment of oil spill boom for shoreline protection.

Approximately 2,469 statute miles of oil spill response boom categorized into two GENERAL types, Containment (approximately 719 statute miles) and Sorbent (approximately 1,750 statute miles) were deployed into the Gulf of Mexico during the DWHOS response and it was very difficult to keep track of from a Common Operational Picture (COP) GEOSPATIAL Command and Control perspective. It was for this problem that the author conducted a smaller research effort to try to determine the total length of boom deployed across the Gulf of Mexico and it was found that the Federal On-Scene Coordinator's Report, Appendix 1 – Timeline of Events (USCG & RRT 2011) was the authoritative source from which to find this information, and this research is summarized with references in Table 1 – Cumulative Summary of Boom and Skimmers Deployed During the DWHOS Event.

Table 1 – Cumulative Summary of Boom and Skimmers Deployed During the DWHOS Event.

Cumulative or Daily?	Date/Days into incident	Containment Boom Deployed (FEET)	Sorbent Boom Deployed (FEET)	Skimmers	FOSC Report Reference	Additional Notes
Cumulative	May 1, 2010 - Day 12	420280			p. 204	
Cumulative	May 15, 2010 - Day 26	1294910	441620	32	p. 206	

Cumulative	May 23, 2010 - Day 34	1750000	997000		p. 207	
Cumulative	June 1, 2010 - Day 43	2002946	219243 0	120	p. 208	
Cumulative	June 15, 2010 - Day 57	2543745	347901 7	136	p. 209- 210	
Cumulative	July 1, 2010 - Day 73	3017472	495473 5	550	p. 211	
Cumulative Table	July 15, 2015 - Day 87	3505921	350592 1	588	p. 212	
Reported	July 21, 2010 - Day 93 - Reported Pinnacle for Containment Boom	3795985			P. 212	Highest Containment Boom Cumulative Total: 3,795,985 ft. (718.93 Statute Miles)
Cumulative Table	July 25, 2010 - Day 97	3710430	781565 6	794	p. 212- 213	
Cumulative Table	August 1, 2010 - Day 104	3646640	803203 6	831	p. 213	
Reported	August 2, 2010 - Day 105 - Reported Pinnacle for Skimmers			835	p. 213	Highest count for deployed skimmers: 835
Cumulative Table	August 15, 2010 - Day 118	2586653	877008 6	835	p.214	

Cumulative Table	September 1, 2010 - Day 135	1755528	9239365	835	p. 215	Highest Sorbent Boom Cumulative Total: 9,239,365 ft. (1749.88 Statute Miles)
Reported	September 7, 2010 - Day 141				p. 216	Aerial observations confirm all containment boom is removed from Alabama, Florida, and Mississippi.
Cumulative Table	September 15, 2010 - Day 149	690638	3437885	835	p. 216	
Cumulative Table	October 1, 2010 - Day 165	23020	389010	835	p. 217	
Reported	October 8, 2010 - Day 172 - Reported Pinnacle for Sorbent Boom - HIGHLY QUESTIONABLE!		566140		p. 217	566,140 feet is HIGHLY QUESTIONABLE as the REPORTED APPEX VALUE for deployed sorbent boom, because 9,239,365 ft. (1749.88

						Statute Miles) was reported in a cumulative table on Sept 1 - Day 135 (37 days earlier).
Reported	October 14, 2010 - Day 178				p. 218	Approximately 33 HESCO Baskets are installed at Perdido Pass East in Alabama.
Daily Table	October 15, 2010 - Day 179			25	p. 218	
Daily Table	November 1, 2010 - Day 196			19	p. 219	
Daily Table	November 9, 2010 - Day 204				p. 220	Responders sign the Environmental Unit Plan to remove all sentinel snares by November 24, 2010.
Daily Table	November 15, 2010 - Day 210			7	p. 220	

Daily Table	November 20, 2010 - Day 215				p. 220	Snare sentinel removal begins
Reported	November 28, 2010 - Day 223				p. 220	Cameron Parish, LA, Hesco Basket Removal Project completes (3, 960 baskets or 59,400 feet of shoreline barrier removed). The contractor expects completion of demobilization activities by November 30, 2010.
Daily Table	December 1, 2010 - Day 226			2	p. 220	

As can be seen in table 1, there were certain discrepancies in reporting pinnacle totals and given the difficulty of keeping track of boom, this is not a surprising finding. During the response, boom was tracked in a number of ways, including remote sensing and field data collection devices and map services, but staying on top of the rapidly changing situation was very difficult. Boom was tracked and traced at many stages on its delivery from warehouse or factory to staging location, and then finally into the water and numerous entities were trying to keep track of it at each stage, to varying degrees of success (and information sharing). This fact is another consideration that must be examined for any future responses. How can new technologies be implemented to keep track of oil spill boom deployed into the

environment? Booming technologies of the DWHOS have been compared to the rotary dial telephone in relation to today's internet connected smartphones and have not significantly evolved in over 40 years (United States. Congress. House. June 15, 2010, [YouTube Video 3:51:00](#)). This discussion will need to occur between federal, state, and local regulators (including technical and scientific support staff and perhaps academia) and oil removal organizations (OSROs) and other industry entities charged with deploying shoreline protection measures. Perhaps there is a place for AIS-based tracking and identification of oil spill boom in the environment? The following paragraph from the President's report (Chapter 5, pp. 132-133, Jan. 2011) explain some of the shortfalls experienced by not keeping pace with emerging technologies in oil spill response.

“Although the National Contingency Plan requires the Coast Guard to supervise an oil-spill response in coastal waters, it does not envision that the Coast Guard will provide all, or even most, of the response equipment. That role is filled by private oil-spill removal organizations (OSROs) which contract with the oil companies that are required to demonstrate response capacity. BP's main oil-spill removal organization in the Gulf is the Marine Spill Response Corporation, a nonprofit created by industry after the Exxon Valdez disaster to respond to oil spills. The Marine Spill Response Corporation dispatched four skimmers within hours of the explosion.²⁰ BP's oil-spill response plan for the Gulf of Mexico claimed that response vessels provided by the Marine Spill Response Corporation and other private oil-spill removal organizations could recover nearly 500,000 barrels of oil per day.²¹ Despite these claims, the oil-spill removal organizations were quickly outmatched. While production technology had made great advances since Exxon Valdez (see Chapter 2), spill response technology had not. The Oil Pollution Act of 1990, by requiring double hulls in oil tankers, had effectively reduced tanker spills.²² But it did not provide incentives for industry or guaranteed funding for federal agencies to conduct research on oil-spill response. Though incremental improvements in skimming and boom had been realized in the intervening 21 years, the technologies used in response to the Deepwater Horizon and Exxon Valdez oil spills were largely the same.²³”

2. Excerpts from the Deepwater Horizon Federal On-Scene Coordinator's Report

Additionally, from the On-Scene Coordinator Report: Deepwater Horizon Oil Spill, Submitted to the National Response Team September 2011 - Executive Summary – Shoreline Protection (p. viii):

“Protecting the shorelines of the impacted states was a critical part of the response operation. Containment boom was another critical resource. The desire of state and local governments to obtain and deploy boom led to negotiations of booming plans in the midst of the response. Generally, Area Contingency Plans identify sensitive areas and habitats for booming. The negotiations process brought beaches used by the public within the scope of areas that had to be boomed. Many other protection strategies were used, including piling projects, water filled boom lined on the shore, and Hesco Baskets filled with sand. Louisiana also obtained funding from the RP at FOSC direction and permitting approval from the Army Corps of Engineers, to build sand berms along barrier islands, at an estimated cost of \$360 million dollars. Alabama also obtained funding for smaller berm projects including a barrier for Katrina cut.”

It should also be mentioned that Alabama received funding from the RP to build a sheet piling structure in Perdido Pass to prevent the entrance of oil into Perdido Bay at an estimated cost of \$3.5 million dollars (personal experience in the DWHOS response). Perdido Bay is an estuary on the border between Alabama and Florida where the state line runs right up the centerline of the bay. Very little information on the tidal inlet circulation dynamics of this pass and estuary exists, even to this day, and none that take into account the exterior jetty system. ((USGS) Dalyander, North, Plant (2015), (USF) Weisberg, Luther, Meyer (2015), (NOAA) Barker, MacFadyen (2015), (FSU) Morey (2013) -personal discussions). This pattern is mirrored across many Northeastern Gulf of Mexico estuaries with some notable exceptions, which will be discussed in depth later. Given another similar incident and the millions of dollars spent on protection, would it not make sense to invest in a better

understanding of the geomorphology and circulation dynamics, if for nothing more than contingency planning purposes? It is however, **these very same efforts** in understanding baseline met-ocean and other environmental conditions that pay numerous dividends in the long term sustainability and resilience of the Gulf of Mexico, even in the face of growing mineral extraction.

Planning Frameworks in a Digital World

As the following narrative from the President's report (Jan. 2011, pages xx-xx) highlight, in the years preceding the DWHOS, contingency planning was a matter of "going through the motions" to produce plans that met regulatory requirements but that were completely inadequate for the needs of an actual response. The position taken by this author is that contingency plans, and particularly geospatial information generated in the contingency planning process should be an inherent part of the response plan itself so that it may be easily recycled into and implemented in support of response management efforts themselves. This can best be characterized as "Technology Contingency Planning" whereby the technologies (including models and interoperability) used in contingency and response are taken into account as an inherent part of the contingency plan itself, and funded appropriately.

"If BP's response capacity was underwhelming, some aspects of its response plan were embarrassing. In the plan, BP had named Peter Lutz as a wildlife expert on whom it would rely; he had died several years before BP submitted its plan. BP listed seals and walruses as two species of concern in case of an oil spill in the Gulf; these species never see Gulf waters. And a link in the plan that purported to go to the Marine Spill Response Corporation website actually led to a Japanese entertainment site.²⁴ (Congressional investigation revealed that the response plans submitted to MMS by ExxonMobil, Chevron, ConocoPhillips, and Shell were almost identical to BP's—they too suggested impressive but unrealistic response capacity and three included the embarrassing reference to walruses.²⁵ (See Chapter 3 for more discussion of these plans.)

By April 25, responders had started to realize that the estimated spill volume of 1,000 barrels per day might be inaccurate. Dispersants applied to break up the surface slick were not having the anticipated effect. Either the dispersants were inexplicably not working, or the amount of oil was greater than previously suspected. Between April 26 and April 28, BP personnel within Unified Command reportedly said that they thought 1,000 to 6,000 barrels were leaking each day.²⁶ To alert government leadership that the spill could be larger than 1,000 barrels per day, a NOAA scientist created a one-page report on April 26 estimating the flow rate at roughly

5,000 barrels per day. He based this estimate on other responders' visual observations of the speed with which oil was leaking from the end of the riser, as well as the size and color of the oil slick on the Gulf's surface.²⁷ Both methodologies, the scientist recognized, were highly imprecise: he relied on rough guesses, for example, of the velocity of the oil as it

left the riser and the thickness of the surface slick. He told a NOAA colleague in Unified Command that the flow could be 5,000 to 10,000 barrels per day.²⁸ At a press conference on April 28, Admiral Landry stated, "NOAA experts believe the output could be as much as 5,000 barrels" (emphasis added).²⁹ Although it represented a five-fold increase over the then-current figure, 5,000 barrels per day was a back-of-the-envelope estimate, and Unified Command did not explain how NOAA calculated it. Nevertheless, for the next four weeks, it remained the official government estimate of the spill size."

It should be noted that years later, the final release estimates totaled nearly 56,000 barrels of oil per day, a number over ten times greater than early estimates, yet still smaller than many worst-case discharge release volumes for other deepwater drilling activities currently underway in the Gulf of Mexico. (review of BOEM/BSEE Oil Spill Response Plans (OSRPs) conducted by the author).

The Response Ramps Up (April 29–May 1)

At the peak of the response, more than 45,000 people participated.³⁰ In addition to deploying active-duty members to the Gulf, the Coast Guard called up reservists. Some 1,100 Louisiana National Guard troops served under the direction of Unified Command.³¹ The Environmental Protection Agency (EPA), NOAA, and other federal agencies shifted hundreds of responders to the region. Consistent with the Unified Command framework, BP played a major role from the outset. Most Coast Guard responders had a BP counterpart. For instance, Doug Suttles, BP's Chief Operating Officer of Exploration and Production, was the counterpart to the Federal On-Scene Coordinator. BP employees were scattered through the command structure, in roles ranging from waste management to environmental assessment. Sometimes, a BP employee supervised Coast Guard or other federal responders. The preference under the National Contingency Plan is for the Federal On-Scene Coordinator to supervise response activities while the responsible party conducts—and funds—them. When a spill “results in a substantial threat to public health or welfare of the United States,” the Plan requires the Federal On-Scene Coordinator to direct all response efforts.³² The Coast Guard also has the option to “federalize” the spill—conducting and funding all aspects of the response through the Oil Spill Liability Trust Fund, and later seeking reimbursement from the responsible party.³³ But in most spills, especially when the responsible party has deep pockets and is willing to carry out response activities, federalizing is not preferred. Coast Guard leaders, shaped by their experience implementing the National Contingency Plan through a unified command system, viewed the responsible party as a co-combatant in the fight against the oil. From their perspective, BP took its role as responsible party seriously and had an open checkbook for response costs. That did not mean BP was happy to pay. Tony Hayward, the Chief Executive Officer of BP, reportedly asked board members, “What the hell did we do to deserve this?”³⁴ Though willing to fund and carry out the response, BP had no available, tested technique to stop a deepwater blowout other than the lengthy process of drilling a relief well. Forty years earlier, the government had recognized the need for subsea containment technology. In 1969, following the Santa Barbara*

Channel spill, the Nixon administration had issued a report recommending, in part, that “[u]nderwater methods to collect oil from subsea leaks should be developed.”³⁵ For deepwater wells, however, such development had never occurred. Within a week of the explosion, BP embarked on what would become a massive effort to generate containment options, either by adapting shallow-water technology to the deepwater environment, or by designing entirely new devices. Different teams at BP’s Houston headquarters focused on different ways either to stop the flow of oil or to collect it at the source. Each team had what amounted to a blank check. As one contractor put it, “Whatever you needed, you got it. If you needed something from a machine shop and you couldn’t jump in line, you bought the machine shop.”³⁶

While the Coast Guard oversaw the response at the surface, MMS primarily oversaw source-control operations. BP would draft detailed procedures describing an operation it wished to perform around the wellhead. MMS and Coast Guard officials in Houston participated in the drafting process to help identify and mitigate hazards, including risks to worker safety. At Unified Area Command, Lars Herbst, MMS Gulf of Mexico Regional Director, or his deputy, Mike Saucier, would review and approve the procedures, before the Federal On-Scene Coordinator gave the final go-ahead. This hierarchy of approvals remained in place throughout the containment effort. MMS was the sole government agency charged with understanding deepwater wells and related technology, such as BOPs. But its supervision of the containment effort was limited, in line with its role in overseeing deepwater drilling more generally. Its staff did not attempt to dictate whether BP should perform an operation, determine whether it had

a significant likelihood of success, or suggest consideration of other options. This limited role stemmed in part from a lack of resources. At most, MMS had four to five employees in Houston trying to oversee BP’s efforts. One employee described his experience as akin to standing in a hurricane. Interviews of MMS staff members involved in the containment effort also suggest that the agency did not view itself as capable of, or responsible for, providing more substantive oversight. One MMS employee asserted that BP, and industry more broadly,

possessed 10 times the expertise that MMS could bring to bear on the complex problem of deepwater spill containment. Another pointed out that MMS had trouble attracting the most talented personnel, who are more likely to work in industry where salaries are higher. A third MMS employee stated that he could count on one hand the people from the agency whom he would trust to make key decisions in an effort of this magnitude. Perhaps most revealingly, two different MMS employees separately recalled being asked—one by Secretary Salazar, and the other by Assistant Secretary Tom Strickland—what they would do if the U.S. government took over the containment effort. Both said they would hire BP or another major oil company.”

3. Summary on The Florida Commission on Oil Spill Response Coordination

Following the DWHOS event, the Florida Commission on Oil Spill Response Coordination (FLCOOSRC) was established through Senate Bill 2156 during the 2011 Legislative Session, and was sponsored by Senator Don Gaetz, R. Niceville. The bill specifies the composition of the commission, and charged them to prepare a report to identify any potential changes to state and federal laws and regulations which would improve response capabilities and processes and protect Florida’s people and resources. The report was presented to the Governor and Legislature on January 1, 2013. In this final report, a series of 14 recommendations were made for the Governor and State Legislature to act upon. The final report and three background reports can be found online at:

<https://www.dep.state.fl.us/deepwaterhorizon/commission.htm>

The Commission consisted of:

- A representative of the office of each Board member (Board of Trustees of the Internal Improvement Trust Fund, (aka the Governor’s cabinet)
- A representative of each state agency that directly and materially responded to the Deepwater Horizon disaster

- The chair of the board of county commissioners from each of the following counties:
 - Bay, Escambia, Franklin, Gulf, Okaloosa, Santa Rosa, Walton, and Wakulla Counties (FL Panhandle coastal counties)
- Governor selected the chair from appointees

The Commission was required to prepare a report that identifies potential changes to state and federal laws and regulations which will improve response capabilities and processes, and protect Florida's people and resources. The Board of Trustees delivered the report to:

- The Governor
- The President of the Senate
- The Speaker of the House of Representatives
- The Secretary of the Department of Environmental Protection
- The Executive Director of the Department of Economic Opportunity

The commission's charge was to produce the Final Report

- Topics ID'd by legislation were researched by Tetra Tech (Contacted to organize and facilitate the meetings and write the reports)
- Members of the Commission were to:
 - Identify key information sources (people & documents)
 - Discuss research reports and findings
 - Review proposed/draft recommendations
 - Approve final recommendations for Final Report
- Decisions were made as follows:
 - Minor decisions – meeting topics, conference calls, meeting invitees, presenters at meetings, draft recommendations, etc. to be made by consensus (“decisions we can live with”)

- Major decisions – recommendations for the Final Report will be made by formal action (motion, second, vote)

These were the overarching goals of the commission:

1. Identify changes to state and federal laws and regulations which will:
 - Improve oversight and monitoring of offshore drilling activities,
 - Increase response capabilities to offshore oil spills, and
 - Improve protections for the public and occupational health and safety, and the environment & natural resources
2. Evaluate the merits of the establishment of a federal **Gulf-wide disaster fund**.
3. Evaluate the need for unified and uniform **advocacy process for damage claims**
4. Evaluate the need for changes to **interstate coordination agreements** in order to reduce the potential for damage claims and lawsuits.
5. Address any other related issues as determined by the Commission.

In addition to the final report, there were three supporting reports created by the commission:

1. An overview of Federal and State Laws regarding oil spill response
2. A summary of Lessons Learned from the DWHOS.
3. An analysis of how well the Incident Command System worked with some comparisons to Stafford Act responses under the National Response Framework and Emergency Support Functions. The conclusion was that something somewhere in the middle of a top down to bottom up structure and procedure was needed to fully engage all available resources toward an effective response. Additionally, that TRAINING for appropriate personnel was critical moving forward.

The 14 Key Final Recommendations were:

#1 - Several Florida agencies currently monitor oil drilling and well production activities from different perspectives and have mechanisms in place to alert state and local officials if a spill occurs. Current Florida laws, regulations, and agency practices regarding oversight and monitoring of offshore drilling appear to be adequate and do not require any changes at this time. (Section 2.1, page 11)

#2 - The Commission strongly recommends that Florida reside within a single USCG district. At a minimum, USCG Districts 7 and 8 should:

- (a) achieve consistency in their general oil spill preparations and their SONS (Spills of National Significance) policies, procedures, and protocols regarding Florida oil spill contingency plans, preparedness activities (e.g., drills and exercises), Incident Command System deployment and operation, communication methods, and requirements for data collection, activity reporting, and response activity reimbursement and other forms; and
- (b) convene conferences on SONS planning, preparedness, and response for the Gulf Coast and Caribbean regions at least every three years. (Section 2.2, page 12)

#3 - State agencies and local agencies – and their respective supervisory local elected officials – with a role in preparing for, responding to, and recovering from a SONS should actively participate in USCG ACP development and biennial drills and exercises. (Section 2.2, page 14)

#4 - RCPs and ACPs should be amended to ensure better organization, deployment, and management protocols for the VOO program and relevant OSROs. These plans should emphasize the importance of airborne surveillance and monitoring, preference in hiring and contracting local resources, and the value of local knowledge and experience in assessing tidal impacts and flow patterns in predicting the movement of spilled oil. (Section 2.2, page 15)

#5 - Initial state and local responses to oil spills threatening Florida's coastline (e.g., boom acquisition and placement, assembling and training cleanup personnel) should be improved

through better area contingency planning, preapproved contracts, preparedness activities, and support for characterizing pre-impact baseline conditions. (Section 2.3, page 16)

#6 - USCG oil spill contingency plans, state spill plans, and other plans, should be amended to ensure support for—and participation in—coastal mapping and oil spill movement, monitoring, modeling, and interoperable spatial data analysis (e.g., The Florida Marine Spill Analysis System, Digital Area Contingency Plans, Geospatial Assessment Tool for Operations and Response [GATOR], and the Environmental Response Management Application [ERMA]). (Section 2.3, page 17)

(The support of these sorts of efforts pay tremendous dividends when it finally comes down to responding, particularly to a SONS. The type of coastal monitoring mentioned are most often known as Coastal Ocean Observing Systems and they are tremendously useful in hurricane response as well.)

#7 - USCG RCPs and ACPs and any incident or unified commands established to respond to SONS affecting Florida should be amended to include

- (a) placing a USCG representative and RP representative in Emergency Operations Centers at each level of government when a spill approaches state waters;
- (b) consolidating public health and scientific research/information services at the incident command level to reduce redundancy and overlap;
- (c) incorporating local branches under the Incident Command System to ensure appropriate local involvement and integration into spill response and cleanup actions; and
- (d) coordinating and sharing data and information. (Section 2.3, page 18)

#8 – Congress (US) should amend OPA90 or other laws to ensure that:

- (a) local governments are provided an official capacity in the incident response framework under the law;
- (b) incident command authorizations provide for reimbursement for actions undertaken by state or local governments to protect their resources and restore damaged areas during SONS events if the actions are included in an ACP; and

(c) the OSLTF is fully capable of addressing a SONS where there is no financially viable or legally accountable RP for whatever reason. (Section 2.3, page 19)

#9 - ACPs should improve identification, prioritization, and protection of environmentally sensitive areas/habitats through the use of state or region-specific information, best available technologies, tidal inlet protection strategies (TIPS), and application of sound science, engineering, and technical principles that consider water currents, tidal variations, and the effects of protective measures used in environmentally and economically sensitive areas. (Section 3.2, page 22)

This again goes toward supporting better science and technology applied to real world applications such as oil spill response and planning, Tidal Inlet Protection Strategies in particular.

#10 - Florida state agencies should provide clear protocols and notification on the use (if any) of dispersants in state waters. (Section 3.2, page 22)

The state is clear. There is no **pre-authorization** for the use of dispersants in any state waters, under any circumstances. Each situation will be evaluated in a case by case manner in coordination with the Regional Response Team (RRT) for Federal Region Four. The 2015 DRAFT Dispersant Use Pre-Authorization Plan is very clear on the boundary and includes a number of detailed maps and well documented geodata (produced by this author) to support this.

#11 - In the event of a SONS affecting Florida, any civil and/or criminal settlement framework should provide full compensation for restoring the impacted ecological and economic conditions within the state. (Section 4.2, page 23)

This would be a similar situation to the Restore Act for the BP spill, but would need to happen again if there were another SONS affecting Florida. The NRDA under OPA90 already provides for compensation for restoring ecological and economic resources, ie; habitat restoration, restoration of ecological services, and compensation for lost uses on economic resources such as recreational beaches. (This author has extensive experience in federal and state Natural Resource Damage Assessments)

#12 - Florida DEP should review the voluntary early restoration program to determine whether it can be streamlined. (Section 5.1, page 25)

#13 - Florida should advocate that future OPA claims processes operate under a practical, equitable, reasonable, fair, efficient, consistent, timely, and transparent framework that includes provisions for

- (a) proper staffing and office accessibility;
- (b) identifying errors in processing;
- (c) recommending claims processing improvements; and
- (d) providing free legal assistance for those who cannot afford it. (Section 5.4, page 25)

#14 - Florida and other Gulf states should establish a common mechanism for access to multistate resources through the EMAC (Emergency Management Assistance Compact) regardless of whether the incident response is handled through the NCP or NRF processes. Such a mechanism should seek to integrate state environmental and wildlife agency resources into the arrangement and develop guidance for national and regional response teams, joint meeting and training materials, integrated drills and exercises, and improvements in communication and coordination. (Section 6.2, page 28)

(This is one effort in particular that the Emergency Management community can help the local Area Committees with because they are much more familiar with the process than Area Committees typically are.)

4. Florida's Geographic Response Planning for Oil Spill Response

The State of Florida, more specifically, the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC-FWRI), primarily through the Center for Spatial Analysis (CSA) has focused on developing and building GIS-based decision support systems for oil spill response and contingency planning throughout the Southeast United States and US Caribbean. This has often resulted in FWRI-CSA being the originator of spatial data that is uniquely tailored to the needs of oil spill response end users. It is important to note that FWRI-CSA was the technical lead on the Digital Area Contingency Plan for the Northern Gulf of Mexico that was directly employed by the Deepwater Horizon Oil Spill Response in Mississippi, Alabama, and Panhandle Florida (US Coast Guard Sector Mobile).

5. The Florida Marine Spill Analysis System

The oil spill program within FWRI originated in the early days of ESRI (Environmental Systems Research Institute, Inc.)© releases of UNIX-based command line Arc/Info© and later ArcView© GIS 1.0 through 3.2a with the Florida Marine Spill Analysis System (FMSAS), a powerful GIS designed to perform “cookie-cutter” drill-down spatial analysis and reporting on multiple layers of data simultaneously. This application has been used for many years and is flexible enough to support multiple missions related to oil spill contingency planning, response, and Natural Resources Damage Assessment in the State of Florida as described by Faass (2010) and was the basis for state legislation issued within Florida Statutes Chapter 376 (Pollutant Discharge Prevention and Removal). For its role in the 1993 Tampa Bay oil spill, the FMSAS was awarded finalist for “Innovations in State and Local Government by the Ford Foundation of the John F. Kennedy School of Government at Harvard University. A YouTube© video of that finalist presentation was posted on July 7, 2011 and may be viewed [here](#): At the heart of the FMSAS is Environmental Sensitivity Index (ESI) data in an overlapping polygon (region.bio) format that is generally in a [Gulf-Wide Information System \(GWIS\)](#) data structure (specification provided in hyperlink) (LSU et al. 1996), a historic project linked with the Mineral Management Service (now BOEM/BSEE) for a planned Gulf-Wide ESI data development project that only Florida fulfilled. In the intervening years of 2005 to 2015, the FMSAS and ESI have both migrated to more modern GIS data formats and software, namely File and Enterprise Geodatabases and

ArcGIS Desktop 10.x. Migrations of FMSAS functionality to internet technology is planned for the future. ESRI based or Open Source focused.

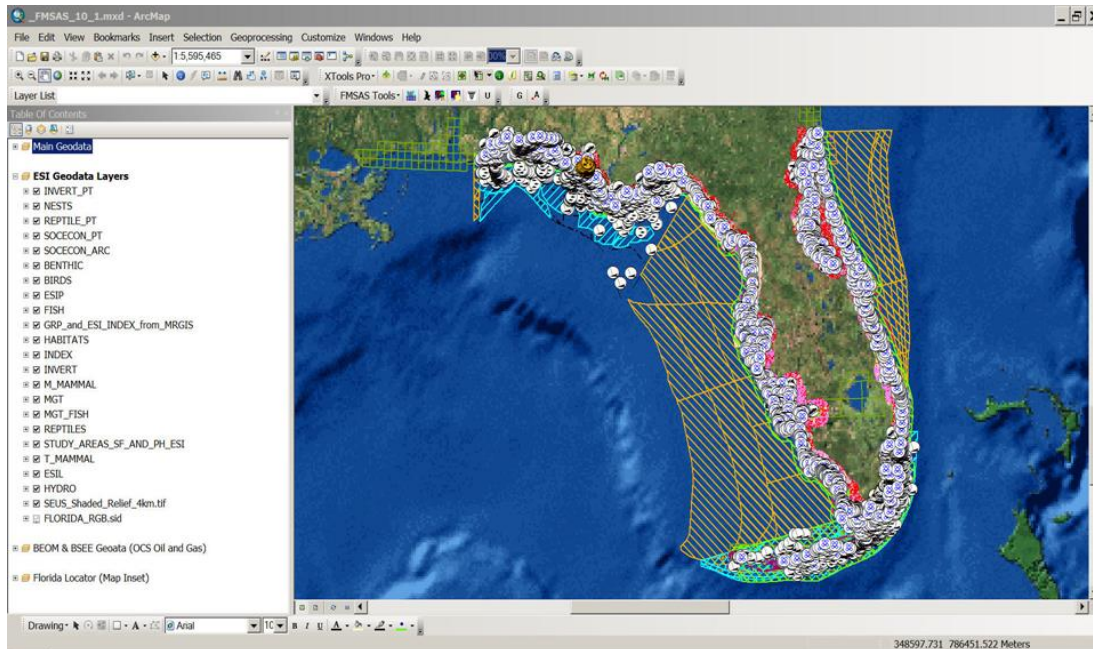


Figure 1: The Florida Marine Spill Analysis System in ArcGIS 10.1 displaying statewide ESI Geodata.

6. Sensitivity of Coastal Habitats and Wildlife to Spilled Oil Atlases, better known as Environmental Sensitivity Index (ESI) Mapping

Environmental Sensitivity Index data are geospatial data and maps designed to provide a concise summary of coastal resources that are at risk if an oil spill occurs nearby. In general, there are four “basemap” components: a “hydro” layer, which is a polygonal representation of the land/water interface at Mean Lower Low Water (MLLW); a “hydro line” layer, where features such as rivers, piers and breakwaters narrower than 10 meters may be presented as a single line; an “ESI polygon” layer which delineates and classifies the intertidal areas and wetlands as polygons; and an “ESI line” layer. The ESI line layer uses the same line as the hydro layer, segmented to show where changes in shoreline type occur. Each segment is classified, based on its sensitivity to oiling. A standardized scale ranging from 1 to 10 (with

modifiers for most numeric values, i.e. 1A, 6A, 10B, etc., resulting in a total of 27 possible shoreline types in Florida) is used. Values of 1 represent the least sensitive shoreline types, values of 10 the most sensitive. The following factors are of primary consideration in the development of the ESI (line and polygon) classification system:

1. Relative exposure to wave and tidal energy
2. Shoreline slope
3. Substrate type (grain size, mobility, penetration and/or burial, and trafficability)
4. Biological productivity and sensitivity to oiling
5. Natural persistence of oil and the ease of cleanup if oiled

The classification scheme is a national “standard” (somewhat loose and flexible) that has evolved over the past 30 years and has been used to map the entire U.S. coastline, including the U.S. territories. It is documented in [NOAA Technical Memorandum NOS OR&R 11, “Environmental Sensitivity Index Guidelines”, Version 3.0](#). All work done on ESI for Florida adhere to these standards. Chapters 1 to 3, and the ESI Data Layer section of chapter 5 of the guidelines are particularly relevant, providing descriptions of shoreline types, classification methodology and data table structures. Florida ESI data varies slightly from the NOAA standard, generally in how biology polygons are represented (layered versus discrete). The ESI guidance overview and links to further information can be viewed online at: http://response.restoration.noaa.gov/esi_guidelines

The second component of ESI mapping includes digital information representing the biological and human use of the specific project area. The ESI data feature vulnerable species represented by polygons, lines or points, as appropriate. These features are attributed with monthly presence/absence, Threatened/Endangered/Special Concern (State and Federal) status, relative concentration, life stage presence/absence and seasonal activity in the area (eg. nesting, inter-nesting, breeding, hatching, juveniles, etc.) and the sources of the geographic and seasonality information. Biological habitats are also included. For further information on what species are included, the previously published ESI maps for the region may serve as a

starting point.

http://ocean.floridamarine.org/ACP/MOBACP/Maps/ESI_MAPS/FL_PANHANDLE_ESI_MAPS/LOWRES/Index.pdf

It is important to note that these ESI cartographic products are now generally 20 years old. However, the geospatial data behind them is being maintained. Revisions to cartographic product are subject to funding availability and they can be rather expensive.

A list of species that have been mapped nationwide in the past can be found at:

<http://response.restoration.noaa.gov/maps-and-spatial-data/esi-species-list.html> This master species list is used when assigning species numbers during the mapping process. This list is for reference only; the ESI is not intended to be an inventory of species present, but a product that focuses on rare, threatened and endangered and oil vulnerable species, or species that occur in high numbers or exhibit critical life stages in the area, or for some other reason are deemed to be important to include within ESI mapping projects.

Human-use and management data are mapped as polygons (management layer), points, or lines (soc-econ layers). Mapped resources are those that are particularly vulnerable to oiling or resources that may be useful in the event of a response. Again, the data mapped in the existing atlases for this area may serve as a starting point to understand what is mapped.

Biological and human use data are collected by researching and identifying the authoritative expert(s) for individual species or groups of species. Correspondence with these experts, which typically involve on-site visits, result in transfer of their information and knowledge to an ESI appropriate mapped representation. Contemporary vector and tabular studies, and other relevant documents may also be included as appropriate. These data are reviewed by the data providers and other local experts before the final digital map data is produced. It is typical that these data will be provided at varying scales. Where the scale is known, it is included as an attribute in the sources table. There are several other attributes associated with the sources data table including the period of time when the data were observed/collected.

The *Environmental Sensitivity Index Guidelines, Version 3.0* (Petersen et al. 2002) defines the minimal information required, as well as the structure of the final data tables and layers. The data delivered includes (as relevant to the geographic area) the spatial extent and life stages/activities for the following broad species groups (within ESI, referred to as “Elements”):

- Fishes
- Invertebrates (polygons and points as appropriate)
- Birds (nests (points), polygons)
- Reptiles and Amphibians (polygons, points)
- Marine Mammals (polygons)
- Terrestrial Mammals (polygons)
- Biological Habitats (polygons)
- Benthic Fabitats (polygons)
- Socio-Economic features (lines, points)

The mapped biology and human use data are presented as an integrated, logical layered GIS product incorporating the data from the various sources via relational table structures as well as the hydro and ESI classified shorelines. All of these data are freely available for download in various geospatial data formats to anyone with interest from the NOAA Office of Response and Restoration’s ESI Data Download website:

<http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html>

Summary of Florida Statewide Environmental Sensitivity Index Mapping:

- 6 Atlases, 297 Quads, 303 Maps (cartographic products)
- 737 Species mapped, 252 Threatened or Endangered (digital geodata)
- Panhandle and S. FL Updated in 2011-2013, updates dependant upon funding availability

- Approximately 24,700 Miles of marine/estuarine/riverine shoreline
- Approximately 14,760 sq mi. of marine waters
- ESI serves as core data for the Marine Spill Analysis System and USCG Area Contingency Plans

Florida has six ESI atlases of recent vintages and two atlases of historical vintage, listed below in Table 1.

Table 1: Florida ESI GIS Data Available for Download

<p>Apalachicola River</p> <p>1984 - Historic Data</p> <p>PDF files [Zip, 11.0 MB]</p>	<p>East Florida</p> <p>1996</p> <p>PDF files [Zip, 459 MB]</p> <p>Metadata: View PDF [PDF, 184 KB]</p>
<p>Northeast Florida</p> <p>1981 - Historic Data</p> <p>PDF files [Zip, 34.8 MB]</p>	<p>St. Johns River</p> <p>1997</p> <p>PDF files [Zip, 33.1 MB]</p>
<p>South Florida</p> <p>1996</p> <p>PDF files [Zip, 200 MB]</p> <p>Metadata: View PDF [PDF, 219 KB]</p> <p>1981 - Historic Data</p> <p>PDF files (Volume 1) [Zip, 29.3 MB]</p> <p>PDF files (Volume 2) [Zip, 48.0 MB]</p>	<p>West Florida</p> <p>1995 - Historic Data</p> <p>PDF files [Zip, 273.9 MB]</p> <p>Metadata: View PDF [PDF, 114 KB]</p> <p>1981 - Historic Data</p> <p>PDF files [Zip, 44.2 MB]</p>

<p>West Peninsular Florida</p> <p>1996</p> <p>PDF files (Volume 1) [Zip, 134 MB]</p> <p>PDF files (Volume 2) [Zip, 367 MB]</p> <p>Metadata: View PDF (Volume 1) [PDF, 255 KB]; View PDF (Volume 2) [PDF, 198 KB]</p> <p>1981 - Historic Data</p> <p>PDF files (Volume 1) [Zip, 38.7 MB]</p> <p>PDF files (Volume 2) [Zip, 24.0 MB]</p>	<p>ESI ArcGIS REST Endpoints – NOAA</p> <p>2015</p> <p>NOAA serves nationwide ESI data of various vintages via ArcGIS Server. The comprehensive set of REST services can be found on the following ArcGIS Server connection:</p> <p>http://egisws02.nos.noaa.gov/ArcGIS/rest/services</p> <p>Folders: ESI & ESI Shoreline</p>
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Florida ESI PDF Maps

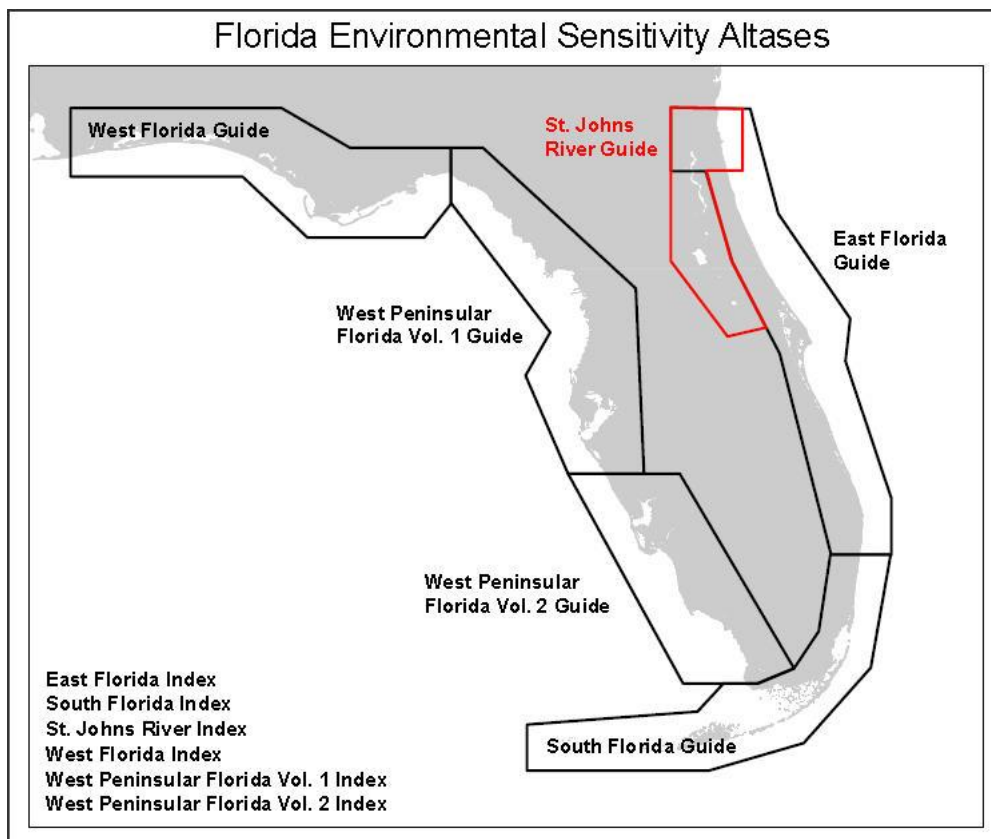


Figure 2: [Index of ESI Atlases & Maps](#) (hyperlinked, opens a PDF)

The benefit of ESI to oil spill responders is that documented, reviewed, vetted, comprehensive geospatially concise information is available for the right place, at the right time, in the right format for use by responders. ESI REST endpoints are particularly useful for GIS practitioners.

7. Digital Area Contingency Plans

During drills and exercises with the US Coast Guard over the years it was discovered that GIS offered a powerful tool to support the Marine Safety and Environmental Protection missions and the USCG funded FWRI to create the first Digital Area Contingency Plan in 1999 for what was then Marine Safety Office Tampa. The Digital Area Contingency Plans are Web and DVD based multi-media products. Distributed on the internet as a web site and produced on DVD as a stand-alone product for times when no internet connection is available, the interface to the various types of information is largely HTML and PDF. Developed in coordination with the Area Committees and Area Committee Geographic Response sub-committees of each Sector, the content of each Digital ACP is driven by the needs and desires of the region in responding to oil and hazardous material spills of most kinds likely to occur in the area. There is however, a general outline and “process” for the development of each. Digital products include documents, maps, and GIS data that support and build upon the response plan and provide baseline mapped information for decision-making. The general “web page” categories include Home, Documents, Maps, Contacts, GIS, Geodata, Applications, Links, and Help with the general contents of each listed below:

Also available at:

http://ocean.floridamarine.org/acp/mobacp/Help/Read_Me_Files/Read_Me.htm

Root:

Applications (Applications Directory)

- ADIOS2 – Adios2 install file. ADIOS is an acronym for “Automated Data Inquiry for Oil Spills”
- Adobe_Reader – Adobe Reader install file
- ALOHA – AIOHA install file. ALOHA is an acronym for “Areal Locations of Hazardous Atmospheres”. ADIOS is a hazardous material atmospheric plume modeling software program produced by the US EPA..
- Arc_GIS_Explorer – ArcGIS Explorer is free GIS data viewing software produced by Environmental Systems Research Incorporated (ESRI).
- ArcReader – ArcReader is free GIS data viewing software produced by Environmental Systems Research Incorporated (ESRI).
- CAMEO – Cameo and Cameofm install file. CAMEO is an acronym for “Computer Aided Management of Emergency Operations”. CAMEO is hazardous materials chemical reference software produced by the US EPA. CAMEOfm is the FileMaker Pro database version..
- GeoPDF_Toolbar – Terrago GeoPDF Toolbar. GeoPDFs are spatially enabled layered PDF documents with special capabilities to interact with GPS data and Google Maps.
- GNOME – GNOME install file and location file if available. GNOME is an acronym for General NOAA Operational Modeling Environment”. GNOME is oil spill trajectory modeling software produced by the NOAA Office of Response and Restoration (Emergency Response Division (ERD)).
- Google_Earth – Google Earth Updater/Installer file. Google Earth is free geospatial imagery and data visualization software produced by Google Inc.
- ICS_Forms – ICS Forms install file. ICS is an acronym for “Incident Command System”. These are special “fill-able” PDF forms of the USCG specific set of ICS forms.
- Install_fonts – fonts and font application (exe). These are a specialized set of fonts for use in ArcMap and ArcGIS Server for marker symbols specifically developed for Nautical Chart and Aids to Navigation features.

- MARPLOT – MARPLOT install file. MARPLOT is the mapping software for the CAMEO software suite produced by the US EPA.
- Spill_Tools – Spill Tools install file. Spill Tools is a set of software applications designed to support oil spill response operations. At the time of publication, Spill Tools is no longer supported by the NOAA Office of Response and Restoration and has now been replaced by the Response Options Calculator (ROC) software. The ROC is beta software as of August 2015.
<http://response.restoration.noaa.gov/spilltools>. From NOAA OR&R website:
*“The **Response Options Calculator** can be used to assess system performance involving mechanical recovery, dispersant application, and the burning of oil. ROC predicts how the spilled oil will weather over time and the volume of oil that can be recovered, burned, or treated for the response systems selected. It is available for download as a zipped program or can be used online.”*
- ESI_Tools – ESI Tools (dll) Zipped folder. ESI Tools are a set of ArcMap extended capabilities (tools) designed to support query and interaction with NOAA ESI geodata.

Contacts

- Area Committee contacts list
- Coast Guard Office Contacts
- GRP Workshop Attendees
- Regional Scientific Experts Contacts List

Geodata (GIS and KML)

- Geodatabase or shapefiles for all data in ArcMap project
- Layer files for geodata symbology
- Geodatabase of nautical charts in raster image catalogues
- ESI personal geodatabase (if data outside of Florida)
- All KML data layers

- Metadata – FGDC Metadata in HTML format
- ArcMap (NOAA Chart One) Fonts Zipped folder

Documents

- ACP – ACP Documents (Word and PDF)
- Appendices - ACP Appendices
- EPA – National Contingency Plan Product Schedule
- FDEP – Approved Contractors
- FWC – Wildlife Contingency Plan for Oil Spill Response
- ICS_Forms – ICS Forms (Fill-able PDF)
- MOU_MOA – Relevant Memorandums of Agreement/Understanding
- NOAA – NERR Disaster Response Plans, NOAA guidance documents, job aids, Coast Pilot and factsheets
- NRT - NRT factsheets
- OSRO – USCG and Industry related equipment inventory lists
- Other – OPA 90, NIOSH Pocket Guide, ACP Satisfaction Survey, ExxonMobile Field Guide, Sensitive Area Update Form
- Policy Letters – District 8 Policy Documents
- RRTIV – RRTIV Pamphlets
- USCG – USCG Documents, Incident Management Handbook, D7 VOSS (Vessels of Opportunity Skimming Systems) info, Dispersant Pre-Authorization Area Maps (if available)

Maps

- GRP_Maps - Geographic Response Plan Maps
- GRP_Maps_20XX – Historical GRP Maps
- Environmental Sensitivity Index Map Atlases (differs for each Sector)

- TIPS – Tidal Inlet Protection Strategies for Oil Spill Response (Peninsular FL only)
- Boating_Guides – FWC or other agency produced boating guides

Help (Fact sheets, user guides for applications and tutorial videos)

- Read_Me_File – Read Me File
- Applications_Help – Factsheets and user manuals
- Tutorial_Video – Digital ACP instructional videos

Templates – HTML Webpage template

WEB – Graphics and Icons

Software used in creation of Digital Area Contingency Plans:

Adobe Dreamweaver – Used in creation of front end interface (website design) of digital area contingency plan and linking to internet.

Adobe Acrobat Pro 10.0 – Used for document conversion to PDF, hyperlinking internally and externally, linking map locations to detailed reports, and formatting.

Environmental Systems Research Institute (ESRI)- ArcMap 9.x to 10.x - Geographic Information System software for spatial data viewing, editing, and management; Used to create ArcMap project (mxd) for creation of ArcReader (pmf) (free GIS data viewer) project files included on the DVD-ROMs. The project file provides a tool for viewing spatial data related to the ACP and allows for customizations to access other information such as PDF maps and images.

Google Earth Pro – A more advanced (fee-based) version of a free program created by the Google Corporation to create and distribute spatial data and view imagery of the world.

8. Where Area Contingency Plans and Geographic Information Systems Co-Mingle

When Area Contingency Plan documents and reference annexes are converted to Digital Area Contingency Plans, every effort is made to identify any information within the plan that has a spatial reference and geocode that information into appropriate spatial data layers. Some examples are response equipment storage locations and potential incident command staffing locations. As a part of the area contingency planning process, general habitat types and ranges are identified based upon sensitivity to spilled oil (similar to how ESI is developed and based upon the same understandings of how spilled oil effects habitats and wildlife). These habitat types and ranges are then prioritized for protection (given limited protection resources and time to deploy them) by the Area Committees. These listings are generally conveyed as three levels of protection priority, A through C, with A being the primary protection priority (A – Protect First), followed by B (Protect after A areas), then C (Protect after B areas). This is very much like the process performed by the Environmental Unit of the Planning Section of the Incident Command System in actual responses, and this planning effort is focused on providing products to support those efforts in response. A generalized Florida-specific listing of these priority resource protection habitats and ranges are listed below:

General Area Contingency Plan/Geographic Response Plan Priorities for Protection in Oil Spill Response:

A - Protect First - In all cases, Human Health and Safety is Highest Priority

- Tidal inlets, tidal creeks, and passes which could convey oil to high priority habitats/areas
- Species of special concern, threatened, or endangered species and their critical habitats/facilities (breeding, nesting, spawning areas, some seasonal). Facilities generally refer to aquaria and aquaculture water intake locations which may house T/E species

- Large areas of Mangroves (fish/bird/reptile habitat concerns)
- Large areas of Salt-, Brackish-, & Fresh-Water Marsh/Wetlands (Tidal & Non-Tidal)
- Coral Reefs and Hard 'live' bottom, shallow (<3 meters deep)
- Seagrass, shallow (<1 meter deep) (less buffering by water depth)
- Public utilities water intakes
- Aquaria, and Aquaculture facilities (inclusive of intakes)
- Cultural (historical, archeological) resources

B - Protect After A Areas

- Coral Reefs and Hard "live" bottom, deeper (>3 meters deep)
- Seagrass, deeper (>1 meter deep) (more buffering by water depth)
- Hard "live" bottom, deeper (>1 meter deep)
- Breeding, nesting, spawning areas, (some seasonal) for more common species not identified in "A" categories
- "Fringe" (smaller areas of) mangroves and fresh-, brackish-, salt-water marshes
- Rocky shorelines
- Tidal flats (sand/mud; no vegetation)
- All other natural shores (including sand beaches) within conservation areas
- Riprap shorelines

C - Protect After B Areas

- Man-made canal systems (w/o riprap shoreline)
- Stormwater outfalls (due to potential tidal influx)

It is with these listings of protection priorities that targeted geodata development can occur to identify and map environmentally sensitive areas as part of the contingency planning process.

It was also with this targeted approach on prioritization that bathymetric data is used extensively. FWRI has created a query-able data layer of polygonal depth ranges sourced from NOAA Nautical Charts (scales ranging from Harbor, Approach, and Coastal scale charts) for all nearshore regions of the state for use in these types of efforts. This allows for the spatial analysis process of mapping areas where both specific benthic habitats/species and specific depth ranges exist within a two-dimensional spatial footprint. This has proven very effective in these contingency planning efforts and additionally supports dispersant use decision-making, as dispersant use policy calls for the exclusion of dispersant application in waters shallower than 10 meters.

Bathymetry Segway to Oceanography

Mapped bathymetric information is a tremendous resource for these types of efforts, but bathymetry is still a static (fixed in time) data source. Significant improvements could be found by developing a means to easily spatially integrate Hindcast, Nowcast and Forecast MetOcean, Ocean Circulation, and Trajectory Modeling data products into these other static Geographic Information Systems that are used extensively by many Federal, State, and Local agencies to manage coastal and marine resources. There is also significant value in developing spatial interfaces into mean oceanographic conditions for specific priority protection areas such as tidal inlets. This provides a local “climatology” for tidal ranges and flood and ebb surface current velocity and direction that are extremely valuable for both contingency planning and response purposes.

The potential products of this present research and development will have practical scientific and effective decision-making value. Potential funding sources may need to be investigated and pursued to expand these efforts to regions outside of the current study area, but this research documentation proposes a potential methodology to so.

A Note on Oil Spill Boom

Booming is a critical factor to consider in oil spill planning and response. It is additionally quite easy to represent as a classified line features in a geographic information system of appropriate scale. It should be noted that the words “boom” or “booming” appears 46 times in the USCG Deepwater Horizon ISPR. These references appear in many contexts from pre-planning discussions regarding identification and protection of environmentally sensitive areas in the Geographic Response Planning process along the shorelines to offshore operations regarding in-situ burning. Boom placement planning is important. Yet booming is not an exact science, nor a generally easy effort. Oil spill boom by nature is a floating object and as such, subject to the forces of water currents, tides, waves, and wind. Without a good understanding of these forces for a given area, an adequate booming strategy cannot be developed. Oil Spill Removal Organizations and industry experts understand this fact, yet the data and information systems typically run by governments, academic institutions, and consortia sometimes have difficulty in recognizing this small but important user community and developing information products tailored to their needs. These are the systems that provide on-demand, fine scale, geographic-specific information on tides, currents, waves, and winds for an area. Much like the National Weather Service has developed “point forecasts” whereby a user clicks on a map and is returned the relevant weather forecast for the immediate vicinity around the latitude/longitude of the map-click location. This functionality applied to oceanography (currents/tides) would be a tremendous resource for oil spill response planners and responders. Until such time that this technology is available for all coastlines of the US (or perhaps the world?) then more primitive means will need to be used for these purposes.

9. Tidal Inlet Protection Strategies – History in Florida

Tidal Inlet Protection Strategies (TIPS) have been produced and are publically available for inlets on the East Coast of Florida, the Florida Keys, and the West Coast of Florida North to Hurricane Pass (Pinellas County) (<http://ocean.floridamarine.org/acp/tips> (as PDF) and via a Web Mapping Application as GIS data layers, <http://ocean.floridamarine.org/ACPGRP/>. There are however, NO Tidal Inlet Protection Strategies for the Big Bend and Panhandle areas of Florida so the first research priority is to focus on those areas where this work has

not yet been done by researching to collate the average and maximum flood and ebb current velocities and directions, as well as average tidal ranges, for the inlets in these regions. The second research priority is to focus on the tidal inlets in the coastal zone of Alabama and Mississippi as this area comprises the balance of US Coast Guard Sector Mobile, the majority of which is Panhandle Florida (approximately two-thirds of the west-east extent of Sector Mobile is Panhandle Florida). The third research priority (and only as time and funding are available) will be to validate the average and maximum flood and ebb current velocities and directions listed in the TIPS that have been completed for Peninsular Florida, referring to the updates that were produced in late 2012 in response to threats from deepwater drilling in Cuba. The listing of those inlets that have had TIPS developed are as follow:

Peninsular Florida Tidal Inlet Protection Strategies (TIPS) – (Completed by USCG Sector) (89 Inlets TOTAL – Updated in 2012 by Research Planning, Inc., M. Hayes et al). (Figure 6)

Inlets surveyed in USCG Sector St. Petersburg:

(Class is a measure of difficulty in protection A-D in decreasing order)

INLET NUMBER/NAME CLASS	INLET NUMBER/NAME CLASS
1. Hurricane Pass (Pinellas Co.) B	20. Captiva Pass A
2. Dunedin Pass D	21. Charley Pass D
3. Clearwater Pass B	22. Redfish Pass B
4. Johns Pass B	23. Blind Pass (Lee Co.) C
5. Blind Pass (Pinellas Co.) C	24. San Carlos Bay Entrance A
6. North/Pass-A-Grille Channels A	25. Estero/Matanzas Pass B
7. Bunces Pass B	26. Big Carlos Pass B
8. Egmont Channel A	27. New Pass (Lee Co.) C
9. Southwest Channel A	28. Big Hickory Pass B

10. Passage Key Inlet A	29. Wiggins Pass B
11. Longboat Pass B	30. Clam Pass D
12. New Pass (Sarasota Co.) B	31. Doctors Pass C
13. Big Sarasota Pass A	32. Gordon Pass C
14. Midnight Pass D	33. Keewaydin Is. Washovers D
15. Venice Inlet B	34. Hurricane Pass (Collier Co.) B
16. Deertown Gully D	35. Big Marco Pass A
17. Stump Pass C	36. Caxambas Pass A
18. Gasparilla Pass B	37. Blind Pass (Collier Co.) C/D
19. Boca Grande Inlet A	38. Morgan Bay A

Inlets surveyed in the USCG Sector Key West:

(Class is a measure of difficulty in protection A-D in decreasing order)

INLET NUMBER/NAME CLASS	INLET NUMBER/NAME CLASS
1. Old Rhodes Channel B	15. Toms Harbor Channel A
2. Broad Creek Channel B	16. Vaca Cut B
3. Angelfish Creek Channel B	17. Boot Key Harbor C
4. Garden Cove C	18. Bahia Honda Channel A
5. South Sound Creek B	19. Spanish Harbor Channel B
6. Tavernier Creek Channel B	20. Pine Channel B
7. Snake Creek Channel B	21. Newfound Harbor Channel B
8. Whale Harbor Channel B	22. Niles Channel B
9. Teatable Key Channel B	23. Kemp Channel B
10. Indian Key Channel B	24. Bow Channel B
11. Lignumvitae Channel B	25. Shark Channel C

12. Channel Two A

26. Boca Chica Channel B

13. Channel Five A

27. Cow Key Channel C

14. Toms Harbor Cut C

Tidal inlets in the USCG Sector Miami

(Class is a measure of difficulty in protection A-D in decreasing order)

INLET NUMBER/NAME CLASS

INLET NUMBER/NAME CLASS

1. Sebastian Inlet B

9. Port Everglades A

2. Fort Pierce Inlet B

10. Bakers Haulover Inlet A

3. St. Lucie Inlet A

11. Government Cut B

4. Jupiter Inlet B

12. Norris Cut B

5. Lake Worth Inlet B

13. Bear Cut A

6. Boynton Inlet B

14. Sands Cut C

7. Boca Raton Inlet B

15. Caesar Creek Channel C

8. Hillsboro Inlet B

Inlets surveyed in USCG Sector Jacksonville:

(Class is a measure of difficulty in protection A-D in decreasing order)

INLET NUMBER/NAME CLASS

1. St. Marys Entrance A

2. Nassau Sound Inlet A

3. Fort George Inlet B

4. St. Johns River Inlet A

5. St. Augustine Inlet A

6. Matanzas Inlet B

7. Ponce de Leon Inlet A

8. Port Canaveral C

9. Sebastian Inlet B

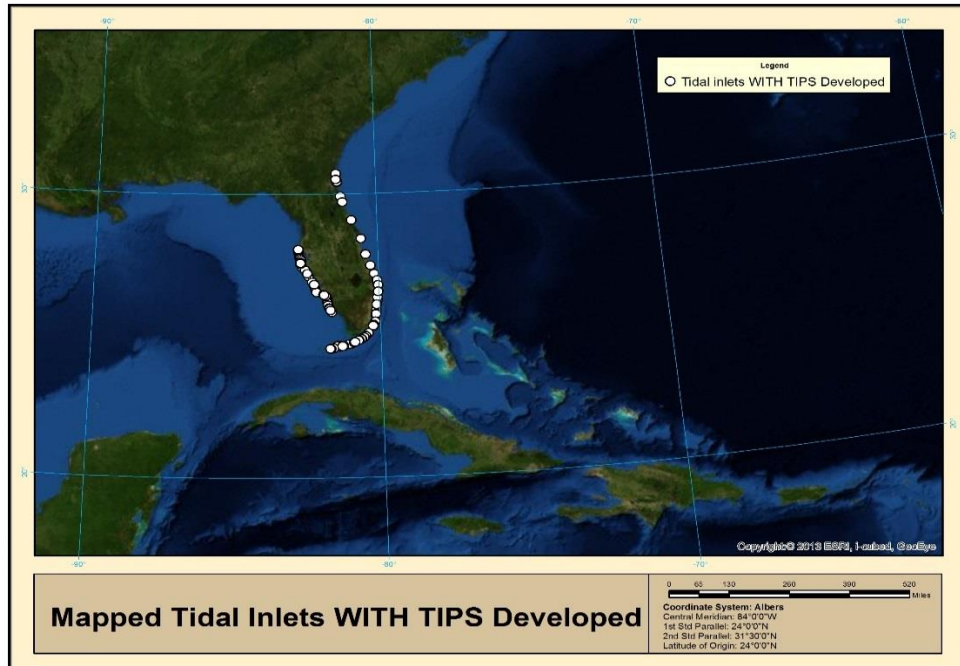


Figure 6: Map of Inlets that HAVE TIPS developed for them

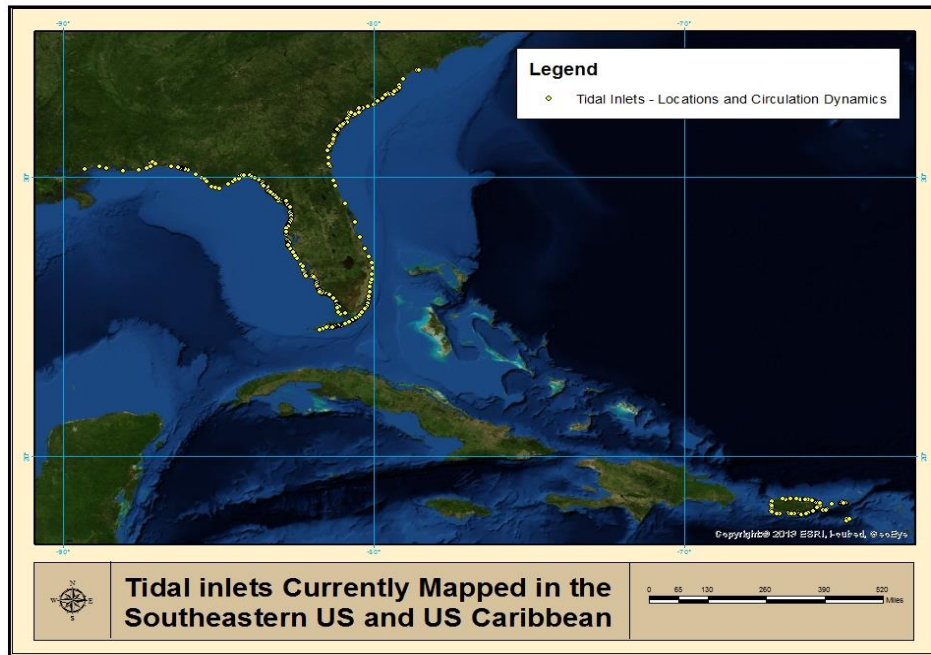


Figure 7: Extent of Mapped Tidal Inlets (all inlets with or without TIPS)

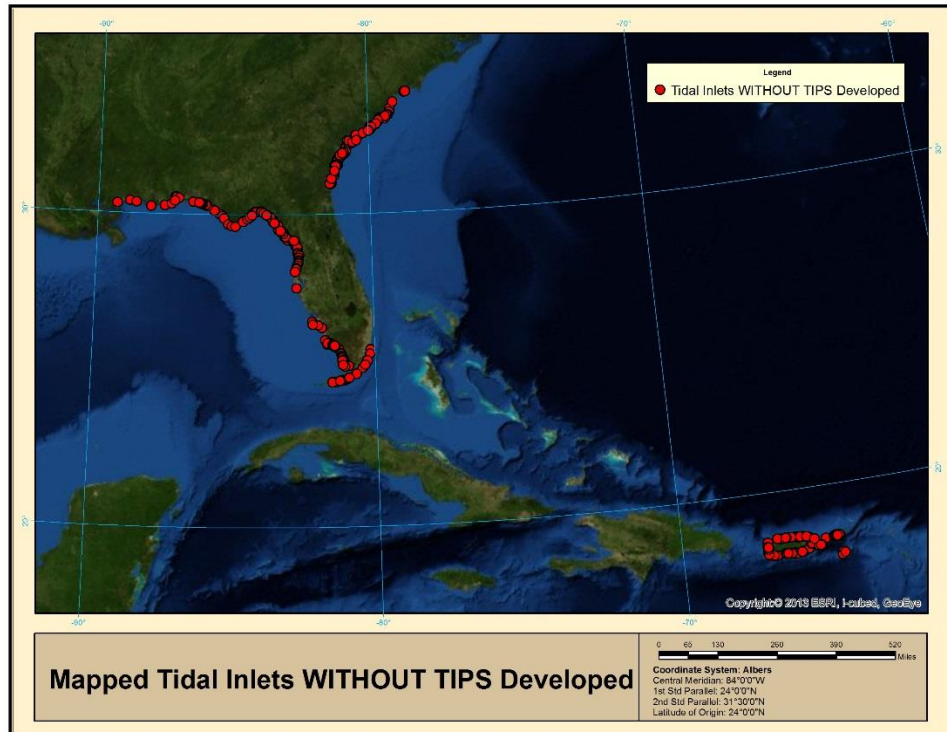


Figure 8: Map of Inlets that DO NOT HAVE TIPS developed for them

**APPENDIX 2 METADATA AND GEODATABASE SCHEMA FOR
“TIDAL INLET LOCATIONS, CHARACTERIZATIONS, AND BASIC
CIRCULATION DYNAMICS FOR THE DEVELOPMENT OF TIDAL
INLET PROTECTION STRATEGIES FOR OIL SPILL RESPONSE”**