Planning for the Impacts of Sea Level Rise and Climate Change

Workshop Summary

Synopsis

Over 50 coastal zone managers and stakeholders from North Carolina were invited to participate in a workshop to discuss and identify potential modeling and mapping tools to plan for, and mitigate the regional impact of future sea level rise and extreme events. The participants were presented with information about the NOAA Sea Level Rise Project, sponsored by the Center for Sponsored Coastal Ocean Research (CSCOR), and then identified four priority applications for scientifically informed decisions:

1. Tools should incorporate information ascertained through scientific research and modeling that can be easily applied by state and local government and large land owners when planning future land use and deciding on policy and regulations that affect coastal resources.

2. Tools should forecast expected habitat changes, especially potential loss of habitats important for ecological services.

3. Tools easy to translate to decision makers.

4. Tools to enable easy understanding of potential risks to people and development due to future flooding and related hazards.

5. Continued engagement of NOAA and their research partners with Workshop attendees via email and websites.

The workshop was a success and heralded as a model NOAA initiative. To continue momentum and maintain contact with participants, a satellite advisory group, the *Sea Level Rise Advisory Group,* is being formed for managers with a keen interest in keeping up with the effort and having input on NOAA"s sea level rise projects. Diverse representation desired! If you are interested in becoming a member of the Advisory group, please contact the NOAA Program Manager, Carol Auer at carol.auer@noaa.gov or 301-713-3338 x164 .

Forward

The Workshop Summary has been made available to provide new information about the needs of managers of coastal lands and natural resources in planning for the effects of sea level rise and long-term climate changes. The results documented in this Report will help NOAA scientists to emphasize state- and community-level management applications and

challenges, as they design the models and modeling products with the ultimate goal of unifying local and national needs.

Background

A workshop was held on Wednesday and Thursday, January 31, 2007 -February 1, 2007 at the North Carolina Aquarium at Pine Knoll Shores, North Carolina. The goal of the workshop was to solicit guidance from the coastal management community for designing scientifically informed modeling and mapping tools that will assist governing agencies and businesses located in North Carolina's coastal zone.

Expert advice from North Carolina coastal managers is invaluable in aiding NOAA"s CSCOR and its academic partners in designing useful management products. Advice from the workshop will help create user friendly mapping and modeling tools that forecast the effects of proposed management activities under various long term sea level rise and storm surge scenarios. For more information about the scientific underpinnings of the program, please see:
http://www.cop.noaa.gov/stressors/climatechange/current/sea_level_rise_wp.pdf

Workshop Objectives

Identify potential applications of sea level rise and long-term climate change modeling to inform current work on hydrodynamic and ecological impacts modeling.

Identify user groups and target audiences for sea level rise and long-term climate change modeling information.

Solicit input from potential end users on the desired content and format of information products and decision-support tools that might be developed based on ongoing modeling efforts.

Share initial knowledge and findings from ongoing modeling projects, and solicit feedback to guide next steps

Summary of priority topic discussions

Topic 1: Incorporating information ascertained through scientific research and modeling into planning, policies, and regulations:

Defining the issue

State Commissions

In North Carolina, probably the best governmental venue to influence legislation relating to sea level rise and other climate change issues is via the Climate Change Commission. Two of the scientists involved in the NOAA project are members of this Commission: Dr. Peterson of University of North Carolina, Chapel Hill (UNC-CH), and Dr. Riggs of East Carolina University (ECU). Our goal should be to develop useful models to forecast various ecological impacts due to SLR and climate effects and then target the planning and policies that can use models first. The resulting ecological forecasts and maps can then guide regulations to implement Implementing rule changes is easier if it starts at the

commission level thus helping get the word out and „soften the playing field". The Commission can then better formulate regulations that will mitigate habitat loss. Other commissions to engage may include the Environmental Management Commission that would then direct the Division of Water Quality to implement policies, as well as the Coastal Resources Commission and the Marine Fisheries Commission. Other possible audiences to whom we could highlight our suite of models, are those involved in the statewide conservation plan and the beach and inlet management plan.

Models and tools used in hazard planning

Can we get sea level rise considered a "disaster" and included in the state hazard mitigation plan? It would be good to encourage climate change topics be considered for Federal Emergency Management Agency list of hazards and disasters. If our models could be developed into applications to display future flooding and surge, sea level rise could logically be included in the state hazard mitigation plan, then into local mitigation and local land use plans. One goal is state and local government development of a sea level rise mitigation plan. North Carolina is currently developing a set of floodplain maps for the entire state. If could get sea level rise predictions on these maps, it would be ideal.

Potential application of models and end users

Models and tools useful to statewide departments

The U.S. Department of Transportation (DOT) needs information about future water levels in planning for roads and other infrastructure. The DOT has interagency meetings including DOT, United States Corps of Engineers (USACE), Department of Water Quality (DWQ), Department of Coastal Management (DCM) as well as federal highway planners.

The U.S. Department of Agriculture has a multi-threat database that should include information about sea level rise and climate change. We could find out if there is interest. In addition, Farm Bill programs could incorporate information about sea level rise and climate change.

The North Carolina Department of Marine Fisheries: Fisheries Habitat Protection Plan.

The North Carolina Department of Environment and Coastal Resources. In some ways sea level rise is already incorporated in North Carolina's setback rules. Can the model forecast sea level rise and work those into setbacks? Thus, a rolling setback based on the vegetation line or a setback line based on average model scenarios, can be proposed. Currently setbacks are biased by shore protection projects which change the average rates of erosion. Beach nourishment also changes how shorelines respond to gradual sea level changes and storm effects. However, models can assist in developing a plan for how areas move from private ownership to public ownership as private land becomes submerged.

North Carolina trust funds

There are several trust funds in North Carolina. If all these funding sources were directed by the legislature to incorporate sea level rise into decision making, the public would see

big changes in how trust fund officials make decisions. The funds are DOT, Natural Heritage, Ecosystem Enhancement Program (EEP), Farmland, Clean Water and Parks and Recreation.

Products and tools

Recommendations for the desired information products and decision-support tools that might be developed based on the ongoing modeling efforts include: ease of interpretation, interactive; scenario-based, model should push out layers that can be incorporated in ESRI products; hard copy maps; and ease of displaying a range of projections or the ability to run a range of projections.

Topic 2: Potential loss of habitats important for ecological services

Defining the issue

Tracking changes in North Carolina's habitats can be done through land cover data sources to predict changes on both land and water. The percent land cover of wetlands, as well as important submerged habitats, will decrease unless efforts are made to allow unheeded migration upland by removal of all barriers such as sea walls and groins.. In order to do this, North Carolina must monitor what is happening on the ground; starting with baseline measurements and continually mapping the habitat changes- thus moving beyond anecdotal evidence. Historic records of sea level rise will help with this.

For conservation lands, how will habitats change? This will influence management decisions, and potentially the selection of new lands for conservation purposes, by not directing money to lands that will disappear. However, groups may want to acquire lands before those lands are affected by rising sea levels and restore them to survive if possible. They may want to "mother" a piece of land' s transition from one ecosystem to another, with an ordered emphasis on ecosystem function, structure and composition …a reason to acquire lands pre-sea level rise.

Review is needed of DOT practice of defending barrier islands and their accompanying bridges and highways, which will affect habitat migration and change. This is happening now on Hwy. 12 and possibly on Hwy. 264. with no environmental impact statement filed before hurricane Isabel's inlet breach was filled.

Potential application of models

Models may help decide where recreational infrastructure should be sited. From a Parks & Recreation perspective, modeling tools can help decision makers to site public access. Conservation decisions upstream, such as the removal of dams will cause salinity change, affecting freshwater input into sounds. Thus, conservation planning could be helped through modeling results.

End users

The end users of this research and modeling information include: resource managers, Councils of Government, local planners and zoning officials, state agencies, county commissioners, private property owners including large corporate land owners, the

General Assembly, and other policy makers and climate change strategic planners. Probably the best approach to reach these users is by making presentations and other forms of personal contacts to get people to use this data and models: the grassroots approach.

Products and tools

The desired information products and decision-support tools that might be developed based on the ongoing modeling efforts include, prioritization maps and geo-databases, including sensitivity analyses and using GIS. There should be no static products. Another idea is a library of scenarios where the user can access the model with existing data or by having the user provide required data. The models should be related to CHPPs (Coastal Habitat Protection Plans) habitats to ensure model interfaces with CHPP classifications. A needed product could picture how sea level rise affects municipal infrastructure, i.e. septic tanks, gas lines, sewer lines, etc. There may be model accuracy issues related to marsh migration, because erosion control structures prevent marsh from migrating inland. Therefore the habitats may not respond as predicted. Models need to incorporate real time land conversions, such as development, clear cutting or other land modifications as they occur, to stay as current as possible

Topic 3: Local government education/translation (translation to decision makers).

Defining the issue

The sea level rise issue needs characterization as commissions and government boards are not getting the message of the need and the efficacy to prepare for future climate change. Other, immediate needs, such as smart growth and immediate economic growth are considered more important than environmental considerations, making future and long term environmental issues not to be seriously considered. In addition, politics come into play and developers and other special interest groups have the attention of the commissioners. Land use plans are not required in many areas, and all growth is seen as good to increase the tax base, create needed jobs, and to bring money to the area. The negative aspects of growth and effective land use planning are not emphasized. Often infrastructure cannot keep up, and development and land fees cannot cover the costs. Perhaps, we could try the economic angle to encourage planning for future sea level rise.

Potential application of models

Outreach and public education, through easy to use maps and tools, will help inform voters on what future habitat landscapes will look like under various sea level rise and storm surge scenarios. The voters can then push for better land use planning and influence commission decisions. A message needs to be structured in order to influence both short and long term land use planners to consider future habitat change due to climate change. Locally, counties can look to other areas, such as Wilmington, as an illustration of land use planning, as well as hazard mitigation.

End users

Creators of the models could get the information to the public by using models and tools to make specific presentations to suit the audience. Some examples of target audiences

include: local watershed groups, educators, and newspapers, keeping the public up to date on modeling efforts. By using modeling results to help design displays at aquariums and parks and using known landmarks for display purposes, locals can better relate to the issues of concern. Other important audiences to reach are regulators of septic system failure and those responsible for permitting the location of landfills/hog lagoons. Educating and engaging these groups can be a proactive step in mitigating the impacts of a rise in sea level.

Products and tools

The desired information products and decision-support tools developed based on the ongoing modeling efforts should include geographically-specific information, for example local and regional with landmarks, to make it relative. Products should be designed with concrete ideas of how this information can be incorporated into decision making processes, and examples should be provided.

The product should also include: clearly presented assumptions and scenarios of the model, a focus on infrastructure impacts to get attention, and should also provide probability of impacts. The timeline is important.

What can the model products accomplish? A new permit process that incorporates sea level rise issues from experts. The products must be local and specific, include GIS layers which may vary county by county. Perhaps we could link to tax map?
Finally, there should be both a map with tools to look at different layers with a range of scenarios/suite of changes including incorporation of historical events and probability.

Topic 4 – Understanding risk (as it pertains to people and development) and related hazards (flooding, surge, etc.)

Defining the issue

We can define the issue as both short term risk and long term risk. The short term risk includes: danger of increased surge/flooding, storm intensity, and an increase in the number of storms. The cumulative change is the important focus.

The long term risk includes a risk to natural habitats, including ecosystem change due to water level rise, accompanying shoreline change, potential increase in number and intensity of storms, marsh disappearance, loss of land, habitat loss (migration due to warming), and biogeochemical changes (fresh to brackish to salt water). There is also a risk to humans including salinization of ground water, road loss, evacuation problems, property loss (insurance) and public infrastructure. There is a need for planning of future settlements. Restoration and mitigation sites should be considered, since potentially mitigating marsh that will be lost to sea level rise in 30 years. Planners should consider the creation of isolated wetlands inland, the shift of habitat on the coast, and impact on beach/erosion.

Potential application of models

The model should address sea level rise risk and related hazards by identifying land areas and infrastructure at high danger of being lost due to a combination of sea level rise and storm surge. Through the model, decisions can be made where property needs to be purchased by government or private groups to insure successful migration of important habitats to higher ground. However, funding must be provided to local communities, because there are too many unfunded mandates. Can products be designed to plan for beach loss (volumetric and erosion) or to predict how long nourishment lasts? There are major concerns in beach nourishment since it is linked to property and tourism

End Users

Those involved in emergency management need model applications to better plan their response with life-saving measures and improve understanding of what resources are needed, in advance, to respond. Products are needed to inform local government for education on what to expect as the climate changes and sea level rises.

Products and tools

The important information includes: maps of vulnerability of specific coastal areas, including risk to property and risk to habitat, and specific scenarios that illustrate potential change or past change. Another important product is a sea level rise timeline of expected impacts, both manmade and habitat related. Can products be designed for septic system failure? Local governments should not be permitting septic systems that may be under water in 20 years; this also includes the permitting location of landfills/hog lagoons. Most importantly don't forget education! Local government needs education. There can be no accountability if we do not follow through on education/training

Putting sea level rise information into public policy can be problematic. The project can plan sea level rise zones for regulation (15, 30, 45 year periods represented on a map). However, restrictions on development could be a takings case. Thus, we must verify our models. If models are wrong – government is legally liable. Could we incorporate our models into HAZUS (for HAZards United States) a GIS-based natural hazard loss estimation software package developed by FEMA. to assess economic risk? By marrying models to HAZUS, we could represent economic, environmental, and social risk. HAZUS is broadly used at the local level.

Topic 5 – General overview about current proposed products

Flooding model products derived from the Advanced Circulation Model (ADCIRC) for the entire study region:

(1) Simulation of tidal variations, wind-driven tides, and hurricane driven surges, baroclinic circulation, as well as changing shoreline and inundation patterns. The model extends from 90 km offshore of the barrier island system inland to the NAVD88 15 m topographic contour, and from just southwest of the New River to the north end of Currituck Sound. Horizontal resolution at the shoreline averages

100 m, and the model uses a 2 second time step. Included in this model is information from a Digital Elevation Model (DEM) with horizontal resolution of 6 m and vertical resolution of 15 cm, The DEM uses a continuous elevation dataset relative to NAVD88 assembled using the vertical datum transformation tool VDATUM.

(2) Maps of changes to the hydrodynamics of the system due to sea level rise (and investigate the effects of any coincidental changes as well). However, the main role of the Coastal Flooding Model providing input to ecological sub-models. The combined product of these models should be a system that provides predictions of ecosystem change as a function of sea level rise (and provides these predictions in a user-friendly format).

East Carolina products for the study region:

(3) Shore-zone and shore-line characterization and GIS tools to understand change for selected areas of marshes, sediment banks, and swamp forests, to calculate the influence of changing water levels, geomorphology, land-use, and hydrodynamics with a 50 m shoreline resolution

* Evaluate shoreline change over 40-year period (1958-1998), provide more realistic maps of shoreline retreat due to flooding (i.e. not just "bathtub" model)

* Evaluate dominant factors affecting shoreline displacement; develop maps displaying differences in forcing factors (e.g. fetch, wave energy, etc.)

* Evaluate the relationship between shoreline retreat and marsh vertical accretion (3 study sites; Roanoke Island, Cedar Island, and Pine Knoll Shores)

* Provide maps of areas at high risk of change due to sea level rise

(4) Ecological state in response to estuarine forcing

* Determination of feedback and transition processes between marsh and forest, marsh and subtidal environments and what thresholds are needed to initiate state changes from one zone to another

* Provide information on the impacts of future sea level rise when making land use decisions, especially in vulnerable coastal wetlands, which are an important habitat for a number of commercially valuable species of fish and shellfish.

* Predict and assess the ecosystem impacts of sea level rise in the sounds, nearby estuaries, and coastal regions, including landscape responses relevant to critical natural resources.

* Develop a combined geological and ecological framework of landscape condition and change relative to sea level rise. This can be used for large-scale policy decision making that acknowledges the underlying eco-geomorphology.

South Carolina/Vanderbilt products for the study region:

(5) First generation model will use the frequency and duration of inundation, the depth below mean high tide, and the proximity to salt marsh creeks to calculate the biomass production of *Spartina alterniflora* and *Juncus roemerianus*. Additionally, suspended sediment concentration is calculated as a function of

distance from the marsh creek, standing biomass on the marsh surface, and the tidal regime.

(6) The model predicts both organic and inorganic sedimentation rates at 1-10 m horizontal scale and cm vertical scale; model predictions also include depth profiles of 210-Pb and 137-Cs to allow for comparison between model predictions and field data.

(7) Thus, the final model will assess the impact of sea level rise on the biomass production rate, accretion rate, and the storage of organic carbon on the marsh surface. This model will be coupled into the final landscape model.

University of North Carolina, Institute of Marine Science products for Back and Bogue Sound

(9) Habitat simulation modules linked to the NOS coastal flooding model that will be shoreline stabilization on the productivity of unvegetated sub-tidal, submerged aquatic vegetation (SAV), inter-tidal flat and oyster reef habitats in Back and Bogue Sounds. GIS friendly.

(10) A map series of the sampling/modeling domain within Back and Bogue Sounds that depicts baseline habitat distribution, baseline biogeochemical and trophic characteristics, and spatially distributed forecasts from different model scenarios.

(11) Short and long term predictions of the functioning of unvegetated and vegetated subtidal and intertidal habitats producing the primary, secondary and higher trophic level utilization of the unvegetated sub-tidal, SAV, inter-tidal flat and oyster reef habitats of Back and Bogue Sounds for use in the Landscape model.

Table X. Summary of habitat sub-models for the NOAA-sponsored UNC-CH study of relative sea level rise (RSLR) in eastern North Carolina. The spatial (m^2) and vertical (m) units are the same among the 5 sub-models. The spatial resolution (grain size) varies depending upon the elevation of the habitat (sub- vs. inter-tidal) and the habitat complexity. Carteret County, NC will provide the spatial extent of mapping and modeling efforts. While the vertical resolution is constant at 0.1 m for all 5 sub-models, the vertical extent varies depending upon the elevation of the habitat relative to mean sea level (MSL).

HABITAT	SPATIAL			VERTICAL		
	unit	*resolution*	*extent*	*unit*	*resolution*	*extent*
SAND	m^2	20,000	Carteret	m	0.1 m	-2.0 to -1.0
SAV	m^2	2500	Carteret	m	0.1 m	-1.0 to -0.5
FLAT	m^2	250 to 2500	Carteret	m	0.1 m	-0.5 to 0.5
MARSH	m^2	1000 to 10,000	Carteret	m	0.1 m	0.0 to 0.5
OYSTER	m^2	???	Carteret	m	0.1 m	???

Final landscape model for entire study region

(12) Landscape model focused at the mid and long -range temporal/spatial scales for a watershed in eastern North Carolina to explore the hydrodynamics and wetland interactions in this estuarine area. The model includes morphological, biological, hydrodynamic and landscape change sub modules, all interacting with each other to predict coastal habitat change. Horizontal resolution 500 meters; 5 cm vertical resolution, time frame 100 yrs, time step 1 day.

Major points from the discussion with project scientists include:

1. Saltwater intrusion will not be addressed by any of the models since a groundwater component is not an area of priority at this time. However, the landscape model will predict salinity on the surface of wetlands and ECU is looking at salinity in their work.

2. The need to map infrastructure/transportation isn't directly part of any model, but the layer could be added to the interface for analysis. The model will need this component because infrastructure affects the ecological impacts.

3. Project activities include some shoreline analysis of pre and post shoreline hardening, looking at hardened vs. sills, plant tolerance to flooding, and this information will be incorporated into the models. Different levels of information will be needed for different audiences.

4. Shoreline change is addressed in the current project through the flooding model, looking at historical shoreline and shoreline change due to geological processes addressed in the Neuse by ECU. UNC is addressing shoreline change from ecological processes, as well as the ecological effects of hardening.

5. Legislation was recently passed that funded a high performance computing center in North Carolina. Several state universities will have an "engagement center" to access the super computer. ECU is among the first of these centers. Enrique Reyes of ECU, who has also been designated as the NOAA-Sea Level Rise project landscape modeler, plans to use this resource to run storm surge models looking at risks to the coastal areas using the Advanced Circulation Model (ADCIRC), a Finite Element Hydrodynamic Model for Coastal Oceans, Inlets, Rivers and Floodplains. It serves as the basis for the flooding model. The ADCIRC model is being developed in turn by Jesse Feyen, a NOAA scientist at Coast Survey Development Lab.

6. The models are not specifically for understanding risk and related hazards but information produced by the model can feed into that possibility. The ADCIRC model can be used for storm surge prediction as well.

7. Rainfall is not captured in the ADCIRC model, and we presently can't incorporate rainfall into the interface. Other models can capture rainfall. Rainfall usually falls for a shorter duration, days, or a week or so. The temporal scale of sea level rise is much longer.

8. Once scenarios are determined, a timeline of how much habitat is lost, when, where – a general timeline -- could be established.

9. Economics and environmental and societal values are not components of the project.

10. The various models will produce useful information for natural resource managers including mapping priority areas. Critical fisheries areas are included in several of the models.

Large group discussion on how attendees would like to get modeling information

1. There should be a hierarchy of interfaces unique for different types of users.
2. The research team could create a library of scenarios with various levels of sophistication looking at basic information commonly required.
3. A goal could be the ability to input information into the scenarios, or run actual scenarios. A choice of multiple interfaces, as well as pre-fabricated files, should be provided.
4. Accessible website with specific area/local scale, individual property owners to relate to county map, with GIS layers – user friendly a must!
5. Could the information be incorporated into the NC OneMap for open accessibility?
6. Outreach is very important. Plans should be made to present the information to as many audiences as possible. Individual property owners may be myopic/shellfish. Land owners need to look at big picture for education. Planners need broader picture, similar to flood plain mapping.
7. General Assembly also needs this information. Potential product users could include study commissions and staff, as well as presentations for county groups. Don't count on elected officials/staff to go to website. We need to be face to face.
8. Training session could explain what the models can do and limitations. A CD or something to take home would be helpful, as well as a regularly updated website.
9. State DOT will be a major user of this information as well as NCEM NC Geodetic Survey, Department of Agriculture, Division of Soil and Water Conservation runs state water management district and have technical people with statewide influence for technical assistance and education.
10. Possible private sector users include: Resource Conservation and Development Program (RC&D) Councils for agriculture/soil issues, coastal land reserves,

nature conservancy's, coastal engineers, home builders associations, realtors, green builders, timber companies, and the military.

11. An interactive kiosk in aquariums/maritime museums, as well as in coastal state and national parks where the public could run scenarios with different parameters would be a great outreach method.
12. Working with the DENR, NC Department of Environmental Education would be a great partnership as they are good at translating science in pamphlets

Final remarks

NOAA and its research partners will stay engaged with the group through email and websites. Face to face discussion will occur through future workshops. We would encourage participants to keep the interaction going! There is a small group being formed, the *Sea Level Rise Advisory Group***,** for those with keen interest in keeping up with the effort and have input on future projects. Diverse representation desired! Please contact the NOAA Program Manager, Carol Auer at carol.auer@noaa.gov or 301-713-
3338X164.

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Sea Level Rise Workshop

January 31 - February 1, 2007: Participant List

First Name	Last Name	Agency/Organization	Email Phone #
Carol	Auer	NOAA National Ocean Service	Carol.auer@noaa.gov 301-713-3338
Traci	Birch	University of New Orleans	tbirch@uno.edu
Sam	Bland	Hammocks Beach State Park	sam.bland@ncmail.net
Rob	Breeding	NC Ecosystem Enhancement Program	Rob.Breeding@ncmail.ne 919-733-5311
David J .	Brower	Department of City and Regional Planning, UNC-CH	brower@email.unc.edu 919-962-4775

Dean E	Carpenter	Albemarle-Pamlico National Estuary Program	Dean.Carpenter@ncmail.net 919-715-7735
Reide	Corbett	East Carolina University	corbettd@ecu.edu
Bill	Crowell	Albemarle-Pamlico National Estuary Program	bill.crowell@ncmail.net 919-715-1327
Mac	Currin	Marine Fisheries Commission	mcurrin1@bellsouth.net 919-881-0049
Carolyn	Currin	NOAA National Ocean Service, Center for Coastal Habitat and Fisheries	Carolyn.currin@noaa.gov 252-728-
Eddy	Davis	Mid-East Commission	edavis@mideastcom.org 252-974-
Lindy	Dingerson	NOAA Coastal Services Center	lynne.dingerson@noaa.gov 843-740-
Michele	Droszcz	NC Ecosystem Enhancement	michele.droszcz@ncmail.net 919-715-
Stephanie	Fauver	NOAA Coastal Services Center	Stephanie.Fauver@noaa.gov 843-740-
John	Fear	NC Coastal Reserve/National Estuarine Research Reserve	john.fear@ncmail.net 252-808-2808 x224
Rebecca	Feldman	Duke University Marine Lab	rebecca.feldman@duke.edu
Patrick N.	Halpin	Nicholas School of the Environment, Duke University	phalpin@duke.edu 919-613-8062
Philip S.	Harris	Natural Environmental Unit, NC Department of Transportation	pharris@dot.state.nc.us
Judy	Hills	Eastern Carolina Council of Governments	jhills@eccog.org 252-638-3185 x3005
Don	Hoss		dhoss@ec.rr.com 252-728-3885
Bryan	Hulka	NC Timberlands	bryan.hulka@weyerhaeuser.com
Whitney	Jenkins	NC Coastal Reserve/National Estuarine Research Reserve	whitney.jenkins@ncmail.net 252-728-2170
Kevin	Keeler	US Fish & Wildlife Service	kevin_keeler@fws.gov
Stanley	Kite	Craven County Emergency Services	skite@co.craven.nc.us252-636-6608

Jean	Lynch	NC Division of Parks and Recreation	jean.lynch@ncmail.net 910-458-8206 x227
Katrina	Marshall	Carteret County	katrinam@carteretcountygov.org
Pat	McNeese	NC Aquarium @ Pine Knoll Shores	patricia.mcneese@ncmail.net
Tancred	Miller	NC Division of Coastal Management	tancred.miller@ncmail.net
Gabriele	Onorato	Open Grounds Farm	gabriele.onorato@opengroundsfarm.com
Linda	Pearsall	NC Natural Heritage	linda.pearsall@ncmail.net
Sam	Pearsall	The Nature Conservancy	sampearsall@tnc.org 919-715-4195
Jason R.	Peterson	NC Department of Transportation	252-514-4716
Pete	Peterson	Institute of Marine Sciences, UNC-CH	cpeters@email.unc.edu
Michael F.	Piehler	Institute of Marine Sciences, UNC-CH	mpiehler@email.unc.edu 252-726-6841 x160
Joe	Ramus	Duke University Marine Lab	jramus@duke.edu 252-504-7617
Heidi	Recksiek	NOAA Coastal Services Center/Gulf Coast Services Center	Heidi.Recksiek@noaa.gov 850-728-1810
Tom	Reeder	NC Division of Water	tom.reeder@ncmail.net 919-733-5083
Enrique	Reyes	East Carolina University	reyese@ecu.edu 252-328-5778
Alex W.	Rickard	Eastern Carolina Council	arickard@eccog.org 252-638-3185
Tammy	Riddle	NC Emergency Management, Geospatial and Technology Management Section	triddle@ncem.org 252-520-4923
Stan	Riggs	East Carolina University	riggss@ecu.edu
Spencer	Rogers	North Carolina Sea Grant	rogerssp@uncw.edu 910-962-2491
Greg "Rudi"	Rudolph	Carteret County Shore Protection Office	252-393-2663
Frank	Rush	Town of Emerald Isle	frush@emeraldisle-nc.org 252-354-3424
Tonda	Shelton	NC Floodplain Mapping Program, Div. Emergency Mgt.	tshelton@ncem.org 919-715-5711 x 114

Allen	Smith	Carteret County Emergency Service	allens@carteretcountygov.org 252-728-8470
Guy	Stefanski	NC Division of Coastal Management	guy.stefanski@ncmail.net 919-733-2293 x253
Jim	Stephenson	NC Coastal Federation	jims@nccoast.org 252-393-8185
Mike	Street	NC Division of Marine Fisheries	mike.street@ncmail.net2 52-726-7021
Penny	Tysinger	Cape Fear Council of Governments	ptysinger@capefearcog.org
Steve	Underwood	NC Division of Coastal Management	steve.underwood@ncmail.net 919-733-2293 x224
Christine M.	Voss	East Carolina University	cmv0509@ecu.edu
Jeff	Warren	NC Division of Coastal Management	jeff.warren@ncmail.net 919-733-2293 x241
Brian F.	Yamamoto	NC Department of Transportation	byamamoto@dot.state.nc.us 919-733-7844 x265

Managers Invited		
Organization	**Potential Attendee**	**Email**
Open Grounds Farm	Gabrielle Onorato	
Weyerhaeuser Co.	Bob Emory	bob.emory@weyerhaeuser.com
	Bryan Hulka	Bryan.Hulka@weyerhaeuser.com
NCDOT	Rob Hanson	rhanson@dot.state.nc.us
	Mike Bruff	mbruff@dot.state.nc.us
Coastal Resources Commission/UNC-Wilmington	Courtney Hackney	hackney@uncw.edu
Marine Fisheries Commission	Mac Currin	mcurrin1@bellsouth.net
	Barbara Garrity- Blake	bgb@coastalnet.com
Environmental Management Commission	David H Moreau	dmoreau@email.unc.edu
NC Division of Coastal Management, DENR	Charles Jones	Charles.S.Jones@ncmail.net
	Steve Underwood	steve.underwood@ncmail.net
	Jeff Warren	jeff.warren@ncmail.net
	Ted Tyndall	Ted.Tyndall@ncmail.net
Division of Water Quality (DENR)	Tom Reeder	tom.reeder@ncmail.net
	John Dorney	JOHN.DORNEY@ncmail.net
	Paul Rawls	PAUL.RAWLS@ncmail.net
	Darlene Kucken	DARLENE.KUCKEN@ncmail.net

Eastern Carolina Council of Governments	Judy Hills	jhills@eccog.org
Division of Marine Fisheries	Mike Street	mike.street@ncmail.net
	Katy West	Katy.West@ncmail.net
DENR Office of Conservation &	Jimmy Johnson	Jimmy.Johnson@ncmail.net
Division of Environmental Health, Onsite Wastewater Management (DENR)	Andy Adams	Andy.Adams@ncmail.net
Natural Heritage Program	Linda Pearsall	Linda.Pearsall@ncmail.net
Clean Water Management Trust	Bill Holman	bill.holman@ncmail.net
Division of Forest Resources	Ralph Cullom	ralph.cullom@ncmail.net
NC Sea Grant	Spencer Rogers	rogerssp@uncw.edu
EEP	Bill Gilmore	bill.gilmore@ncmail.net
Ecosystem Enhancement	Kevin Miller	Kevin.Miller@ncmail.net
	Rob Breeding	Rob.Breeding@ncmail.net
US Fish & Wildlife Service - South Atlantic Fisheries	Wilson Laney	wilson_laney@fws.gov
Cedar Island National Wildlife	Kevin Keeler	kevin_keeler@fws.gov
Hammocks Beach State Park	Sam Bland	sam.bland@ncmail.net
Cape Lookout National	Mike Rikard	michael_rikard@nps.gov
Fort Macon State Park	Jody Merritt	Jody.Merritt@ncmail.net
NC National Estuarine Research Reserve/Coastal	John Fear	john.fear@ncmail.net
	Anthony Snider	snidera@uncw.edu
Albemarle-Pamlico National Estuary Program	Bill Crowell	bill.crowell@ncmail.net
	Dean Carpenter	dean.carpenter@ncmail.net
ED	Dave McNaught	Dmcnaught@edf.org
ED	Doug Rader	doug_rader@edf.org
Environmental Defense	Michelle Duval	mduval@environmentaldefense.org
	Sarah King	sarahk@nccoast.org
NC Coastal Federation	Jim Stephenson	jims@nccoast.org
	Tracy Skrabal	tracys@nccoast.org
Carteret County Emergency	Allen Smith	allens@carteretcountygov.org
Craven County Emergency	Stanley Kite	skite@co.craven.nc.us
Pamlico County Emergency	Ben Barnett	emc@cconnect.net
Division of Emergency Mgt.	Tammy Riddle	triddle@ncem.org

Carteret Co. Crossroads	Don Hoss	dhoss@ec.rr.com
NC Scientists	Pete Peterson	cpeters@email.unc.edu
	Orrin Pilkey	opilkey@duke.edu
	Stan Riggs	riggss@ecu.edu
	Mark Brinson	brinsonm@ecu.edu
	Carolyn Currin	Carolyn.Currin@noaa.gov
	Richard Rheinhardt	RheinhardtR@mail.ecu.edu
NC House	Pricey Taylor Harrison	priceyh@ncleg.net
NC Senate	Charles Albertson	charliea@ncleg.net
President Pro temp	Marc Basnight	**marcb@ncleg.net**
Nature conservency	Jeff De Blieu	jdeblieu@tnc.org
Builders/developers	Joe Tarascio	joebet@ec.rr.com
Builders/developers	ed mitchell	edmitchell@riverdunes.com
Builders/developers	buddy milliken	themillikencompany@ec.rr.com.
planner	Katrina Marshall	katrinam@carteretcountygov.org

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