DRAFT

APNEP Scientific and Technical Advisory Committee
Sea-Level Rise Meeting Notes
November 30, 2012

Auditorium and First Floor Combined Conference Room
Coastal North Carolina National Wildlife Refuges Gateway Visitor Center
100 Conservation Way, Manteo, North Carolina

STAC Members Present: David Kimmel (ECU), Andy Keeler (ECU), Burrell Montz (ECU), Randy Swilling (NPS), Tom Crawford (ECU), Rich Whittacre (ODU), Kirk Havens (CWM-VIMS), Heather Jacobs Deck (PTRF), Maurice Crawford (ECSU), Robin Dennis (USEPA), Jud Kenworthy (NOAA retired), Tim Spruill (USGS retired), Bob Miller (UWSP retired), Erin Fleckenstein (NCCF), Wilson Laney (USFWS), Michelle Moorman (USGS), Jess Whitehead (NCSG), Curtis Richardson (Duke), Heidi Wadman (USACE), Reide Corbett (ECU)

State Agency Liaisons Present: Jack McCambridge (VA-DOT), Bill Swartley (NC-FS), Scott King (NC-EEP)

Guests/Public Present: Janine Nicholson (NC-OCPCA), Linda Pearsall (NC-OCPCA), Tancred Miller (NC-DCM), David Mallinson (ECU), Sam Pearsall (EDF), Ben McFarlane (Hampton Roads PDC), Carl Hershner (VIMS), Lin Yuan (Duke)

APNEP Staff Present: Dean Carpenter, Bill Crowell, Jim Hawhee, Jimmy Johnson

Call to Order

STAC Co-Chair Reide welcomed everyone and noted that he was glad everyone made it to the meeting.

Minutes from the summer (July 25) meeting were approved.

Bonnie Strawser, Visitor Services Manager, welcomed the group to the facility. Bonnie noted that the Center is a "gateway" to 11 National Wildlife Refuges and one National Fish Hatchery, all located in Northeast North Carolina and Southeast Virginia. They are proud of the fact that while Alligator River NWR received American Recovery & Reinvestment Act (ARRA) funding for the Center, they decided to take a landscape-level approach to the design of the facility. She noted that the Pocosin Lakes NWR Visitor Center in Columbia is also supposed to be a gateway to the North Carolina coast, but because of the design of that facility, it is perceived by the public more as a rest stop. The Refuge Visitor Center, at the far end of that building, is often overlooked by the public. They hope that this new Center will become a tourist destination, like the North Carolina Aquarium and other attractions. Bonnie briefed the group on the exhibits in the facility. She addressed the major exhibits, including the biologically correct diorama, which includes 37 different species, along with tracks, and examples of scat. There is a real Cessna airplane, with aerial video of all 12 of the FWS facilities which are introduced here. The airplane was secured through surplus property, for low cost, so they were able to procure very good high-definition footage. There are waterfowl, red wolf and other exhibits as

well. There is also an object theater, with several six-minute presentations, and Bonnie encouraged the audience to sit through at least two of those. The videography is wonderful.

APNEP Briefing, Dean Carpenter: Dean introduced himself, and noted that he was now the APNEP "Partnership" Scientist. He thanked USFWS and particularly Bonnie for hosting us in this new facility. Dean updated us on the events of the past four months. Todd Herbert, APNEP's Virginia Field Representative, has resigned from the Virginia Department of Conservation & Recreation and APNEP to take a position as a contract employee at the NASA Langley Research Center in Hampton, Virginia. APNEP staff will work to get a new representative soon. Dean welcomed the attendance of Scott King, Bill Swartley, and Jack McCambridge as state agency liaisons. He also welcomed guests Linda and Sam Pearsall. Regarding recent STAC membership changes, John Hefner has resigned and Rich Whittacre was elected. Jud Kenworthy was elected as STAC co-chair. The tentative date for the next STAC meeting is March 26, but that may need to change. During October aerial imagery was acquired for the northeastern coast (Back Bay; Currituck, Roanoke, Croatan Sounds) for SAV monitoring. Image acquisition for the remainder of the outer coast within the APNEP region is scheduled for the May-June period. APNEP staff are working with NCDOT Photogrammetry staff to map SAV extent. The big news is that there is a new North Carolina Governor's executive order for the Partnership. As part of implementing the order STAC members had to be reappointed by the DENR Secretary, so that is why Dean is handing out new appointment letters. The last "P" in APNEP has changed from "Program" to "Partnership." The Policy Board has shrunk to about half its former size, and while the Citizens Advisory Committee (CAC) and Management Advisory Committee (MAC) is no more, there is a new body: the Implementation Committee. In mid-November APNEP celebrated its 25th anniversary. The 2012 ecosystem assessment has been completed, and a pre-publication copy is available on the APNEP web site. A final version should be available near year's end. Staff is interviewing to replace the project coordinator position formerly occupied by Scott Gentry. The STAC Executive Board will be meeting next Tuesday. The Policy Board is scheduled for February and hopefully by then the new DENR Secretary will be in office, and transition will be well underway.

Tim Spruill asked for confirmation that the CAC and MAC had been replaced by the new Implementation Committee. Bill Crowell explained that some members from those former committees will serve on the new Implementation Committee. No member of the former committees was told they couldn't continue to serve in some capacity, and everyone has been really supportive. Tim asked what the projected size of the new Implementation Committee will be. Bill replied that committee size has not yet been determined. Staff is reviewing CCMP actions to understand better the type of support needed. Tim asked how the citizen dimension will be included. Bill noted that there are some CCMP actions, such as those involving communication, for which citizen input will be needed. A member of the audience asked, "what drove the change?" Bill responded that in concert with updating the CCMP, staff wanted a new structure for implementation. The North Carolina General Assembly also wanted a reduction in the number of advisory bodies. When the executive order was requested, the North Carolina Governor asked a lot of questions and the new structure addresses some of

those. A number of the other National Estuary Programs (NEPs) have also changed their title to reflect that they are a partnership. The web site will be retained, and other aspects will remain the same.

Bill welcomed everyone to the very first meeting of the new STAC, and noted that he will be around all day should members have further questions. He thanked all the STAC members who agreed to continue serving.

Dean noted that under the new STAC leadership the meetings are theme-based. This first one is on sea-level rise (SLR), two others this year on water quality and shoreline development, and a third, probably in early 2014, on ecological outcomes.

Dean explained that when the meeting breaks for lunch the venue will move to the other end of the building, so to avoid interrupting USFWS staff all will migrate outside the front of the building and reconvene in the conference room for the remainder.

Editor's note: Because of a delay in meeting starting time due to technical difficulties with a new theater projection system, Dean restricted his APNEP briefing to November activities and informed the audience that activities for August through October would be included in these notes. During early August, Bill Crowell attended a Southeast Natural Resource Leaders Group (SENRLG) meeting in Atlanta. STAC member Don Field and Dean met with NCDOT Photogrammetry staff in Raleigh to facilitate cost estimates for SAV image acquisition. STAC Executive Board held a teleconference. During late August and mid- September, Dean joined STAC members Erin Fleckenstein and Wilson Laney in two two-day workshops in Manteo to support the Estuarine Core Team for the US Department of Interior's Eastern North Carolina/Southeastern Virginia (ENCSEVA) Strategic Habitat Conservation (SHC) planning. During early September, Dean attended a SAV Partnership meeting in Washington, NC with STAC members Jud Kenworthy, Don Field, and Wilson Laney. During late September APNEP submitted a SAV monitoring protocols report to funder North Carolina Coastal Recreational Fishing License (CRFL) program: the report's senior author is STAC Co-Chair Jud Kenworthy, with Don Field and Dean also contributing. Wilson Laney and Dean participated on a teleconference for a South Atlantic Landscape Conservation Cooperative (SALCC) natural resource indicator team. During early October, Wilson Laney and APNEP staff attended a two-day SALCC biological objectives workshop in Raleigh. Jud Kenworthy with APNEP staff members Jim Hawhee and Dean spent two days sampling SAV in the Swan Island area, followed a week later by Dean joining STAC member Maurice Crawford and North Carolina Division of Marine Fisheries staffer Brad Fitzgerald for another day SAV sampling in the Knotts Island area. Erin Fleckenstein also assisted by organizing volunteer monitoring of Secchi depths in southern Currituck Sound. These events in Currituck Sound all support the aforementioned 2012-2013 SAV monitoring. During mid- October and mid-November, Dean joined STAC member Randy Swilling in two two-day workshops in Raleigh to support Uplands Core Team for ENCSEVA-SHC planning.

Everything You Wanted to Know About Sea Level in 30 Minutes or Less, Dr. David Mallinson, Associate Professor in the Department of Geological Sciences, East Carolina University and STAC alumnus: Dave gave a PowerPoint presentation entitled "Sorting out Sea Level." He doesn't consider himself an expert on SLR, but he is a coastal geologist and uses sea level a lot in his work. STAC Co-Chair Reide had asked him to address SLR relative to North Carolina. Dave will address what is sea level, why does it change, what the past tells us, what's happening now, and what the future looks like.

First, a definition of sea level. It is looking at the sea surface, relative to some datum. Eustatic sea level is relative to the center of the earth. Relative sea level (RSL) is referenced to a local datum. Another factor is called "water depth," which is just the amount of water above the substrate. Sedimentation occurs, plus some charts still have old data, so the depth changes.

"Eustasy" sea level change is measured relative to a fixed datum; and relative sea level, which incorporates local factors (e.g., vertical land motion) and is level change relative to a local datum (e.g., crystalline basement). If land is rising, the RSL may remain unchanged. A eustatic rise can also cause an apparent drop in RLS.

Dave addressed causes of sea-level change. Eustatic changes are driven by changes in the total volume of water, or by changes in the volume of the ocean basins. Factors which play a role include rates of seafloor spreading, sedimentation, juvenile water, land-ice volume, deep sea hydro-isostasy, density change of the water, and terrestrial water storage. There is a lot of water stored behind dams and that has to be taken into account as well.

There are also relative changes, eustatic plus the following local/regional effects, including: tectonism, local vertical land motion; glacial and hydro-isostasy-local variations; geoid changes; sediment compaction; groundwater extraction; redistribution of water masses; currents, tides, and wind patterns or other meteorological conditions. Dave explained how each of these factors can contribute to relative changes. The Gulf Stream, for example, can vary its speed and thereby raise or lower RSL.

Dave showed a figure which summarized some of these cause of sea-level change.

Scientists try to incorporate all of these factors to understand local RSL. There is an equation which has multiple terms for all of these factors.

Dave addressed the reason for spatial variation in sea-level change. He discussed mass contribution to sea-level change from ice-sheet melting. Sea level is not level. When you lose mass from existing ice sheets you get corresponding rise in sea level but in opposite hemispheres, which is counter-intuitive.

A figure depicted how changes in temperature also contribute to changes in SLR. A graph showed the contribution of terrestrial water storage and meteorological phenomena, to changes in mean sea level. La Nina is one meteorological event which can result in significant changes in sea level. Water can actually be redistributed between water and land. Gravity Recovery and Climate Experiment (GRACE) shows these changes which have occurred.

Another factor is the slowing of thermohaline circulation. When water cools it sinks, and if you slow that sinking down the whole system can back up. If circulation slows down, you can get spatial variability in where sea-level rises or falls.

Northern North Carolina is subsiding, faster than southern North Carolina. This is related to past continental ice sheets north of here. So there are glacio-isostatic effects, near-field, which cause lands formerly near the ice sheets to rebound. So in Hudson Bay the land is uplifting, because the ice sheet melted. North Carolina sits on the forebulge, part of the intermediate-field effects. Once the ice sheet has melted, the bulge begins to subside, and North Carolina is doing so, so that makes SLR appear to be even faster. If you go even farther away, say to the Southern Hemisphere, then you see far-field effects. The weight of added water from melting ice causes some depression. A figure of glacio-isostasy summarized all of these changes.

A figure showed forebulge collapse due to glacio-isostasy. In our area, forebulge collapse is about 3 mm per year.

A study of North Carolina tide gages show various rises in sea level, with northern gages showing greater rises than in the south.

A table displayed all of the components necessary for a sea-level budget. There are many of them, including shallow thermal, deep thermal, and groundwater withdrawal, among others.

A graph showed the geologic record of sea-level change. Foraminifera are used as indicators of the change in SLR. Coral reefs around the globe are also indicators of past sea level changes. There are uplifted coral reefs, for example, in Papua, New Guinea. Tom Crews asked if they were uplifted, or exposed. Dave indicated that they were definitely uplifted.

The geologic record allows an understanding of process relationships and what is possible. The past 500,000 years of sea-level change show that in the past, sea level was actually higher than it is today. There have been some rapid drops and rises. Such changes explain the Suffolk Shoreline, which was present about 120,000 to 80,000 years ago. That change occurred without any anthropogenic forces. That is a scary scenario, but lets us know what is possible.

Another method used to develop sea-level curves for this immediate area is to core peat in marshes. Once again, you can look at the different foraminifera which were living on the marsh surface at different sea levels. They are related to the mean tide level, about sea level. Andy Kemp and Ben Horton did this work. Their analysis shows that 2,000 years ago sea level was

about 8 feet lower than it is today. Since about 1900 there has been a rapid acceleration. The rate went from 1 or 2 mm per year, to about 3 mm per year in more recent times.

Tide gage data provides additional information and there is some very good gage data in North Carolina. There is a lot of variability due to land changes and wind influence. A number of curves from gage data exhibit non-uniformity and much variability. There are ways to accommodate this variability and normalize the data.

Satellite altimetry data also show the trend in SLR. A figure showed spatial trends in sea level from 1993-2008. Our area is complicated by the Gulf Stream dynamics, but the change is around 3-4 mm per year.

To forecast future sea level changes, we must understand past temperature and sea level changes. In recent years there has been a pretty dramatic rise in temperatures. The ocean is warming. We can monitor change via satellite, through GRACE and the Geoscience Laser Altimeter System. The GRACE estimates Greenland Ice Sheet loss. Last year there was a net loss everywhere on the Greenland Ice Sheet. Melting affects sea level as well as deep water formation. Reduced deep water formation may cool temperatures in Europe. Meltwater from Greenland alone is adding 0.5 mm per year of SLR.

Dave explained how extrapolations are made for future SLR. They have worked on models with Stefan Rahmstorf (Potsdam University). The models regress past temperature, or radiative forcing, with sea-level change to project into the future, using emission scenarios (which indicate future radiative forcing, based on CO_2 projections).

The model projects about a 1 m rise in sea level, but Dave noted that the error bars were pretty large. Dave and Reide were both part of the science panel which estimated SLR in North Carolina, for which they were pretty heavily criticized by some folks down east. Dave noted that there are multiple modeling approaches to estimating SLR, and all of them show from 50-100 cm SLR. Stefan decided to take a look at all of the models, and all of them wind up in about the same place, showing about a 1-m SLR.

The IPCC temperature forecasts, based on a new paper, are all right on the money. On the other hand, the SLR is at the uppermost limit of IPCC forecasts. So, they way underestimated the SLR rate, which is scary. A graph of Stefan Rahmstorf's comparison of all of the models suggested a 1-m rise is fairly well anticipated.

Dave turned to the question of whether SLR is accelerating now. Scientists can't say with confidence, statistically. Another 5-10 years of data is needed, depending upon how rapidly it might be accelerating. The more rapid, the sooner we will know.

Dave noted what has happened to the barrier islands in the past, during periods of relative low and high SLR. Dave noted that the islands are on the verge of serious collapse, if and when we get a Category 4 or higher storm.

One thousand years ago there were marine sediments in the sounds, and sediment movement can be estimated with a hydrodynamic model. If through storm activity the Outer Banks develops broad inlets, the tidal range can go to a meter. That is a significant concern and a more immediate threat than the 100-year SLR. The biggest problem may NOT be the slow, steady inundation caused by SLR, but the rapid morphodynamic response that could potentially cause a change to a higher tidal regime.

Bill Swartley noted that NOAA had projected a 23-cm rise a number of years ago, so what changed? Dave indicated that they were using an IPCC model which didn't take the ice melting into account. Dave Kimmel asked why the change in the upward direction appears to happen more rapidly. Dave Mallinson explained that the melting, which lowers the surface of the ice, also moves it closer to warmer temperatures, so melting happens faster. Tim asked if Dave had presented this to the NC-20 organization. Dave said that much of it has been presented to them in the first SLR report by the Science Advisory Board for the NC Coastal Resources Commission. This CRC-SAB will be preparing a second report, but all of the models appear to be converging on about the same rate of rise. Tom Crews asked if solar variation had been incorporated into the models. Yes, it has, but it doesn't appear to contribute very much: most of the change has to do with increasing greenhouse gases.

Carl Hershner asked for a return to the previous slide and noted that it has a lot of import for APNEP. Dave noted that STAC produced a technical issue paper which addressed the potential changes. Dave hasn't published this figure yet, but noted that the model he used could be used to project changes in salinity as well. Carl noted that a lot of changes could occur based on the changes in salinity, especially with regard to the changes in fauna. Dave and Reide noted that they are on the verge of being able to make some of these projections. They need to couple the model. Dave noted that you may actually increase marsh area and that the intertidal zone may expand broadly. He asked us to consider what Hurricane Sandy did to this region, and it was 150 miles offshore. A category 2 or 3 hurricane will be devastating to this area. Reide noted that this area has never had a Category 4 or 5. Dave noted that several category 2's or 3's may have the same effect. There could easily be some new inlets into Currituck Sound, but they may close quickly.

Recurrent Flooding in Virginia, Dr. Carl Hershner, Associate Professor, Virginia Institute of Marine Sciences and Director, Center for Coastal Resources Management: Carl noted that Virginia was in the process of conducting a study, which is the Virginia legislature's way of kicking the can down the road. The study is being driven by recurrent flooding in some high-dollar areas, particularly in Norfolk. Flooded localities wanted to get the issue back on the front page. Four years ago, under a Democratic administration, Virginia had a climate change commission, which produced a report and a web site. The report was shelved and the web site

was taken down. Now, they are finding that all of the recommendations made four years ago are pertinent and should have been implemented then. They decided to call SLR "recurrent flooding," and that turned out to be a pretty good term. In southeastern Virginia, the flooding is as much precipitation-driven as it is by storm surge.

Virginia has all the same issues and all of the same data as North Carolina. Rate of change in SLR is faster in Virginia than in North Carolina, by several mm a year. Virginia's coast is experiencing land subsidence, which is driven by glacial isostasy, groundwater withdrawal, and by a meteor which struck the area many years ago. The two groundwater epicenters of change are both associated with paper mills, in West Point, and Franklin, Virginia.

Carl addressed the Chesapeake Bay impact crater and the changes which are resulting from that impact. There is still some subsidence occurring from that impact.

Carl addressed the Atlantic Meridional Overturning Circulation, and the North Atlantic Oscillation. A graph showed the bottom line for Virginia. There are four southeast Virginia SLR scenarios: ranging from historic, through low, to high, to highest. The highest scenario is based on everything happening as fast as possible. The high would be driven by temperature changes, the low if management actions are undertaken, and the historic just an extrapolation. The Virginia Climate Commission projected a level in between the historic and low scenarios. Boon (2012) projected a point on the high curve.

When Virginia researchers looked at all the data and tried to provide advice to the managers and local politicians they thought about 2100, but that was a long way in the future. The decision-making time frame for those building public infrastructure, they concluded that a 20-50 year planning horizon was appropriate. They elected to go with a 1.5-foot rise anticipated in that period. Currently, the empirical data is tracking the curve for the "high" projection. A lot depends on what happens with the ocean circulation, which is cyclic. Some accelerations in the mid-Atlantic are at 2.5 mm per year.

Their findings regarding recurrent flooding: flooding is bad and becoming worse; risk varies; planning data are lacking; options require time for implementation. It makes no sense to talk to politicians about impacts on natural resources, because in general they don't care about the future location of marshes. All they care about is where the public infrastructure will be affected. They are motivated by the economic impacts which will occur. The flooding is impacting potentially billions of dollars of infrastructure. The data needed for doing planning do not exist in formats easily assembled. There are some data held by FEMA and insurance companies, but they aren't easily assembled. Looking at adaptation options, they found that even the most highly-dedicated groups can take decades to complete planning, engineering, installation and operations, and even the ones on the Thames River will be good for only 40 years.

They noted that delayed action will only increase impacts and costs, and the state should take a lead role, because flooding is a cross-jurisdictional issue and for other reasons.

Scientists in Virginia started years ago collecting information and putting it in a format useful for local officials. They put these online, in Comprehensive Coastal Resource Management Plans. Carl showed the web site for CCRMPs in Fairfax County and the City of Alexandria. There are all kinds of data on these sites available for citizens. They are developing these for all of the coastal localities in the Virginia coastal zone. They did get the Virginia legislature to require incorporation of these into local land use planning. They are trying to motivate state policy. The messages have to be simple, and focus on human impacts and infrastructure, and have straightforward messages. They aren't trying to hide anything, and not to downplay the expenses.

Sam Pearsall noted that Carl mentioned the difficulty of getting any response to concern for natural resources and that most of the concern was for public infrastructure but he didn't mention private property. Have they taken private property into consideration? Carl said yes. There are three approaches to dealing with SLR: adaptation, accommodation and defense. He noted that Norfolk had looked at defending two small areas, and the cost was over $100 million for each area. Residents can stay in an area as long as possible, but at some point they need to leave. They are concerned about the legal authority which the government has when services are withdrawn. There is some risk that private property owners could claim a taking, and they are working on that issue with legal experts. There are two areas in Virginia where private property is going to become public property, when it falls below mean high water (MHW). The Norfolk mayor has been talking about the need to selectively abandon parts of his city, and he was hammered, big time, so he hasn't mentioned it again. The discussion is there, but not as much as the public policy discussion.

Tim suggested in jest that Virginians should do as North Carolina and just prohibit SLR. Carl noted they were very impressed.

Reide noted that the STAC had actually discussed at their summer meeting whether members should use the terms "climate change" and "sea-level rise." Do Virginia researchers use select terms in closed versus open meetings?

Carl said that they are very direct in all the conversations. It is just the politicians who choose to use code words. Virginia is a Dillon's Rule state, where the local governments have only the authority which is given them by the General Assembly. The local governments in Virginia already have the authority to deal with local flooding, but not with climate change and SLR. In their reports Carl and colleagues say climate change and SLR, and don't use code words.

Linda Pearsall asked how the insurance companies are dealing with this. Carl indicated that one Virginia scientist has been talking to many insurers. Some of them are writing policies which don't cover winds over 74 mph and which exclude coastal flooding. The decision is individual-

by-individual, and has to do more with credit ratings. They are trying to determine whether climate change and SLR are considered in the insurance industry, but it appears that other factors are more important to them. Someone asked if they have talked to the reinsurance providers, and Carl indicated they have. They are trying to get all of the insurers engaged.

The comment was made that if local regulations change regarding construction then insurance regulations or policies will often follow.

Carl noted that if communities implement appropriate regulations, insurance rates will often drop. Yet there doesn't seem to be any governmental awareness to take advantageous of that fact.

Andy Keeler noted that the Flood Insurance Program has been ineffective in transferring risk. There are some interesting questions now, such as when you require protective measures do you get in the way of other folks who want to retreat.

Sam Pearsall noted that there was a relevant article in the New York Times yesterday.

Carl noted that they have been looking at the potential impacts on SAV and oysters. They anticipate losing about 50% of the tidal wetlands in Virginia. They are interested to see what happens here in North Carolina, where there is a higher likelihood of developing policies which will allow our habitats to retreat. They are looking to North Carolina for informative policies.

Reide noted that Tancred has taken the brunt of the criticism for the North Carolina SLR report, and he will give us the history of it and how they see things moving forward.

NC DCM Policy Perspectives – How Can Science Best Serve?, Tancred Miller, Coastal Policy Analyst, DENR Division of Coastal Management: Tancred noted that North Carolina is ground zero for SLR. He gave a presentation on HB 819 requirements. They had taken the CRC on a field trip a couple of weeks ago and tried to give them a first-hand view of drainage issues, and what SLR is doing to land. They heard that salt water is moving further inland, and farmers are seeing coastal wetland vegetation where they haven't seen it before. The North Carolina Division of Coastal Management (DCM) is trying to get a handle on SLR, and minimize the negative consequences.

Once DCM had the CRC Science Panel on Coastal Hazards report, they assembled a draft policy. They took a non-regulatory approach, and provided advice to local governments and planners. DCM distributed a series of broad guidelines, and told them that the state would support them. They tried to be forceful and recommend proactive action.

Tancred reviewed what HB 819 sections mandate: Section 1 defines the coastal area; Section 2 mandates that CRC/DCM shall be the only state agency authorized to define rates of sea-level

change for regulatory purposes (except that the CRC may not define rates of SLR for regulatory purposes prior to July 1, 2016). The postponement in rate definition wouldn't really impact the CRC or DCM. In response to some of the ridicule over the General Assembly's actions, coastal counties, municipalities and other entities are allowed to determine their own rates.

A CRC science panel is required to deliver a five-year updated assessment no later than March 31, 2015. It must include a comprehensive literature review of the full range of global, regional and North Carolina-specific sea-level change data and hypotheses; it must define assumptions and limitations of modeling; and must be made available for public comment. The CRC must compare the determination of sea-level based on historical calculations versus predictive models. The CRC must evaluate different sea-level rates for different parts of the coast. The CRC shall study economic and environmental costs and benefits of developing, or not developing, SL regulations and policies. The CRC must present its reports, including public comments and any policies the Commission has adopted or may be considering that address sea-level policies to the General Assembly's Environmental Rules Commission no later than March 1, 2016. Tancred noted that DCM will do these tasks.

DCM produced a rough implementation timeline. The science panel assessment report is due March 31, 2014, and the goal is to have a draft available by late summer/early fall 2014.

A list of the 13 Science Panel members was displayed. The General Assembly did not give the panel any resources to do their work, thus they are working on a pro-bono basis. The CRC will be the determiner of who will draft the report.

The bill brought a lot of negative focus to the state, but it really doesn't move DCM too far away from what the agency originally envisioned. Having it laid out legislatively takes away some of the uncertainty regarding how they were to do the work. There is a good dialog ongoing within the state. DCM staff wants to communicate a sense of what is actually happening, and cause CRC to see the impacts. They want them to see that ditches originally cut to drain land are now bringing in saltwater and contaminating the soil. Some of the aspects of SLR are fairly abstract, so they are trying to supplement the numbers and make it real for citizens.

Tim Spruill noted that there are no outside reviewers on the panel, and he felt that is a bad idea. Also, they put off the decision regarding what to regulate, and they didn't put in a moratorium, so if the economic climate improves and more development occurs the decision is just being delayed.

Tancred stated that there were a handful of out-of-state reviewers, and they will probably try to formalize that in the future. With regard to development between now and 2016, they felt that there was too much uncertainty regarding the exact amount of SLR, and also it has proven a difficult thing to regulate local development in other states based on the SLR projections. DCM will be trying to help local governments to develop appropriate ordinances.

Carl asked Tancred to return to the slide which stated, "coastal counties, municipalities, or other local government entities may define rates of sea-level change for regulatory purposes." He asked whose rate could trump someone else's rate, and who is really in charge. Tancred stated that is an interesting question, if a local authority says they are adopting 2 inches, and the state adopts 6 inches in 2016. In that case, he stated that the state's level would trump the local rate selected. Carl felt that it didn't make much sense to allow the locals to go ahead and select a rate.

The question was asked whether there are local governments interested in designating a rate. Tancred noted that some of them are. For example, the mayor of Plymouth is very interested. That town sees it coming, but such foresight is not widespread.

Kirk asked if it was required that they put some climate change skeptics on the science panel. Tancred stated that they are not required to do so, but he felt that it might be useful to include some skeptics to brunt the criticism that the panel was biased.

Tom Crawford asked if they are required to proclaim an official rate. Tancred confirmed that an official rate is not required, but CRC will be the state voice if a rate is proclaimed. Tom noted that he had heard that only historic data and no models could be used, but he didn't see that on the presentation. Tancred noted that it was thanks to Steven Colbert that provision was removed.

The question was asked whether there is any indication that the new North Carolina governor and legislators are more science-literate than the previous ones, but the question was withdrawn before it could be answered.

Dean asked about the environmental impacts of SLR. Tancred noted that is a part of the mandate, but they have no resources and will be seeking expertise to conduct that evaluation.

Working Lunch: Sea-Level Rise Research on Atlantic Coast, Dr. Reide Corbett, STAC Co-Chair and Professor, Department of Geological Sciences, East Carolina University and Program Head, Coastal Processes, University of North Carolina's Coastal Studies Institute: Reide gave the STAC a presentation on the project which Ben Horton, Reide and five other principal investigators are doing, which will be looking at SLR along the entire east coast. This is part of a NOAA competition which focused on improving NOAA's Climate Services for the Coastal Zone. Their proposal entailed integrated work across four thematic areas: observations, modeling, earth system science, and decision support. The research team also were mandated to involve the public, hence the workshops they held along the coast. In the past, sea levels have been much higher at the same temperatures. The ice sheets in Greenland and the Antarctic are retreating at dramatically higher rates, so that is contributing to increased projections for SLR. The ice sheets weren't considered by the IPCC. The new study from the journal Science has better data for the ice sheets and will probably be included in the next IPCC report. Again, there is a

reminder that the Greenland and Antarctic ice sheets influence sea level in their opposite hemispheres.

The team's study sites range from Boston in the north to Miami in the south. The North Carolina site, in the middle of the range, has the longest and best data set. They have collected sediment cores from all of the sites and are developing good sea-level curves for each site, back 2000 years.

They are identifying past sea-level variations. They are looking at the Medieval Climate Anomaly, the Little Ice Age, and the 20th Century periods. They are developing semi-empirical models, which he noted have not in the past been included in the IPCC reports, but are included in the present IPCC draft. The point is that one can develop regression models between temperature and SLR, and use the models to predict the future. The relationship between temperature and the forcing variable is based on real data.

Reide explained how the sea-level curves are developed, and noted that Dave had already explained these. Chronologies are very important and are developed using various techniques. Their regression is initially based on 2000 years because that was the longest core they had at the time.

There are some big questions relative to SLR rates. Even members of NC-20 don't argue that sea level is rising, they only disagree on the rate. Some published studies have varying time frames. They are trying to understand in the North Carolina dataset how the rates have changed with time, and what factors caused the changes.

There was a secondary change in SLR rate around 1930. In their North Carolina reconstruction they see a significant change as well just prior to 1900. The most recent paper that Rahmstorf published addresses some of these more rapid changes in sea level. There is a new empirical model which addresses these periods of rapid change.

Another part of the equation focuses on cyclone activity and couple it with SLR projections. The idea is to look at modern sea level and run simulations to see the extent to which inundation is related to tropical cyclones. Putting these two models together is critical if we want to see the impact on natural resources as well as infrastructure. When this was presented at the May stakeholder meeting, Jeff Donley from Woods Holes Oceanographic Institute used a Category 5 hurricane coming into North Carolina. There was a wide range of stakeholders in the audience, and they tuned out on this example. It isn't that we won't ever have a Category 5, but we never have in the past, and thus some stakeholders believe that we never will. That projection was a mistake, and Jeff changed his presentation after that initial workshop to avoid losing a lot of the managers.

The intent is to understand the inundation on top of the SLR.

Reide showed us the flow chart of their project. The ultimate intent is to understand regional coastal inundation scenarios along the Gulf and Atlantic coasts. They have asked stakeholders what sort of products they want. Many of the town managers want to do analysis, but they are at odds with their stakeholders. This is beyond what many of them can do.

Reide and colleagues want to hold another stakeholder meeting in a year's time, and present what they have done.

Reide asked for questions. Carl Hershner asked if Reide and colleagues are connected with Larry Overton. No, they aren't. Carl noted that there is some work Larry will be doing, which will be of interest to Reide and colleagues. Reide noted that he was pretty sure that Ben Horton was involved with Larry. Also, Ben may be involved in the national efforts for climate change. Carl suggested that it would be good for the two of them to reinforce each other, rather than duplicating work.

Tom Crawford noted that SLR will be related to the position of the shoreline. Reide agreed and noted that isn't the only thing which is affecting shoreline change. Tom asked that if SLR is nonlinear and is accelerating, are there people out there who are examining that issue? Reide didn't believe so.

Reide noted that in addition to the vertical changes in SLR there are changes in the horizontal shoreline. Reide noted that some changes, such as shoreline erosion, will occur regardless of changes in sea level. Some of the erosion is unrelated to SLR. Tom asked if people should be studying the horizontal component. Reide noted that people are looking at that parameter in marshes, but he is not aware of anyone studying it on the front side

Andy indicated that some people at Duke are looking at the front side and considering SLR as well.

Economics and Policy for Adapting to Sea-Level Rise, Dr. Andrew Keeler, STAC Executive Board Member and Professor, Department of Economics, East Carolina University and Program Head, Public Policy and Coastal Sustainability, University of North Carolina's Coastal Studies Institute: Andy gave a presentation entitled "Adapting to SLR: Government Actions and Private Responses". One point he would like to make is that adaptation takes place, with or without government involvement. He noted that communities come and go, for example, Diamond City on the Outer Banks. If you ignore autonomous responses, you are missing a big part of how people respond. There hasn't been enough focus in North Carolina on private market adaptation. Three key issues are timing; consistency versus flexibility; and compensation, flexibility and adaptation.

Adaptation is defined as "Actions by individuals or systems to avoid, withstand, or take advantage of current and projected climate changes and impacts. Adaptation decreases a system's vulnerability, or increases its resilience to impacts."

Adaptation doesn't insulate us from climate change. Efficient adaptation minimizes the sum of net damages from climate change, and the cost of adaptive actions. Adaptive actions are taken largely by private agents, and existing local and regional government entities.

Key roles for centralized institutions are public good provision, finance and resource transfers, rules, regulations and investments that affect adaptation possibilities, incentives, and research. The federal government will have a big role in who wins, who loses, and who pays. Our ability to adapt will depend to a great extent on how much we understand. As we learn more about what will happen to our climate and ecosystem services, the more we will be able to understand, and such research is a key role of federal and state governments.

One case for not making adaptive policy is the market/libertarian case: individuals and institutions make risk assessments and adaptive decisions all the time. Poor decisions in response to change will bring about bad outcomes, and spur incentives for adaptation.

Rationales for government involvement include the market failure paradigm: fundamental decisions about adaptation involve public goods, which are not provided by private markets. Decision-making under risks, uncertainty, and ignorance prevent efficient market outcomes. Information and research as a public good. Externalities created by adaptive actions. When people adapt upstream, it will affect people in the estuary. As Nags Head takes measures to stabilize their ocean front it affects landowners both upstream and down, due to changes in the sand budget.

Andy gave an overview of economics and adaptation. Government failure paradigm: disaster relief and moral hazard; implicit and explicit subsidies; consistency and setting expectations, mitigation policy, adaptation policy. Equity, costs (broadly defined) visited disproportionately relative to responsibility.

Tim Spruill asked if the government must bear some responsibility for creating the infrastructure which allows people to develop in these areas, and the private sector pushes them to do so. Should the government be bright enough to develop rules to keep this from happening? Andy noted that there have been a number of attempts to do this, and they usually have been dismal failures. Former Speaker Dennis Hastert from Illinois actually wondered whether New Orleans should even be rebuilt and he was hammered for it. Tim noted that Rapids City, North Dakota is another area which routinely floods and always seems to be rebuilt. Andy noted that there are many Midwest locations where people make money off the insurance settlement, so there are some problems with the way the flood insurance program works. It has both negative and positive effects in that since 1972, most things have been built to much higher standards. There are implicit and explicit subsidies. How the state maintains Highway NC 12 has big implications for how much it cost for people to live in Buxton. If government gets it wrong, it is sending the wrong signal.

Andy provided an example, using energy and Wall Street, and investment. Government must set some expectations, otherwise the result is inefficient expectations. In addition to market and government failure, there is the issue of equity. It is not people living on the coast who have caused SLR, but they will face a larger share of the damages. Should and will government transfer resources to people who face a larger share, and Andy thought that the answer is yes, but he asked how you do that in such a way as to not provide coastal residents with the wrong incentives.

The planning-dominated approach has not given much attention to the private sector actions, and he displayed flow diagrams to explain how he thinks the world works. People and institutions make choices that determine outcomes. It is more complicated than planning alone can accommodate. Autonomous actions by private sector individuals and institutions are affected by local land use law and infrastructure planning, future housing stock, federal and state policies, insurance, roads, disaster assistance, and other factors.

Climatic drivers transmit incentives and rules through different but interdependent mechanisms: direct, such as risk of flooding, change in growing conditions; policy-induced change in prices, insurance, energy transportation, and water; and policy-induced changes in rights and obligations, building codes and zoning ordinances, water quality, and disaster assistance.

It is absolutely essential to pay attention to timing. The effect of policy on aspects of climate change with big demographic implications are more about timing and transition dynamics and costs than about the eventual outcome. There are two important implications: assuming immediate adjustments impose potentially large costs (foregoes benefits); shielding the private sector from facing the full cost of risk potentially imposes large costs from not making decisions soon enough.

Predictions about SLR strongly imply that coastal areas will become uninhabitable at some point in the future. Andy gave an example of NC 12 and Hurricane Irene changes. Responses: short run concern is how to keep road links to the mainland open; in the long run, when to stop leaving road links to the mainland open. Halting road links now would impose large costs on a fairly small segment of the population, etc. Classes of responses: hold the road, build a more climate-resistant road at higher up-front costs; give up the road link and rely on ferries and planes. All might be relied on at some point, but the choice and timing is absolutely critical to individual and community. Four hundred years from now, no one will be there. The essence of adaptation is how we manage that change. If the end game is no inhabitants, then how you understand the transition is the essence of adaptation policy. Andy is engaged with some others in modeling what we might see, under various scenarios.

Reide asked if climate adaptation has ever come into the discussion with regard to the replacement of the Bonner Bridge. Andy thought that discussion was primarily driven by

erosion. Andy asked if anyone knew. Bill Crowell stated that one engineer had raised the issue in conjunction with erosion.

Sam Pearsall noted that some stakeholders thought that building a road that would only last 30 years was still a good thing, because of all of the associated jobs.

Andy stated that locally, Irene had a big impact on people's risk perceptions, but it didn't last long. If we have a disaster here and another there, it may actually result in some policy changes.

Andy addressed law, policy and private-sector responses, noting they are interrelated and endogenous. Existing and anticipated choices about transportation infrastructure affect location decisions for younger residents, retirees, potential business owners, etc.; housing choices, size, maintenance choices, asset specificity; and erosion and flood mitigation choices; and those choices then directly affect the economic and political incentives toward future transportation, etc.

Consistency versus flexibility: The private sector likes clear signals and certainty to facilitate efficient investment and remove controllable risk; climate policy, prices, and utility investment; price of hazard insurance. Good policy under uncertainty requires that policy be changed as better information becomes available.

Andy has personally been interested in whether one can come up with some middle ground. There is a fundamental difficulty of choosing a time path and credibility. In the example of Highway NC 12, a plausible time path is the life of the next big highway investment. People must believe this time is really the last investment. There is inherent uncertainty in how long the investment will last, etc.

Compensation: ethical case for compensation is fairly clear. Providing resources in a way that does not prevent successful adaptation will be critical. If compensation is an element of public policy response to climate change, and if autonomous adaptation depends in part of people making optimal financial decision given expectations, then establishing how people could reasonably been expected to make decisions at different dates end up as a critical component of adaptation policy.

Importance of Uncertainty: all aspects of the problem are highly uncertain: Greenhouse gas emissions, climatic drivers, etc.

Summary: private sector responses are central to adaptation; etc.; timing is critical; the tension between certainty and adaptive management is a particularly difficult challenge; compensation will be one aspect of adaptation law and policy where it is important to get incentives right.

Tim Spruill asked, what is the cost of maintaining what we have? And is it a good idea to spend money on infrastructure, etc.? Andy stated Tim had asked a lot of good questions, and felt the cost was incalculable. Whether it is worth it is dependent on who is the target. Clearly it is important to people who live here, but the country will still have tourism.

Tim noted that if he was king, no one would live at the coast because it is stupid.

Andy stated that there are many different misperceptions about flood insurance, which is critical right now because you can't get a home mortgage without it. Without flood insurance, you would have different kinds of development. Many people can't buy without it.

Tim noted that ultimately you will only have rich people living on the coast. In his view, the land is worth more than for development, and how do you quantify it. Andy replied that if it is worth that much, then some would say buy an easement on it.

Tim stated if government exists, it is there for the public good. If citizens pay taxes, they expect services and expect good decisions about using the land. In some cases, the best decision is not using the land at all. All of these things make it even more complex than what Andy conveyed.

Kirk stated that someone else's opinion may be you should develop all of that land.

Tim agreed and noted that in some respects, having a king wasn't a bad idea.

Curt Richardson noted that two communities, Princeville here in North Carolina and the town in North Dakota, were offered to be bought out but they refused, so what is the mechanism for change? Andy stated that a lot of it comes down to the moral hazard and disaster. If the expectation is that your community will be rebuilt every time there is a disaster, then that is a problem. He felt the best mechanism is likely to use FEMA in some way.

It was noted that there are some examples where you have local buy-in, and some of these policies work. When we talk about government, there is not just one entity we should consider. After the disastrous floods on the Mississippi, there was discussion by a task force about not rebuilding the levees at the same time the Army Corps of Engineers was rebuilding them.

Curt noted that Duke and Johns Hopkins Universities both had been involved in post-Katrina studies regarding New Orleans, and these institutions didn't anticipate what would happen, which is that FEMA refused to accept their reports, so from a policy perspective they didn't exist.

Committee Discussion and Action, Reide Corbett:

Reide asked Tancred what he would like to see with regard to STAC actions on SLR. Bill Crowell suggested that the STAC could look at the CCMP, and consider how it might help to begin to implement some of the actions. Reide noted that the record of this meeting may help to inform the discussion. Bill noted that stakeholders are most informed if they have information which will inform them about what is happening locally. Reide noted that Andy's work may also be informative. Andy noted that work is not especially locally-based. Jim Hawhee noted that he has been working with some local municipalities, and they simply don't have the resources to deal with some of these issues. The water infrastructure is one place where we may have an impact, by helping them to develop localized projections, perhaps out to 25 years, for their planning purposes. In the projects in which Jim was involved, they did the best they could with what they had. Jim suggested that we can work with local governments and planners, and noted that they are rebuilding their water infrastructure all the time. Reide asked if the locals have a good understanding of what we discussed today. He noted that Carl had noted we are going to reach a meter rise at some point, so perhaps if we draw the box more narrowly, that would be useful, and would be more acceptable. Reide asked if the people with whom Jim is working have a handle on that concept, dealing with the temporal dimension, as well as the vertical dimension. Jim noted he had been asked if they could overlay their systems on a map. Bill noted they want to know which manhole covers will be inundated. Jim noted that they don't want to be prescriptive. They asked if stakeholders wanted to be more long-range, or shorter-term. In one sense they used the national model, and another thing they did was to use a constant-acceleration model. Sam Pearsall stated it impresses him that we seem to be saying that we have missed the bus and are trying to catch up. He noted that one author has noted that we have already paid enough due to SLR to last through the year 3000. The real issue is how we manage for uncertainty. Few people argue that the sea isn't rising. Reide agreed that is the case. Tancred stated that some see that it isn't SLR we are seeing, it is planning. Even 25 years is too distant a horizon for some planners. He suggested that we need to come up with some way to get people to accept the fact that something is changing. Kirk felt that there is something to be said for using a shorter timeframe. Bill Crowell noted that people can relate to a 30-year mortgage, or a 50-year project life, but beyond that it is hard for people to relate. It was noted that when people talked about a 100-year flood probability they didn't relate, but when told they had a 26% chance of being flooded during their 30-year mortgage life, they could relate. Michelle asked if much of this information had been capsulated anywhere. Jessica Whitehead indicated that North Carolina Sea Grant (NCSG) had produced some fact sheets which were studied by ECU, and they have some feedback. Use of technical terms really bombed. Materials which targeted the county level were more effective. Their report has been turned in to NCSG and if people are interested it may be available. The question was asked, how partners handle updating fact sheets when the science is changing so rapidly. There needs to be some policy regarding how information is revised. It was noted that printing costs enter into the decision. Tim asked if the fact sheets are produced in paper form, or on a web page. Usually on paper, but a backup is on the web. Jessica is half-time in North Carolina, and half-time in South Carolina, both for Sea Grant. Reide felt that there was some utility to developing a fact sheet. Sea Grant has developed a climate change working group for people working with educators. Jim Hawhee noted that there is more happening with regard to

education. Jessica noted that she took copious notes during the talk, but she wouldn't want to use some of the technical terminology used. Reide noted that we are interested in finding something like this, which this committee can assist. Reide noted that he knew Michelle and Donna had put this together, and had tested them. Jim Hawhee noted that water operations, and the general public, and homeowners, all could be targets for some outreach. Rich asked whether some SLOSH models had been done for the Albemarle-Pamlico area. Others confirmed yes. He asked about other models, which projected flooding from upstream as well, and suggested that combining that information with information on SLR would be more useful. Rich noted that it isn't usually SLR which drives impacts, it is the storm surge. That has been their experience in Norfolk. Erin noted that she agreed you need to show people what is happening now. We need to be able to visualize that for the general public at an eighth grade science level so they will be able to make decisions. We need to make the information available for the general public. Jud stated one way to reach the North Carolina public is to somehow integrate the lay information through a vehicle like the North Carolina Aquariums. Those are places visited by people who are interested, and can serve as a consistent vector of information. They could take publically consumable information and make it ring a bell. Reide asked if APNEP has a partnership with the Aquariums. Bill Crowell stated APNEP has a relationship with them. Linda Pearsall stated she didn't believe the aquariums are clamoring to be involved in educating the public about climate change and SLR, because she didn't believe that would be within their mission. She stated that it didn't make sense to talk about this until we talk with them. Jud asked whether we should be trying to influence policy or educating people. Carl felt that going after the private sector and individual citizens should be important, because that is where the decisions are made. Curt noted that he takes students out to places in North Carolina where the flood heights have been documented, and this is also the case in Florida. When people see that the water was over their heads, then that gets their attention. It was noted that Virginia Beach had partnered with Virginia state agencies in having listening sessions, including a participatory mapping exercise to document localized flooding. About 150 people participated in the sessions and the maps were presented to the City Council. This helped to document the extent of the problem. Reide thanked all of the speakers, and noted that he had some ideas about directions in which we should go, perhaps getting some things started, before he leaves for the Antarctic. Dean indicated that they would try to get all the presentations up on the web site soon. Also, if STAC members have any comments regarding the meeting, please provide members of the STAC Executive Board feedback so they can incorporate ideas into the next meeting.

Meeting adjourned at 3:00 pm.