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APNEP Scientific and Technical Advisory Committee
Water Resource Quantity Meeting Notes
March 26, 2013

Auditorium
Pitt County Agricultural Center
403 Government Circle, Greenville, North Carolina

STAC Members Present: Bob Miller (UWSP retired), Peter Caldwell (USFS), Tim Spruill (USGS retired), Marcelo Ardon (ECU), Burrell Montz (ECU), Lisa Campbell (Duke), Rua Mordecai (SALCC), Reide Corbett (ECU), Andy Keeler (ECU), Mike Piehler (UNC), Robin Dennis (USEPA), Jud Kenworthy (NOAA retired), Wilson Laney (USFWS), David Kimmel (ECU)

State Agency Liaisons Present: Jon Blanchard (NC-DPR), Allison Schwartz Weakley (NC-OCPCA)

Guests/Public Present: Robert Christian (ECU), Scott Ensign (USGS), Fred Tarver (NC-DWR), Judy Ratcliffe (NC-NHP), J.P. Walsh (ECU)

Staff Members Present: Dean Carpenter, Bill Crowell, Jim Hawhee, Lindsey Smart, Jimmy Johnson

Call to Order

STAC Co-Chair Jud Kenworthy called the meeting to order and thanked everyone for coming today, especially the invited speakers for sharing their time and intellectual property with the Committee. This meeting on water quantity is the second theme that STAC has established for their 2012-2014 agenda. The first session was on sea-level rise. Many in the audience work in estuaries, and they wouldn't be estuaries without river flow, and the quality and quantity of that water makes a difference to the Albemarle-Pamlico estuarine system. Jud noted that Dean (APNEP Program Scientist) wanted to link this theme with the ongoing North Carolina effort regarding ecological flows.

Jud named the meeting's three speakers, J.P. Walsh, Scott Ensign, and Tim Spruill, and thanked them again for coming.

Notes of the fall (November 30) 2012 meeting were approved as written.

APNEP Update, Dean Carpenter:

Dean echoed Jud's welcome and expressed appreciation for everyone coming, and wished everyone a happy new year. He noted that STAC meetings in 2013 will be less frequent than

years past. He thanked the Pitt County Agricultural Extension staff for use of the facility, and Jimmy Johnson for lunch planning.

Dean recognized the new (as of March 1) APNEP Project Coordinator, Lindsey Smart, and asked her to share a little bit about her background. Lindsey did so.

Dean recognized Jon Blanchard and Alison Weakley as state agency liaisons who are attending this meeting. Fred Tarver and Judith Ratcliffe are also here representing NC-DWR and NC-NHP, respectively.

While there have been no resignations from the STAC since the last meeting, six members have been elected during that time: Lisa Campbell, Rua Mordecai, Rachel Noble, Hans Paerl, Ken Stolte, and Dean Urban. Hans and Ken are STAC alumni returning for a second tour. Dean welcomed Lisa and Rua to their first meeting. The one-third of STAC membership whose terms expire on June 30 will soon receive an inquiry asking if they wish to continue serving. Those members are: Pete Caldwell, Don Field, Erin Fleckenstein, Joel Fodrie, Andy Keeler, Jud Kenworthy, Dave Kimmel, Hans Paerl, Mike Piehler, Heidi Wadman, and Rich Whittecar. Dean noted that APNEP staff really appreciates their service and hoped they would be willing to continue.

Dean reminded members about the STAC attendance policy. The meetings are scheduled at least six months in advance, and regular attendance is encouraged. If members miss two or more consecutive meetings, they will be receiving a letter on behalf of the Policy Board. Dean noted that the federal budget sequester has prevented at least one of STAC's federal members to attend this meeting. The next STAC meeting will be July 23, with the location to be announced at a later date. APNEP is planning an "all-hands" meeting in the fall, with partners giving presentations on science, outreach, and other aspects of the partnership.

Dean asked Jim Hawhee (APNEP Policy & Engagement Manager) to share an opportunity with members. Jim noted that there are STAC members and other scientists who help the partnership, and he has fact sheets with the APNEP mission statement which can be used as an outreach tool. Jim encouraged members to take some fact sheets. He also reminded them that the APNEP home base is now in the new Nature Research Center, and staff wish to take advantage of new technology associated with the facility. He is considering organizing a summer lecture series there, because many DENR staff have offices nearby and may be able to attend. Members who have an interest in doing such a lecture should let Jim know.

Regarding recent science and technology events: In early December, the STAC Executive Board held a teleconference. In late January, Dean participated in the Department of Interior's Eastern North Carolina-Southeast Virginia (ENC-SEVA) Barrier Island Core Team Workshop. The barrier island habitat was to be the fifth of six workshop themes, but the sixth (marine)

workshop was dropped. STAC member Randy Swilling was also on the Barrier Island Team. Dean asked Wilson or Rua if they knew when the final report is expected, but neither were aware. Dean and STAC member Don Field met with the NCDOT Photogrammetry Team about planning for aerial image acquisition this spring to support SAV monitoring. Dean and other APNEP staff, along with STAC members Kirk Havens and Wilson Laney (who represent the STAC on the Policy Board) attended the APNEP Policy Board meeting. Dean briefed the Policy Board on recent and planned APNEP assessment activities, while Wilson briefed them on the STAC 2012-2014 Action Plan.

While on the topic of APNEP assessments, Dean noted that hard copies of the APNEP 2012 Ecosystem Assessment and the APNEP 2012-2022 Comprehensive Conservation Management Plan (CCMP) are available at the back of the auditorium. He noted that the assessment is targeted more to environmental managers, whereas the CCMP is targeted more for the general citizenry. Specific plans for the fall all-hands meeting are tentative, but staff are now considering preparation of a "report card" for citizens, perhaps on the order of ten pages, which says how the Albemarle-Pamlico Ecosystem is doing. The 2012 assessment did not include evaluations and just reported trends. Staff are considering unveiling the report card at the APNEP fall conference.

In mid-February, at the request of STAC co-chair Jud, Dean attended the North Carolina Ecological Flows Science Advisory Board meeting. Fred Tarver (NC-DWR) provides staff support for that committee. Members will learn more about this effort soon during Bob Christian's presentation.

In late winter, Bill Crowell (APNEP Director) attended the semiannual meeting of all the National Estuary Programs. Bill noted that EPA host a late winter meeting each year. Much of the discussion centered on the federal budget. The APNEP budget lags behind the federal budget by a year. EPA is anticipating a minimum 5% cut which may climb to 8%, the impact anticipated to APNEP would be on the number of grants awarded. EPA is also very interested in seeing nutrient standards for the sounds.

Dean and Reide Corbett attended the North Carolina Sentinel Site Cooperative, Sea-Level Research & Monitoring Workshop on March 12-13 in Beaufort. The main focus of that meeting is to being a cooperative effort on sea-level rise from New River up to Ocracoke Inlet, and from the mouth of the Neuse River to the Outer Banks. They want to develop coordination, and will release a technical report from that conference.

Regarding action items from the STAC November meeting on sea-level rise, Reide noted that there wasn't any real consensus on what action(s) should take priority. He has talked to Tancred Miller, NC-DCM, about potential STAC deliverables that would be of interest. Reide

noted that NOAA has five top priorities, and one of them for North Carolina was dealing with water level monitoring. He welcomed STAC members to share any thoughts on the topic. There have been several meetings already in North Carolina dealing with water level monitoring in the state. Reide noted that outreach and education also arose. He suggested that one way that STAC could help is to develop a flier for outreach use and also a multimedia video, which focuses on this North Carolina sea-level-rise debacle. He has talked to a UNC-CH student about the possibilities. So, he is trying to move ahead with some sea-level-rise products.

Dean stated that North Carolina is one of five NOAA sentinel sites in the nation. At the workshop he received confirmation that other issues, such as ocean acidification, which could be included with sea-level-rise as the research and monitoring cooperative matures.

In March, Jim Hawhee and Dean gave a presentation on grappling with sea-level rise and coastal storms to ECSU undergraduates, hosted by STAC member Maurice Crawford, and also gave a similar presentation later that day at a local "science café" hosted by the Port Discover Museum.

Dean asked Bill to discuss the DENR transition under the new administration. Bill summarized the changes which have occurred. Bill noted that DENR has a new mission statement and encouraged STAC members to review it.

Dean noted some of the future activities. The STAC Executive Board will have a teleconference in early April. Any STAC members who want to reflect on today's meeting, or have ideas for future ones, should contact Dean or any Executive Board member. The APNEP Policy Board will meet April 30 and will be discussing 2014 activities. There is a new Implementation Committee under APNEP's new organizational structure, with the CAC and MAC having been dissolved. There will be a number of CCMP implementation teams, which will focus on the 58 identified actions in the CCMP. Individual teams will generally be assigned multiple actions. There will be 15 or 16 implementation teams, some of which are already formed. Dean asked for questions.

Michael Piehler asked if there are any other subjects which APNEP is unlikely to be able to address. Bill noted that remains to be seen. APNEP has made a distinction between science and policy, with the STAC handling the former, and Policy Board the latter. DENR's new Assistant Secretary for Natural Resources, Brad Ives, is very supportive of the Partnership. Michael asked if last November's STAC meeting addressing sea-level rise would have been prohibited. Bill indicated that it might have been structured differently. Dean noted that as an advisory body the STAC is somewhat more independent. Bill noted that STAC could have held the discussion, but APNEP staff might have been unable to provide lunch. Michael noted that he wanted to clarify that the STAC was essentially independent. Bill noted that they have made

the point that the committees are independent, and can say what they wish. The whole purpose of the NEP is to provide for engagement outside government.

Robert Miller asked if the North Carolina governor gets science. Bill noted that he was not sure of the governor's background. Michael Piehler noted that there are alternative ways to interpret things, which are science-based. Bill stated that he didn't believe that any sea-level-rise meeting would have been prohibited, but there might have been a lack of support.

Dean apologized for taking a bit longer with the update. Michael noted that this was an important discussion. Bill noted that APNEP's CCMP was a ten-year plan, and some of the issues which need to be addressed within it, are controversial, such as climate change.

Wilson noted that another aspect of this is the current "emergency" request for dredging 1.7 million cubic yards of sand from Wimble Shoals and depositing it on the beach to protect NC 12.

Jim noted that there is some separation between science and policy in APNEP, and the STAC definitely provides a forum for discussions of the science.

Jud noted that we have three presentations this morning. He asked members to keep questions after the presentations focused on the details, and asked that members keep the larger questions for the working session this afternoon. He introduced J.P Walsh for the first presentation.

Land-Sea Interactions in the AP Estuarine System, Dr. J.P. Walsh:

J.P. noted that he was affiliated with ECU and UNC Coastal Studies Institute, located on the Outer Banks. He will focus on the sediment dynamics of the system today, and hoped that would enlighten the audience. Sediment and solute cycling is critical to ecosystem distribution and function. Science must determine the impact of humans on the coast and its processes and vice versa. Science also wants to understand the past, and to inform the public.

J.P. indicated that he would discuss today sediment in the Albemarle-Pamlico system. There is a source of sediment in the mountains and a sink in the estuaries. But the picture is more complicated, with lots of land uses, multiple rivers, and multiple estuaries. JP displayed a simple Albemarle-Pamlico Estuarine System (APES) sediment budget. The figure showed the Chowan, Roanoke, Tar and Neuse systems as inputs. The system is really low-gradient in the Coastal Plain. Flow here is not uni-directional and sometimes reverses flow, and of course everything changes with time. It is complicated. They use sediment rating curves to estimate the amount of sediment coming into the system. Such curves are available from limited systems, and many are tidally affected. Low gradient rivers have larger scatter and less dominance of peak events. Land-use has key control on yields. Most of the North Carolina

systems are low-gradient, which means the rating curves are less accurate. One challenge is determining what happens during peak flows. Land-use has important controls on sediment discharge. Flux from tributaries to the mainstream varies, and of course the resultant deposition in the estuaries varies as a result.

The four primary rivers in North Carolina together release about 900,000 tons annually, based on water discharge and sediment load. Sediment inputs = outputs: the source balances the sink. River inputs from gauges are about a million tons annually. Annual sediment accumulation in the APES are about 1-10 mm. Using these data and assuming a bulk density and average accumulation rate, estuarine storage is potentially much higher. But the devil is in the details. It isn't surprising that we have a balanced sediment budget, but we need to know more to understand the system.

One Master thesis study focused on the Tar River. The author focused on how much sediment reached the estuary of the Tar. The Tar River drainage is about 11,500 km^2. The annual load is 189,000 tons at Tarboro, which is about 50 km upstream from the river mouth. Seven sites were analyzed, all far downstream in the low gradient portion of the system. The author investigated flooding frequency at each site, which essentially maps the active floodplain. The elevation data and the hydrograph were merged to show the active part of the floodplain. Data for the seven sites were graphed and mapped. At Site 1 near Tarboro, the floodplain was broad, but downstream near Greenville the flood plain is at sea level. The investigator also took cores across the floodplain and looked at different constituents, and thus was able to calculate storage down the Tar River system. Storage decreases as you move away from the channel. About 60% of the sediment leaving the vicinity of Tarboro is being stored before it makes it to Washington. There is a lot of exchange of water, carbon and other constituents between the river and the floodplain.

J.P. asked about river channel storage. Their research shows some active bedload transport of sand, with mud being stored in the floodplain, which he stated was rather counter-intuitive. Dams also affect sediment transport, although there are not many dams in North Carolina. The upper part of the Roanoke sediment is being trapped in the big dams on the Roanoke River. Dams on the upper Roanoke and Neuse River alter hydrology and cause particulate storage, and affect migration of aquatic organisms. J.P. is working with Roger Rulifson and Wes Patrick of ECU to determine how dams have affected fish migration.

Another student's Master's thesis focused on the functioning of tributaries. That the system is lined by a lot of tributaries is often not recognized. The author looked at sedimentation in areas to the east and west of Cherry Point MCAS. They looked again at different radioactive isotopes. They looked at accumulation rates in Slocum and Hancock creeks. The tributaries were storing quite a lot of sediment. Another thing they did was to look at trace metals. They

found a peak in metals around 1960 in Slocum Creek. Metals decrease as the core sediments become more recent, but some sites do have fairly large concentrations.

Another question was how dynamic the system is, relative to hurricanes. Part of the Dillard dataset was collected before Hurricane Ophelia, and some after. The profiles were similar in shape, but were shifted about 6 cm, since the storm removed sediments. The seabed is therefore dramatically reworked during such storm events. They used a tripod on the bed of the Neuse River Estuary to measure the changes in sediment flux. Waves were up to 1.5 m in height, which re-worked sediments and moved materials around, in some cases upstream. Cores taken during the year following Hurricane Ophelia show that sediments can be redeposited relatively rapidly. The seabed is re-worked often and allows for resuspension.

They have also worked with Rick Miller and Ryan Mulligan to look at the impact of strong wind events. The seabed in the entire Albemarle-Pamlico system is re-worked and moved around as a result of wave stresses. There is a lot of material moving around, over a large area, and this happens a lot. During winter there may be as many as 40 nor'easters. Resuspension occurs around four percent of the time, with about 50 events annually.

Another question which has arisen is how the shoreline may be contributing material to the system. J.P. noted that they are continuing to do a lot of research relative to shoreline erosion, including whether wetlands are trapping any of these sediments. They looked at estuarine shoreline erosion throughout the entire Neuse River Estuary. Most of the system is eroding to some degree. More open regions have a higher rate. The type of shoreline plus the fetch are two important controls on the erosion rate. APNEP funded a doctoral student to look in great detail at the type erosion occurring at a number of sites in the Albemarle-Pamlico system. They used digitizing with balloon aerial photography to document changes. At Palmetto Peartree sites for June 2010 - January 2011 the average rates of change vary seasonally. Change (erosion) was low in June-August, greater in August-October, and then changed to accretion later in the year. The shoreline changed dramatically as sediments eroded then were redeposited. The shoreline at this location was really dramatic, which was not appreciated prior to the study.

Another study at Huddy Gut and Porpoise Point looked at sedimentation from the shoreline into a couple of marsh systems. They measured accumulation on tiles placed in the marsh. These marshes both had some relief on the order of tens of cm. There was a berm present in both locations, which affected the degree of sedimentation.

J.P. touched on storm surge, overwash and inlet opening. He showed an image of the new inlet created by Hurricane Isabel. The new inlets affect salinity and exchange with the estuary. They found about 25 cm of sediment, deposited on the back side of the Outer Banks. This

documents the island "rollover" phenomenon. J.P. showed a map of the historical Outer Banks inlets, and noted that we now have a new, New Inlet. He also showed the areas which have high potential for the formation of new inlets. Hurricane Irene crossed the sounds in August 2011, and winds and flooding caused considerable storm surges, which were modeled. A southwest wind caused flooding on the western side of the barrier islands. The town of Rodanthe was flooded from the west. A wrack line was deposited on the back side of the oceanfront dunes.

What appears at first simple is in fact much more complex, due to floodplain storage, dams, exchange between the sounds and surrounding landscape, and resuspension, and storms which create new inlets.

Robert Miller asked if the amounts coming down the river system were stable over time. J.P. indicated that it was addressed a while back by a USGS-NAWQA study, and it suggested that the load is going down with time, but it depends on which system and what time scale you are discussing.

Tim Spruill noted that some work was done in the system, and Tim had a slide showing the change through time for the Neuse but he took the slide out. The load has declined for sure.

Wilson asked if J.P. could see the historic sedimentation which resulted from the post-European colonization era, as Stan Riggs has documented for the Roanoke. J.P. stated that it probably does exist but researchers haven't looked for it. Scott Ensign noted that Cliff Hupp has done some work on that question on the lower Roanoke. J.P. noted that some others, including Sherry Cooper, have also done some work on this question.

Judy Ratcliffe noted that she works more in the streams and little in the sounds. There was a period of time when beavers were in the systems, and those would have affected fish migrations. Then beavers were lost and now they are coming back. She asked if that would have been a significant factor. J.P. said he wasn't sure but that it was a good question. He noted that there are some pretty big error bars on their calculations. Suspended sediment concentrations are not measured continuously, so it is difficult to know how sediment transport changes. The federal government is reducing their monitoring effort, so we will have fewer time series to monitor the changes.

Pete Caldwell asked if these studies were based on particulates and suspended solids. J.P. noted that they are, and don't include the bedload transport. Local rivers are often thought as slow moving, but they clearly can move sediments under high discharge.

Dean confirmed with J.P. that J.P. was able to attend the remainder of the meeting. Dean asked how climate change will affect the transport of sediment to the floodplain, and other

factors. J.P. noted that we barely understand it as it is now. Every watershed is different, and how the sediment responds to the bedload and the system depends on different factors.

Bill Crowell noted that one CCMP action is to develop an environmental atlas. One need is to produce a bathymetry map of the sounds, and now he is questioning the utility of mapping the bathymetry if it is this dynamic. J.P. noted that because mapping the sounds and river bottoms would take much time, perhaps some areas should be targeted which are not so dynamic. Some other areas are very dynamic, like around Rodanthe, but other areas have been very stable for a long period. He argued for doing some specific areas, but perhaps mapping the entire state would not be appropriate.

Implications of Discharge Frequency and magnitude on Water, Carbon and Nitrogen Flux Through Tidal Freshwater Rivers, Dr. Scott Ensign:

Scott noted that his presentation would complement J.P.'s presentation. He would drill into only one of J.P.'s boxes from his chart figure. He would jump around among North Carolina, South Carolina, and Maryland, yet remaining on the theme of environmental flows. Magnitude and frequency are two key variables, and are key to understanding the freshwater zone. Plumbing watershed to estuaries often involved the treating the river-estuary transition zone as a black box (or no box at all). There may be extensive zones that are tidally-influenced, but never see saltwater. He is trying to understand the key drivers. There are fluvial systems that have huge floodplains but with a relatively confined channel. A normal floodplain may only get flooded once a year.

Scott asked how to incorporate the dynamics of riparian inundation and river discharge into empirical models of material flux. He would begin with water, then cover carbon, and end with nitrogen.

In the Waccamaw River, South Carolina, there are two gages near Longs and Conway respectively. The frequency-magnitude of daily mean (net) discharge is similar in the two systems, but the water level is strongly affected by tide. The tidal events occur during low-flow summer months. The evapotranspiration on the floodplain exceeds downstream river flow during the summer. This may yield a net upstream flux. So there is a lot of contrast between the non-tidal site at Longs and the tidal site at Conway.

Scott moved to some data from the Pocomoke River, Maryland. He showed graphs from the non-tidal, upper tidal freshwater, and lower tidal freshwater/oligohaline sites on the river. Velocities at the non-tidal site were much less than at the tidal sites. Flow velocities at the tidal sites not only show an increase, but also reverse direction. The figure has some implications for the movement of water downstream. The only time that particles from the river can get on the

floodplain, is during flood tide. This is counter-intuitive to fluvial systems where water is always moving in one direction.

So in summary, gradients exist in hydrology along the tidal freshwater zone: uni-direction flow and discharge occur in the non-tidal zone, and there is bimodal water level distribution; whereas in the tidal freshwater zone, there is high frequency, low magnitude velocity, etc.

Scott turned to carbon. He investigated how flow magnitude and frequency affect inundation of the riparian zone and carbon storage, in two Maryland rivers: the Choptank and Pocomoke. These are typical floodplain forests upstream, but difficult to navigate on foot in the lower portions of the systems. They put out water level recorders on the floodplain. It turned out that Hurricane Lee produced the flood of record on the Choptank, but little impact on the Pocomoke. The sites sampled were separated by only two km. On the Choptank there was rapid recovery. The flood wave was preserved in the Pocomoke as it moved downstream from site to site. They measured carbon accumulation in wetlands and found that it is driven by contrasting frequency-magnitude regimes at opposite ends of the tidal freshwater gradient. Ceramic tile collections show a lot of deposition in the upper-tidal zone of the Choptank. There is a switch in the dynamic of the drivers, at the two ends of the tidal freshwater zone. The tides drive things at the lower end, with river dynamics driving things at the upper end.

The final section deals with nitrogen. Scott noted that riparian denitrification flux can be modeled as a function of denitrification rate and the surface area of floodplain inundated. It takes about 4.2 hours after flooding for denitrification to begin. LIDAR data can be used to quantify elevation and determine how it interacts with water. They developed a model and applied it to the Newport River, White Oak River, New River and Northeast Cape Fear River. The four systems are different in geomorphology and the frequency of storm events, yet the model predicted the daily nitrogen flux fairly well. They used the model to look at the northeast Cape Fear River near Burgaw to provide a long-term dataset for analysis. They developed a histogram of water levels. They determined that a frequency-magnitude analysis reveals that high-frequency, low-magnitude flooding is the predominant driver of denitrification. Relatively low discharge events are the ones, rather than the hurricane-driven events, which result in most denitrification.

Patterns in carbon and nitrogen biogeochemistry in the tidal freshwater zone differ based on their particulate and dissolved form: in the tidal freshwater zone low-frequency, high-magnitude floods drive carbon accumulation; high-frequency, low-magnitude tidal flooding is he predominant control on denitrification flux; and high-frequency, low-magnitude tidal flooding drives carbon accumulation.

Tim asked if they measured sources of the nitrogen, and whether it was complete or going to ammonia. Scott indicated that in the lab experiments they measured complete denitrification. Tim said that has some implications for atmospheric deposition.

Robert Miller asked what was happening as a consequence of wind tides. Scott said it was a great question, noting that it was a totally different situation in these wind-driven systems. The ones he evaluated were all tidally-driven.

Pete Caldwell asked if was always assumed that nitrogen was available, that there were no nitrogen limitations. Scott replied in the affirmative.

Jud asked how Scott defined "floodplain." Does it include the subtidal areas? Scott said for their purposes, the floodplain was anything they could remove, using polygons. The work in Maryland was based on a 15-year transect. In some cases they were aware that was conservative. In most cases they used 15 years from the channel as a boundary.

Pete Caldwell asked why the New River system didn't model quite as well. Scott's reply: because it is wind-tidal driven.

Marcel asked how frequent the velocity measurements were taken. Scott's answer: about every three minutes.

Dean noted that because the meeting was running about 30 minutes behind schedule, he proposed that we break for lunch and then have two presentations after lunch. He asked all the STAC members to gather outside for a group photo.

Flow and Mass Transport in River Basins of the Eastern US: Characteristics, Trends and Implications for Estuarine Health, Tim Spruill:

Tim began by showing a photograph of the Palmetto Peartree shoreline. The part of his presentation dealing with flow comes from Dr. Brian Richter. Tim invited Brian to discuss his flow work, but Brian was in Australia. Tim also was trying to tease out flow effects from land use effects, but noted that most of the variability is explained by the flows.

Tim gave us an overview of some of the questions which he wants to address. Tim began with a quote from the Richter et al. 1997 paper, and indicated he will address alteration of river regimes due to dam operations; non-point source pollution (sediment, bacteria, and nutrients are the most important); and invasive species. Tim noted that flow and mass loads are highly correlated. He projected a couple of graphs from the Neuse River at Fort Barnwell, showing the relationship between flows and total nitrogen in tons. When the Crop Reserve Program came into play in the early 1980's, sedimentation really decreased. Tim addressed loads and yields, showing us the equation used.

EDIT Flow is a major control on the habitat, physical, and chemical aquatic environment characteristics. Tim noted this stream flow is the primary mass transport medium and affects major erosion and corrosion processes that occur in a watershed. The flow of water affects the nature of all aquatic environments, and noted the difference between slow and fast-moving systems.

Tim addressed Brian Richter's Indicators of Hydrologic Alteration (IHA). He reviewed some of these, including magnitude (average monthly conditions characterized, median and mean). Magnitude and duration of annual extreme flow events; timing of annual extreme conditions; frequency and duration of high and low pulses; and rate and frequency of change in conditions. Tim provided the metrics associated with each of these.

Changes in flow can affect chemistry, biological behavior, habitat and ultimately ecological integrity.

Determination of ecosystem health depends on identification and characterization of flow characteristics before changes are implemented and require comprehensive and well thought out monitoring program. Impacts should be measured and evaluated according to standard procedures and modified as necessary to achieve healthy river ecosystems (system that approximate the undisturbed setting).

Tim showed us the hydrograph of the Roanoke River, before and after the dams were constructed. Most of the change was relative to the extreme flows. Medians and means remained about the same. Tim showed annual hydrographs for 1942 and 1975, pre- and post-dam, which graphically illustrates the removal of flow peaks and prolongation of flooding. Tim showed graphs for a number of the IHA variables. Tim showed another example of the Apalachicola-Flint system, where ever more water has been appropriated upstream for human consumption.

Tim shared the rationale behind the establishment of ecological flows.

He reviewed the impact of high flows due to dam releases or to changes in landscape vegetation due to urban and agricultural activities: these include increase scour and erosion in uplands and increased deposition in lakes and estuaries where velocity drops; increased turbidity and sediment transport; increase nutrient and contaminant transport; increased oxygen from turbulent flow; increased freshwater volume; and extremely high flows due to hurricanes. Reduced flows due to controlled dam releases, water withdrawals, diversions, drought, groundwater, etc.

Tim reviewed the rationale behind the objective of obtaining sustainable rivers. In river systems with dams, one should strive to maintain natural flows. He shared Richter et al. (2001) process to achieve sustainable rivers.

Tim turned to loads and yields useful to characterize nutrient transport processes in different environments and land uses. Loads are useful primarily as indicators of change through time, but they indicate all transport processes taking place at all upstream areas and it is difficult to tease out specifics.

Tim reviewed the reasons why movement of nutrient loads into coastal waters is important. Excess nutrients can exacerbate eutrophication processes: in freshwater systems, it is usually phosphorus that is the limiting factor; in brackish and marine systems it is usually nitrogen. He noted Diaz's work which documents the increasing number of dead zones around the world. Sources of nitrogen and phosphorus have increased dramatically through time. Worldwide, loads and yields have increased about three times between the 1970's and 1990's (Smith et al. 2003). Total nitrogen has also increased as has total P.

Tim provided a table showing the typical world, southeastern US and North Carolina (Albemarle-Pamlico) nitrogen and phosphorus yields in tons/mi^2 (tpsm). He noted that North Carolina is really not that bad in terms of nitrogen transport. The table was based on sources which Tim documented.

One must control nutrient loading in order to maintain ecosystem integrity. The Albemarle-Pamlico system is very sensitive to nutrient inputs. There hasn't been a lot of progress in controlling non-point sources. Excess nitrogen is still moving into US estuaries which will require more active controls by the states to maintain healthy coastal ecosystems. You have to have a target toward which to shoot.

Tim noted that Vollenweider (1975, 1976) had done a lot of the work on establishing the limits for nutrients. Tim noted that fast moving streams can sustain higher nutrient loading without exhibiting eutrophication. Lakes and estuaries on the other had are highly susceptible to nutrient pollution. Maximum phosphorus loading to a shallow slow lake/estuary is about 0.1 tpsm making the nitrogen maximum about 1 tpsm.

Tim noted another study done in the late 1990's which looked at 42 different estuaries in the eastern US (Valigura et al. 2001). The USGS SPARROW model was used to estimate nutrient loading. If you get much above 1 ton total nitrogen per square mile, the system will be overloaded.

Tim showed us a graph of total nitrogen, for a bunch of North Carolina streams. Most of them are at or below the standard, but some of well above (Bear Creek, New River, Gum Branch, N. Buff Creek, Buff Creek, New Hope Creek, etc.)

Tim showed us the same graph for total phosphorus. Systems above the standard were Dan River, Chicod, Crabtree reek, Bear Creek, Buffalo Creek, New Hope Creek, etc.

Tim's conclusions: Attaining sustainable aquatic ecosystems will require identifying natural flow and mass loading features of each system, attempt to duplicate them as closely as possible while trying to resolve conflicts between people's needs and specific ecosystem needs.

The scientific basis for determining sustainable flow and mass load management is available, the data are there and more earnest efforts should be made to use it. Populations are increasing in these basins and limits need to be defined.

Tim was asked if the Vollenweider study took atmospheric deposition into account. They did to a degree.

Tim was asked about the use of chlorophyll a as an indicator. Tim noted that the most seriously affected parts of aquatic systems are always lakes and estuaries, so that is where you need to look.

Reide asked if the individual streams which were above the 1 tpsm level were dominated by any particular factor. Tim indicated that the general findings were about the same, with the northeastern streams dominated by urbanization, and the southeastern streams dominated more by agricultural impacts.

Working Lunch: North Carolina Ecological Flows Science Advisory Board, Dr. Robert Christian:

Bob's presentation title was coastal systems and issues associated with them (for the Ecological Flows Science Advisory Board). Bob noted that the three previous talks were a good introduction for his talk. He is on the North Carolina Ecological Flows Science Advisory Board (EFSAB). He provided a presentation outline, including: progress of the EFSAB, coastal issues, and a proposal to the STAC. Regarding the latter, he would like to bring a more robust discussion, or model into the dialog.

Bob explained how the EFSAB arose. It was designed to help the North Carolina Division of Water Resources (NC-DWR) with planning efforts on water flow modifications and impact. He stressed it was a planning effort, not a regulatory effort. It is to provide advice on ways to use "ecological flows" in planning. The intent is to keep ecosystems as similar to nature as possible. The legislation defines ecological flows as those that will maintain ecological integrity. Ecological integrity is defined as "the ability of an aquatic system to support and maintain a

balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to prevailing ecological conditions and, when subject to disruption, to recover and continue to provide the natural goods and services that normally accrue from the system."

The steps toward ecological flows: develop stream classification; model flows; define biology of ecosystem as assemblages based on available information, i.e., fish and benthic invertebrates; link all; and have useful at multiple scales. In this particular case, they must use data available: fish and invertebrates. These two communities will define ecological integrity.

EFSAB began with a classification of about seven different kinds of streams, but that became difficult in trying to define diversity and/or compatibility. They are now evaluating different kinds of stream classifications. They are looking at the BEC, which includes biological and environmental variables; South Atlantic Landscape Conservation Collaborative (SALCC) system; and at physiographic regions, e.g., mountain, piedmont and coastal plain. A geographic reference system allows classification to be determined for any water planning node in hydrological model based on location. The approach used for determining ecological flow is according to stream classification.

Bob reminded us that the bottom line is how do modifications to flow affect the ecology of the system. In North Carolina, hydrological models are being developed using OASIS, a patented, mass balance, water resources simulation/optimization model; NC-DWR invested; based on long-term gage records and environmental factors; and basin-wide. Jud asked what it meant that the model was patented, and whether the code can be accessed. Fred Tarver explained that Hydrologics had developed the model, but that variants of it were posted, once developed. The other model being used is Waterfall (an RTI model). Bob explained that one. The problem is that neither of these models is particularly appropriate for the Coastal Plain.

The evaluation of ecological integrity is the Instream Flow Incremental Methodology. PHabSim (one approach) can be used to focus on how flow affects habitat and thereby community composition. This links bathymetry to flow rate and habitat amount. The process is to identify guilds, and link guilds to habitat use through time. Therefore link guild presence to flow through time under reference conditions. You can link effect on guilds to flow modification. You can also evaluate the generality of your findings.

Robin asked if you basically have to calibrate it. Bob's answer: Yes.

Bob noted that the model is often used for wadable streams. He gave us a generic example of the application of PHabSim. The intent is to see how the community changes with changes in flows. This is a pretty labor- and information-intensive exercise. It is a challenge to take the limited places where you can do these studies, and apply the results across the state.

Bob discussed the approach they are taking. BEC, fish by RTI, benthos by USGS; biological metric versus the degree of flow alteration; requires use of Waterfall; and consistent with biological/environmental stream classification. PHABSim was described, but for the BEC and PHABSIM, data are lacking from the Coastal Plan so they can't do these analyses at this time. The remaining option is a literature review.

Bob provided a status update. The process began in later 2010. The report is due by December 2013, and EFSAB are beginning to organize their recommendations. To gain something more than a literature review, we have to move quickly.

There are three overarching concerns that may challenge application of the approach to the Coastal Plain. They involve hydrogeomorphology. The area is flat, with low slope. Reverse flow is common, and tidal action must be considered, as well as backflow from larger rivers during high flows. Topographic relief makes watershed designations difficult, and there is high connectivity with adjacent wetlands. Sea-level rise is also important, despite what some may say.

What we do have, is the North Carolina Coastal Habitat Protection Plan (CHPP). On the coast, species are often different than those found in inland waters or have a different ecology than those inland. Examples: anadromous fish (blueback herring, alewife, American shad, Atlantic sturgeon, shortnose sturgeon, striped bass). We have some information on physical factors and how those influence the different life stages of these fish species. Also, North Carolina Division of Water Quality (NC-DWQ) has some information on benthic invertebrates within the Coastal Plain (swamp method). There is no estuarine IBI for coastal waters.

Wetlands and their services are inextricably linked to the waterways. Human alterations dominate the Coastal Plain, including dams and other blockages, agricultural ditching, roadside ditching, channelization, snagging, and navigational dredging. There are also several kinds of water withdrawal issues: community water supply is not necessarily based on surface withdrawal and reservoir use, etc. There is also water withdrawals not related to water supply.

Bob summarized: Coastal Plain waterways are potentially different in numerous ways. There is a need to find some answers to the issues.

Bob proposed a plan for coastal systems: he volunteered to make a presentation to EFSAB in July to advance coastal models; he proposed a group meet in May to determine if we can do better; he would like to have representatives from DMF, APNEP, and others like ECU. He asked for any volunteers from the audience.

J.P. wanted to know what was going to be done to characterize habitat. Bob explained that it was characterizing the preference of animals for riffles, deep pools, or edge habitat.

Reide asked if North Carolina Division of Marine Fisheries' (NC-DMF) Strategic Habitat Area classification was a useful classification. Bob was not aware of that one and was not able to say. It was noted that Regions 1 and 2 are done.

J.P. noted that the ditching dataset may be useful once you can characterize the hydrologic connections.

Bob agreed. He stated the purpose of this exercise is that some community will want to extract more water in the next 10 or 20 years, and we need to have an idea that if they take it from a particular stream what guidelines can be provided. These are issues in the interconnectedness of stream for the Coastal Plain, and not so much for the Piedmont and Mountains where you don't see this kind of ditching.

Jud asked if he was correct when he said that the larger rivers have their heads in the Piedmont, whereas the Coastal Plain ones are basically Coastal Plain streams. Bob concurred that was the case. He noted that we are trying to give advice about large reaches, not necessarily the entire river. There may be an impact in a tributary, which may not affect the larger tributary into which the stream flows. The tool is statewide and we want to understand the impact on streams statewide.

Rua asked how much they were able to talk to USGS staff in South Carolina, or the USGS staff using Waterfall. Bob said unless Fred Tarver has had such contact, no one on EFSAB has made those kinds of contacts.

The question was asked as to what sort of magnitude they were looking for in terms of types within classifications: 3 or 500? Bob noted that seven wasn't enough. He felt that they needed probably around 25 types. Judy noted that the classification with seven types was based exclusively on hydrologic factors. It didn't involve biology, or other factors that people would want to see. There were some inherent problems with the model. It could be that seven might be sufficient. She understood the point. If there are 17 different reaches from which they are withdrawing water, that isn't practical. Judy noted that it has been a struggle, to say the least.

Bob Christian noted that Jay Sauber represents NC-DWQ on the EFSAB. Bob didn't remember Jay bringing this issue up in any way. They have not talked about any NC-DWQ stream-mapping exercise. It was noted that Periann Russell is one of the NC-DWQ staff working on models.

Tim noted that the technology has advanced to the point where we have the capability of trying to identify what ecological needs may be for the mouths of streams near where they enter the estuary. Bob noted that we may begin working in little Washington and New Bern, and we tend not to work in that transitional zone. Tim was not aware of much work done in those zones.

Pete Caldwell wondered if the flows were not as critical further downstream as the depth may be. Bob noted that elevation is related to flow. You either have astronomical, or wind-related, tides.

Judy noted that since 2010 she has been thinking about the water-related issues for the coast. She had learned a lot today, that tidal influence goes pretty far upstream. She asked if the system was so dynamic at this point that it would override the influence of total discharge at a given point, or not. Is there information that can be brought to the table that will illustrate the vulnerability of the coast? That would be critical information to bring to the table in the short run, because we can't put the gages out there now and have sufficient information in place by December 2013 to understand the system. We just need to understand how vulnerable the coastal systems are to water withdrawals.

Bob noted that the salinity wedge will shift in position, and that is a factor that we don't have elsewhere. Bob noted that we tend to think that major water withdrawals will happen in the Piedmont, but that isn't always true. We have Wilmington, for example, which has growth similar to the Piedmont.

It was noted that Apalachicola Bay shows what happens when you withdraw too much water. Same is true for the Colorado River. In both cases, productivity dropped (Florida) or a marsh disappeared (at the mouth of the Colorado).

Marcelo wondered if to a certain degree the problem in the Mountains and Piedmont was to keep the water on the landscape, but in the Coastal Plain the problem was to get it off the landscape. Marcel noted that the systems are completely different in the Coastal Plain.

Bob noted that Tim had suggested more work needs to be done. That is certainly true, and one recommendation that EFSAB will make is that more work needs to be done in the Coastal Plain. That will be said, but we need more than just one sentence. If we can't have a tool in 2014, what needs to be known before we can do that?

Michael Piehler noted that we don't want to have stormwater driving our flows. There are two questions, one is how inland withdrawals will affect the Coastal Plain? The other is how the dynamics of coastal streams function? Perhaps the values for coastal streams would be captured by something other than flows. Perhaps we can come together with the best we can find about the values of coastal streams.

Jud stated it was pretty clear to him that we need a different set of metrics. PHABSim simply won't work in coastal streams. Bob said there are some models that do predict water height under certain conditions.

Bob returned to his slide showing the extent of ditching in the Coastal Plain. He asked Fred if someone wanted to put in a set of ditches which would modify water flow, would that be a part of the mission NC-DWR would address? Fred said that the mechanism he hoped would be to trigger some sort of permitting mechanism. If the modeling efforts for the Coastal Plain fall apart, other DENR agencies could assist. Bob felt that Marcelo had brought up an interesting question.

J.P. noted that the Coastal Plain is getting more research attention. The areas are flat and they are not a focus of fluvial work. But there is a complex dynamic which affects the hydrology and the bed of the system. The Tar River for example has a flat floodplain downstream of Greenville, and one key limit is that we don't have the bathymetry to run the model even if we had a model to run. We are limited in what has been done. We can run computer models but we have to have the data to run them. J.P. noted that there has been some multibeam work done in some reaches of the rivers.

Wilson noted that some of the fishery researchers are doing multi-beam in the course of tracking their acoustically-tagged fish.

Wilson asked Bob if EFSAB had been able to glean anything of use from other states like Texas, who have already been through similar exercises. Bob said they are looking at what other states are doing, but they are getting close to the end of the process. He is concerned that they are so close to the end and are running out of time.

Fred noted in response to Wilson's question that he has reviewed the processes in Florida and Texas, and both of them have looked at production of certain species as possible criteria.

The point was noted that we seemed to have moved away from classification of streams by the biology, quickly to how these could be used. It seemed to the questioner that we could look at species, rather than trying to link a lot to flows. It could be that 90% of the coastal streams have already been highly affected.

Bob thought he agreed. You would have to classify the reference standard, whether it was based on solely biology, or with biology in concert with some other factor. The next step would be to determine what isn't a referenced standard. He felt that we could find some truly reference conditions, but there aren't many of them.

Judy noted that the reference data are not there either, relative to what is available in the Mountains or Piedmont. Those sampling regimes were designed to address water quality, not natural conditions. So, that is why they have been developing a swamp model. The Coastal Plain stations simply are not there, for use in the BEC. What must happen is that the research is the mandate that has to go out. We are only working with existing data in the Piedmont and Mountains. We are really at a loss for the Coastal Plain.

Robin noted that he was under the impression that the Coastal Plain was more influenced by groundwater than the other areas. Tim wasn't sure that was the case, although he agreed that there was a lot of push on that topic, and agreed groundwater can be an important component. With regard to the Neuse River, you do get some significant groundwater flows, but in some places, it is minimal. Perhaps in some areas, that is why you get a lot of algal blooms, and the absence of groundwater may be a significant factor. It certainly needs to be taken into account. It should certainly be a component of study.

Bob stated we could all agree that we need a good water level station in the Pamlico.

Jud noted that Bob had said that he was thinking of how the STAC could help in the next couple of months. It wasn't so much that the problem would be solved, but rather that STAC could help with developing some recommendations. Jud asked for his thoughts in formalizing the product from the STAC. Bob asked Dean to send out an e-mail and solicit volunteers from the STAC. Bob suggested that we could build this around two or three meetings in May and June.

Dean indicated that he could certainly send out a message and APNEP was aware that the state's process was wrapping up. Dean suggested that EFSAB could perhaps hand off some things to APNEP for post-report processing. He asked what the process was, once the state process ends.

Bob stated that there was some discussion last week about an implementation board which might be able to get into the implementation aspect of the recommendations.

Fred Tarver explained that modeling was occurring prior to the statute, and NC-DWR staff are working on a number of the coastal-related basins. There is a big, black empty area in the tidal portions of the rivers. They are looking to EFSAB for advice. One concern is that they don't have a way to model the Coastal Plain in terms of water use 50 years out. If the recommendation is that we need more data, the blanks will remain until we develop a model or come up with some other way to address the needs.

Dean noted that one of APNEP's objectives is to come up with ecological flows and thus APNEP can certainly assist in helping to fill the gaps. The EFSAB's recommendations may provide a way for APNEP to assist. Bob felt that APNEP could certainly assist in developing a more long-term

perspective. Dean indicated again that he would be pleased to send out a message. Bob will provide a paragraph for Dean to distribute.

Jud asked if anyone else had any questions. There were none. Jud thanked everyone for coming and noted that we had generated something for potential action. Dean noted that he would be sending a notice about the next meeting, after the next STAC Executive Board meeting.