APNEP's Water Resources Monitoring & Assessment Activity Phase I (2008-2010) and Pre-Phase II (2011-2016)

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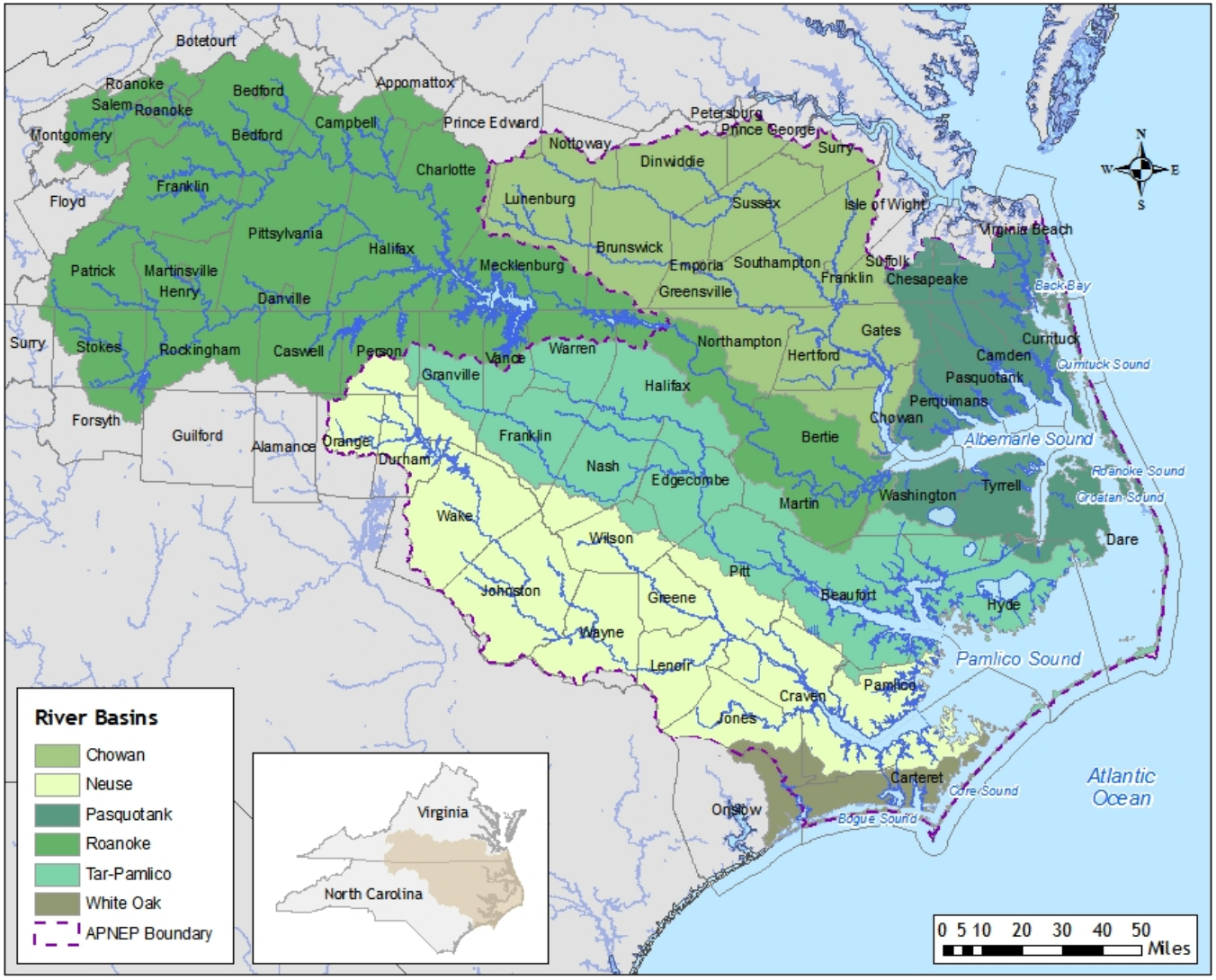
Albemarle-Pamlico National Estuary Partnership

Water Resources Monitoring & Assessment Workshop
Imperial Centre for Arts and Sciences
19 June 2017

APNEP Mission

"To identify, restore, and protect the significant resources of the Albemarle-Pamlico estuarine system."

APNEP Implementation Area and Management Institutions



APNEP Water Resources Monitoring & Assessment (Phase I)

- Develop a monitoring strategy for Water Resource metrics within the APNEP region
- Metric-specific monitoring proposals
- Indicators to be featured in the 2012 APNEP Regional Ecosystem Assessment

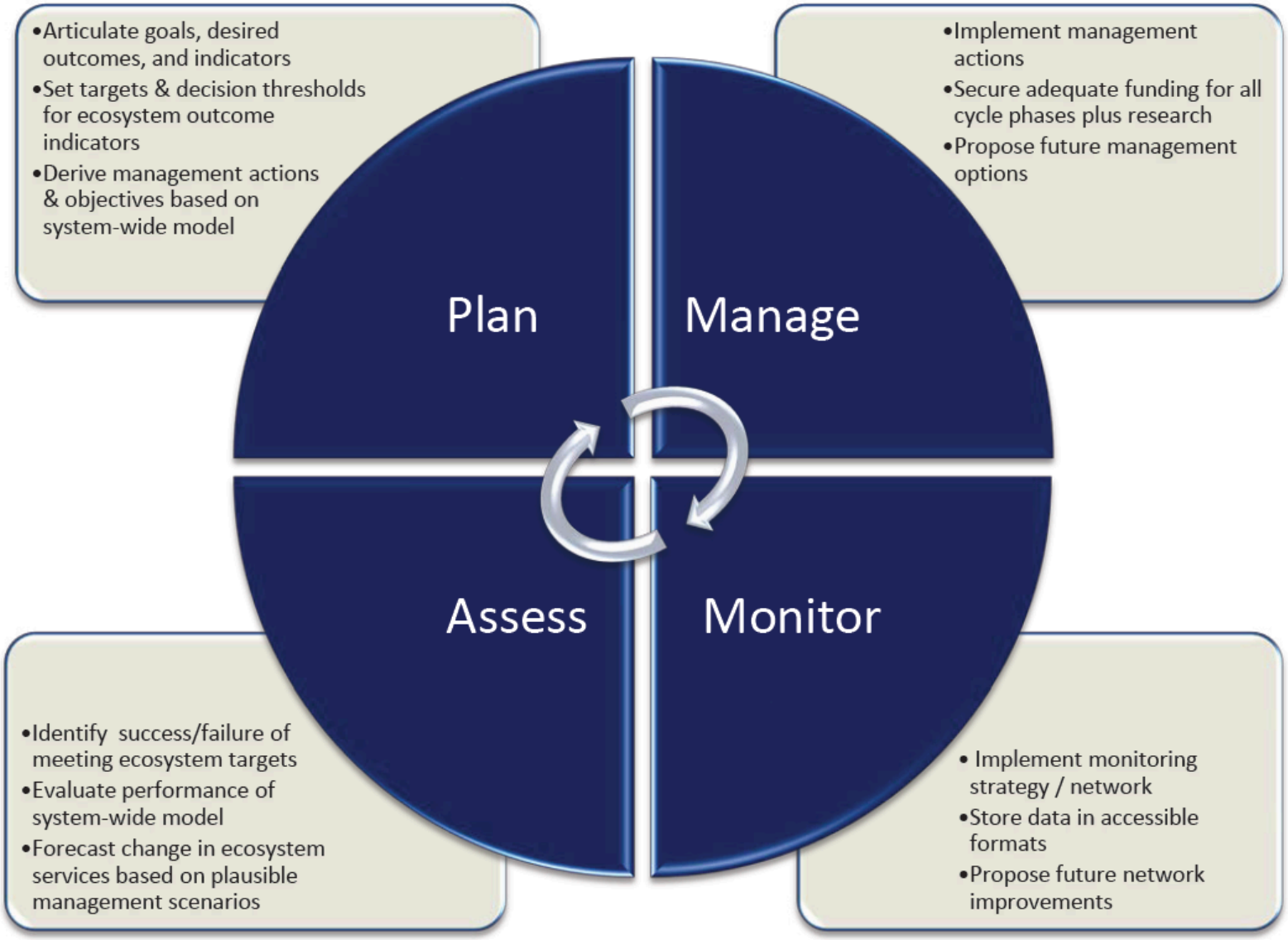
APNEP's Transition to Ecosystem-Based Management

- A holistic vision and plan that includes a comprehensive description of the A-P system and articulation of multiple management objectives.
- A community that has effective engagement of policy makers, managers, scientists, & stakeholders.
- A process that includes effective adaptive management to address a changing system.
- A framework that includes appropriate authority, implementation area, management institutions, financial resources, and effective communications.

APNEP's Ecosystem Health Goals

- **A region where human communities are sustained by a functioning ecosystem**
- **A region where aquatic, wetland, and upland habitats support viable populations of native species**
- **A region where water quantity and quality maintain ecological integrity**

Figure 2: APNEP's adaptive management cycle.



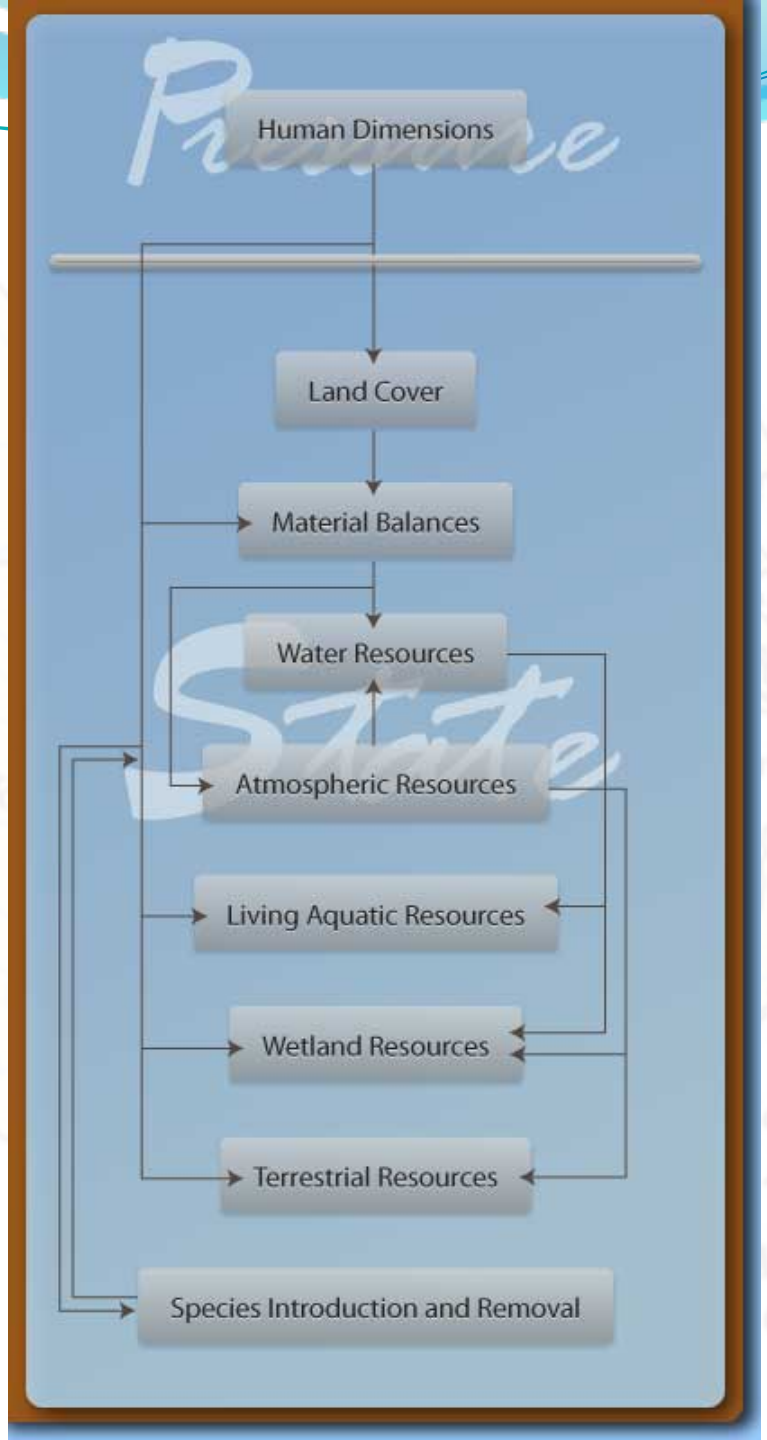
APNEP Targets 2017-2018

- Regional Ecosystem Assessment 2.0
  - Indicator Specification 1.1
- Comprehensive Conservation & Management Plan (CCMP) 2.1
  - Ecosystem-Based Management (EBM) Plan 1.0
- Integrated Monitoring Strategy 1.0
  - Indicator Specification 1.1

APNEP Monitoring & Assessment 2008-2010

- APNEP staff adopt indicators/metrics in 2007
- Plan in 2008 to develop an integrated monitoring strategy for those indicators
- In concert with APNEP revising its Comprehensive Conservation & Management Plan (CCMP)
- Six APNEP resource monitoring & assessment teams

Regional Ecosystem Model



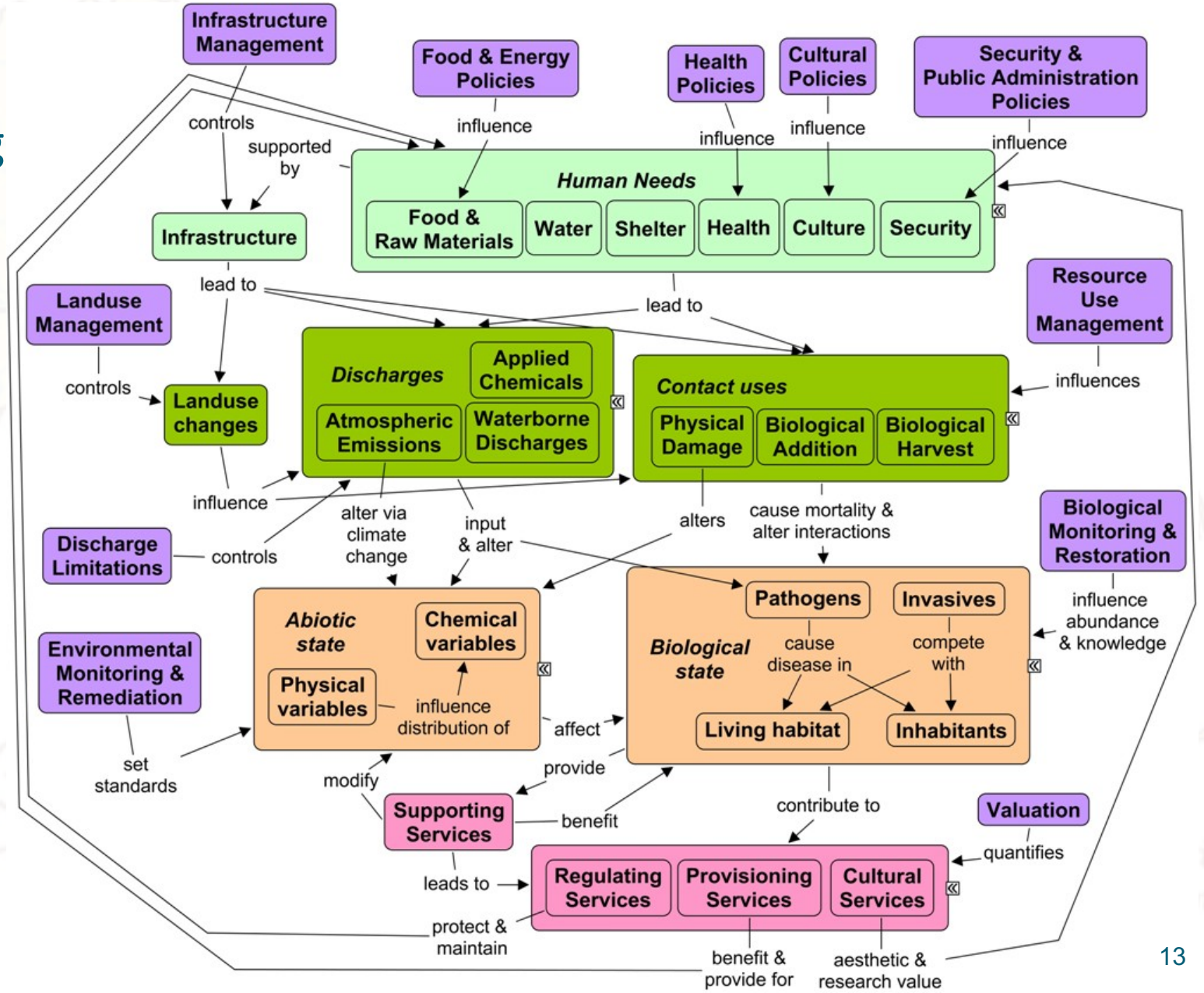
Water Resources Monitoring & Assessment Team Representation (Phase I)

- APNEP
- NC-DA&CS
  - FS
- NC-DENR
  - DMF
  - DWQ
  - DWR
  - NERR
- NC-WRC
- VA-SNR
  - DCR
  - DEH
  - DEQ
- Federal
  - COE
  - EPA
  - FS
  - FWS
  - NOAA
  - NPS
  - USGS
- STAC/ Ex-STAC
  - ECU
  - NCSU
  - UNC-CH
  - PTRF

EPA Indicator Development for Estuaries

- Program Planning
- Conceptual Model Development
- Indicator Specification
- Monitoring Program Development
- Implementation
- Reassessment

DPSER Modeling



Lt. green = Drivers
Dk. Green = Pressure
Orange = State
Red = Ecosystem Services
Purple = Response

EPA-ORD-ESRP 2010

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APNEP Indicator Definition

"A numerical value derived from actual measurements of a pressure, state or ambient condition, exposure, ecological condition, or measure of human health or wellbeing over a specified geographic domain, whose trends over time represent or draw attention to underlying trends in the condition of the environment in the A-P region."

APNEP Indicator Criteria

- Utilization: Address a key process or property, and answers (or makes an important contribution toward answering) an important question about conditions in the A-P region
- Objectivity: Developed and presented in an accurate, clear, complete, and unbiased manner
- Integrity: Underlying data should be characterized by sound collection methodologies and data management systems adequate to protect its integrity, and to comply with quality assurance procedures
- Availability: Data should be available and timely, or will likely be available in the future, to maintain the indicator's utility
- Representation: Trends should accurately represent the underlying trends in the target population
- Clarity: The indicator should be clearly defined and reproducible. The specific data used and the specific assumptions, analytical methods, and statistical procedures employed are clearly stated

APNEP Objectives-Metrics Hierarchy

- Modules
- Categories
- Dimensions
- Metrics

Candidate Water Resource Indicators

Module	Category	Dimension	Indicator	
IV: Water Resources	IV-A: Water Quality Threats (Load)	IV-A-1: Nutrient Loads	IV-A-1-a	Nitrogen & Phosphorus Loading
		IV-A-2: Oxygen-Depleting Substances Loads	IV-A-2-a	Biochemical Oxygen Demand
		IV-A-3: Sediment Loads	IV-A-3-a	Sediments from Land
		IV-A-4: Toxicant Loads	IV-A-4-a	Toxicants from Land
	IV-B: Surface Water Quality (In Column)	IV-B-1: Water Quality Degradation	IV-B-1-a	Amount & Extent of Impaired Waters
			IV-B-1-b	WQ Standard Violations
			IV-B-1-c	Acute WQ Problem Sites
		IV-B-2: Water Quality in High-Value Sites	IV-B-2-a	WQ in Nursery Areas
			IV-B-2-b	WQ in SAV Habitats & Shellfish Waters
		IV-B-3: Nutrient Sensitive Waters	IV-B-3-a	Nutrient Concentrations in NSW
		IV-B-4: Physical Contaminants	IV-B-4-a	Dissolved Oxygen Standard Violations
			IV-B-4-b	Sediment Standard Violations
			IV-B-4-c	Salinity Concentration
			IV-B-4-d	Estuarine Debris
			IV-B-4-e	Underwater Acoustics
		IV-B-5: Algae	IV-B-5-a	Chlorophyll-a Concentration
		IV-B-6: Pathogens	IV-B-6-a	Shellfish & Swimming Area Closures
		IV-B-7: Toxicants	IV-B-7-a	Toxicant Standards Violations
			IV-B-7-b	Metals Standards Violations
		IV-B-8: Emerging Contaminants	IV-B-8-a	Personal Care & Pharmaceutical By-Products/Nanoparticles
	IV-C: Ground Water Quality	IV-C-1: GW Quality Degradation	IV-C-1-a	Drinking Water Standard Violations (Water-supply Aquifers)
			IV-C-1-b	Acute WQ Problem Sites
		IV-C-2: GW Physico-Chemical Contaminants	IV-C-2-a	Saltwater Intrusion
		IV-C-3: GW Pathogens	IV-C-3-a	E. coli in Land Use Categories (Shallow Aquifer)
		IV-C-4: GW Toxicants	IV-C-4-a	Toxicant Concentrations in Land Use Categories (Shallow Aquifer)
		IV-C-5: GW Emerging Contaminants	IV-C-5-a	Emerging Contaminants in Land Use Categories (Shallow Aquifer)
		IV-C-6: GW Nutrients	IV-C-6-a	Nutrient Concentrations in Land Use Categories (Shallow Aquifer)
	IV-D: Sediment Quality	IV-D-1: Sediment Toxicants	IV-D-1-a	Sediment Quality Triad
		IV-D-2: Sediment Nutrients	IV-D-2-a	Sediment Nutrient Concentration
II: Land Cover	II-A: Landscape Vulnerability	II-A-1: Sea Level	II-A-1-a	Sea Level/Relative Sea Level
			II-A-1-b	Shoreline/Beach Width: Inundation Frequency
III: Material Cycles	III-A: Water Cycle	III-A-1: Mainstem Hydrograph	III-A-1-a	Flows, Severity, Frequency, Duration of Droughts & Floods
		III-A-2: Sounds Water Balance	III-A-2-a	Estuarine Residence Time
		III-A-3: Ground Water Levels	III-A-3-a	Ground Water Levels
	III-B: Aquatic Element of Carbon Cycle	III-B-1: Sequestered Carbon	III-B-1-a	Stored Carbon in Water Column & Sediments
	III-D: Aquatic Element of Toxicants Cycle	III-D-1: Non-Metals Contaminants	III-D-1-a	Toxicant (TBD) Discharges

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A-P Ambient Monitoring Program

- Precise goals and specific measures for monitoring policy effectiveness should be designed and tested at the time that a policy is implemented
- Status Quo: APNEP 2000 monitoring survey update

APNEP Monitoring Proposal

- Justification for indicator
- Goal of sampling/monitoring program
  - What the optimum sampling/monitoring program will achieve and why that is important
- Existing sampling/monitoring program
  - Objectives - What the existing program is designed to measure.
    - Example: *Conduct periodic aerial mapping to monitor dramatic change of SAV presence over 5-year increments in four of six APES regions*
  - Methods
  - Costs
  - Data quality control (data quality objective)
  - Data analysis, statistical methods and hypotheses

APNEP Monitoring Proposal

- Enhanced sampling/monitoring program
  - Objectives - what the enhanced sampling/monitoring program is designed to measure.
    - Example: *Estimate the areal distribution and abundance of SAV along the western shorelines of APES and be capable of detecting significant change in SAV distribution and abundance*
  - Methods
  - Costs
  - Data quality control (data quality objective)
  - Data analysis, statistical methods and hypotheses
- Reference(s)
- Contact Person

Monitoring Integration Continuum

- Independence: Knowledge of partners monitoring strategies
- Cooperation: Taking advantage of common geography, timing
- Collaboration: Opportunities to leverage partners' monitoring networks
- Integration: Working toward a common set of regional ecosystem objectives

APNEP EBM Transition Team

- Policy Board
- Science & Technical Advisory Committee
- Citizens Advisory Committee
- State Planner
- Federal Planner
- EBM Tech Transfer
- Staff

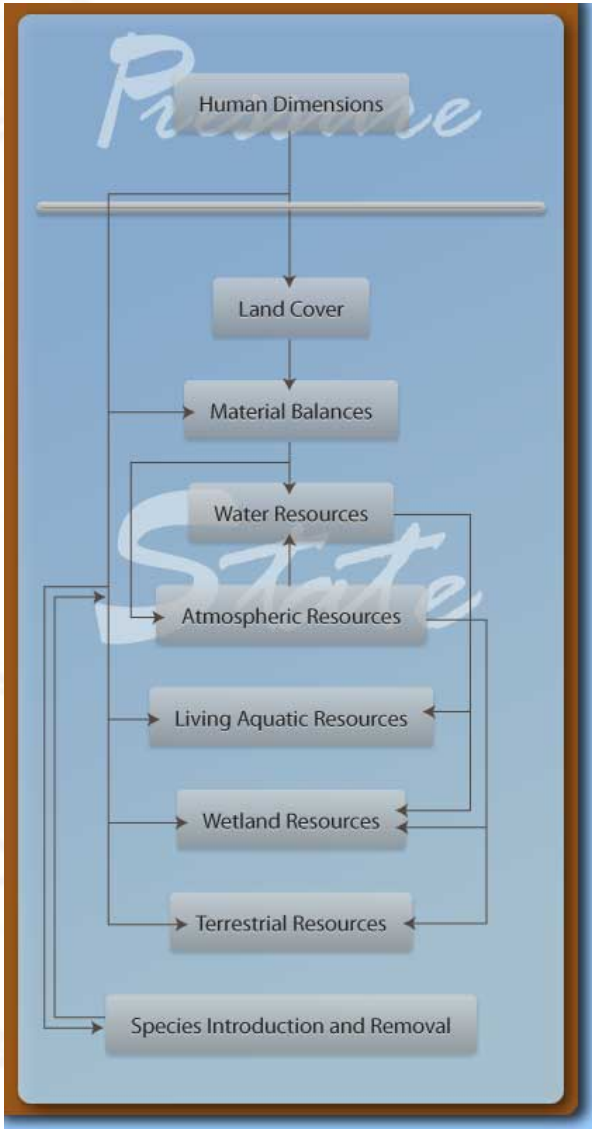
Step 1: Articulate program goals

- Objectives Hierarchy Structure
  - Goal-Objective-Management Action-Step (1994)
  - Goal-Subgoal-Objective-Management Action (2008-2010)
  - Goal-Outcome + Component-Objective-Action (2012)
- Objectives Hierarchy Content
  - Five Goals, 15 Objectives, 49 Actions (1994)
  - Three Goals, 12 Outcomes + 5 Components, 15 Objectives, 58 Actions (2012)

Step 2: Develop system level model for goal attainment

Ecological management actions (stressor mitigation) can impact multiple ecosystem endpoints

Multiple stressors (including other endpoints) impact directly and indirectly ecosystem endpoints

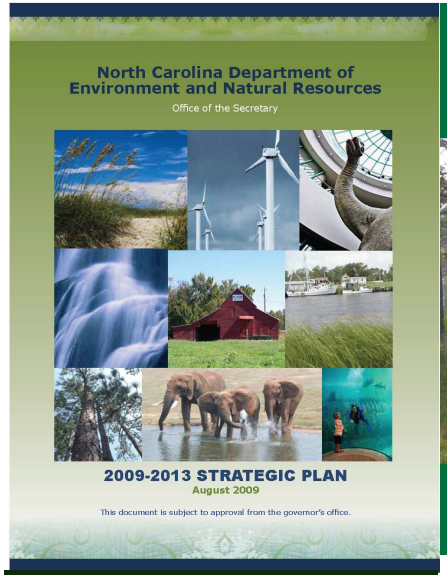


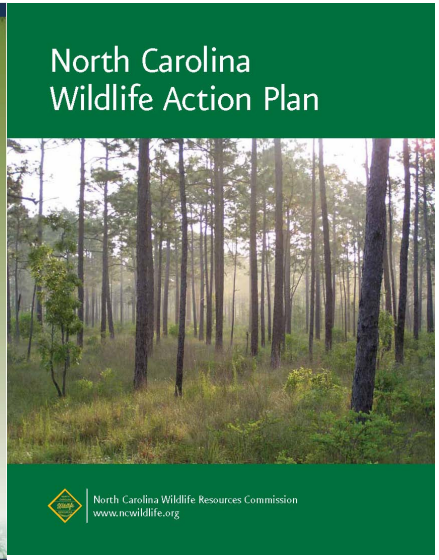
	Goal 1: human communities sustained by functioning system						Goal 2: habitats protected, enhanced, restored, supporting native species							Goal 3: water quantity and quality										
	safe contact	safe consume	support activities	fish/game safe	access protected	sustained harvesting	aquatic community	wetland community	upland community	estuarine habitats	freshwater habitats	upland habitats	non-native	hydrologic regime	nutrients and germs	toxics		identify	protect	restore	preve nt	collab orate	monit or
biological factors																							
• fauna																							
• manage non-native species introduction and impacts						M-M	M-M	M-M	L-M	L-L	M-L						3		x				
• preserve/protect RTE species							M-M										1		x				
• preserve and restore shellfish communities (reefs)										H-H							1		x	x			
• management of native/non-native grazers (deer)												H-M					1		x				
• management of predators (red wolf, coyote, domestic animals)												L-M					1		x				
• flora																							
• manage non-native species introduction and impacts						M-M	M-M	M-M	M-M	L-L	M-L						4		x				
• preserve/protect RTE species							M-M										1		x				
• preserve and restore submerged aquatic vegetation										H-M/L							1		x	x			
• preserve and restore coastal wetlands										H-M							1		x	x			
• preserve and restore coastal forests																	1		x	x			
• management of native forests, shrub/scrub communities (fire management)												H-M					1		x				
• microorganisms																							
• manage sources and loads of pathogens	H-M	H-M		H-M									L-L				3		x				
• manage introduction/spread of pathogens						M-M	L-L						L-L				1		x				
physical factors																							
• structure																							
• preserve/establish public access to public lands and waters					H-H												1		x				
• manage landuse to minimize conflict/negative impacts on use diversity						H-M											1		x				
• manage conversion of aquatic habitats							H-H			H-H							2		x				
• manage wetland buffer conversion								H-M									1		x				
• preserve wetland migration opportunities								H-M/L									1		x				
• maintain hubs and corridors for green infrastructure									H-M								1		x				
• identify critical conservation areas									H-H			H-H					2	x					
• manage floodplain and riparian area conversion											H-M						1		x				
• manage channel modification											H-H						1		x				
• green infrastructure												H-M					1		x				
• hydrology																							
• MIF adequate to support all desired uses			H-M														1						
• manage consumptive uses of water						H-H											2		x				
• preserve natural hydrographs							H-M	H-M			L-H						2		x				
• temperature																							
manage alteration of natural temperature regimes						L-L					L-H						2		x				
• control modification of riparian vegetation											L-M						1		x				
chemical factors																							
• salinity																							
• pH																							
• nutrients																							
• implement TMDL management for nutrients							M-M				M-M				H-M/L		2		x				
• toxics																							
• manage sources and loads	L-L			H-M		H-H	L-M				L-M					H-M	1		x				
human factors																							
• use objectives																							
• establish appropriate use designation for waters	H-H	H-H		H-H											H-H		4	x					
• establish and implement public access/use plan					H-H												1	x					
• manage potential use conflicts that reduce sustainability of natural capital						H-M											1	x	x				
• manage potential use impacts on habitat diversity and quality							H-M			H-M							2	x	x				
• manage landuse in wetlands and wetland buffers								H-H									1		x				
• identify and control incompatible uses (receiving waters, shipping, recreation, etc.)			H-H														1	x	x				
• land use management (maintain green infrastructure)												H-H					1	x	x	x			
• forestry management												H-H					1		x				
• manage consumptive uses														H-H			1		x				
• management of agricultural pollutant sources															H-M		1		x				
• management of developed land pollutant sources (stormwater)																			x				
• modification of system																							
• establish/implement TMDL for pollutants	H-H	H-H		H-M													2	x	x				
• avoid privatization of public lands and access points					H-M												1	x			x		
• manage conversion of habitats that reduce diversity or productivity										H-M							1		x				
• manage dredging, filling, and water withdraw							H-H										1		x				
• manage hydrology modification			M-H					H-M			H-M						2		x				
• manage permanent conversion of wetland buffers								H-M									1		x		x		
• manage landuse/green infrastructure									H-M								1		x		x		
• manage channel modification											H-H						1		x				
• manage floodplain/riparian land conversion											H-M				H-M		1		x		x		
• manage road development												H-H					1		x				
• manage development												H-H					1		x				
• manage dam construction														M-H			1		x				
• manage flood plain conversion														H-M			1		x		x		
• knowledge																							
• technical understanding of health risks (sources, thresholds)	M-H	H-H		H-H													2	x					
• technical understanding of use thresholds for sustainability					M-M	H-M	M-M										1	x					
• technical understanding of system trajectory and implications for sustainable uses						H-M		H-M		M-M							2	x					
• technical understanding of landuse impacts on wetland function								M-M									1	x					
• technical knowledge of structure-function relationship									M-M	M-M							2	x					
• technical understanding of critical blue infrastructure											M-M						1	x					
• technical understanding of green infrastructure requirements												M-M					1	x					
• technical understanding of non-native species impacts													H-M				1	x					
• technical understanding of MIF requirements			H-H											H-M			1	x					
• tech understanding of TMDLs to meet WQ standards															M-M/L		1	x					
• technical understanding of compound toxicities																H-M	1	x					
• technical understanding of source/route of introduction																H-M	1	x					
• public understanding of monitoring and advisories	H-H	H-H		H-H													3					x	
• public appreciation of the values of natural capital					M-M	M-M/L	M-M	H-M		M-L	M-L						1					x	
• public appreciation of the thresholds for sustainable use			M-M/L		H-M				H-M			M-M					2					x	
• public understanding of actions that negatively impact							H-M										1					x	
• public appreciation of need/methods for control of non-native introduction																	1					x	
• public appreciation of MIF needs														M-L			1					x	
• public appreciation of risks and need for management															M-L/M	M-M	1					x	
• policy understanding of need for monitoring	H-H	H-H		H-H													3					x	
• policy understanding of need for regulation	H-H	H-H	M-H	H-M	M-M	H-L	H-M	H-H	H-M	M-M	M-M		M-L		M-M	H-M	3					x	

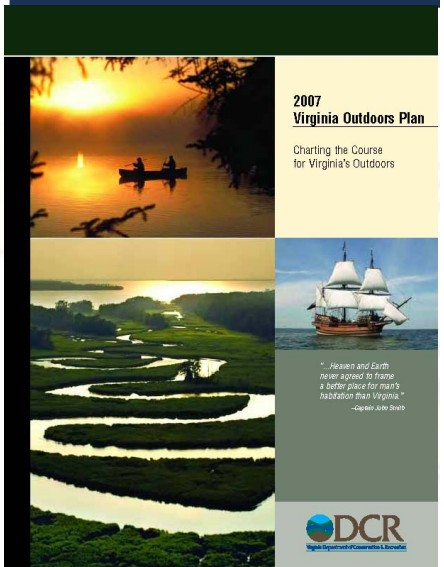
H-H	
H-M	
H-M/L	
H-L	
M-H	
M-M	
M-L	
L-H	
L-M	
L-L	

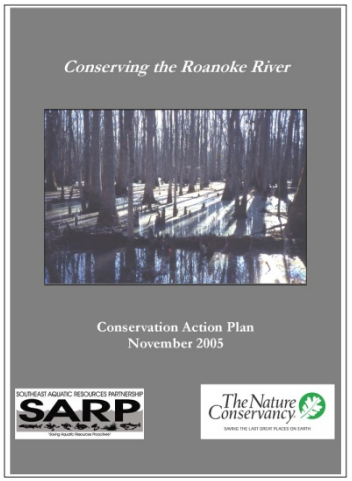
EBM Step 3: Assess current management efforts –identify gaps

- Directed by conceptual models
- Survey of partners' strategic/action plans
  - Specificity and publication date
  - Action extraction
  - Align with APNEP outcomes/strategies
- Interview senior management









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Implement CCMP

- Fourth CCMP question
- Ten-year horizon
- 58 CCMP actions
- Super-Aggregated into five components
- Aggregated into 15 CCMP objectives

2b. The extent and quality of upland, freshwater, estuarine and near-shore marine habitats fully support biodiversity and ecosystem function

Outcomes	Actions					Workgroups
1a	A1.1	B1.1	C1.1	D1.1	E1.1	Freshwater Habitats and Fish Passage
1b	A1.2	B1.2	C1.2	D1.2	E1.2	Policy & Economics
1c	A2.1	B1.3	C1.3	D1.3	E1.3	Decision Support Tools
1d	A2.2	B1.4	C1.4	D1.4	E2.1	Education & Engagement
1e	A2.3	B1.5	C1.5	D1.5	E2.2	Water Quality Improvements
2a	A2.4	B2.1	C2.1	D2.1		Shorelines
2b	A2.5	B2.2	C2.2	D2.2		Contaminant Management
2c	A3.1	B2.3	C2.3	D2.3		Invasives
3a	A3.2	B2.4	C3.1	D3.1		Restoration Strategies
3b	A3.3	B2.5	C3.2	D3.2		Monitoring Networks
3c		B2.6	C3.3	D3.3		Oysters
3d		B3.1	C4.1			SAV
		B3.2	C4.2			Flows
		B3.3	C4.3			
			C4.4			
			C5.1			
			C5.2			
			C5.3			

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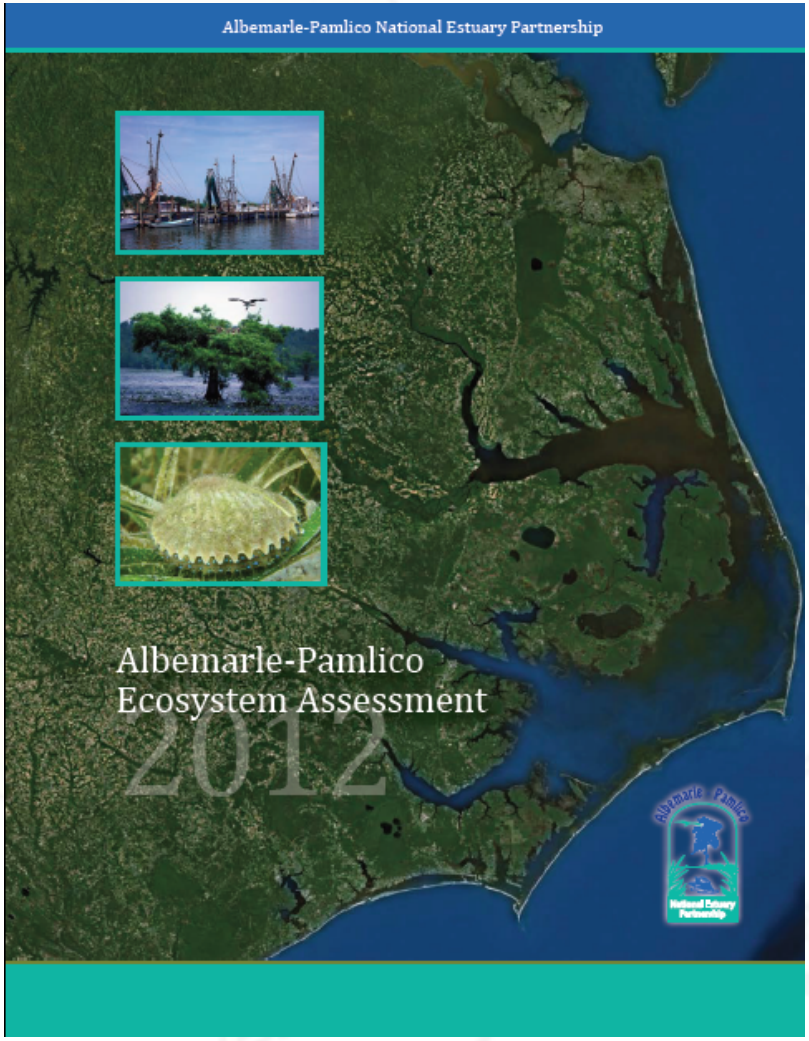
Step 5: Develop monitoring program

- Linking candidate indicators to CCMP outcomes
- Indicator-specific monitoring strategies
  - Justification for indicator
  - Goal of sampling/monitoring program
  - Existing sampling/monitoring program
  - Enhanced sampling/monitoring program
  - Reference(s)
- Integrated monitoring strategy

Step 6: Assess performance

- "Interim" regional ecosystem assessment (2012)
  - Select provisional indicators
  - Status & trends from 1995 to present
  - Heinz Center format
- Phase 2 assessment
  - Diagnosis
- Phase 3 assessment
  - Forecasting



APNEP Ecosystem Assessment
System-Wide: Chemical & Physical

- *Dissolved Oxygen Concentration Violations*
  - Why Is DO Concentration Important?
  - What Will This Indicator Report?
  - What Do the Data Show?
  - Why Can't This Entire Indicator Be Reported at This Time?
  - Understanding the Data
  - Technical Notes

Assessment Planning

- "The greatest challenge in developing a large-scale biogeographic assessment is the synthesis and subsequent analysis of spatial data collected at different scales for varied objectives."

  Source: NOAA 2003, citing Gotway and Young 2002

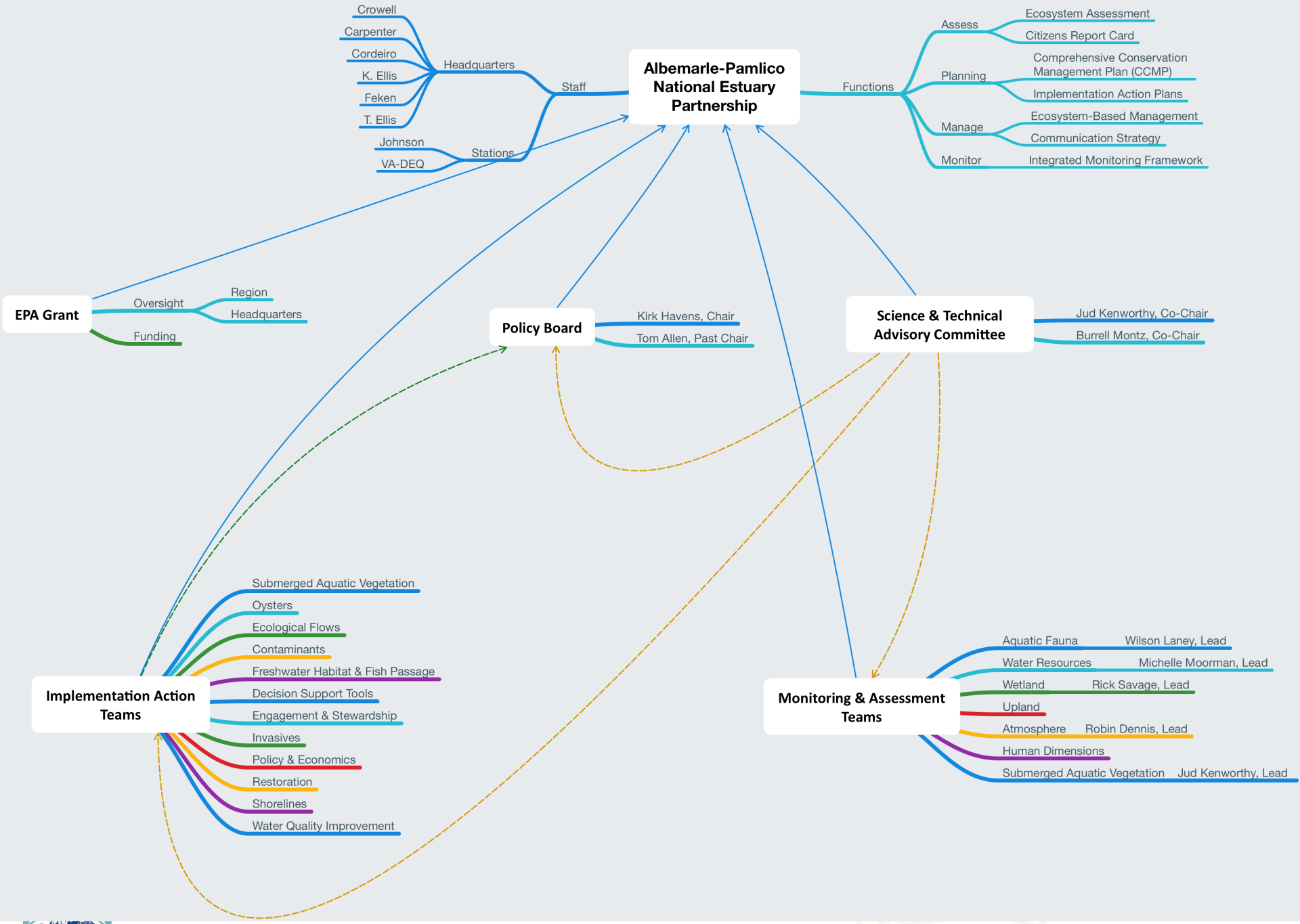
Bioregional Assessment Questions

- What were historic ecological, social, and economic conditions, trends, and variability?
- What are current ecological, social, and economic conditions?
- What are trends and risks under current policies and management?
- What policy choices will achieve ecological sustainability consistent with social well-being?
- What are the implications of these choices?

Source: Erman (1999)

Step 7: Manage adaptively

- Most difficult step?
- Senior management engagement
- Trigger levels in plan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Staff
Headquarters
Crowell
Carpenter
Cordeiro
K. Ellis
Feken
T. Ellis
Stations
Johnson
VA-DEQ
Functions
Assess
Ecosystem Assessment
Citizens Report Card
Planning
Comprehensive Conservation Management Plan (CCMP)
Implementation Action Plans
Manage
Ecosystem-Based Management
Communication Strategy
Monitor
Integrated Monitoring Framework
EPA Grant
Oversight
Region
Headquarters
Funding
Policy Board
Kirk Havens, Chair
Tom Allen, Past Chair
Science & Technical Advisory Committee
Jud Kenworthy, Co-Chair
Burrell Montz, Co-Chair
Implementation Action Teams
Submerged Aquatic Vegetation
Oysters
Ecological Flows
Contaminants
Freshwater Habitat & Fish Passage
Decision Support Tools
Engagement & Stewardship
Invasives
Policy & Economics
Restoration
Shorelines
Water Quality Improvement
Monitoring & Assessment Teams
Aquatic Fauna
Wilson Laney, Lead
Water Resources
Michelle Moorman, Lead
Wetland
Rick Savage, Lead
Upland
Atmosphere
Robin Dennis, Lead
Human Dimensions
Submerged Aquatic Vegetation
Jud Kenworthy, Lead

Category	Dimension	Indicator Type	Code	Provisional Indicator	Key Partner	Units	Extent	Resolution	Extent	Frequency	Extent	Resolution	Extent	Frequency
Ecosystem Stressors	Atmospheric Stressors	Air Physics, Climate Change	V-B-a-b	Precipitation	NC-State Climate Office									
			III-D-c-a	Evapotranspiration by Land Cover Type	US-EPA-ORD, NCSU									
	Liquid Stressors	Liquid Waste Generation	I-A-a-a	Wastewater Per Capita	DENR-DWQ									
			I-A-a-b	Water Reuse	DENR-DWQ									
		Water Physics, Sea Level Rise	III-D-c-a	Toxicant (TBD) Discharges	US-FWS-SEVANENC									
			IV-A-c-a	Sea Level/Relative Sea Level	US-ACE-NC									
				Water Temperature										
			III-D-c-a	Toxicant (TBD) Discharges	US-FWS-SEVANENC									
	Terrestrial Stressors	Land-Based Contaminants	IV-A-q-a	Toxicants from Land	US-FWS-SEVANENC									
			IV-C-6-a	Nutrient Concentrations in Land Use Categories (Shallow Aquifer)	USGS-NC									
			IV-C-7-a	E. coli in Land Use Categories (Shallow Aquifer)	USGS-NC									
			IV-C-a-a	Toxicant Concentrations in Land Use Categories (Shallow Aquifer)	USGS-NC									
			IV-C-5-a	Emerging Contaminants in Land Use Categories (Shallow Aquifer)	USGS-NC									
		Land-Based Sediment	IV-A-3-a	Sediments from Land	NCSU									
			III-D-c-a	Sedimentation in Wetlands	ECU									
			III-D-2-a	Soil Loss from Agricultural Lands & Forests	NC-DFR, NRCS_AG									
		Water Physics	III-D-c-a	Evapotranspiration by Land Cover Type										
	Elemental Cycles	Carbon Cycle	III-B-1-a	Stored Carbon in Water Column & Sediments	US-EPA-Reg4									
		Nutrient Cycles	III-C-a-a	Phosphorus Cycle Condition	USGS									
			III-C-3-a	Sulfur Cycle Condition	USFS-FIA									
1: A region where human communities are sustained by a functioning ecosystem	1A: Waters are safe for personal contact	Swimming		Human Pathogen Concentration	NC-DENR-DEH									
	1B: Designated surface and ground water supplies are safe for human consumption	Potable Surface Waters		Drinking Water Contaminant Concentrations in Surface Waters	NCSU									
		Potable Groundwaters	IV-C-2-a	Saltwater Intrusion in Surface Waters	USGS-NC									
				Drinking Water Contaminant Concentrations in Water-supply Aquifers	USGS-NC									
			IV-C-2-a	Saltwater Intrusion	USGS-NC									
	1C: Surface hydrologic regimes sustain regulated human uses		III-A-1-a	Flows, Severity, Frequency, Duration of Droughts & Floods	USGS-NC									
	1E: Opportunities for recreation and access to public lands and waters are protected and enhanced		IV-B-4-d	Estuarine Debris	US-NOAA-NC									
2: A region where aquatic, wetland, and upland habitats support viable populations of native species		Estuarine/Marine Habitats (Stressors)	IV-B-4-e	Underwater Acoustics	US-NOAA-NC									
		Freshwater Habitats (Stressors)	VI-B-1-c	Freshwater Hard Bottom	NC-WRC, VA-DGIF									
	2B: The extent and quality of upland, freshwater, estuarine, and near-shore marine habitats fully support biodiversity and ecosystem function	Wetland Habitats (Stressors)	VII-B-2-a	Hydrological Alteration in Wetlands	NC-DWQ, US-DOD-ACE, US-DA-NRCS									
			III-E-1-b	Water Quality: Toxicant Concentrations (e.g., Mercury, Non-Metals Prevalence in Wetland Biota)	NC-DENR-DWQ, VA-DEQ									
3: A region where water quantity and quality maintain ecological integrity	3A: Appropriate hydrologic regimes support ecological integrity			Dissolved Oxygen Concentration										
			IV-A-2-a	Biochemical Oxygen Demand	NC-DENR-DWQ, VA-DEQ									
			IV-B-4-c	Salinity	NCSU									
			III-A-1-a	Flows, Severity, Frequency, Duration of Droughts & Floods	USGS-NC									
			III-A-2-a	Estuarine Residence Time	USGS-NC									
			III-A-3-a	(Shallow) Ground Water Levels	USGS-NC									
	3B: Nutrients and pathogens do not harm species that depend on the waters		IV-B-5-a	Chlorophyll-a Concentration	NC-DENR-DWQ, VA-DEQ									
			IV-A-1-a	Nitrogen & Phosphorus Loading	USGS-NC									
			IV-B-3-a	Nutrient Concentrations in Nutrient-Sensitive Waters	USGS-NC									
			IV-D-2-a	Sediment Nutrient Concentration	US-NOAA-SC									
	3C: Toxics in waters and sediments do not harm species that depend on the waters			Toxicant Concentration										
				Metals Concentration										
			IV-B-8-a	Personal Care & Pharmaceutical By-Products/Nanoparticles	NC-DENR-DEH, VA-DEQ									
			IV-D-1-a	Sediment Quality Triad	US-NOAA-SC									
	III-D: Sediments do not harm species that depend on the waters			Suspended Sediment Concentration										
				Average Secchi Depth		m								
Management Actions	1A: Waters are safe for personal contact	Swimming	IV-B-6-a	(Shellfish &) Swimming Area Closures	NC-DENR-DEH									
				Beach Action Days/Closings by Water Body Type Sounds, Freshwater River, Lake, Brackish River)		days								
	1B: Designated surface and ground water supplies are safe for human consumption	Potable Surface Waters	IV-B-1-b	WQ Standard Violations (Surface)	NCSU									
			IV-B-1-c	Acute WQ Problem Sites (Surface)	NCSU									
		Potable Groundwaters	IV-C-1-a	Drinking Water Standard Violations (Water-supply Aquifers)	USGS-NC									
			IV-C-1-b	Acute WQ Problem Sites (Water-supply Aquifers)	USGS-NC									
	2B: The extent and quality of upland, freshwater, estuarine, and near-shore marine habitats fully support biodiversity and ecosystem function	Estuarine/Marine Habitats (Stressors)	IV-B-2-b	Water Quality in SAV Habitats & Shellfish Waters	NC-DENR-DEH									
			IV-B-2-a	Water Quality in Nursery Areas	NC-DENR-DEH									
	3A: Appropriate hydrologic regimes support ecological integrity		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b	WQ Standard Violations	NCSU									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									
			IV-B-4-a	Dissolved Oxygen Standard Violations	NCSU									
	3B: Nutrients and pathogens do not harm species that depend on the waters		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b	WQ Standard Violations	NCSU									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									
	3C: Toxics in waters and sediments do not harm species that depend on the waters		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b, IV-B-7-a	Toxicant Standards Violations	US-FWS-SEVANENC									
			IV-B-1-b, IV-B-7-b	Metals Standards Violations	US-FWS-SEVANENC									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									
	III-D: Sediments do not harm species that depend on the waters		IV-B-1-a	Amount & Extent of Impaired Waters	NCSU									
			IV-B-1-b, IV-B-4-b	Sediment Standard Violations	NCSU									
			IV-B-1-c	Acute WQ Problem Sites	NCSU									

Indicator Planning Decisions

- **What indicator(s) map to each environmental outcome?**
- **What are the fair, good, and excellent health target values for each ecosystem outcome indicator?**
- **What is the expected trajectory of an indicator value, based on how CCMP actions are implemented?**
- **What is the "trigger" value for a given interval since action steps are implemented, outside of which means the system is not behaving as forecast and change in business (e.g., research, revised action step, partner commitment) is required?**

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CCMP's Four Questions

- **What is a healthy Albemarle-Pamlico Estuarine System?**
- **What is the status of Albemarle-Pamlico Estuarine System?**
- **What are the biggest threats to Albemarle-Pamlico Estuarine System?**
- **What actions should be taken that will move us from where we are today to a healthier Albemarle-Pamlico Sounds by 2022?**

Water Monitoring & Assessment Refs

- NC-DNR&CD Coastal Water Quality Trends (1984)
- APES Baseline Water Quality Monitoring Plan (1988)
- USGS-NAWQA WQ Assessment of the A-P Basin (1995)
- EPA Elements of State Water Monitor & Assess (2003)
- NWQMC National WQ Monitor Network for US Coastal Waters and their Tributaries (2006)
- NRC Integrating Multiscale Observations, US Waters (2008)
- USGS Estuarine Monitoring Programs in the Albemarle Sound Study Area, NC (2014)
- EPA National Rivers & Streams Assessment 2008-2009: Technical Report (2016)
- EPA National Coastal Condition Assessment 2010 (2016)
- USGS Water Quality and Bed Sediment Quality in Albemarle Sound 2012-2014 (2016)

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REPORT

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