CHAPTER 1

Climate Change Solutions

Climate Change **Solutions** Introduction

Climate change is one of the biggest challenges facing the Chesapeake Bay ecosystem, which is already stressed by pollution, development and increasing population.

Scientists have firmly established that the world is warming, due in large part to the burning of fossil fuels and land use changes, and that the climate system is changing in response to increasing levels of greenhouse gases in the atmosphere. For the Chesapeake region, a warming trend has clearly been established. Rising temperatures and deeper waters are likely to alter Bay ecosystem dynamics, affecting fisheries, plants, and terrestrial wildlife as well as endangering man-made infrastructure. Perhaps most importantly, the Bay region's low elevation makes it among the most vulnerable in the nation to sea level rise and storm surge induced by climate change, which poses numerous problems, including: shoreline erosion, loss of islands, coastal flooding, wetlands retreat, salt water intrusion and inundation of some coastal areas.

While there has been a monumental effort to research and understand climate change and its potential impacts, until recently little has been done on-the-ground in the Bay region to mitigate causes or adapt to changes.

The case studies in this chapter were chosen to provide tangible examples of mitigation, adaptation, and climate change education. One of the primary challenges our society faces is the reduction and stabilization of greenhouse gas concentrations in the atmosphere. The first profile details the Maryland Department of Natural Resources' (DNR) carbon footprint evaluation, and their subsequent carbon reduction and sequestration program. Despite mitigation efforts like these, coastal landowners in low lying areas of the Chesapeake will one day be forced to retreat, adapt or defend their property. Therefore, the editors have included a profile of DNR's exemplary process to assess the effects of climate change in coastal areas, particularly sea level rise and storm surge, and implement adaptation strategies that minimize future impacts. Last, we recognize that education is the backbone of conservation, so we have included a detailed profile of a creative partnership with the National Geographic Society that developed innovative tools to improve public understanding and awareness of potential climate change impacts in the Bay region.

Some of the principles underlying these successful climate change profiles, which are essential to attaining a sustainable Chesapeake, include:

- **Use the best available data, assessment protocols and geospatial planning tools:** The scientific and technological dimensions of climate change prediction and mitigation techniques are complex and dynamic. Planners and managers charged with addressing the impacts of climate must rigorously document the data, assumptions and methods used in their decision making processes. They must also identify natural and public resource management priorities and risks in response to climate change. Plans should be modified or updated in accordance with advances in science and technology.
- **Encourage local government innovation and application of regional adaptation strategies:** The magnitude and seriousness of the potential impacts from climate change will be different based on varying physiographic and economic conditions and settlement patterns. Government policy makers should encourage and support a diversity of adaptation approaches that will collectively advance our capacity to address threats to the local environment and built infrastructure.
- **Improve public awareness of climate change risks and adaptation responses:** A significant degree of public skepticism and inertia still persists regarding the risks and challenges society will confront as a result of climate change. The slow pace of observable change works to reinforce public apathy. New communication and education strategies and incremental goals for change must be developed to redefine the actions different sectors of society should adopt to prevent potentially disastrous results.

Sea Level Rise

Maryland's Model for Adapting to Change

Maryland's Department of Natural Resources' sea level rise adaptation program provides other states in the Chesapeake Bay watershed with a process for assessing and addressing the impacts of climate change in coastal areas.

CASE STUDY SUMMARY

The State of Maryland has over 4,000 miles of coastline and is vulnerable to the impacts of climate change, particularly those associated with sea level rise and episodic storm events, such as shore erosion, coastal flooding, storm surge, and inundation. The Maryland Department of Natural Resources (DNR) recognized the significant risks this problem poses to the built and natural environment. Working with Governor Martin O'Malley, the Maryland State Legislature and the Maryland Climate Change Commission, DNR has been instrumental in the development of adaptation policy, local government capacity building and public engagement. In an effort to accurately assess vulnerabilities, DNR acquired high-resolution topographic data, which was then used to develop a series of tools, perform strategic planning, and produce guidance documents.

Given the enormity of the problem, DNR is committed to finding innovative solutions to the challenges of climate change and continues to pursue new approaches, mechanisms and partnerships to further develop effective adaptation policy and implement on-the-ground projects. Their immediate future efforts are focused on high-risk coastal communities and unsustainable policies affecting public infrastructure and damaged infrastructure. They currently have a series of innovative policy tools under development including: sea level rise adaptation easements; community infrastructure service designations, sound investment policy criteria, and strategic partnership development. DNR's pioneering work in adaptation policy has resulted in a better model for conservation in the face of climate change and is valuable information for other states in the watershed with similar coastal vulnerability.

RESOURCE MANAGEMENT CHALLENGE

Tide gauge records show that sea levels in the Mid-Atlantic have risen over one foot in the last century and it is anticipated that the combined forces of climate change and regional land subsidence may result in as much as 3

1/2 feet of sea level rise in Chesapeake Bay waters by the year 2100.[1]

A rise of such magnitude will cause increased coastal flooding, inundation of low-lying lands, submergence of tidal marshes, more shore erosion, salt-water intrusion, and higher water tables. Over time, Maryland's entire coast will be affected but coastal areas at low elevation or with large amounts of exposed shoreline generally are most at risk. In fact, impacts to some of these areas are already visible to the naked eye. Thirteen Chesapeake Bay islands once mapped on nautical charts have disappeared beneath the surface; an estimated 400,000 acres of land on the State's Eastern Shore is gradually becoming submerged;[2] and the State is currently losing approximately 580 acres of shoreline per year to erosion.[3]

The threat of sea level rise poses many resource management challenges. One of the most pressing is how to address the potential loss of barrier islands, sandy beaches, and large expanses of tidal wetland and marsh systems which serve as the primary nursery and feeding grounds for many of the Chesapeake and Coastal Bay's aquatic species. If the rate of sea level rise outpaces the rate of sediment accretion in tidal marsh systems or if upland development prevents inland migration, vast amounts of wetlands in the region will ultimately be lost. Another serious challenge is how to protect thousands of miles of developed waterfront property from increased coastal flooding and accelerated shore erosion. Hard policy decisions will soon need to be made regarding the protection, relocation and/or ultimate abandonment of many of Maryland's inhabited coastal communities.

A structure threatened by sea level rise at Holland Island, Maryland.

Vulnerability to sea level rise will ultimately depend upon actual rise, as well as how state and local governments plan for and respond to the problem. As a society, we are continuing to invest, live, and actively manage lands in areas that we know with near certainty will be severely impacted by sea level rise. And, as a result, more and more of Maryland's people, property, public investments and natural resources, including vital fish and wildlife habitat, will be at risk. State and local governments must move beyond traditional land use planning and resource management practices and begin to aggressively plan for future change. Building in hazardous coastal areas must be avoided and laws and policies that enable the rebuilding of structures damaged time and time again by coastal storms must be re-evaluated. In the face of climate change — now more than ever — there is also a critical need to protect and restore Maryland's natural resources that are already under human-induced stress.

Maryland Climate Commission

On April 20, 2007, Governor Martin O'Malley signed an Executive Order establishing the Maryland Climate Change Commission (MCCC) charged with collectively developing an action plan to address the causes of climate change, prepare for the likely consequences and impacts of climate change to Maryland, and establish firm benchmarks and timetables for implementing the Commission's recommendations.

Three work groups carried out the work of the Commission: Adaptation & Response Working Group; Greenhouse Gas & Carbon Mitigation Working Group; Scientific and Technical Working Group.

The Adaptation and Response Working Group was comprised of 34 local government, non-governmental environmental organizations, trade associations, and academic, business, and citizen representatives. This broad mix of participants were engaged for over a year to develop and ultimately recommend the conservation vision and underlying suite of 19 priority policy options for sea level rise adaptation and response.

Coastal shore erosion and tree mortality due to see level rise at Taylors Island, Maryland.

CONSERVATION VISION

Maryland has set forth the following four pronged vision for protecting its future economic well-being, environmental heritage and public safety.[4]

- Promote programs and policies aimed at the avoidance and/or reduction of impact to the existing-built environment, as well as to future growth and development in vulnerable coastal areas;
- Shift to sustainable economies and investments; and, avoid assumption of the financial risk of development and redevelopment in highly hazardous coastal areas;
- Enhance preparedness and planning efforts to protect human health, safety and welfare; and
- Protect and restore Maryland's natural shoreline and its resources, including its tidal wetlands and marshes, vegetated buffers, and Bay Islands, that inherently shield coastal lands.

Underlying this vision are 19 priority policy recommendations of the *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*, a key component of Maryland's Climate Action Plan.[5]

IMPLEMENTATION RESOURCES

Maryland sea level rise adaptation planning efforts have been supported by a mix of financial and technical resources, as well as through many cooperative partnerships. DNR has maintained a staff of up to three coastal hazard planners since 1998 to oversee its many data acquisition, strategic planning, public outreach, and local government capacity building activities. Planning efforts have also been generously supported by the National Oceanic and Atmospheric Administration (NOAA) through Section 309 of the Coastal Zone Management Act. Approximately 5 million federal, state and local dollars have been spent in Maryland over the last decade on public engagement, planning and technical assistance, and LIDAR and shoreline erosion data acquisition efforts. Various local governments, non-governmental organizations, academic institutions, and stakeholder based entities have also worked in partnership with the State to advance sea level rise data, research and planning efforts.

CONSERVATION STRATEGY

Maryland's strategy to prepare for sea level rise has evolved over the past decade. The State developed its first state-level sea level rise

response strategy in 2000,[6] and over the following years successfully implemented a number of its priority recommendations, including data acquisition and technical tool creation; adaptation policy development; local government capacity building; and public engagement. In August, 2008 the State released a *Comprehensive Strategy for Reducing Maryland's Vulnerability* to Climate Change, a key component of Maryland's Climate Action Plan.[7] The State is now in the midst of undertaking specific actions to advance three of its underlying planning priorities: (1) Improve the capacity of local governments to plan for and respond to sea level rise; (2) Develop adaptation policies (i.e., protect, retreat, abandon) for vulnerable public and private sector infrastructure; and (3) Pursue both conservation and restoration opportunities to protect natural resources and coastal habitat. Key elements of the State's past and present planning strategies are presented below.

Data Acquisition and Technical Tools: Perhaps the most essential piece of Maryland's sea level rise planning strategy has been the steadfast focus on the acquisition of data and development of technical tools. Maryland is one of a few coastal states to acquire the high-resolution topographic data, known as light detection and ranging (LIDAR), necessary for modeling sea level rise inundation and assess vulnerability at state and local levels.

Adaptation policy development is now moving forward thanks to the availability of the state-wide sea level rise vulnerability mapping, historic shoreline position and erosion rate calculations, a comprehensive coastal inventory, a sea level rise economic impact assessment and such technical tools as the Erosion Vulnerability Assessment Tool, the Living Shoreline Suitability Model, and the Worcester County Sea Level Rise Inundation Model.

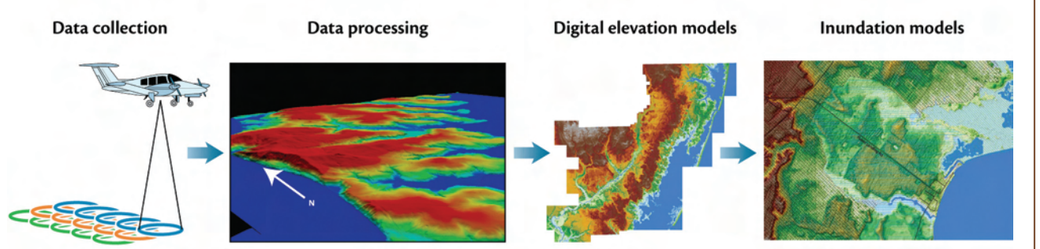
Adaptation Policy Development: Both the 2000 sea level rise response strategy and the recent strategy released by the Maryland Commission on Climate Change identified a number of policy, regulatory, and programmatic changes to assist with sea level rise adaptation. In 2008, two key pieces of sea level rise adaptation policy were adopted. One of these is the Living Shorelines Protection Act of 2008 which requires the use of nonstructural, "living shoreline" stabilization measures that preserve the natural environment, except in areas mapped by the state as being appropriate for structural stabilization measures. As sea level rises the need for shore protection along the coast will increase. The benefit behind "living shorelines" is that while they control erosion they also allow for preservation of the natural shoreline, maintain coastal processes, and provide aquatic habitat.

A second key piece of adaptation policy was included in the strengthened provisions of the Chesapeake and Atlantic Coastal Bays Critical Area Protection Program Act, passed in 2008. Among other things the Act now requires an update of the jurisdictional boundaries of the program to reflect changes in tidal wetlands caused by sea level rise; an increase in the vegetated buffer requirement from 100 to 200 feet for new development; and the inclusion of coastal flood hazards as a factor to consider during "growth allocation" decisions.

Local Government Capacity Building: Building the capacity of local governments to address sea level rise challenges has been a chief focus of state planning efforts. To date, technical and financial assistance has or is currently being provided to Worcester, Somerset, Dorchester, Kent, Prince George's, Baltimore and Anne Arundel counties, the Town of Crisfield and the City of Annapolis. These projects have all been tailored to specific sea level rise or coastal hazard data and/or planning needs of the locale, with several providing specific written sea level rise planning guidance. The Worcester, Somerset and Dorchester sea level rise guidance documents contain valuable recommendations

A living shoreline constructed with a low profile stone sill that allows tidal waters to freely exchange with the planted marsh area.

Sea Level Rise Mapping and Modeling Process



and are now serving as "best practice" manuals for many other coastal counties and communities facing similar management challenges.

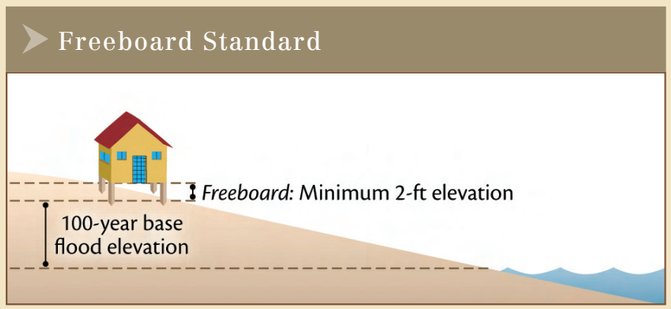
Some of the most valuable components of the three reports include sea level rise vulnerability assessments; "critical action" identification; planning and regulatory development; and recommended public investment policies. In general, sea level rise vulnerability was assessed using mapping products derived from the LIDAR high resolution topographic data. The range of storm surge and "relative" sea level rise projections, such as low (steady state 1 ft./century), medium (2.7 ft./century), and high (3.4 ft./century) were assessed for two of the jurisdictions over 25, 50, 100-year timeframes. The documents evaluate the impact of rising waters on each jurisdiction's infrastructure, including: transportation networks, emergency evacuation routes, and critical facilities, such as hospitals, and fire stations; private infrastructure; and natural features, including beaches, wetlands and vegetated buffers. All three reports highlight the importance of integrating the sea level rise mapping and impact analysis information into comprehensive and emergency response planning within each jurisdiction.

The identification of current threats and immediate impacts expected to occur within the next 25 years along with remedial "critical actions" is another vital element of the guidance documents. The primary focus of critical actions is to identify current needs for the protection of existing infrastructure and development. The reports advocate for the creation of "sea level rise overlay zoning districts" within which to implement measures to protect against and/or to promote "avoidance" of impact within next 50 years. Recommended measures could include restricting future development in areas subject to sea level rise within the next 50 years and the adoption of increased elevation or "freeboard" standards for new development as depicted in the graphic below.

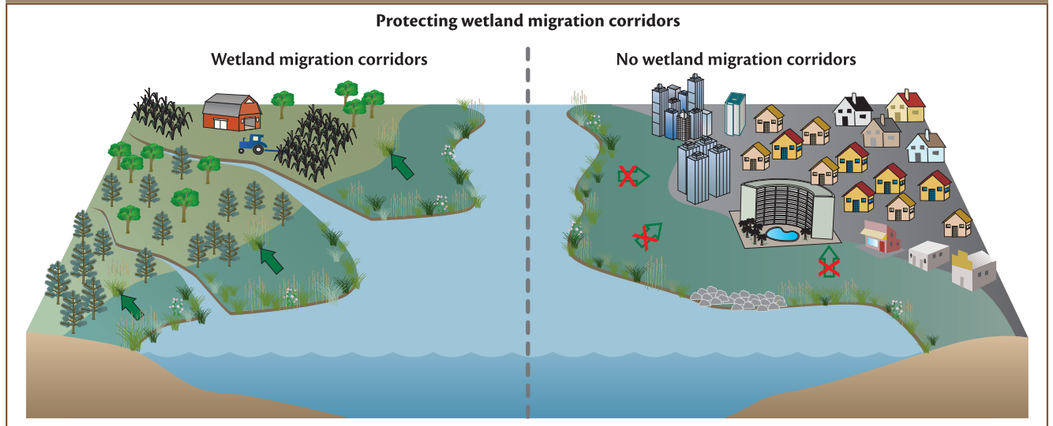
In terms of public investment, the reports recommend that local governments designate frequently flooded and publicly maintained roads as "low-water crossings" and require affected property owners to acknowledge access limitations. Another suggestion for local governments is to consider lowering the design elevation of maintained roads to avoid drainage problems. Somerset County maintains a list of 80 "frequently flooded roads" which are typically affected by above average tides. The gradual upgrade of these roads in response to sea level rise will simply overwhelm the budget of one of Maryland's poorest counties.

Public Engagement: Public outreach and engagement has also been a mainstay of Maryland's sea level rise adaptation program. DNR staff has conducted numerous workshops, participated in hundreds of public events, and developed handfuls of print and web-based outreach materials to improve public awareness of climate change and sea level rise planning

Freeboard Standard



Protecting Wetland Migration Corridors



As sea level rises, wetlands may migrate into open spaces such as forests and fields. However, wetlands cannot migrate into areas with man-made barriers such as hardened shorelines and heavy development such as urban, commercial, and residential areas.

needs. Public access to Maryland specific sea level rise and coastal hazard data and technical planning resources through *Shorelines Online,*[8] an interactive web portal, has remained a major programmatic priority.

Stakeholder engagement is another critical element of strategic planning for sea level rise as it helps to ensure buy-in and future support for project development and policy adoption. Maryland employed a stakeholder-based planning process to develop its Climate Action Plan.[9] The Adaptation and Response Working Group of the Maryland Commission on Climate Change was comprised of 34 local government, non-governmental environmental organizations, trade associations, and academic, business, and citizen representatives. This broad mix of participants were engaged for over a year to develop and ultimately recommend the conservation vision and underlying suite of 19 priority policy options for sea level rise adaptation and response.

Building off the recommendations contained in the Climate Action Plan, DNR further engaged the public by hosting the *Building Coast-Smart Communities* interactive summit in April 2009.[10] The centerpiece of the summit was an innovative role-play where participants negotiated policy options on a scorecard aimed at reducing coastal communities' vulnerability. Areas of discussion were centered on how to protect Maryland's built environment, including its critical infrastructure and public and private structures; and, on how to ensure the protection of the State's vital natural resources, such as wetlands, wildlife, farms and forests. Materials from the Coast-Smart forum are available and can be used to replicate the summit in other communities facing similar sea level rise planning challenges.

Future Directions: The sea level rise research and planning initiatives above provide the State with a vision, framework and the impetus for moving forward. And thanks to these efforts, Maryland has been recognized as a national leader in sea level rise adaptation and response. However, much work including further policy development and on-the-ground implementation of "best practices" still remains. The State is now shifting its adaptation strategy to explore and pursue new approaches, mechanisms, and partnerships.

Fresh ideas are needed to help coastal communities move beyond the current model of "build-insure-rebuild" in vulnerable coastal areas. New solutions also will be required to avoid the assumption of the financial risk of development and redevelopment in vulnerable areas. Innovative mechanisms will be necessary to achieve such adaptation objectives as protecting wetland migration corridors, storm surge buffer, and flood storage areas. Community infrastructure service designations, sea level rise adaptation easements, strategic partnerships, and sound public investment policies are four of the emerging mechanisms.

Community Infrastructure Service Designations: Building new public infrastructure and/or rebuilding damaged infrastructure in high-risk coastal communities is not a sustainable policy particularly in light of climate change and sea level rise in which entire areas may be inundated and/or cutoff from inland resources. One mechanism to address this risk is the creation of "community infrastructure service level designations" for roads, water, wastewater, and public facilities. These designations could be established to signal local government intentions for construction/reconstruction based on future sea level rise scenarios and to direct future infrastructure monies as part of broader local-based adaptation plans. Such designations (see Potential Community Infrastructure Service Level Designations table) could be reviewed every 5 years as more accurate data is collected and mapped.

Sea Level Rise Adaptation Easements: Land right purchase and easement programs, e.g., Rural Legacy, Maryland Agricultural Land Preservation Foundation, Maryland Environmental Trust, have been in existence for many years. These programs are voluntary and involve public or charitable finance measures to fund the acquisition and retirement of development rights in order to preserve and increase stewardship of culturally and environmentally significant rural resources in perpetuity. A "Sea level Rise Adaptation Easement" is an emerging concept that could either work in concert with existing land purchase or easement programs or independently. Through such an easement a landowner could receive payment for adaptation stewardship activities, e.g., living shoreline, increased storm buffer or a wetland migration corridor.

Other ideas to explore include using these easements to limit development in highly vulnerable areas or to assist with retreat by phasing out remaining development rights subject to certain specified catastrophic events associated with predicted sea level rise or massive storm surge damage. One additional thought is that the easement agreement could specify reclamation requirements, such as the removal of septic system and roadways from abandoned properties.

Strategic Partnerships: Strategic partnerships between private landowners and governmental and non-profit sectors can enhance on-the-ground implementation. Partnerships can help build resiliency of the natural and built infrastructure by testing and implementing adaptation strategies and communicating lessons learned to other communities in Maryland and beyond. Innovative cutting-edge partnerships should be encouraged and considered essential enhancements to state initiated efforts.

Sound Investment Policy: One of the next steps for federal, state and local governments is to account for sea level rise in decision-making regarding: land acquisition;[11] land and facility management; and the siting and design of facilities and infrastructure. Calls for these three "Lead by Example" policies were set forth in the Maryland Climate Action Plan and movement is afoot to establish each component. In the fall of 2009, DNR began a two-year project to develop coastal land conservation targeting tools to facilitate sea level rise adaptation. Assessment criteria for adaptation objectives, including wetland migration corridors, storm surge buffers, and flood storage areas, will be one of the primary project outcomes. Policies for land management and the siting and design of state-owned facilities and infrastructure are also under development.

RESULTS

Technical Tools: The acquisition of LIDAR data and the other key coastal hazard data sets have allowed DNR to develop a suite of tools necessary for modeling sea level rise inundation and assess vulnerability at state and local levels.

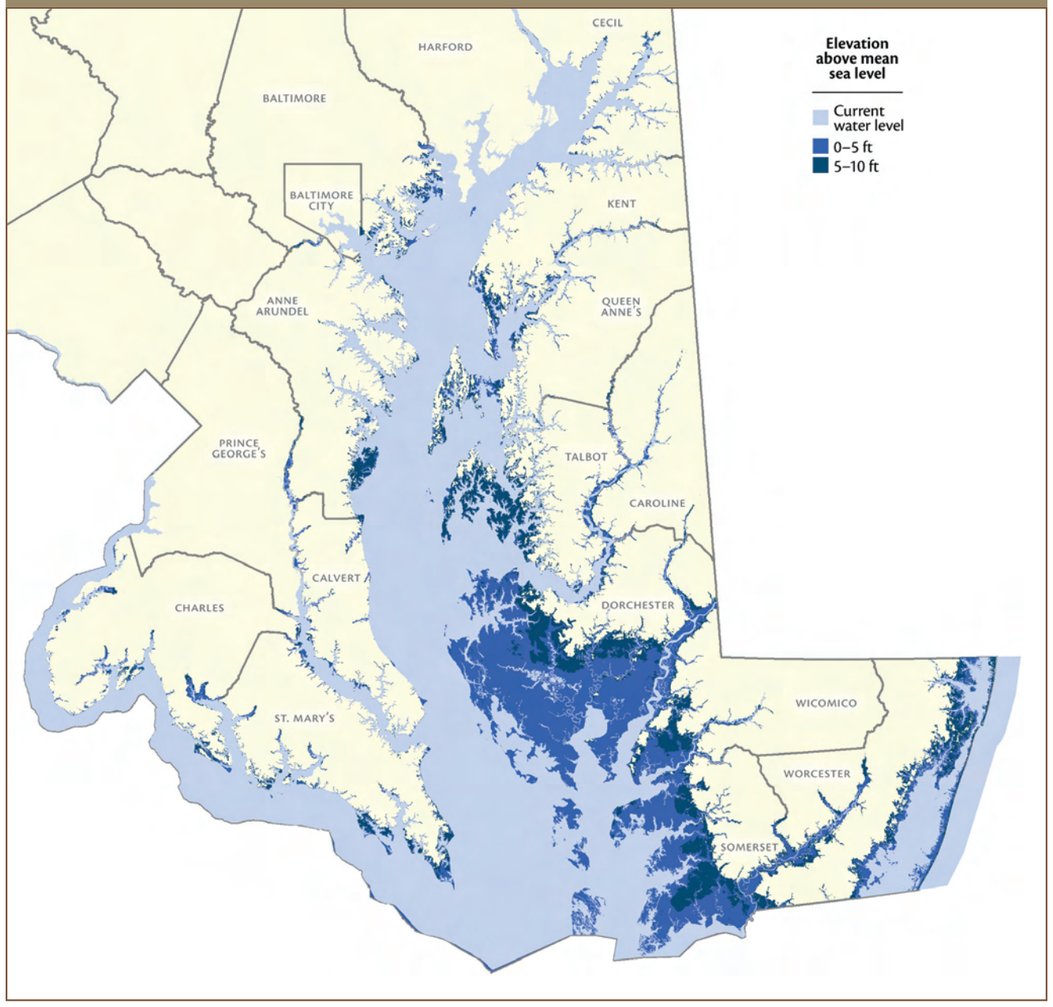
Sea Level Rise Vulnerability Mapping: Over a five-year time span, DNR worked with State and local partners to acquire LIDAR data for 15 of the State's 16 coastal counties. Detailed sea level rise modeling has been completed for Worcester and Dorchester County, and pilot areas within Anne Arundel and St. Mary's Counties. State-wide Sea Level Rise Vulnerability Maps have been created for 14 coastal counties, depicting lands at potential risk.

Shoreline Change Maps: In 2003, the Maryland Geological Survey (MGS) completed an update of digital shoreline positions and calculations of linear rates of shoreline erosion across the State. The multi-phase study was undertaken to support research and management of sources of non-point source pollutants, buffer areas of

Potential Community Infrastructure Service Level Designations

Designation	Action
Improve/Augment	Proactive adjustments to improve safety
Maintain/Replace	Holding steady as no adjustments are anticipated
Reduce Footprint	Situations where maintenance is problematic
Remove/Relocate	Situations after significantly damaging events

Sea Level Rise Vulnerability Map



critical concern, and to reduce vulnerability to coastal hazards. In 2005, the Shoreline Changes Study and historical shorelines were made available through an interactive mapping application, *Shorelines Online*.[12]

Comprehensive Shoreline Inventory (CSI): CSI captures baseline shoreline conditions throughout the tidal portions of Maryland's coastal counties. Shoreline features and conditions were identified through a three-tiered shoreline assessment approach. Data from the survey was processed to create three GIS coverages, displayed through reports, summary tables, and maps, which are viewable online.[13]

Erosion Vulnerability Assessment Tool (EVA): The Baltimore District Army Corps of Engineers and DNR developed EVA under a joint partnership to identify areas along the shore that have demonstrated historic patterns of instability, and currently support valued natural, social, or economic resources. As a planning tool, EVA uses a 50-year planning window to project shoreline position in 50 years to inform local planners where community infrastructure, cultural resources, and habitat are potentially at risk in the future. The map outputs identify where resources will be vulnerable, and can enhance or redirect future development options for individual communities, and define areas where opportunities for sea level rise adaptation easements could be directed.

Living Shoreline Suitability Model: The Virginia Institute of Marine Sciences developed a model for DNR to geographically target shoreline areas suitable for the placement of living shorelines to counteract erosion problems. The suitability model classifies the shoreline into three major categories: suitable for soft stabilization, suitable for hybrid options, and not suitable for living shoreline. To date, models have been completed for Worcester, Calvert and Somerset Counties.

Strategic Planning: Over the course of the last 10 years, DNR has released three seminal documents regarding responses to sea level rise and storm surge.

- *A Sea Level Rise Response Strategy for the State of Maryland*[14]
- *Maryland Coastal Zone Management, Section 309 Coastal Hazard Enhancement Strategy*[15]
- *Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change*[16]

These documents are a good source of information for other coastal and natural resource managers that are undertaking sea level rise adaptation planning efforts. In 2009, the Sea Level Rise Response Strategy for the State of Maryland was accessed via the Internet more than 1,350 times.

Guidance Documents: In Fall 2008, DNR released sea level rise planning guidance for Worcester, Somerset and Dorchester Counties:

- *Sea Level Rise: Technical Guidance for Dorchester County*[17]
- *Sea Level Rise Response Strategy: Worcester County, Maryland*[18]
- *Rising Sea Level Guidance: Somerset County, Maryland*[19]

Regulatory Reform: Maryland's State Legislature and Governor have taken significant steps to update state law to address some of the most pressing and immediate impacts of sea level rise and storm surge.

- The Chesapeake and Atlantic Coastal Bays Critical Area Protection Program has been updated to account for sea level rise in its jurisdictional boundaries; increase the required vegetated buffer requirement from 100 to 200 feet for new development; and include coastal flood hazards as a factor to consider during "growth allocation" decisions.
- The Living Shoreline Protection Act was passed in 2008 and requires the use of nonstructural, "living shoreline" stabilization measures that preserve the natural environment, except in areas mapped by the state as being appropriate for structural stabilization measures.
- The Greenhouse Gas Emissions Reduction Act, passed by the Maryland State Legislature in 2009, seeks to address the long-term causes of sea level rise by reducing greenhouse gas emissions 25% by 2020.

KEYS TO SUCCESS

Problem Recognition: DNR staff raised concerns about climate change in a series of ground breaking reports. Subsequently, Governor Martin O'Malley's Executive Order (01.01.2007.07) recognized that Maryland is particularly vulnerable to the climate change impacts of sea level rise, increased storm intensity, extreme droughts and heat waves, and increased wind and rainfall events. Maryland's Commission on Climate Change then developed a Climate Action Plan that the Legislature acted upon.

Financial Support: Planning efforts have also been supported by the National Oceanic and Atmospheric Administration (NOAA) through Section 309 of the Coastal Zone Management Act. Approximately 5 million federal, state and local dollars have been spent in Maryland over the last decade on public engagement, planning and technical assistance, as well as LIDAR and shoreline erosion data acquisition efforts. The acquisition of key data sets early in state planning efforts was of utmost importance.

Dedicated staffing: DNR has maintained a staff of up to three coastal hazard planners since 1998 to oversee its many data acquisition, strategic planning, public outreach, and local government capacity building activities. The success Maryland has achieved thus far would not have been possible without staff dedicated to sea level rise and coastal hazard planning.

Hurricane Isabel: The State used the increased public awareness of coastal flooding and storm surge created by the arrival of Hurricane Isabel in September 2003 to further sea level rise planning efforts. DNR was a major cosponsor of the *Hurricane Isabel in Perspective Conference* held in November 2004. The conference was organized to discuss the many factors that exacerbated Isabel's impact on the Chesapeake Bay ecosystems and its coastal communities.

Partnerships: Numerous local governments, non-governmental organizations, academic institutions, and stakeholder based entities have also worked in partnership with the State to advance sea level rise data, research and planning efforts. They will also play a vital role in the testing and implementation of adaptation strategies in years to come.

PHOTOS AND FIGURES

Page 3: Photo, Chelsie Papiez; figure, Maryland Climate Action Plan 2008
Page 4: Photo, Olivia Campbell

This wetland has been subjected to excessive saturation from elevated water levels, causing the marsh to die back and the substrate to erode - leaving barren clumps of marsh peat.

Page 5, 6: Photos, David Burke
Page 7: Figure (top), Maryland Department of Natural Resources; figure (bottom), Maryland Climate Action Plan, 2008
Page 8, 10: Figures, Maryland Climate Action Plan 2008
Page 12: Photo, Chelsie Papiez

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FOR MORE INFORMATION

Project Contact:
Zoë Johnson
Program Manager for Climate Change Policy
Office for a Sustainable Future
Maryland Department of Natural Resources
Tawes State Office Building, C3
Annapolis, Maryland 21401
Phone: (410) 260-8741 | Email: zjohnson@dnr.state.md.us

A Carbon Footprint Analysis and Forest Carbon Sequestration Pilot Program

Climate Leadership by the Maryland Department of Natural Resources

The Maryland Department of Natural Resources evaluated its carbon footprint, identified ways to reduce it, and implemented a pilot forest carbon sequestration program to offset a portion of the greenhouse gas emissions.

CASE STUDY SUMMARY

The climate in the Chesapeake Bay region is warming.[1,2,3,4] Manmade greenhouse gases have been identified as the primary cause of these increasing temperatures.[5] The associated environmental changes are happening so rapidly that residents of the Bay watershed will likely perceive the effects within their lifetimes. Immediate impacts will be felt along the coasts due to rising sea levels and strong storms.[6] The combination of predicted environmental changes due to climate change will make Bay restoration efforts more difficult.[7]

Minimizing climate change will require the reduction and stabilization of greenhouse gas concentrations in the atmosphere. This very serious and very difficult challenge requires that our society become carbon neutral – which means that individuals, corporations, and governments must collectively reduce their carbon emissions, and sequester as much carbon as they produce. In an effort to lead by example, the Maryland Department of Natural Resources (DNR) has evaluated its carbon footprint, identified ways to reduce it, and implemented a pilot forest carbon sequestration program to offset a portion of the greenhouse gas emissions that cannot be immediately eliminated.

DNR estimated that its fiscal 2006 baseline carbon footprint was approximately 17,284 metric tons of carbon dioxide equivalents (CO_2e) – an amount approximately equal to emissions from 40,195 barrels of oil or the annual electricity use of 2,289 households. The results of the carbon footprint calculation provided a baseline for DNR to set greenhouse gas emission reduction benchmarks and to determine the level of carbon sequestration activities needed to move towards carbon neutrality. The DNR calculation led the way to a larger effort to calculate the environmental footprint of the entire Maryland State Government.

DNR designed and implemented a plan to plant 171.4 acres of forest on non-forested land, which would offset a significant portion of the Department's greenhouse gas emissions for one year. The planting also complements DNR's effort to accelerate progress towards pending forest protection goals associated with the Chesapeake Bay Agreement and subsequent commitments.

RESOURCE MANAGEMENT CHALLENGE

The earth's atmosphere is remarkably thin compared to the overall size of the planet, which makes it extremely vulnerable to changes in chemical composition from human activities. Over the last two centuries, humans have added significant amounts of greenhouse gases to the atmosphere, including: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Even though the other gases have higher global warming potential coefficients, CO_2 is the most important of the greenhouse gases because of its abundance. Higher CO_2 concentrations have essentially thickened the atmosphere, which has enabled it to hold more heat on the earth's surface. These atmospheric changes will likely raise temperature and sea level, and cause changes in precipitation regimes in the Bay region, all significant challenges for an already stressed ecosystem.[8]

Maryland DNR manages 467,340 acres of land across the State. The Department's mission is to lead Maryland in securing a sustainable

The Department owns, operates or leases 1,923 buildings, which total over 3 million square feet. Stationary combustion at these facilities is responsible for 8,296 metric tons of CO_2 a year.

Governor O'Malley signs executive order establishing the Maryland Climate Change Commission.

future for our environment, society, and economy by preserving, protecting, restoring, and enhancing the State's natural resources. To support its mission, the Agency uses 1,941 vehicles, and owns, operates or leases 1,923 buildings (3,141,711 square feet). The resultant use of vehicle fuels, electricity, and heating/cooling fuels gives the Department a significant carbon footprint. A carbon footprint is defined here as a measure of the amount of carbon dioxide equivalents, in metric tons, emitted directly or indirectly because of activities under the DNR's operational control.

State agencies across the watershed do not typically have systems in place that allow for quick tabulation of statistics on greenhouse gas emissions. Data on energy use is divided among 14 units within the Department, with numerous locations throughout the State. Posing an additional challenge, some of this data is available only from other State agencies. Coordination of such information has not been expected or required until now. Lastly, no State agency has laid out a process for sequestering carbon using forests that includes guidance on site selection, planting and management plans, monitoring protocols, or registry protocols.

CONSERVATION VISION

On April 20, 2007, Governor Martin O'Malley signed an Executive Order establishing the Maryland Climate Change Commission (MCCC) charged with collectively developing an action plan to address the causes of climate change, prepare for the likely consequences and impacts of climate change to Maryland, and establish firm benchmarks and timetables for implementing the Commission's recommendations. The resulting Climate Action Plan details the effects of climate change and recommends specific policies to reduce carbon emissions and protect Maryland's people and property from rising sea levels and changing weather patterns.[9] The Plan recommends that DNR "lead by example" by calculating its carbon footprint and implementing innovative carbon reduction strategies, including offsetting a portion of the Agency's footprint through forest carbon sequestration.

The long-term vision for the program is to devise a carbon management blueprint involving emission reductions and voluntary offsets that all other State agencies, private corporations and individuals can replicate. With strong leadership, fairly simple methods and a bigger scale effort, Maryland can begin to address its overall contribution to the larger challenge of stabilizing greenhouse gases and combating climate change. This can simultaneously accomplish other objectives, such as green infrastructure corridor conservation and restoration, no-net-loss of forest cover and water quality improvement through buffer plantings. This type of program will necessarily involve a suite of partners, including government, nonprofits and corporations working together to accomplish the carbon management objective.

IMPLEMENTATION RESOURCES

Based upon the findings of the Climate Change Commission, John Griffin, Secretary of Natural Resources, asked DNR agency staff to conduct a carbon footprint analysis and a pilot CO_2 sequestration project to offset emissions. The DNR hired David Palange, a graduate student from the Nicholas School of the Environment at Duke University, as a summer intern to conduct the analysis. The funding for the internship came from the National Oceanic and Atmospheric Administration and DNR's Chesapeake and Coastal Program.

The State of Maryland's Program Open Space (POS) was designed to offset development trends by conserving open space and building recreational infrastructure. Funded through a 0.5% real estate transfer tax, POS revenues now support additional conservation programs. The State used POS funds to purchase a site south of Cambridge, Maryland, to prevent an unwanted development, to improve water quality and enhance wildlife habitat on the property. Approximately 588 acres of the 728 acre site were in agriculture production prior to restoration. The entire property was purchased for $10,321,000 ($14,177/acre). Terms of the sale stipulated that over $1.9 million was to be provided by the sellers for site restoration. To date, approximately $1,430,000 has been spent on site restoration. The primary goal of the overall restoration project was to improve water quality of on-site runoff and stormwater flowing into and from the site. A secondary goal was to improve habitat for the federally endangered Delmarva fox squirrel, migratory waterfowl, and songbirds. Subsequently, in planning for the restoration of the property, DNR determined that 171.4 acres of it were well suited to be a forest carbon sequestration site. Of the 171.4 acres, 30 acres will be intensively monitored for carbon. DNR's Power Plant Research Program is funding the monitoring effort associated with the sequestration project. The initial cost of monitoring is $10,000.

CONSERVATION STRATEGY

The DNR's carbon management strategy involves three main components: a carbon footprint analysis, emission cutting strategies, and a forest carbon sequestration demonstration project.

Carbon Footprint Analysis: To calculate its carbon footprint. The DNR used the Climate Registry's General Reporting Protocol (TCRGP), which is an amalgamation of various well respected greenhouse gas programs and protocols.[10] The analysis focused mainly on direct emissions, such as stationary and mobile combustion sources, and indirect emissions, such as the consumption of purchased electricity. Only emissions from DNR vehicles or buildings were considered, so leased buildings and personal commuting were not included in the analysis. Some data had to be estimated or extrapolated to complete the carbon footprint estimate within the available time. The DNR analysis did not include data on HFCs and PFCs and does not produce SF_6.

The carbon footprint calculation focuses primarily on DNR's vehicle fleet (highway, aircraft, marine, off-road, heavy truck and equipment) and its mobile combustion (natural gas, ethanol, gasoline, jet fuel, biodiesel and diesel), and facilities combustion (fuel oil #2, propane, natural gas, biomass, electricity). Greenhouse gas emissions were calculated by multiplying the total gallons of each fuel type used by the emission factor for each fuel type and adding up all the emissions. CH_4 and N_2O emissions were calculated based on default CH_4 and N_2O emission factors for vehicle model year or for fuel type and converted to units of CO_2e. Total CO_2e emissions were categorized as mobile combustion, indirect combustion (i.e. purchased electricity) and stationary combustion (i.e. heating fuels and biomass).

Carbon Cutting Strategies: DNR staff examined the emissions generated by its vehicles and facilities and determined various ways to promote efficiency, substitution, and carbon capture. Efficiency actions are those that use fewer resources to achieve the same result. The main ways to improve efficiency are through technology and behavioral changes. Substitution actions are those that replace high emission fuels and energy sources with renewable sources and/or low emission fuels. A series of short and long term efficiency and substitution actions that could be taken to reduce the Department's carbon footprint were subsequently identified. To supplement the carbon footprint reduction efforts, it was determined that a carbon capture project would also be needed.

Forest Carbon Sequestration: Forests cover 44% of Maryland and offer significant opportunities for

The Climate Registry Voluntary Reporting Protocol

The goal of the Climate Registry is to standardize greenhouse gas accounting and reporting rules across multiple jurisdictions and to provide guidance on the production of a comprehensive, consistent and comparable report. The Climate Registry is the first multinational effort to standardize greenhouse gas accounting and reporting.

carbon sequestration.[11] Forests are also the most beneficial land use for restoring and maintaining water quality.[12] In 2000, Maryland forests absorbed an estimated 11.5 million metric tons more of CO_2 than they emitted.[13] DNR determined that the three most important components to the sequestration project were site selection, a planting plan and a monitoring strategy.

Site Selection: After reviewing several recent POS purchases, DNR identified a 171.4 acre area called the Little Blackwater property, south of Cambridge, Maryland, as the forest carbon sequestration pilot project demonstration site.

Planting Plan: Three forest management scenarios were selected for planting and future carbon sequestration monitoring.

- Low Management (100% Hardwoods): 37.1 acres – A mixture of oaks were planted in this area on 10' X 10' spacing. Oaks planted include red oak *(Quercus rubra)*, swamp white oak *(Quercus bicolor)* and willow oak *(Quercus phellos)*. This stand will be allowed to mature in excess of 80 years with minimal management activity.

Little Blackwater Forest Carbon Sequestration Pilot	
Forest Type	Acres
Mixed oaks	37.1
Mixed pine-hardwood	97.5
Loblolly	36.8

- Moderate Management (50-70% Pine & 30 – 50% Oaks): 97.5 acres – A mixed pine-hardwood forest was planted in this area on 10' X 10' spacing. This stand represents a typical natural mixed stand on the Delmarva Peninsula. Loblolly pine *(Pinus taeda)*, red oak, swamp white oak and willow oak were planted. Rotation length of this stand will be 60 to 80 years in age.
- High Management (100 % Pine): 36.8 acres – A loblolly pine plantation was planted in this area on 10' X 10' spacing. This stand represents the intensively managed pine plantations on the Delmarva. Rotation length of this stand will be 40 to 60 years of age.

Monitoring Strategy: There are two parts to the monitoring plan. The first establishes the baseline condition of the parcel. The second tracks the accumulation of carbon over time. The difference between the carbon accumulated some time after planting minus the baseline condition is the amount sequestered. Carbon occurs in several "pools" including at least above-ground biomass, below-ground biomass, forest litter and soil carbon. Protocols for monitoring these pools have been developed and are currently being reviewed.

The Maryland Geological Survey (MGS), a component of DNR, developed a monitoring plan to measure carbon sequestration below-ground as forest growth occurs on three, 10 acre plots within each separate planting regimes. MGS will develop a random sampling protocol for selecting the below ground soil sampling sites and a suitable sampling methodology, and will produce a sampling procedure that can be used by the Department of Public Safety and Correctional Services inmates to collect the soil samples.

Photo showing swamp white oak seedling planted in 2009 at the Little Blackwater site. This wetlands adapted species is tolerant of the saturated soil conditions often found on the Delmarva Peninsula.

At each sampling location, subsamples will be collected from identified soil horizons A, B, and C, with appropriate subsampling within each horizon as necessary to fully characterize the belowground carbon. It is anticipated that the samples should be collected yearly to determine the increase in belowground carbon over time within each soil horizon. Samples will be returned to the MGS laboratory for analysis of total Carbon, Nitrogen and Sulfur using a Carlo-Erba NCS Analyzer. Results will be reported for each forest management scenario plot and for each soil horizon within the plots. Anticipated increases in carbon over time will also be evaluated.

RESULTS

Carbon Footprint Analysis: In the Fiscal Year 2006 baseline year, Maryland DNR produced approximately 17,284 metric tons of CO_2e. Carbon dioxide was responsible for 99% of the total greenhouse gas emissions. The remaining 1% was due to CH_4 and N_2O emissions. The total CO_2e emissions are comparable to 3,166 passenger cars, 40,196 barrels of oil, 2,289 households' annual electricity use, or 196 acres of deforestation. DNR's vehicle fleets are responsible for 52% of the agency's emissions and indirect emissions, and stationary combustion at DNR's facilities is responsible for the remaining 48%. The Agency's highway vehicle fleet, made up of cars, trucks, SUVs and vans, is responsible for 74% of the mobile combustion emissions.

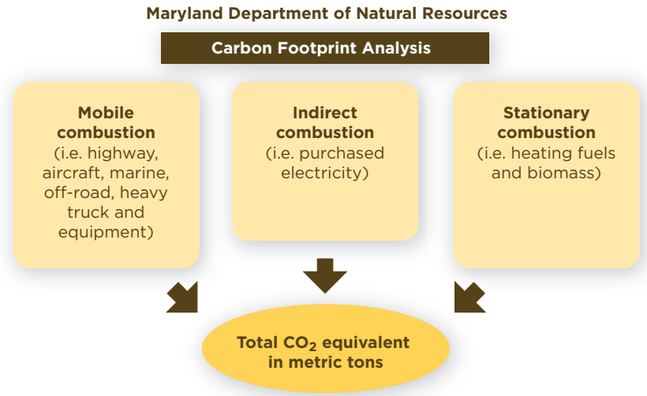


Chart depicts carbon footprint calculation methodology for the Maryland Department of Natural Resources.

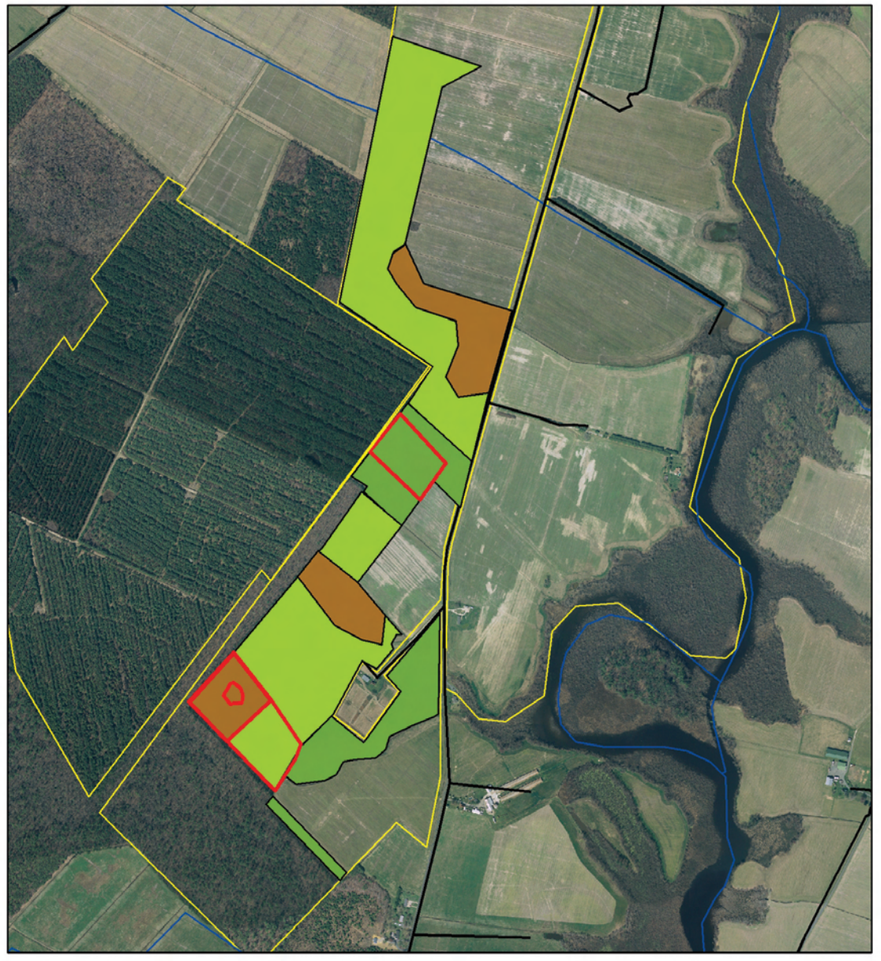
The Carbon Footprint analysis has led to a larger statewide effort to calculate the entire Maryland State government's environmental footprint. In addition to the carbon footprint and its components, the State is measuring each agency's water usage and waste reduction, reuse and recycling. The progress each agency has made towards specific reduction goals will be tracked and updated at regular intervals to maintain momentum and accountability. Once the initial data-gathering is complete, as much of the detailed information as possible will be made available to the public via the internet.

Carbon Cutting Strategies: Upon completion of the carbon footprint analysis, the DNR project team recommended strategies to reduce carbon emissions coming from transportation and facilities. For transportation, recommendations included the implementation of several policies and training to decrease annual miles driven by the highway vehicle fleet and improve the fuel economy of the fleet, such as reducing vehicle gallons bought by tightening the commuting policy; clearly communicating that necessary vehicles will not be taken away if driven less than 10,000 miles; training DNR staff in vehicle maintenance; and downsizing the fleet where necessary. For facilities, recommendations included using new or upgraded building standards, performing energy upgrades at

Protecting the Forests of the Chesapeake Watershed

In 2007, following The Conservation Fund's landmark report, *The State of Chesapeake Forests*, the Chesapeake Executive Council adopted a commitment to identify, protect and expand forests in the Chesapeake Bay watershed through Directive No. 06-01.[14] Subsequently, Maryland made a commitment to protect 250,000 acres of forest by 2050. Along with sequestering carbon, these forests also improve air and water quality and provide critical wildlife habitat.

Little Blackwater Property Forest Carbon Sequestration Plan



Maryland Department of Natural Resources staff monitors survival of loblolly pine trees planted as part of the carbon sequestration project. This species grows rapidly and has great potential to sequester atmospheric carbon.

small and large-scale buildings, and committing to renewable energy projects. Implementation of electricity upgrades can be accomplished in a cost effective manner and have significant education potential, e.g., compact fluorescent light bulbs, light sensors, power-saving software, and insulation.

Forest Carbon Sequestration: In accordance with the conservation strategy, 171.4 acres were planted at the Little Blackwater site. This new forest will offset a significant amount of the DNR's greenhouse gas emissions for one year. MGS will provide annual reporting of the belowground carbon sequestration and changes through time and will report those results to DNR forest management team members. This will assist in the determination of improved methods and forest management practice for carbon capture. These results demonstrate that forest carbon sequestration activities can be quickly implemented and offer a cost-effective greenhouse gas mitigation option that provides additional environmental benefits.

KEYS TO SUCCESS

- **Leadership:** Governor Martin O'Malley signed the Maryland Commission on Climate Change into action early in his inaugural year, thus sending a clear message that under his leadership the State was committed to mitigating the drivers of climate change.
- **Scientific and public review:** The foundation for this project was established by the MCCC in its Interim Report and final Climate Action Plan.
- **Site acquisition:** Maryland's Program Open Space enabled the Department to purchase the Little Blackwater site, which prevented an unwanted development, improved water quality, enhanced wildlife habitat and sequestered carbon.
- **Internal collaboration:** The Secretary of DNR, John R. Griffin, created an Office for a Sustainable Future to assist the Agency with achieving a new mission, to secure a sustainable future for our environment, society, and economy by preserving, protecting, restoring, and enhancing the State's natural resources. This new office served as the project lead and worked across the Agency's many Units and Programs, including the Chesapeake & Coastal Program, the Maryland Forest Service, Maryland Parks Service, the Power Plant Research Program, Maryland Geological Survey, Program Open Space, Watershed Restoration, Financial & Administrative Services, Engineering and Construction, as well as many others, to conduct the overall project.

The Maryland Department of Natural Resources has reconfigured their vehicle fleet to improve fuel economy and reduce emissions of carbon dioxide and other greenhouse gases.

- **External collaboration:** The Conservation Fund and Burke Environmental Associates provided the original request that DNR consider doing this project as an element of the Commission on Climate Change's work. These partners worked with DNR to develop the scope of the carbon footprint and carbon sequestration project components, as well as to assist with development of this profile.

PHOTOS AND FIGURES

All photos by Joel Dunn; except page 14 (bottom), Maryland Department of the Environment
Page 17: Figure, Joel Dunn
Page 18: Figure, Maryland Department of Natural Resources

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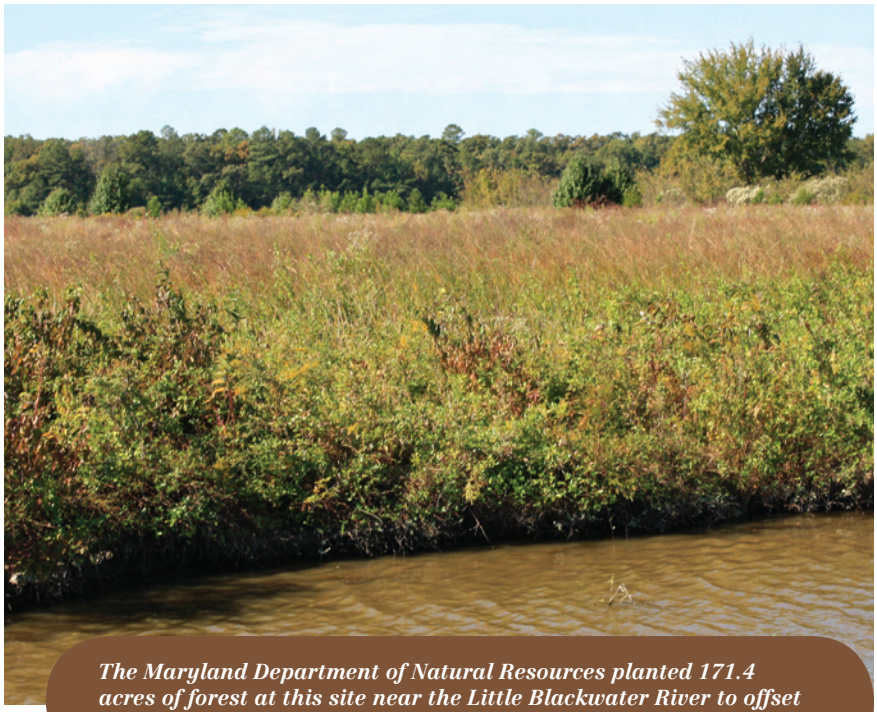


The Maryland Department of Natural Resources planted 171.4 acres of forest at this site near the Little Blackwater River to offset a portion of their greenhouse gas emissions for one year.

FOR MORE INFORMATION

Project Contact:
Zoë Johnson
Program Manager for Climate Change Policy
Office for a Sustainable Future
Maryland Department of Natural Resources
Tawes State Office Building, C3
Annapolis, Maryland 21401
Phone: (410) 260-8741 | Email: zjohnson@dnr.state.md.us

A Climate Change Challenge

Focusing Public Attention on Sea Level Rise and Storm Surge Threats in the Chesapeake Bay

The Chesapeake Sea Level Rise and Storm Surge Awareness and Response team was funded by the National Oceanic and Atmospheric Administration to produce visually oriented, active-learning, education tools that use innovative computer modeling techniques to demonstrate how sea level rise and storm surge will affect natural resources and public infrastructure in the Chesapeake Bay.

CASE STUDY SUMMARY

Natural resource professionals and conservationists have done extensive analysis of projected sea level rise impacts on coastal habitats along the Chesapeake Bay. These analyses indicate that the Bay will be dramatically altered by climate change and that sea level rise should be a major consideration in the region's coastal management and ecological restoration plans.[1] These analyses used well respected research tools to model a range of sea level rise scenarios.[2,3,4] The results highlighted the intense challenges posed by sea level rise induced by climate change. Nevertheless, these analyses used a static inundation model that could not consider the effects of storm surge. Storm surge combined with sea level rise and increased storm intensity, can carry floodwaters much farther inland, endangering lives, property and ecosystems. More detailed and accurate models were needed to produce inundation products for students, professionals, businesses and governments to explore the predicted impacts of both sea level rise and storm surge on the Chesapeake Bay.

In 2008, The Conservation Fund assembled and coordinated the interdisciplinary Chesapeake Sea Level Rise and Storm Surge Awareness and Response (CSSPAR) team to develop prototype tools and products that visualize the effects of sea level rise and storm surge inundation in the Chesapeake Bay region. Specifically, the team applied innovative computer modeling techniques to demonstrate how sea level rise and storm surge in the Chesapeake Bay will affect natural resources, such as wetlands and coastal forests, and public infrastructure, such as roads, emergency services, hospitals, schools, and residential structures. These models were then used to produce educational resources including an interactive website and printed map for students, natural resource managers, decision makers, and the general public. The models were also used to design a new course at the National Conservation Training Center for natural resource professionals interested in integrating sea level rise and storm surge into green infrastructure conservation planning and local land use master plans.

The CSSPAR team included the National Oceanic and Atmospheric Administration (NOAA), Chesapeake Research Consortium (CRC), Chesapeake Bay Observing System (CBOS), Maryland Department of Natural Resources (MDNR), Virginia Coastal Zone Management Program (VCZMP), Burke Environmental Associates (BEA), National Geographic Society (National Geographic), Virginia Institute of Marine Science (VIMS), Noblis, Inc. (Noblis), and additional local and regional stakeholders. National Geographic, VIMS and Noblis produced the resulting visually oriented, active-learning, education tools.

RESOURCE MANAGEMENT CHALLENGE

According to the Intergovernmental Panel on Climate Change, an overwhelming number of observations indicate that the world is warming, the climate system is changing and

that these changes will be unstoppable for decades.[5] In the ocean in particular, changes are occurring in global ocean heat content, salinity, sea level, thermal expansion, water mass evolution and biogeochemical parameters.[6] Sea level rise and storm surge pose particularly significant threats to the ecological health of our nation's estuaries, such as Chesapeake Bay, and the economy and safety of the surrounding communities. Although there has been coverage of sea level rise and storm surge in the press, the knowledge has not been available to the general public in a tangible form that allows for exploration of the topic, under various plausible scenarios, to make it more realistic for people.

The Chesapeake Bay region is one of the most vulnerable areas in the nation to sea level rise, trailing only parts of Louisiana, Florida, Texas and North Carolina in national assessments.[7,8,9] Several recent studies have indicated that sea level is predicted to rise steadily along the East coast in the coming decades.[10,11,12,13] Coincidentally, the land of the Chesapeake Bay region is also subsiding due to rebound from the previous glacial period, which increases the relative rate of sea level rise. The effects of sea level rise induced by climate change include shoreline erosion, coastal flooding, salt water intrusion of freshwater resources, and inundation of some coastal areas. The Chesapeake Bay has 11,684 miles of coastline along its main body of water and tidal tributaries, which suggests the Bay has a large area at risk.

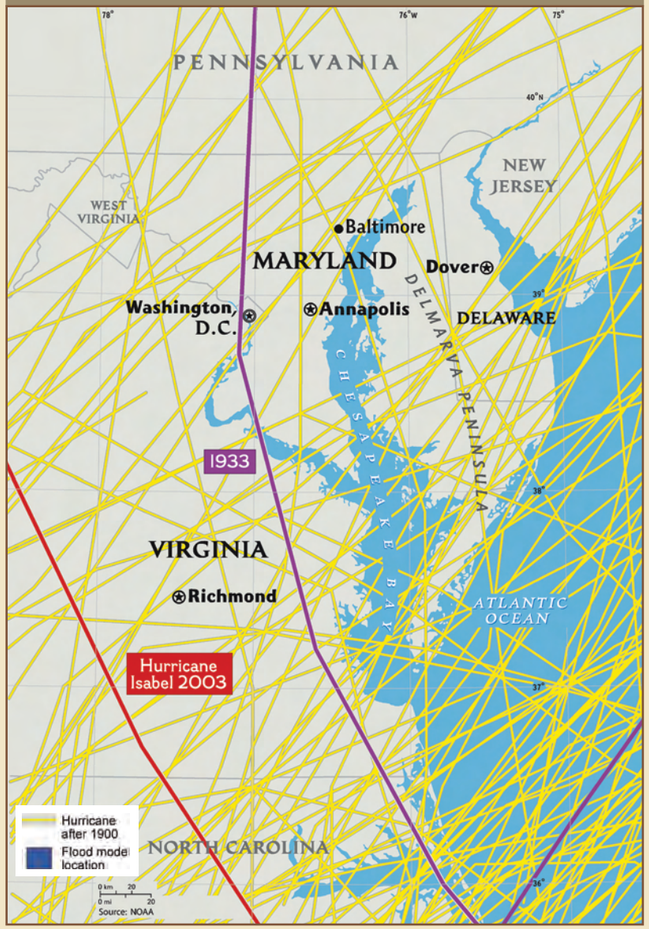
Relative sea level in the Bay has risen approximately one foot in the last century, nearly twice the global average.[14] An analysis by the Scientific and Technical Workgroup of the Maryland Commission on Climate Change indicates that sea level could rise from 0.6 to 1.3 feet (0.18 to 0.39 meters) by the middle of this century. The analysis also states that accelerated melting could produce a relative sea level rise at the end of the century from 2.7 feet (0.82 meters), under a lower emissions scenario, to 3.4 feet (1.03 meters) under a higher emissions scenario.[15] Given the current and predicted rates of sea level rise, low-lying areas, such as islands, coastal wetlands and beaches, will be dominated by open water by 2050.[16,17]

Bayside homes in Bowleys Quarters are surrounded by water the day after Hurricane Isabel. The six-foot storm surge generated by Hurricane Isabel caused extensive damage in this east Baltimore County community.

Flooding from tropical storms, hurricanes and nor'easters, poses a much more immediate threat to the Bay's human and natural infrastructure, particularly because these storms are often accompanied by a storm surge. Storm surge can devastate entire communities, just as Katrina's storm surge destroyed New Orleans,[18] especially if it occurs at high tide.[19] Storm surge has been a significant concern for the Chesapeake Bay region and was first modeled for Norfolk, Washington, and Baltimore by the United States Army Corps of Engineers in 1959.[20] The size of a storm surge depends on atmospheric forcing, storm path, and an area's bathymetry and water body shape and size.[21] More recent models suggested that a category 4 hurricane could produce storm surges as high as 18 or 20 feet in Baltimore at high tide.[22] In 2003, Hurricane Isabel produced a large and memorable storm surge in the Bay, which significantly raised the public's awareness of the phenomenon. With rising levels of greenhouse gases in the atmosphere and continued warming, the Chesapeake Bay region may face more powerful storms in the future depending upon the storm tracks.[23]

Climate change has become an important topic of discussion throughout our society, and the public, particularly younger generations, want to know how climate change will affect their lives and the world around them. Although the states of Maryland and Virginia have developed strategies for reducing the region's vulnerability to climate change,[24,25] the general public remains fairly unaware of the significant potential impacts of sea level rise and storm surge on coastal areas. The CSSPAR team identified a need to produce visually oriented, education tools that go beyond simply reading about the phenomenon in a textbook or in the newspaper and includes an opportunity for active learning.

Hurricane Map



Storm tracks of hurricanes and nor'easters after 1900 (yellow) form clots in the Chesapeake region. The great hurricane of 1933 passed right through Washington, D.C. Hurricane Isabel in 2003 veered west, but the hurricane's eastern flank caused great damage throughout the Bay.

CONSERVATION VISION

Communities around the Chesapeake are just beginning the process of determining how to adapt to projected sea level rise increases and more severe storm surge events. The impact of climate change on the Chesapeake Bay is widely recognized to be significant by institutions and government. Members of the CSSPAR team felt there were few reliable and easily accessible educational resources and training opportunities available for students, professionals, businesses and government to explore the phenomena. In response, the CSSPAR project was created to increase public awareness and provide tools for vulnerability assessment that will enhance community resilience to sea level rise, storm surge and inundation, and other biological and physical challenges of climate change in the Chesapeake Bay region.

IMPLEMENTATION RESOURCES

The Conservation Fund received a $298,000 grant from the NOAA Climate Program Office's Sectoral Applications Research Program (SARP) on behalf of the CSSPAR team. SARP is a program designed to support the dissemination and exchange of climate-related research findings critical for understanding and addressing resource management challenges. This funding was used by The Conservation Fund to manage the project and coordinate the work of several partners. Key contractor efforts included the work of VIMS to produce models and land inundation data; Noblis to convert the data into visualizations; and National Geographic to design and produce a map and website. The funding was also used by The Conservation Fund to design and conduct a climate related green infrastructure training course. The Conservation Fund received an $8000 grant from the Bancroft

Foundation to print 25,000 copies of the map, which will be distributed to public high schools in Maryland and Virginia.

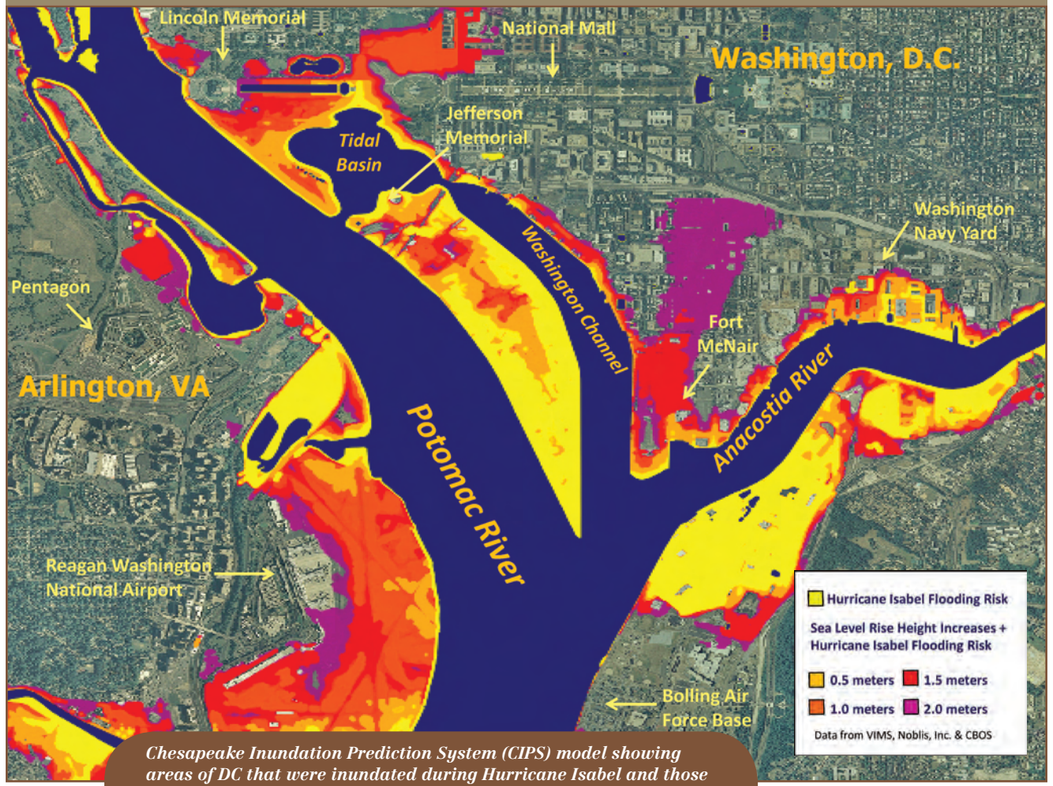
CONSERVATION STRATEGY

The CSSPAR team felt that an effective way to improve public understanding of sea level rise and storm surge was through visual imagery and information on maps, websites and course material for use by the general public, planners, emergency managers and policy makers. Specific deliverables identified by the team included: a double sided foldout map with Bay-wide sea level rise impacts on one side and area specific storm surge impacts on the other side; an interactive website where the user can control environmental conditions and storm path and intensity; and a course where government managers and planner will be trained how to use accurate spatial information to develop conservation strategies in light of sea level rise and storm surge projections.

These objectives required scientific models capable of producing visualizations of sea level rise and storm surge that are accurate, reliable, and show flood predictions for hurricanes and nor'easters. Scientists had previously produced ground breaking models, such as the Sea Level Rise Affecting Marshes Model (SLAMM) and the Sea, Lake and Overland Surges from Hurricanes (SLOSH), but the CSSPAR team determined that they needed higher resolution models to produce more visually oriented products capable of animating storm surge and inundation at a spatial scale of less than a city block for the various audiences in need of the information.

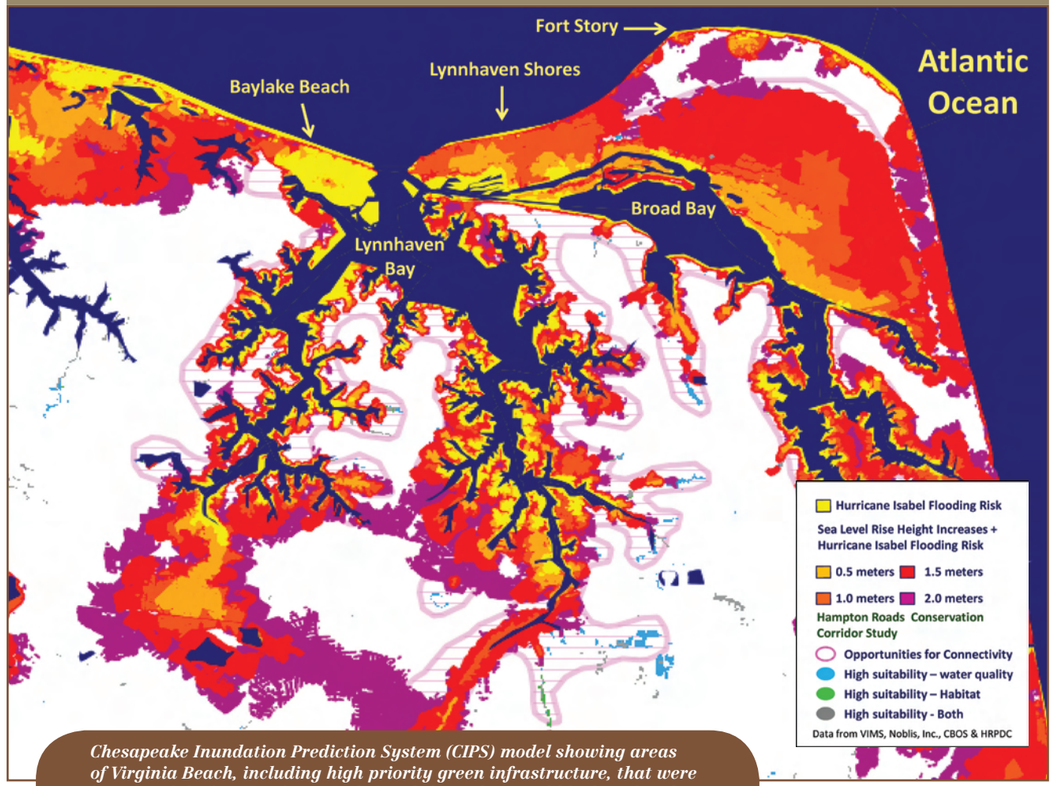
The CSSPAR team used the Chesapeake Inundation Prediction System (CIPS) to model the impact of various storm surge and sea level rise scenarios on three distinct areas of the Chesapeake Bay. CIPS is a computer modeling system that uses high resolution atmospheric and hydrodynamic models; highly accurate light detection and ranging (LIDAR) data for fine scale topographic and elevation references; and emerging GIS techniques to produce flooding forecasts for tropical cyclones and nor'easters in the Chesapeake Bay. CIPS was originated by organizations involved with the Chesapeake Bay Observing System (CBOS) to visualize expected on-land storm surge inundation along the Chesapeake Bay and its tributaries.[26] CIPS predicts the combined effect of storm surge, tide, and river flow inundation. The inundation model was developed by scientists at VIMS who build detailed three-dimensional simulations of storm surge and inundation.[27,28,29]

Upper Tidal Potomac River, Washington, D.C.



Chesapeake Inundation Prediction System (CIPS) model showing areas of DC that were inundated during Hurricane Isabel and those that would be inundated under another Isabel-like storm under various sea level rise scenarios.

Hampton Roads, Virginia Beach, VA



Chesapeake Inundation Prediction System (CIPS) model showing areas of Virginia Beach, including high priority green infrastructure, that were inundated during Hurricane Isabel and those that would be inundated under another Isabel-like storm given various sea level rise scenarios.

The output from the VIMS model is then used by scientists at Noblis who transform the data into GIS-based visualizations to show water moving onto the land and to produce fine-scale inundation forecasts for the Bay.[30]

While most scientists are confident that sea level will rise over the next century, the rate of relative sea level rise varies geographically and will be significantly affected by current and future global greenhouse gas emissions to the atmosphere. A high emissions scenario, one in which global emissions continue to increase unabated, could result in additional melting of glaciers, further expansion of the ocean, and a change in ocean currents, such as slowing the North Atlantic conveyor belt, all of which influence sea levels. For the purpose of analytical comparison and illustration, the CSSPAR team chose to model four sea level rise scenarios: 0.5, 1.0, 1.5, and 2.0 meters. This allowed for interpretation and consideration of some of the lower and higher emission scenarios.

The Chesapeake region has a long recorded history of being affected by hurricanes and nor'easters.[31] Nevertheless, the unnamed hurricane of 1933 and hurricane Isabel of 2003 really stand out in the minds of scientists. Both of these storms caused

High winds and floodwaters brought by hurricane Isabel caused extensive flooding to numerous classrooms, dormitories, athletic facilities and main roads throughout the U.S. Naval Academy in Annapolis, Maryland. Hurricane Isabel, which cost the Navy nearly $130 million in damage in the Mid-Atlantic region, was a Category 2 storm when it made landfall near Cape Hatteras, North Carolina, several hundred miles south of Annapolis.

substantial damage to the region due to high winds and storm surge. The CSSPAR team used CIPS to model the impact of these storms under the four sea level rise scenarios listed above, so that one can examine the impact of a hurricane to the land in a world where sea level is higher. The results provide important visual insight to the effects of future storm events and a foundation for consideration of mitigation approaches that could be evaluated in future work to minimize these impacts.

VIMS and Noblis used their innovative modeling techniques to develop data and visualizations for scenarios in three distinct areas of the Chesapeake Bay including:

- **Upper Tidal Potomac River:** Home to our Nation's capital, this area is heavily populated and contains significant cultural resources in low elevation areas, such as the National Mall and associated monuments.
- **Hampton Roads:** Hurricane storm surge presents a significant hazard to this highly populated region,[32] which has numerous important military installations and several economically-critical cities for ocean commerce.
- **Lower Eastern Shore of Maryland:** Rich in wildlife, this area has freshwater impoundments, brackish tidal wetlands, open fields, and mixed evergreen and deciduous forests. This area is home to the Blackwater National Wildlife Refuge, sometimes referred to as the "Everglades of the North," and also has the lowest elevation land in the Bay watershed, particularly in Dorchester County.

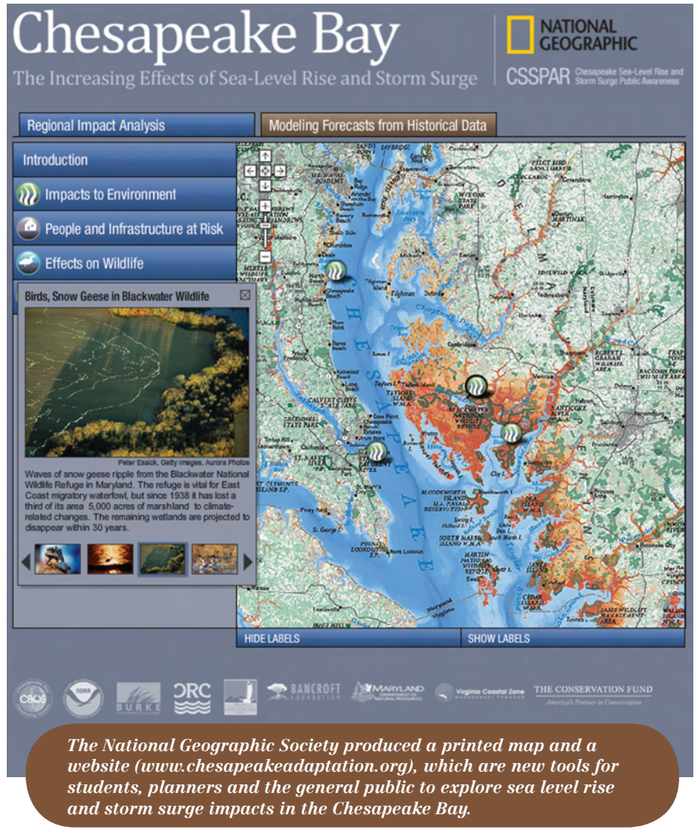
RESULTS

Interpretive Products and Tools for Education: National Geographic brought together all of the work of the CSSPAR team and produced visually oriented, active-learning, education tools. National Geographic is world-renowned for their commitment to increasing and diffusing geographic knowledge while promoting the conservation of the world's cultural, historical, and natural resources. Their visual products have captured the public imagination for over 100 years – significantly influencing our cultural values and public policies through straightforward and effective, education.

Printed Map: National Geographic and the CSSPAR team produced a visually stunning double-sided printed map highlighting the impacts of rising sea level and storm surge on the Chesapeake Bay and its surrounding lands. The map includes text that details: the evidence of sea level rise and the potential impacts it will have on natural infrastructure, built infrastructure, and wildlife; the impacts of potential storm surge on the three focal areas in the Bay, and; the need for society to prepare for and adapt to the predicted changes. These maps are being distributed to schools and public officials around the Bay.

Web Resource: National Geographic and the CSSPAR team produced an enhanced Chesapeake Bay web resource, with a map viewer at its heart, summarizing potential impacts of climate change and presenting map layers charting sea level rise and potential storm surge extents for the three focal areas described above (visit www.chesapeakeadaptation.org). The website covers the four major themes presented on the printed maps and provides the user with the means to inspect the broader concepts using two main tools: photo-story galleries and dynamic mapping services.

Each theme includes photo-story galleries, presented as sets of icons on the map, which highlight specific points of interest related to climate change. The dynamic mapping services allow the user to explore the history of hurricanes and tropical storms in the Chesapeake Bay region, and their impact on the natural and built environment. The site provides an expanded comparison of the unnamed 1933 storm and Hurricane Isabel of 2003, and using the sea level rise and storm surge data models and high resolution satellite imagery, visualizes the potential impact of hurricane storm surge on the three focal areas of the Bay under various sea level rise scenarios. The website is the first up close and personal look for the public at the threat to institutions, homes, schools and other infrastructure from projected impacts of climate change in the Bay.



The National Geographic Society produced a printed map and a website (www.chesapeakeadaptation.org), which are new tools for students, planners and the general public to explore sea level rise and storm surge impacts in the Chesapeake Bay.

Professional Training: Although the predicted impacts of sea level rise and storm surge pose a severe threat to businesses, homes and natural and cultural landscapes, there isn't a safe environment for individuals from concerned disciplines and government sectors to explore this difficult topic. In April of 2010, The Conservation Fund will conduct a 2.5 day course on green infrastructure and climate change. The course will allow planners and decision makers to examine the projected impacts of sea level rise and storm surge on the Chesapeake Bay region and its green infrastructure. Through hands-on class projects using data layers for two coastal communities, and lectures from cutting edge experts and on-the-ground practitioners, participants will learn and experience first-hand the challenges of deciding what to protect and how to protect it in the face of rising waters and increased storm events.

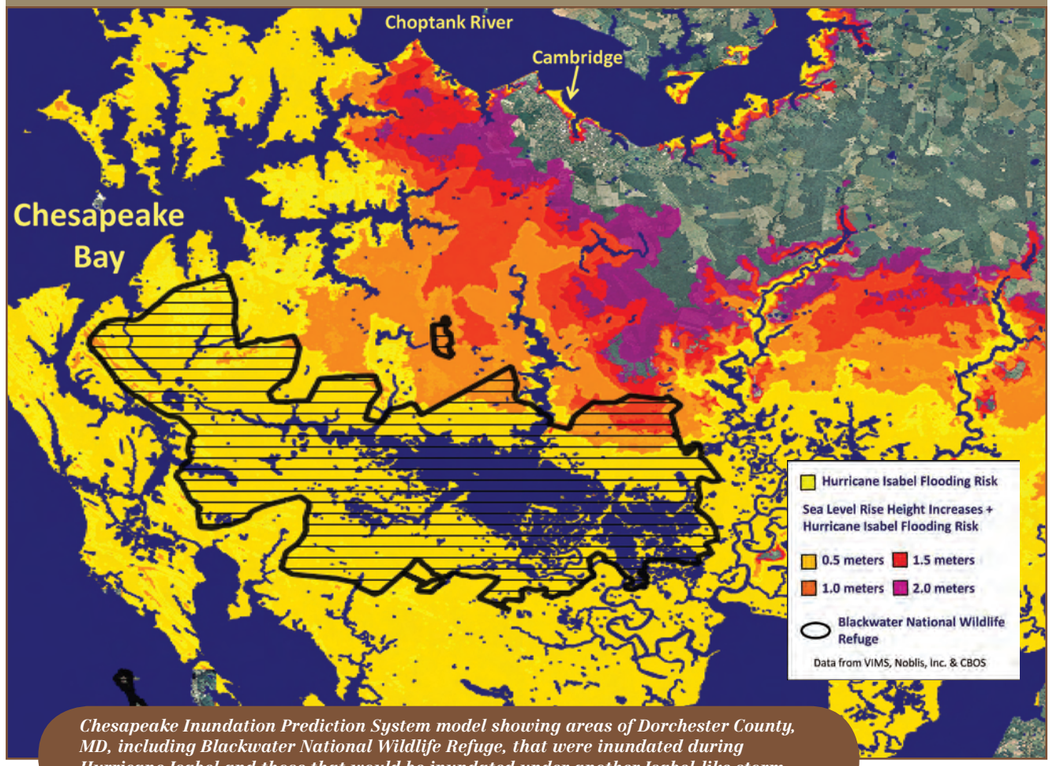
Course Objectives:

- Describe green infrastructure concepts and principles;
- Explore techniques for planning and designing green infrastructure networks at the statewide, regional, and local levels;
- Identify the potential impacts of climate change on coastal communities and effective communication strategies for conveying those impacts; and
- Discover how green infrastructure can be used to facilitate adaptation and mitigation of potential climate change impacts.

The course will be a collaborative learning experience applicable to who are engaged in land use planning and management. The Conservation Fund designed the course with the assistance of several government entities in the Chesapeake Bay that have already begun planning processes to address the implications of sea level rise and storm surge on their jurisdiction, including the State of Maryland, the Northern Virginia Planning District Commission, the Hampton Roads Planning District Commission and NOAA.

The map, website and course will raise awareness of climate change throughout the Chesapeake and provide people with the inspiration and tools needed to begin addressing this major environmental challenge. The overall intent is to expose the public to the intense and complex potential realities of these phenomena, making it more real than theory. Children and

Lower Eastern Shore, Dorchester County, MD



Chesapeake Inundation Prediction System model showing areas of Dorchester County, MD, including Blackwater National Wildlife Refuge, that were inundated during Hurricane Isabel and those that would be inundated under another Isabel-like storm given various sea level rise scenarios.

young adults are perhaps the most important demographic reached by these materials. After all, they will be the ones grappling with the most severe impacts and this may be their first true exploration of the topic, which will give these leaders of tomorrow an advantage when they are faced with the difficult decisions to retreat, adapt or defend our coastal areas.

KEYS TO SUCCESS

- **Effective communication about climate change.** In general, scientists, emergency managers, planners and natural resource professionals agree that sea level rise and storm surge will have a significant impact on the Chesapeake Bay. While some may argue about the extent of sea level rise or the frequency of storms, few professionals deny that the ocean is rising and that storm intensity is increasing. Information about the topic, particularly in low-lying areas like the Chesapeake Bay, needs to be presented in a way that both professionals and the general public can understand.
- **Scientific innovation and partnership.** Scientists at VIMS developed highly advanced models capable of predicting storm surge and inundation throughout the Bay much more accurately than previous models. The scientists partnered with Noblis and National Geographic, who had the special skills and experience needed to make attractive visualizations of the VIMS model data.
- **Strong partner reputation.** All of the organizations and government agencies involved in this project had excellent reputations, but partnership with National Geographic provided a globally recognized and trusted lead brand.
- **State government support and information.** Maryland and Virginia provided valuable data and knowledge on sea level rise and storm surge. Partnership with the states provided the project with strong support and leveraged resources.
- **Funding from the NOAA climate program.** This project was made possible through a grant The Conservation Fund received from NOAA's climate program office.

PHOTOS AND FIGURES

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Endnote

Financial assistance for this Sector Applications Research Program project was provided by the Climate Program Office of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) pursuant to NOAA Award No. NA08OAR4310723. Technical assistance was provided by the NOAA Chesapeake Bay Program Office, Annapolis, Maryland. The statements, findings, conclusions, and recommendations are those of the Chesapeake Sea Level and Storm Surge Public Awareness and Response research partners and do not necessarily reflect the views of NOAA, U.S. Department of Commerce, or the U.S. Government.

FOR MORE INFORMATION

Project Contacts
Joel Dunn
Coordinator, Sustainable Chesapeake Program
The Conservation Fund
Annapolis, MD 21403
Phone: (443) 482-2826 | Email: jdunn@conservationfund.org

Barry Stamey
Director, Strategic Collaboration
Noblis, Inc.
3150 Fairview Park Drive
Falls Church, VA 22042
Phone: (703) 610-1652 | Email: barry.stamey@noblis.org

High resolution products are available for specific climate change and sea level rise planning from Noblis and the Chesapeake Inundation Predictions System partners. Please contact Barry Stamey for more information.