Utilizing Regional Collaboration to Build Community Resilience in Northern Virginia

Northern Virginia Regional Commission

THE INNOVATION REGION | 3040 WILLIAMS DR., FAIRFAX, VA 22031

MAY 2019

Virginia Coastal Zone
MANAGEMENT PROGRAM

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Executive Summary

Northern Virginia is predicted to experience an increase in extreme precipitation events, more frequent and longer heat waves, and low-lying coastal areas are projected to see increased flooding from sea level rise and storm surge. These stressors combined with the staggering population growth and conversion of land from open green space to urban/suburban, pose a risk for vulnerable people, assets, infrastructure, and economies. The economic consequences of extreme climate events make resiliency planning at the regional level imperative and urgent.

The aftermath of Hurricane Sandy has repeatedly pointed to the frailties of planning strategies that are generally designed to withstand the range of extremes in the 100-year historical record. However, based on the climate projections provided by National Climate Assessment, using the past 100-year record will no longer provide an adequate range of extremes for planning and design.

In response to these acute and chronic challenges raised above, NVRC formed the "Northern Virginia Climate Resiliency Team" (NVCRT) in November 2016 with funding from a FY16 grant from the Virginia Coastal Zone Management Program. The purpose of the grant and team was to develop a *Roadmap for Resilient Critical Infrastructure* by October of 2017. The "Roadmap" has already started the process of identifying the primary climate-related stressors facing the region, developing challenge statements for each agency, and supporting regular regional coordination, communication and collaboration (https://www.novaregion.org/index.aspx?nid=1354).

The work conducted under this grant allowed NVRC to continue this important work by sustaining the Northern Virginia Climate Resiliency Team for three years to assist in developing a robust plan to increase resiliency across each of the participating jurisdictions of the region.

The specific objectives that were accomplished through this FY 17 scope of work include:

1) Coordinated five meetings for a working group of technical and policy experts from across the region to
2) Developed a semi-quantitative Risk Characterization Tool to assess the level of risk to infrastructure from climate stressors;
3) Developed a "resiliency index" to evaluate adaptive capacity relative to risk;
4) Developed a monitoring protocol for living shorelines in Northern Virginia; and
5) Piloted use of the Risk Characterization Tool in a desktop exercise.

DELIVERABLES

NOVA Climate Resilience Team

NVRC continued to sustain and coordinate the existing regional, multi-stakeholder "Northern Virginia Climate Resilience Team" created under the first year of the grant. The team's members represent academic, non-governmental, state, regional and local government stakeholders from the region.

The stakeholders are a wealth of knowledge about the region and have a vested interest in how climate stressors may affect operation of critical infrastructure that they manage. Therefore, it is important to communicate about the project status as well as bring them information that is relevant to developing a deeper understanding of climate resilience planning.

The focus of the meetings was twofold; 1) hear from subject matter experts on the climate predictions for heat, precipitation, and sea level rise; and 2) assess how these stressors can pose a risk for critical infrastructure.

Meeting summaries are located in **Appendix A**.

Risk Matrix

The key to increasing the resiliency of the various priority sectors is to provide quantitative information about those risks in formats that are useful to decision makers and the public in their joint efforts to reduce vulnerability and increase resilience in multiple sectors.

Many approaches are available for analyzing and characterizing hazards and risks including climate-related risks. Some methods estimate the likelihoods of particular hazardous events occurring in a particular place and time frame (e.g., 100-year flood maps). Other methods provide qualitative ratings of risks, and others assess readiness. Each method has potential advantages and limitations. The methods also differ in the extent to which they are developed by consultation between risk analysts and the potential users of risk information. But the variety of approaches that have been developed for different sectors (e.g. transportation, drinking water, public health, stormwater), leads to a cacophony when an interdisciplinary group of decision makers need to collaborate on a plan for all sectors of infrastructure need to respond to a common set of core stressors.

The semi-quantitative or qualitative risk assessment matrix that was developed for this project is a useful resiliency planning tool which:

- Highlighted the most vulnerable infrastructure sectors
- Allowed management agencies to ask "what if" questions regarding the consequences of various potential events under different climate change scenarios

- Facilitated discussion on issues concern
- Identified critical knowledge gaps
- Helped to prioritize actions to reduce consequences

Risk assessment basically involves the calculation of the magnitude of potential consequences of an event (levels of impacts) and the likelihood (levels of probability) that those consequences will occur.

Risk = Consequence x Likelihood; where; Consequence (C) is the relative impact of that event and Likelihood (L) is the Probability of occurrence or *R=C*L.*

The C × L matrix method combines the scores from the qualitative or semi-quantitative ratings of consequence (levels of impact) and the likelihood (levels of probability) that a specific

likelihood x consequence	**Consequence**			
	Minor (1)	**Moderate (2)**	**Major (3)**	**Extreme (4)**
Scenario **Sector**	Relatively minor changes. Unlikely there would be measurable changes outside of normal variation.	Some measurable changes but will not affect function. These changes are acceptable	Service and function will be altered significantly. The level of change is not acceptable.	Service and function could be eliminated. Response and recovery efforts are beyond the authority and capability of local communities and outside coordination is needed to meet the needs of the multiple jurisdictions affected.
Likely (4) Expected to occur with a probability of 50-100%				
Possible (3) May occur with a probability of 20-50%				
Unlikely (2) Not expected to occur but a 5-20% chance it could				
Remote (1) Not likely but not impossible. Probability >5%				

consequence will occur (not just any consequence) to generate a risk score and risk rating. Essentially, the higher the probability of a "worse" effect occurring, the greater the level of risk.

This characterization template allowed flexibility to score consequences across various sectors of infrastructure. For example, a high probability of a low-consequence outcome (for example, prolonged and elevated summer temperatures affecting bridge infrastructure), would be weighted less than a high probability of a moderate-consequence outcomes (such as prolonged and elevated summer temperatures creating higher incidences of heat stroke within vulnerable populations).

Monitoring Plan for Living Shorelines

Leesylvania State Park is located along the Potomac River in Prince William County, Virginia. It is one of the most highly visited state parks in Virginia. A portion of coast is very low and is exposed to long fetches across and down river. Prior to the project, the shoreline had a scarped bank, exposed tree roots, and falling trees which was unsafe for park visitors.

In 2011, NVRC contracted the Shoreline Studies Program at the Virginia Institute of Marine Science (VIMS) perform a site assessment and develop a plan for a Living Shoreline demonstration project at Leesylvania. The project consisted of four, gapped rock sills with sand fill and marsh grass plantings along approximately 800 feet of shoreline. Project partners, Virginia State Parks, VIMS, Prince William County, and the Northern Virginia Regional Commission (NVRC) cooperated to obtain grant funding for construction. The project was constructed in two phases and was concluded in early 2018.

Under this grant, NVRC contracted with the Virginia Institute of Marine Science to develop a monitoring protocol for the Leesylvania State Park Living Shoreline.

The monitoring plan was developed specifically for the site conditions at Leesylvania State Park but can be used to inform a monitoring plans at additional sites as well.

Core Performance Metrics in the monitoring plan include:

- Vegetation cover
- Tidal inundation
- Sediment monitoring

The monitoring protocol developed by VIMS is attached as **Appendix C.**

Pilot-Scale Implementation of Risk Assessment Matrix

When the probability of natural disaster increases or the severity increases, the exposure of infrastructure to risk increases in ways that are difficult to predict using historical events—the typical method used to assess risk. The uncertainty of future risk is problematic for policy makers and infrastructure planners who must make decisions about public investment that will take place over a long time horizon. It is not possible to eliminate risk entirely. Resilience planning aims to identify those risks that can be significantly reduced and identify those that need to be managed.

A risk assessment such as the one presented here is one of the first and most important steps for cities in creating a more resilient community.

NVRC in partnership with Booz Allen Hamilton carried out This paper presents the results of the risk analysis and discusses the evaluation of the identified risks.

Steps in Risk-Assessment Process

1. Define types of relevant hazards

2. Define event scenarios

3. Identify affected assets

4. Assess the damages to each asset

The risk assessment matrix was pilot tested using several different scenarios as a desktop exercise with the resilience stakeholder work group. Pilot testing the matrix as a desktop exercise with the group allowed us to capitalize on the most up to date information available and the collective knowledge of the group (including stakeholders, planners, managers, and technical staff) involved in the exercise.

During the exercise, if the group concluded that the most appropriate combination for a particular scenario is that there is a possible likelihood that a major consequence could occur, this is scored as a Major Consequence (3) and a Possible Likelihood (3). These two scores are multiplied to generate a High Risk (9) which is an unacceptable level of risk. Therefore, increased management actions would be needed to achieve the objective.

Method:

The three main stressors that could affect Northern Virginia in the future are an increase in precipitation intensity and volume, longer and hotter summer temperatures, and sea level rise. Interactive maps populated with data layers depicting precipitation, heat, and sea level rise, were overlaid onto layers containing critical infrastructure such as roads, bridges, dams, power plants, wastewater treatment plants, storage tanks, railroads, metro stations, airports, and transmission lines. During the exercise, small groups led by subject matter experts from Booz Allen Hamilton used the risk matrix sheet to evaluate the likelihood and consequence on sectors of infrastructure from the scenario. The groups were able to use the interactive maps to locate vulnerable infrastructure for each scenario. The group discussed scores and came to a consensus on the ranking. The facilitator recorded the comments and scores on a master score sheet.

Sea Level Rise

In the Washington DC region, tidal water levels have risen 11 inches since 1924. It is anticipated that sea level rise will continue, and even accelerate in the future. The Virginia Institute of

Marine Science recommends using the NOAA curves for projections. The scenarios we considered for this analysis were:

Short Term (2050)	Long Term (2080)
1 ft. of rise above current MHHW	4 ft. of rise above current MHHW

Precipitation and Inland Flooding

Over the next 60 years, the region can expect to see the frequency, intensity and duration of extreme precipitation events increase. Currently we have average of 10 days per year >1 inch of rain in a 24-hour period, and 1 day per year with greater than 2 inches of rain in a 24-hour period. By the 2050s that is projected to increase to 12 days per year >1 inch and 3.5 days with >2 inches of rain in a 24-hour period. By 2080's days per year with > 1 inch per 24-hour period will be 13 days and > 2 inches of rainfall per 24-hour period is expected to be between 3.5 to 4.5 days per. These trends will result in more frequent floods.

The scenarios we considered for this analysis were:

Short Term (2050)	Long Term (2080)
100 year flood + 3 ft elevation	500 year flood becomes 100 year flood

Heat and humidity can be a dangerous combination for vulnerable populations. Dangerously hot days are when the heat index is greater than 95F. Dangerously hot conditions can be exacerbated by the urban heat island effect. Predicted urbanization and development in the region, coupled with warming from climate change could cause increased stress on infrastructure

Days with heat index >95F could rise from 15 days currently to 70 days by 2080.

Short Term Scenario (2050)	Long Term Scenario (2080)
By 2050, there could 30-45 dangerous heat days per year	By 2080, there could be 45-75 dangerous heat days per year

The combination of consequence and likelihood chosen was based on the risk of something happening within a defined time period – not the risk of it happening at any point in the future. For example, given what is projected to occur to temperature in Northern Virginia as a result of climate change, a heat wave is more likely under 2050 conditions than it is under 2020 conditions.

It is not necessary to have full certainty about issues to rate risk. The level of uncertainty is only a component of the risk calculation process. The aim is to make the most informed decision that includes uncertainty.

One of the advantages of doing a qualitative risk assessment as a desktop exercise is that it can be used in situations where quantitative data are uncertain or when only qualitative data are available.

Risk Matrix Results from small groups

Sea Level Rise Scenarios

Sector	C x L Matrix Score: Short Term 1 ft rslr by 2040		Notes (priority assets and areas impacted)	C x L Matrix Score: Long Term 4 ft. Rslr by 2080		Notes (priority assets and areas and impacted)
Transportation Metrorail lines and stations, regional railroad infrastructure, roadways, and Capital Bikeshare stations. Bridges, tunnels, underpasses, airports	A	4	GW Parkway bridge South of Old Town – Dyke Marsh -some parking and potentially a runway at DCA impacted	A	16	Need railroad/metro tunnel entrance elevations to determine if water infiltration will be an issue. National Airport underwater GW Parkway underwater Bike trails along river gone; Historic Alexandria flooded; No access to Roosevelt Island Bridges to DC impacted
	B	8		B:	9	
	C:	9		C:	9	
	D:	8		D:	16	
Energy Power stations, electric substations. distribution and electrical transmission lines	A	4	-Airport substation? -Are the major substations in the area vulnerable?	A	8	Buried lines underwater. Hopefully electric companies look for workaround long before 2080 -underground gas lines will become difficult to monitor and repair/replace
	B	4		B	9	
	C:	4		C:	12	
	D:	4		D:	12	
Water and Wastewater stormwater and combined sewer collection systems, pumping stations, treatment plants. Surface water supply source area, drinking water treatment and distribution systems Dams/ Impoundments	A	8	Sea level rise combined with storm surge and extreme rain is much more concerning -stormwater plus slr is major data gap -Outfalls backing up	A	16	-Blue Plains plant – water supply for VA residents -Fairfax Norman Cole plant ok -What about combined sewer system in Arlington? -Aqueduct near Chain Bridge? If impacted could disrupt water supply for many in the area. -Sanitary sewer will not drain
	B:	4		B:	9	
	C	3		C:	9	
	D	4		D:	16	
Non-defense Government Facilities	A	4		A	8	Loss of parkland
	B:	4		B:	8	
	C	1		C	4	
	D:	4		D:	4	
Defense Facilities	A	4		A	12	-sea level rise will interfere with

Installations, Guard, Reserve	B	1		B	4		mission activities that are along shoreline Watch Langley airfield and Navy Yard Anacostia and Belvoir impacted
	C	1		C	4		
	D	4		D:	4		
Other : Hospitals	4		Did not see any hospitals that would be impacted	16			Loss of estuary Mt. Vernon Commercial marinas impacted Residential areas impacted

Inland Flooding Scenarios

Sector	C x L Matrix Score: Short Term 100 year=10 year flood by 2040		Notes (priority assets and areas impacted)	C x L Matrix Score: Long Term 500 year flood = 100 year flood by 2080		Notes (priority assets and areas and impacted)
	Group	Score				
Transportation Metrorail lines and stations, regional railroad infrastructure, roadways, and Capital Bikeshare stations. Bridges, tunnels, underpasses, airports	A	16	Parts of I-95 and Route 1 impacted Flash flooding in steep, urban areas makes assets in stream valleys extremely vulnerable Old Town Alexandria flooding	Group A	16	Some impact to Reagan National in addition to parts of I-95 and Route 1 impacted I-66 impacted Parts of Dulles underwater Ballston Metro
	B	12		Group B:	16	
	C	12		Group C:	16	
	D	16		Group D:	16	
Energy Power stations, electric substations. distribution and electrical transmission lines	A	8		A	12	Impact depends on how power companies can reroute electricity in flooded areas.
	B	8		B:	12	
	C	8		C	12	
	D	8		D	16	
Water and Wastewater stormwater and combined sewer collection systems, pumping stations, treatment plants. Surface water supply source area, drinking water treatment and distribution systems Dams/ Impoundments	A	12	Stormwater overflows Potential contamination of drinking water -outfalls not draining	A	16	Impoundments and dams are already stressed. Additional stress could cause failure -Norman Cole wastewater plant will be impacted -Four Mile Run Wastewater plant impacted
	B:	8		B:	16	
	C:	8		C	12	
	D:	16		D:	16	
Non-defense Government Facilities	A	8	Services may be impacted in rural areas Low-lying assets	Group A	12	Schools could be impacted
	B:	4		Group B:	4	
	C:	8		Group C:	8	
	D:	12		Group D:	16	
Defense Facilities Installations, Guard, Reserve	A	12	Belvoir airfield	A	16	Belvoir could be flooded
	B	8		B	12	

	C	8		C	8 or 12	
	D	8		D	16	
Other :						

Temperature Scenarios

Sector	**C x L Matrix Score: Short Term** 30-45 days >95F annually by 2050		**Notes (priority assets and areas impacted)**	**C x L Matrix Score: Long Term** 45-75 days >95F annually by 2050		**Notes (priority assets and areas and impacted)**
Transportation Metrorail lines and stations, regional railroad infrastructure, roadways, and Capital Bikeshare stations. Bridges, tunnels, underpasses, airports	Group A:	8	-Are asphalt roads impacted more/differently than concrete roads? -Rail buckling is most likely an issue -in a forested area like this region we have to consider heat stress on trees; weak trees fail and lose branches impacting power lines, and roads -reduced train speeds	Group A:	12	-How much would rail lines be impacted due to increased heat? -pavement could melt or buckle -airport runway becomes too hot to safely land planes -reduced train speeds -metro rail lines can buckle
	Group B:	8		Group B:	8	
	Group C:	8		C	8 or 12	
	Group D:	16		Group D:	16	
Energy Power stations, electric substations. distribution and electrical transmission lines	Group A:	16	-Increased stress on infrastructure -brownouts -heavier load on the grid for a/c -rural areas more vulnerable -sagging lines more likely to come in contact with trees -capacity may not meet demand	Group A:	16	-Solar panels efficiency degrades at temps above 95F -enough energy to meet needs of the region's data centers to carry internet traffic -strategic green infrastructure could help mitigate urban heat -microgrids
	Group B:	12		Group B:	12	
	C	12		C	12	
	Group D:	16		Group D:	16	
Water and Wastewater stormwater and combined sewer collection systems, pumping stations, treatment plants. Surface water supply source area, drinking water treatment and distribution systems Dams/ Impoundments	Group A:	8	-drought impacting flow to WW treatment plants making them less efficient	Group A:	12	-increased brownouts and impact to pumping stations -need to make sure critical assets have backup power -higher demand plus population growth may impact water supply capacity
	Group B:	8		Group B:	8 or 12	
	Group C:	8		Group C:	8 or 12	
	Group D:	8		Group D:	16	
Non-defense Government Facilities Schools, Police, Fire, Community Centers	Group A:	16	More heat related illness calls put strain on first responders -Community Centers may have to become cooling centers at times	Group A:	16	-potential to see more brush and forest fires -more dead trees -pest infestations
	Group B:	8		Group B:	8	
	Group C:	8		Group C:	8 or 12	
	Group D:	8		Group D:	16	

			-need cooling center plan; where to put them and how to get people in them -schools and children			-outdoor workers more vulnerable -outdoor work curtailed -need cooling centers
Defense Facilities Installations, Guard, Reserve	Group A:	8		Group A:	12	-outdoor training can be dangerous in extreme heat -training curtailed during heat
	B	8		12	12	
	C	8		C:	12(Personnel) 8 (Facilities)	
	D:			D:		
Other : Hospitals			-already have a high demand for energy; higher temps will increase energy usage -health care -nursing homes -need microgrids	Group D:		-already have a high demand for energy; higher temps will increase energy usage -will have extreme ecological impacts; trees will die (e.g. maples) won't survive increased heat -aquatic ecosystems will change (e.g. cold water species will outcompeted by more heat tolerant species)

Resilience Index

Sectors of critical infrastructure differ in their vulnerability, exposure, and adaptive capacity. Adaptive capacity refers in vulnerability studies and hazard research mean any action taken either to reduce or avoid risk or damage from hazard events, or to reduce or avoid people's or places' exposure and/or sensitivity to hazard events (Petit et al., 2013). While greater exposure and higher sensitivity to hazards increase the vulnerability of the people or the place, the adaptive capacity of the people or the place reduce their vulnerability to hazard events.

Adaptive capacity is a function of available financial recourses, human resources and adaptation options, and will differ between risks and sectors. For example, an infrastructure sector that is well prepared to cope with floods may be taken aback by a heat wave.

Enhancing the resilience of critical infrastructures requires an understanding of the systems exposure and vulnerability to a threat (risk) as well as ability of the system to withstand specific threats and to return to normal operations after degradation (adaptive capacity).

The Argonne National Laboratory (Petit et al., 2013) identified indicators of adaptive capacity. These were used as a model and then modified for specific use to critical infrastructure in Northern Virginia:

- Preparedness
- Coordination
- Response Capabilities
- Exposure
- Recovery Capabilities
- Economic Capabilities

The work developed under this product will equip localities in Northern Virginia with stronger means to prioritize resilience building activities.

Preparedness

Preparedness can be considered an indicator of adaptive capacity because it means that the facility has taken precautionary measures in the face of potential disasters. These actions can include hazard mitigation planning and trainings for personnel. For example, Fairfax Water has a drought contingency plan where they can release water from Jennings-Randolph Reservoir in Garrett County Maryland to supplement the local supply if necessary.

Metrics:

- Emergency/Contingency plan in place
- Hazard Mitigation Plan is followed
- Personnel undertake training to implement plan
- Percent of buildings that comply with resilient building codes

- Continuity of operations plan in place

Coordination

Effective coordination between and among jurisdictions is an important aspect of adaptive capacity. align regional hazard mitigation planning efforts and leverage funding opportunities.

This information developed could be used to inform integrated strategies across the political jurisdictions of the region while implemented by numerous players. When multiple partners and communities work in cooperation to tackle an array of interconnected implications associated with climate stressors, there is less duplication of effort and substantial cost savings.

Metrics:

- A mechanism for regional governance is in place
- Owner/Operator engages in regional collaboration and governance
- Has regional partnerships or MOU's in place for emergency support, redundancy or capacity

Response Capabilities

Metrics:

- Communication systems are interoperable
- Multiple Ingress/Egress points to infrastructure location
- Mitigation measures for response to acute and chronic climate stressors
- Back-up generators
- Built in redundancy
- Regional partnerships in place to enhance level of response
- Shelter capacity

Exposure

Metrics:

- Percent of infrastructure that is highly vulnerable
- Cooling center plan
- Widespread urban heat island effect
- Air quality in non-attainment
- Institutional denial of hazards related to climate stressors
- Percent of transportation network available as evacuation route

Recovery Capabilities

Metrics:

- Maintenance/repair designs include future climate scenarios considerations
- Infrastructure can be transformed into something less vulnerable/more adaptive
- Percent of urban land that can accommodate green infrastructure
- Time between impact and response and recovery

Economic Capacity

Metrics:

- Investments in adaptive capacity exceed the value of the system

Combining these indicators into a score provides some means to evaluate the level of adaptive capacity relative to the level of risk. The resulting index can be used to determine where additional capacity might be needed. In general, when risk is high and adaptive capacity is low, the level of resilience is also low. More information is needed to refine these metrics and develop a weighting system to capture the relative impact of each metric on overall resilience.

Appendices

Appendix A

Meeting Agendas and Summaries

Notes from Climate Adaptation Planning:

Workshop #5

May 1, 2018
12:00PM to 1:45 PM
Web Meeting
15 participants

Goals: Re-convene after release of "Resilient Critical Infrastructure-A Roadmap for Northern Virginia", share lessons learned from the Institute of Sustainable Communities Leadership Academy (http://us.iscvt.org/event/innovations-resilient-communities-ii/) , and discuss the scope of the next steps for 2018

12:00 Re-cap of process so far – feedback on roadmap
(Corey Miles, NVRC)

12:05 Panel Discussion: Innovations in Building Resilient Communities – Re-cap from National Capitol Region Team

Evelyn Kasongo-Equity Planner, DC Office of Planning
Erica Brennerman, Energy Manager, Prince Georges County
Rich Dooley – Energy Manager, Arlington County
Annette Osso – Resilient VA
Corey Miles - NVRC

12:45 Thriving Earth Exchange Project: George Mason University and Northern VA Regional Commission
"Planning Resilient Stormwater Infrastructure with Non-stationarity Prediction Tools"
Dr. Dale Medearis, NVRC and Dr. Paul Houser, GMU (Invited)

1:00 Question and Answer ||Discussion of 2018 Projects
Corey Miles, NVRC and Amanda Campbell, MWCOG

1:15 Other Business

Recap of Process || Outcomes from Phase #1

- 5 Webinars and the successful production and review of the "Resilient Critical Infrastructure: A Raodmap for Northern Virginia" https://www.novaregion.org/DocumentCenter/View/11933/Resilient-Roadmap-Final-PDF

Recap From National Capitol Region Team at ISC Conference

The National Capitol Region Team attended the Sustainable Communities Leadership Academy (SCLA) Innovations in Building Resilient Communities in Pittsburgh http://us.iscvt.org/event/innovations-resilient-communities-ii/. Five representatives were on the team: Corey Miles of NVRC, Erica Bannerman of Prince George's County, Rich Dooley of Arlington County, Evelyn Kasongo of Washington D.C., and Annette Osso of Resilient Virginia.

The team observed easy synergies between ISC conferences' focus on social equity/resiliency potential to inform work in Washington DC with under-served wards as well as DC's comprehensive planning efforts and economic development work;

Observed resiliency lessons from ISC conference for projects in Prince Georges County, especially those involving management of microgrids;
Found inspiration in the expressions such as "resiliency is a lifestyle", "resiliency is more grassroots and less a top-down approach", "let people speak for themselves", "work in solidarity with community", and "commit to self-transformation";

Valued ISC conference's work with "team huddles" and means for Arlington's Community Energy Plan (CEP) to include resiliency and social inclusion themes. See opportunities for Arlington County to work across departments to integrate resiliency-based themes and even the possibility of a separate Resiliency Plan for Arlington County – perhaps informed by NLC's Race Equity and Leadership tool.

Appreciated ISC's attention to cross-sectional issues and social equity and the work of the "Gulf of Mexico Alliance https://gulfofmexicoalliance.org/our-priorities/priority-issue-teams/community-resilience-team/" on coastal resiliency;

Drew parallels between challenges with urban heat islands and Chicago's experiences with the 1995 heat wave in which 800 people died.

Sees opportunities for NOVA to learn from lessons of Southeast Florida Regional Compact http://www.southeastfloridaclimatecompact.org/and bottom-up policy changes to building codes following Hurricane Andrew in which Miami-Dade County raised codes for wind tolerance from 120 to 180 miles per hour.

Sees opportunities in NOVA for "Resiliency Art." Example Maxx Moses (https://posetwo.com/)

Learned of tools such as the National Equity Atlas http://nationalequityatlas.org/indicators which provides data on equity indicators.

Review of "Thriving Earth Exchange" (TEX) Project

Reviewed the work proposed under the "Thriving Earth Exchange" (TEX) of the American Geophysical Union (AGU). The "Resiliency Roadmap" identified more frequent and intense precipitation events as a core stressor emanating from climate change. The effects will be particularly impact local authorities' abilities to plan for capital projects on stormwater infrastructure. With the help of the National Association for Environment and Science and the AGU's TEX initiative, NVRC will partner with four climate scientists from George Mason University to better understand regional vulnerability scenarios to flooding and runoff based on a comprehensive look at precipitation, population and land use/land change projections for the region. Current conversations envision that the team of scientists from George Mason University will aid in the collection of data about past, current, and future projected rainfall patterns in the northern Virginia region. These data will be integrate with population projections (and development plans, where available) to produce probability statements, scenarios, or perhaps a GIS layer(s) for use by city and county-level planners to help inform future needs for and demands on stormwater infrastructure while considering climate change and regional growth.

Question and Answer || Looking Ahead for 2018

- The Team will continue working together. At least four more meetings/webinars are scheduled for 2018;
- For 2018, aspirations for the team include development of:
  1) A template for characterizing risks to infrastructure and climate stressors;
  2) A resiliency index to quantify existing resiliency strategies to help frame and interpret capacity adaption process;
  3) Develop a monitoring protocol for living shorelines;
  4) Pilot a risk characterization template

Other Business

- Fairfax County to revise Comprehensive Plan in 2018 with eye towards resiliency, public health and social inclusion;
- DC Government is weaving resiliency and social equity themes into joint resiliency work with MWCOG and the "Region Forward" Initiative;
- The City of Fairfax is working on its comprehensive plan and intends to add language and lessons on resiliency
- Resilient Virginia will finalize its "Resilient Virginia Plan" by the end of May 2018.

AGENDA

Climate Resiliency Team Virtual Meeting #7

September 21, 2018

12:00PM to 2:00PM

Go-to meeting link to be provided

Call (515) 604-9302 and use code 761754

Goals: The Northern Virginia Climate Resiliency Team will convene for a discussion of tools and data that can be used to inform an implementation plan for the Roadmap. First, we'll hear about the evolving American Geophysical Union/Northern Virginia Regional Commission/George Mason University project "Thriving Earth Exchange – (TEX)," which looks to assess future precipitation patterns in a changing climate and model effects on stormwater runoff. The call will also discuss the potential utility of and interest in creation of a sub-committee (four or five people?) to steer the TEX project.

Next, we will hear back from the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) program on the Climate Data Portal and other initiatives.

12:00 Introductions and Roll-Call

12:10 Overview of TEX project

12:15 Climate Related Challenges: Precipitation, Runoff, and Inundation

(Dr. James Kinter, Director of the Center for Ocean-Land-Atmosphere Studies, George Mason University)

* Sub-committee interest/needs/desires for TEX project? NVRC would like to ensure the outcome and products are accessible and useful to meet stakeholder-driven needs.

1:00 Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA)

1:45 Risk Characterization Matrix from NOAA

Question and Answer ||Discussion || Round Robin –

Corey Miles, NVRC and Amanda Campbell, MWCOG

Next meeting will be December 4, 2018 to discuss application of qualitative and quantitative resiliency tools.

AGENDA

Climate Resiliency Team Virtual Meeting

December 17, 2018

12:00 PM to 1:30 PM

Join the meeting by clicking link below

https://global.gotomeeting.com/join/931614565

Call (515) 604-9302 and use code 761754

Goals: To convene for a discussion with FEMA to learn about their new resilience planning tools and identify their priorities for funding resilient infrastructure projects. Identify ways in which Northern Virginia can position itself to take advantage of FEMA and other resilience building programs.

Share updates on 1) regional stormwater modeling project, 2) USACE Coastal Storm Risk Management Feasibility Study 3) Northam Executive Order: Increasing Virginia's Resilience to Sea Level Rise And Natural Hazards 4) Community Rating System Technical Assistance, and 4) Development of a statewide resilient projects database

Anticipated Outcomes: A list of mechanisms and partnerships that can be used to help plan and pay for resilient infrastructure projects. Increased communication of resiliency initiatives within the region.

12:00 Introductions and Roll-Call

12:10 FEMA Resilience Initiatives

Mari Radford, Community Planning Lead, Risk Analysis Branch, FEMA Region 3

1:00 Community Rating System Assistance and Resilient Projects Database

Mary-Carson Stiff, Policy Director, Wetlands Watch

1:15 Updates || Round Robin –

Corey Miles, NVRC and Amanda Campbell, MWCOG

1) Regional stormwater modeling project, 2) USACE Coastal Storm Risk Management Feasibility Study 3) Northam Executive Order: Increasing Virginia's Resilience to Sea Level Rise And Natural Hazards

Appendix B

Pilot Scale Implementation of Risk Assessment Matrix

Primary Climate Stressors

Heat – Urban heat island effect

Extreme precipitation – flash flooding, increased pollution from stormwater runoff

Sea level rise and storm surge – along tidal areas of the Potomac River and tributaries

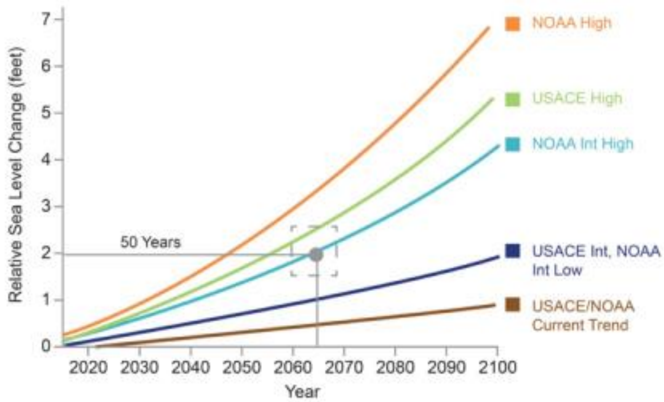
Extreme weather event – tropical storm or hurricane

Northern Virginia Region

Counties
Arlington
Fairfax
Loudoun
Prince William

Cities
Alexandria
Fairfax
Falls Church
Manassas
Manassas Park

Towns
Dumfries
Herndon
Leesburg
Vienna



Sea Level Rise Scenarios for Northern Virginia

Short Term (2050)	Long Term (2080)
1 ft. of rise above current MHHW	4 ft. of rise above current MHHW

- In the Washington DC region, water levels have risen 11 inches since 1924;
- Sea level rise will continue, and even accelerate in the future
- VIMS recommends using the NOAA curves for projections

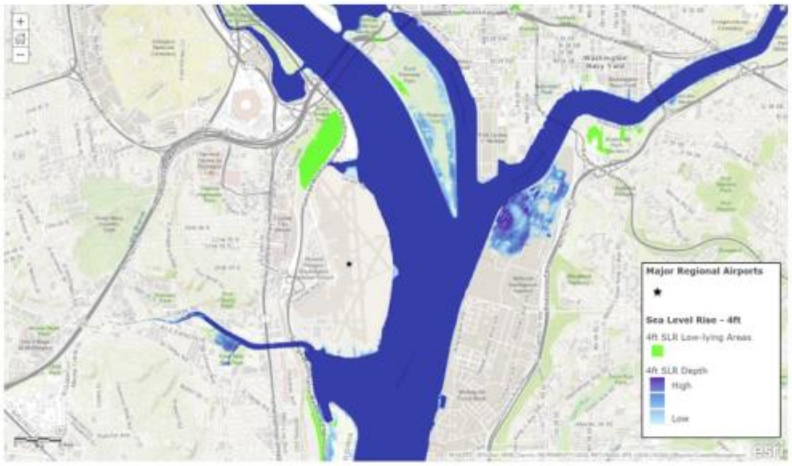
Potential Impacts

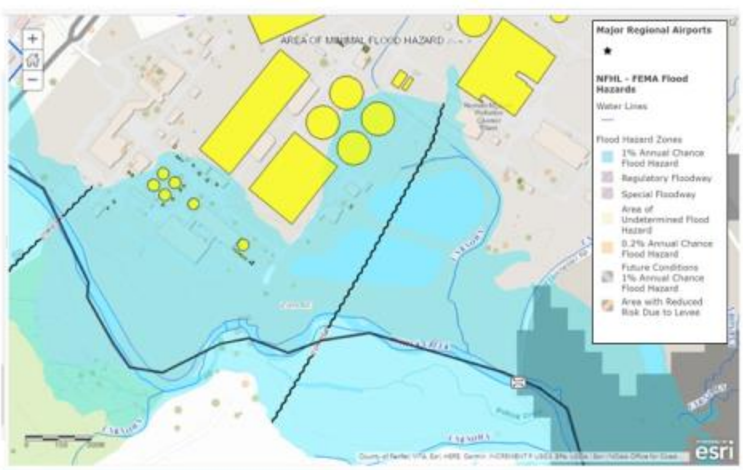
- Loss of land/homes
- Loss of wetland
- Increased flooding and storm surge height

Sea Level Rise Case Study: Alexandria, VA

- Nuisance flooding caused by high tides and exacerbated by heavy rainfall.
- Negative impacts on Old Town businesses near foot of King Street
- City is building a bulkhead along the waterfront and on top of that, will be a promenade as an amenity, as part of city's flood mitigation plan
- Cost is approximately $60 million

Sea Level Rise Scenario – 4 ft





Projected Precipitation Scenarios for Northern Virginia

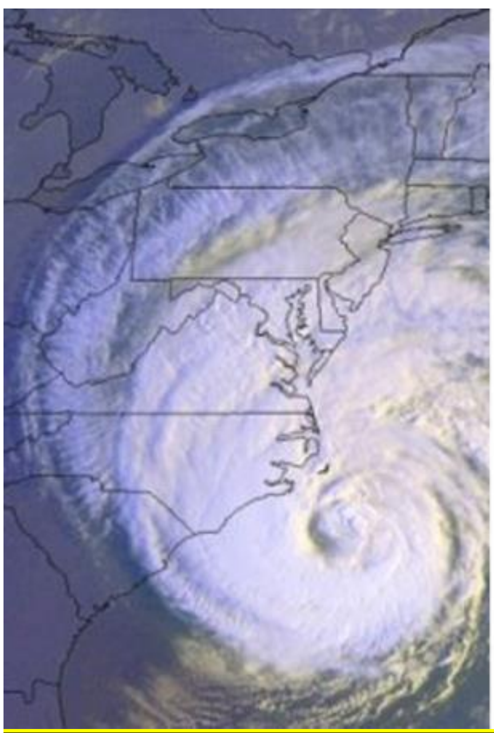
Short Term (2050)	Long Term (2080)
100 year flood + 3 ft	500 year flood becomes 100 year flood

Next 50 years to see frequency, intensity and duration of extreme precipitation events increase

- currently we have average of 10 days per year >1 inch of rain in a 24-hour period, and 1 day per year with greater than 2 inches of rain in a 24-hour period.
- By 2050s that is projected to increase to 12 days and 3.5 days
- By 2080's days per year with> 1 inch per 24-hour period will be 13 days and > 2 inches of rainfall per 24-hour period is expected to be between 3.5 to 4.5 days per
- Potential Impacts
- Erosion
- Flooding
- Degraded drinking water quality
- Road/Culvert Impacts
- Sinkholes

Extreme Precipitation Case Study: Ellicott City May, 2018

- Two 1,000-year floods within 24 months;
- 8 inches of rain over 2 hours on May 27, 2018;
- The Patapsco River ran 17 feet beyond flood stage;
- Extreme flooding claimed one life and $16 gadzillion in damages to property
- Flooding accelerated due to inability of culverts and surrounding landscape to absorb runoff

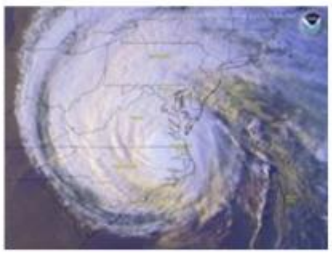


Hurricane Scenarios for Northern Virginia

Short Term (2050)	Long-Term (2080)
Direct hit from Category 2 hurricane (sustained winds of 96-110 mph)	Direct hit from Category 4 hurricane (130-156 mph sustained winds)

- Limited research and modeling available concerning the probability of extreme storms and hurricanes.
- But, the general assumption is that as temperatures continue to rise, the trend towards larger and more severe storms will continue as there is greater energy (heat) in the atmosphere and oceans to fuel the development and duration of these storms.

Hurricane Case Study: Isabel 2003 Category 2



•storm surge across northern Virginia, reaching 9.5 feet in Alexandria.
•storm surge washed out 160 homes and 60 condominiums in Fairfax County, 2,000 units reporting minor to severe damage from the flooding.
•One section of CSX Transportation railway tracks in Prince William County collapsed into the Potomac River from the surge.
•winds downed several trees across Alexandria, causing about $2 million in damage (2003 USD)
•In Arlington County, flooding and downed trees destroyed two houses and damaged 192 homes, 46 severely.
•The storm surge flooded a parking lot at the Reagan National Airport. Damage in the county totaled $2.5 million (2003 USD)
•Falling trees caused major damage to 15 homes in the City of Fairfax, and damage throughout Fairfax County totaled $18 million (2003 USD).
•In Prince William County, seven homes were destroyed, with 24 homes and three businesses experienced major damage.
•Several roads were closed due to downed trees.
•The Marine Corps Base Quantico reported severe damage amounting to $9.5 million. Extensive power outages and damaged power lines

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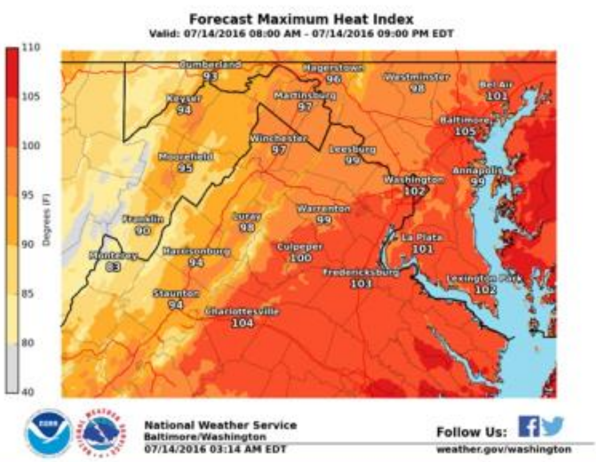

Projected Heat Scenarios for Northern Virginia

Short Term Scenario (2050)	Long Term Scenario (2080)
By 2050, there could 30-45 dangerous heat days per year	By 2080, there could be 45-75 dangerous heat days per year

Dangerously hot days are heat index >95F

Days with heat index >95F could rise from 15 days currently to 70 days by 2080

Potential Impacts

- Vulnerable population death
- Airport runway
- Above ground rail lines
- Air quality
- Water chemistry
- Water quantity
- Fire
- Restrictions on outdoor work
- Emergency Cooling Center
- Transmission Lines
- Substations
- Grid Stress

Chicago in summer heat and smog, July 1995 • © Gary Braasch • *Earth Under Fire*

Heat Case Study: Chicago Heat Wave of 1995

- 739 heat-related deaths over a period of five days
- victims were elderly poor residents with no air conditioning and did not open windows or sleep outside for fear of crime.
- from July 12 to July 16, daytime temps were >100 degrees
- Nighttime temps stayed near 90 due to urban heat island effect
- aggravating factors were inadequate warnings, power failures, inadequate ambulance service and hospital facilities, and lack of preparation.
- City officials did not release a heat emergency warning until the last day of the heat wave. Thus, such emergency measures as Chicago's five cooling centers were not fully utilized.
- The medical system of Chicago was severely taxed as thousands were taken to local hospitals with heat-related problems
- coroner had to call in nine refrigerated trucks to store the bodies

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Process

1. Cycle through 8 scenarios; two for each stressor
   i. Sea Level Rise short term and long term
   ii. Precipitation short term and long term
   iii. Temperature short term and long term
   iv. Hurricane short term and long term

2. You will use the risk matrix sheet and evaluate the likelihood and consequence on sectors of infrastructure from the scenario

3. Your group must discuss your scores and come to a consensus

4. The facilitator will record the scores on a master score sheet

5. Repeat steps 2-4 with the next set of scenarios

Risk Matrix

likelihood x consequence	Consequence			
	Minor (1)	Moderate (2)	Major (3)	Extreme (4)
	Relatively minor changes. Unlikely there would be measurable changes outside of normal variation.	Some measurable changes but will not affect function. These changes are acceptable	Service and function will be altered significantly. The level of change is not acceptable.	Service and function could be eliminated. Response and recovery efforts are beyond the authority and capability of local communities and outside coordination is needed to meet the needs of the multiple jurisdictions affected.
Likely (4) Expected to occur with a probability of 50-100%				
Possible (3) May occur with a probability of 20-50%				
Unlikely (2) Not expected to occur but a 5-20% chance it could				
Remote (1) Not likely but not impossible. Probability >5%				

Sectors of Critical Infrastructure

Water and Wastewater Systems Sector • public drinking water systems • wastewater treatment systems • Reservoir dams • storm water impoundments • other impoundments	**Government Facilities Sector** • special-use military installations, • embassies, • courthouses, • national laboratories, and • structures that may house critical equipment, systems, networks
Energy Sector • Substations • Oil and natural gas storage • LNG facilities	**Emergency Services Sector** • EOC's • Police and Fire Stations
Transportation Systems Sector • major airports • metro stations and lines • major highways and bridges • rail • ports and ferries	**Defense Industrial Base Sector** • DOD bases • DOD access
Healthcare and Public Health Sector • Hospitals • Superfund sites • Air quality non-attainment zones • Coal Ash Ponds	**Telecomm** Towers Buried lines Data Centers

Master Score Sheet

Sector	C x L Matrix Score: Short Term 1 ft rslr by 2040	Notes (priority assets and areas impacted)	C x L Matrix Score: Long Term 4 ft. Rslr by 2100	Notes (priority assets and areas and impacted)
Transportation Metrorail lines and stations, regional railroad infrastructure, roadways, and Capital Bikeshare stations. Bridges, tunnels, underpasses, airports				
Energy Power stations, electric substations. distribution and electrical transmission lines				
Water and Wastewater stormwater and combined sewer collection systems, pumping stations, treatment plants. Surface water supply source area, drinking water treatment and distribution systems Dams/ Impoundments				
Defense Facilities Installations, Guard, Reserve				
Other				

Scoring Process for Each Climate Stressor

Appendix C

Living Shoreline Monitoring Protocol

Leesylvania State Park Living Shoreline Project Monitoring Protocol

Shoreline Studies Program
Virginia Institute of Marine Science
William & Mary

May 2019

Leesylvania State Park
Living Shoreline Project
Monitoring Protocol

Donna A. Milligan
Walter I. Priest*
C. Scott Hardaway, Jr.

Shoreline Studies Program
Virginia Institute of Marine Science
William & Mary

*Wetland Design and Restoration

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May 2019

Introduction

Living Shoreline Project

Leesylvania State Park is located along the Potomac River in Prince William County, Virginia (Figure 1). It is one of the most highly used state parks in Virginia with attendance topping 600,000 (Anne, 2017). The project shoreline occurs on the southeast-facing Potomac River shore north of the marina (Figure 2). This section of coast is very low and is exposed to long fetches across and down river. Prior to the project, the shoreline had a scarped bank, exposed tree roots, and falling trees which was unsafe for park visitors (Figure 3).

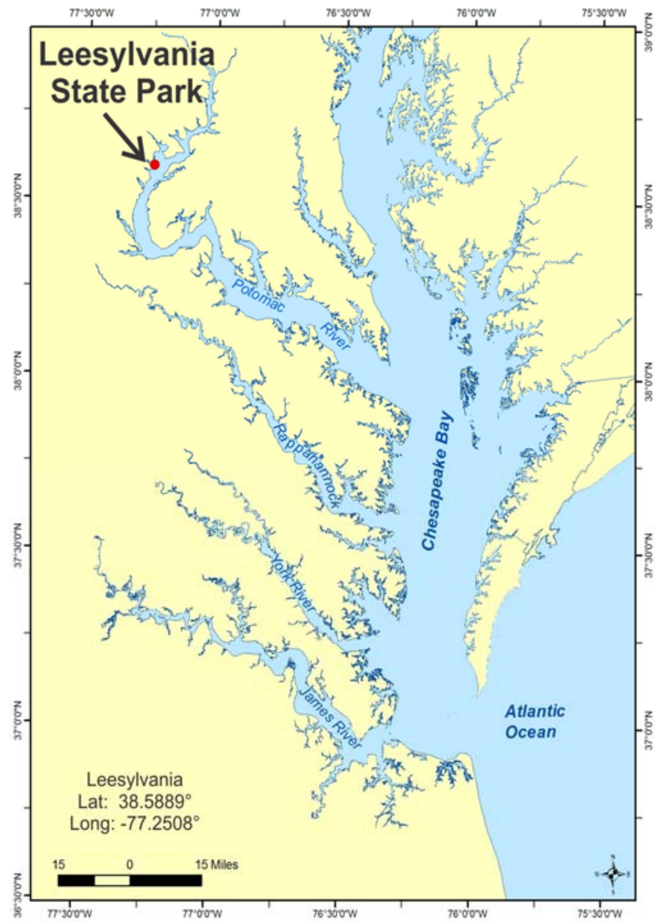

Figure 1. Location of Leesylvania State Park within the Chesapeake Bay estuarine system.

In 2011, the Shoreline Studies Program at the Virginia Institute of Marine Science (VIMS) performed a site assessment and developed the plan for a Living Shoreline demonstration project. The project consisted of four gapped rock sills with sand fill and marsh grass plantings (Figure 4). Project partners, Virginia State Parks, VIMS, Prince William County, and the Northern Virginia Regional Commission (NVRC) cooperated to obtain grant funding for construction.

Figure 2. Location of the Living Shoreline sill project at Leesylvania State Park.

Figure 3. Pre-project eroding Potomac River shoreline at Leesylvania State Park. The scarped bank, exposed roots, and fallen trees made the shoreline unsafe for visitors. Photo taken by Shoreline Studies Program, 21 March 2012.

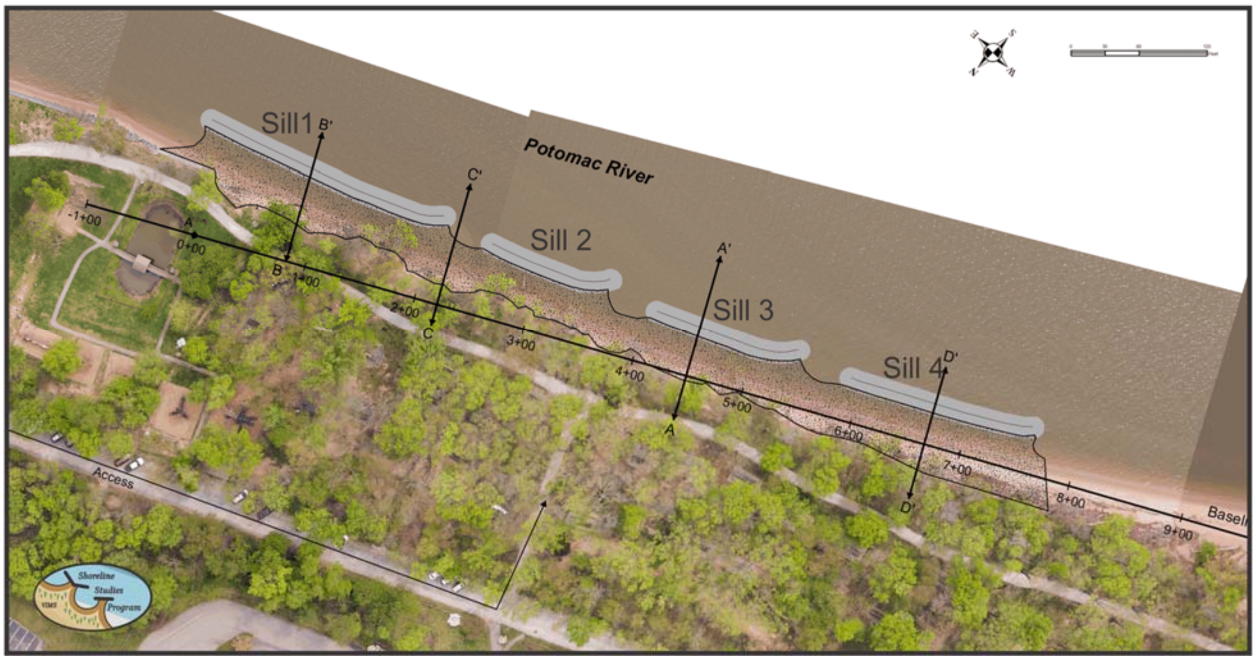

Figure 4. Living Shoreline sill project designed by Shoreline Studies Program, VIMS.

This project was funded, in part, through the Living Shorelines Initiative grant program, administered by the Chesapeake Bay Trust in conjunction with the National Oceanic and Atmospheric Administration (NOAA) Restoration Center and Maryland Department of the Environment. The first phase of the project was built in 2016 and included rocks sills 1, 2 and part of 3 along with sand fill (Figure 5A). The marsh grasses (*Schoenoplectus pungens* and *Panicum virgatum*) were planted, and exclusion fencing installed a month later (Figure 5B). A year later, the marsh grasses were well established (Figure 5C & D). The rest of the designed Living Shoreline project, the remainder of sill 3 and sill 4 was installed in 2018 (Figure 6).

Monitoring of the Living Shoreline project at Leesylvania was performed by the Shoreline Studies Program, VIMS and consisted of two elevation surveys using a Real-Time Kinematic Global Positioning System. The first survey took place just after installation for the

Figure 5. A) Rock sill 1 and sand fill after installation but before marsh planting (12Aug2016); B) Marsh grass planting and goose fence installation (1Sep2016); C) Sill 1 approximately one year after installation (23Oct2017); and D) high marsh grasses behind sill 1 after about one year (23Oct2017). Photos by Shoreline Studies Program, VIMS.

Figure 6. Google Earth image showing the installation of all four sills as designed. As of the photo date, sills 1 and 2 had been in place for about 1.75 years. The remainder of sill 3 and sill 4 had just recently been installed.

as-built survey in August 2016. The goal of this survey was to determine if the system had been built to design, and the survey occurred pre-planting. Typically, a Living Shoreline system is planted in late spring or early summer to provide a full season of marsh grass growth before the system is exposed to the stronger hydrodynamic conditions that occur during the winter. Grasses in August only have a fair probability of success while those planted in September have a poor probability of success because they typically do not develop the root stock to overwinter (Perry *et al*., 2001). Because the system was finished and the marsh grass planted in late summer, the second elevation survey occurred in March 2017 to determine how the system was maintained over the winter. At that time, the marsh grass was just starting to grow so no vegetation monitoring occurred for the system.

After this survey, no funding was available to continue monitoring the effectiveness of the Living Shoreline demonstration project. However, the project partners were concerned about the determining the status of the system on an ongoing basis. As a result, NVRC received funding to develop monitoring protocols for the site. With many types of monitoring plans and tools available, the Shoreline Studies Program, VIMS was tasked with defining the most useful way to monitor the efficacy of this Living Shoreline demonstration project at Leesylvania and other similar sites.

Monitoring Protocol Goals

Monitoring of shoreline stabilization projects with wetland restoration, like Living Shorelines, can be designed to accomplish many different tasks including information on their structural and functional aspects. Many monitoring plans are designed to determine if the project is similar to a reference area and how long it takes the project to reach parity in ecological function (Currin et al., 2008; Kreeger & Moody, 2014; Yepson, et al., 2016). These comparisons are very valid for scientific research but are not absolutely necessary to determine the success of a shoreline stabilization project. In fact, many eroding shorelines without wetlands vegetation do not have pertinent reference areas for any factor other than the erosion rate. However, if a natural shoreline with similar conditions of fetch and vegetation can be located nearby, it also can be sampled using this protocol for comparative purposes.

Natural resource managers and homeowners generally want to establish the effectiveness of their Living Shoreline for shoreline stabilization, not, necessarily, its parity with adjacent marshes. Therefore, the objective of this monitoring protocol is to use metrics that document sand retention, movement and elevation variability, tidal inundation, evaluate the success of the plantings and, where necessary, provide information for remedial actions. At the risk of being too simplistic, the data from these metrics are the information needed to answer the critical questions about the success of a Living Shoreline designed primarily for shoreline stabilization i.e. Are the measured parameters improving? staying the same? or deteriorating?

This monitoring protocol describes how to develop a monitoring plan for Living Shoreline projects that is applicable to the various types of shoreline protection systems that are installed throughout Chesapeake Bay. It is designed to be very simple and is aimed primarily at Virginia's natural resource managers and interested homeowners who do not have access to sophisticated equipment, laboratory facilities, or funding for a more extensive monitoring project as described by other existing frameworks. Following this protocol will allow the practitioner to determine basic characteristics of the structural effectiveness, functional success, and overall stability of the project. It also can provide an assessment of deficiencies that require remedial attention such as excessive sand loss or plant mortality.

Monitoring Plan Development

Establish Goals and Objectives for Project Phases

The first step in developing a monitoring plan for a project is to establish the goals and objectives for the plan that provides the answers needed by the owners. The goals need to be simple and easily achieved with a limited amount effort. A typical goal for the overall monitoring plan would be: Is the Living Shoreline performing as expected to provide shore protection?

The answer to this question is different based on when it is asked. Generally, a living shoreline project monitoring program has three phases: pre-construction and design, as-built and planting plan after construction, and long-term monitoring to document changes to the project as constructed and evaluate the success or failure of the Living Shoreline at achieving the goal of shoreline stabilization.

Monitoring for the pre-construction phase typically includes the topographic survey done for the design which documents the existing conditions at the site. It should also include photographs of the site taken at strategic permanent locations that provide a clear depiction of the site to compare with future photographs. The final component of this phase is the design drawings which indicate the location and dimensions of structures, fill elevations, the types and locations of proposed plantings and critical elevations like mean low water and mean high water.

The second phase of the monitoring plan includes the as-built survey showing the actual final location and dimensions of structures, substrate elevations, and the location and types of vegetation plantings. This phase serves as the baseline from which changes are measured and evaluated regarding the success and effectiveness of the project. This phase should also include photographic documentation of the site from the same strategic permanent stations used in the pre-construction phase as well as additional ones that document the structures.

The final phase is the actual long-term monitoring. This can be further divided into two separate phases: first year monitoring and subsequent years. The first year is different because it focuses on any rapid changes in substrate elevation and inordinate plant mortality that might indicate design flaws or deleterious conditions that need to be addressed with remedial measures to prevent future problems. The subsequent years of monitoring will determine the long-term viability and effectiveness of the Living Shoreline.

To develop the long-term monitoring plan decisions must be made on what parameters need to be sampled and the criteria for success. They should be easy to accurately quantify, require a minimum of time and effort, pertinent to achievement of stated objectives. For the purposes of this protocol, the wetland vegetation planted, tidal inundation and changes in substrate elevation are used to evaluate the success and effectiveness of the Living Shoreline.

Metrics

During the first year of monitoring it is critical to identify areas of rapid sand loss and large areas of plant mortality if these should occur. These factors can indicate flaws in the design or implementation. The causes of these problems need to be identified so remedial actions can be implemented to ensure the long-term success of the project. For example, if there is an area of rapid sand loss, you need to ask: Are the sill gaps too wide? Is the sill too low? Is the sand the right grain size? In the case of excessive vegetation mortality, you need to ask: Have the plants been planted at the wrong elevation? Are the plants not suited for the salinity regime? Were the plants washed out by a storm event? Is there a herbivory problem from geese or muskrats? Remedial for actions for sand loss can include: adjustment to the sill design to increase sand retention or the addition of coarser sand. For vegetation loss remedial actions might include: planting different species of plants better suited to the existing elevations or salinity regime or providing goose exclusion fencing to eliminate herbivory problems.

For long-term monitoring the vegetation will be sampled each year by using permanent meter square plots systematically placed along randomly selected transects (Neckles *et al*., 2002). Using a baseline established along the upland-wetland boundary, transects are randomly selected behind each sill using a random numbers table (Figure 7). Systematically locate the plots along these transects beginning at the upper limits of the wetland and ending at the back of the sill. These plots should be located at regularly spaced intervals of a few meters so as to ensure coverage of all of the vegetation communities present. Two to four transects with three to four plots behind each sill should be sufficient.

Figure 7. Vegetation sampling schematic. The baseline occurs along the upland/marsh boundary. Transects are selected by random numbers table along the baseline. The plots are selected randomly from the baseline.

These plots should be sampled in the late summer or early fall for percent cover, tallest stem length, and the number of flowering shoots. Percent cover (Figure 8) is usually defined as the vertical projection of the shoot area to the ground surface expressed as a percentage of the plot area (Mueller-Dombois & Ellenberg, 1974). Another way of expressing this is to assume a light bulb is hanging directly over the plot with the shade from the light on the ground being the percent cover. This should be determined for each species. The percent bare area, the area not shaded by vegetation, should be recorded as the percent no cover. Stem height and flowering shoots are measures of plant vigor that indicate the development of a viable plant population.

As an alternative to actual percent cover, cover classes can be used to simplify the process (Daubenmire, 1959). In this process, a range of percent cover is used to quantify the cover in each plot (Table 1 and Figure 8). This can facilitate the determination of cover and reduce the time and effort involved. The midpoint of each cover class can be used to calculate the average percent cover for the site. Vegetation is an important component of the overall shore protection system and must be thriving for the project to be a success. If plants are not thriving, shading should be considered as a cause. Growth of trees and shrubs over time can impact the amount of sunlight hitting the shore thereby reducing plant growth.

Tidal inundation can be qualitatively monitored be observing daily wrack lines, the accumulation of debris left at the upper limit of tidal inundation, along the shoreline or quantitatively measured with a tide staff calibrated to the local mean low water. These observations are important to ensure that the wetland vegetation is being regularly inundated. In addition, any observed accumulations of wrack, vegetation debris and flotsam and jetsam, should be periodically removed to prevent smothering the planted vegetation.

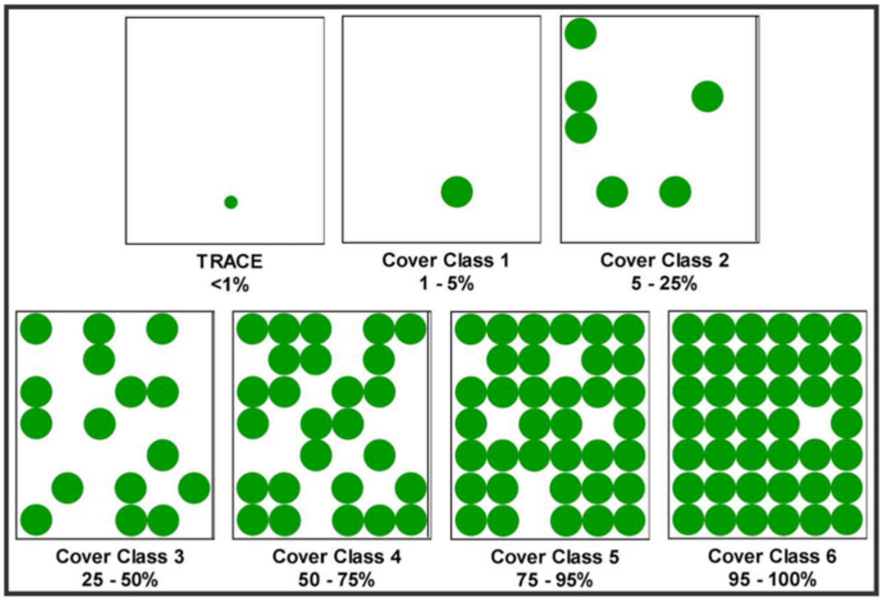

Figure 8. Percent cover depiction for vegetation monitoring. From Connecticut Sea Grant (n.d.).

The best way to measure changes in elevation is to periodically conduct a topographic survey of the site. As this can be costly, an alternative, an easy way to measure changes in elevation is to use strategically placed stakes driven into the substrate with a measurement from the top of the stake to the substrate surface. Periodically recording the changes in the exposed height of the stake can provide a semi-quantitative record of areas where sediment is being lost and where it accreting. This information can be used to identify areas where additional sand may be needed. These stakes should be placed within the permanent vegetation plots and along the centerline and immediately adjacent to the bays between the sills.

Table 1. Cover classes (Daubenmire, 1959)

Cover Class	Range of Coverage	Midpoint of Range
Trace	<1%	0.50%
1	1 - 5%	3.00%
2	5 - 25%	15%
3	25 - 50%	37.50%
4	50 -75%	62.50%
5	75 - 95%	85%
6	95 - 100%	97.50%

In addition to these measurements, photographs from the permanent stations should be taken every year in the late summer or early fall.

Measures of Success

Vegetation monitoring should indicate increasing cover, stem height and flowering shoots for the first three to four years until the cover stabilizes around 70% - 80%. There should also be a concomitant decrease in percent no cover.

Tidal inundation monitoring should indicate almost daily inundation of the wetlands vegetation at the lower elevations. The high marsh areas should also be periodically inundated during spring tides and storm events.

Sediment monitoring during the first year might reveal substantial changes in sediment elevation with some relocation as the system adjusts to wave action and tidal inundation. This is normal in most Living Shorelines as long as there is no radical loss of sand. After the first year, variation in sediment elevations and distribution should be relatively minimal.

Summary

In summary, this proposed monitoring plan is designed to make observations about a Living Shoreline constructed for shoreline stabilization and provide an accurate depiction of its effectiveness and stability with a minimum of time and effort. The goal is to ask and answer the simple questions, is the project improving? staying the same? Or deteriorating? These questions should be asked in the post installation monitoring period as well as in the longer-term monitoring period. Because the monitoring protocol does not require sophisticated equipment or extensive funding, it is appropriate for natural resource managers and homeowners that require quick and easy, yet accurate monitoring. Though many different, and more complex frameworks exist for monitoring of Living Shoreline projects, this methodology is provided so that monitoring does not become an onerous task but rather one that is simply useful.

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