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Striving for Resilience in Virginia's Transportation Sector

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About the Virginia Coastal Policy Center

The Virginia Coastal Policy Center (VCPC) at William & Mary Law School provides science-based legal and policy analysis of ecological issues affecting the state's coastal resources, by offering education and advice to a host of Virginia's decision-makers, from government officials and legal scholars to non-profit and business leaders. With two nationally prominent science partners – the Virginia Institute of Marine Science and Virginia Sea Grant – VCPC works with scientists, local and state political figures, community leaders, the military, and others to integrate the latest science with legal and policy analysis to solve coastal resource management issues. VCPC activities are inherently interdisciplinary, drawing on scientific, economic, public policy, sociological, and other expertise from within the University and across the country. With access to internationally recognized scientists at VIMS, to Sea Grant's national network of legal and science scholars, and to elected and appointed officials across the nation, VCPC engages in a host of information exchanges and collaborative partnerships.

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VCPC grounds its pedagogical goals in the law school's philosophy of the citizen lawyer. VCPC students' highly diverse interactions beyond the borders of the legal community provide the framework for their efforts in solving the complex coastal resource management issues that currently face Virginia and the nation.

I. BACKGROUND

Transportation infrastructure faces a myriad of current and future challenges related to natural hazards and climate change, including recurrent flooding, sea-level rise, storm surge, increased salinity in flood waters, and increased precipitation, temperature, and severe storm events.[1] Sea-level rise along the Virginia coast is projected to be greater than the global average for almost all future global mean sea-level rise scenarios, meaning that Virginia may experience worse flooding sooner than adjacent coastal states.[2] Flood damage to transportation infrastructure is caused by inundation, water pressure on structures, uplift forces on structures, scouring at foundations, wash out of the soil and culverts that support roads, tunnels, and bridges, clogged intakes of constrictions by floating debris, and corrosion of steel and concrete bridges.[3] Tidal flooding, also called "nuisance" flooding, leads to inundation that over time impacts roads, bridges, tunnels, and storm sewer systems.[4] Nuisance flooding in Virginia is occurring more often during seasonal high tides or minor wind events, and the frequency is expected to increase dramatically in the coming decades.[5] Damages from flooding cost billions of dollars annually and may ultimately require roads, bridges, rail lines, and subway infrastructure to be rebuilt or raised in future expansion projects, which in turn may prove to be cost prohibitive absent project prioritization.[6]

In March 2021, the Virginia General Assembly signed into law a bill aimed at helping the state adapt to the effects of climate change.[7] The law included an enactment clause requiring the Commissioner of Highways to "ensure resiliency is incorporated into the design standards for new construction projects."[8] It also modified sections 33.2-214.2 and 33.2-353 of the Code of Virginia to require the Commonwealth Transportation Board to promote resiliency in their projects and the Statewide Transportation Plan, and identify when transportation projects have been designed to be

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[1] *See* MOLLY MITCHELL ET AL.,VA. INST. OF MARINE SCI., RECURRENT FLOODING STUDY FOR TIDEWATER VIRGINIA 4 (2013), http://ccrm.vims.edu/recurrent_flooding/Recurrent_Flooding_Study_web.pdf.
There are many causes of recurrent flooding (i.e., flooding that occurs repeatedly in the same area over time) such as precipitation events, high tides, or storm surge. *Id*.

[2] *See* NAT'L OCEAN SERV. CTR. FOR OPERATIONAL OCEANOGRAPHIC PRODUCTS AND SERVICES, NAT'L OCEANIC AND ATMOSPHERIC ADMIN., GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES 9-10 (2017), https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf. Sea-level rise in Virginia is projected to be greater than the global average due to natural, non-climatic processes like glacial isostatic adjustment and sediment compaction. *Id.*

[3] *See* TRANSPORTATION RESEARCH BOARD, MINIMIZING ROADWAY EMBANKMENT DAMAGE FROM FLOODING 6, 11-13, 17, 23, 42, 47, 50, 61-62, 71, 76 (National Academies of Sciences, Engineering, and Medicine ed., 2016).

[4] *See* A.G. Burgos et al., *Future Nuisance Flooding in Norfolk, VA, From Astronomical Tides and Annual to Decadal Internal Climate Variability*, 45 GEOPHYSICAL RSCH. LETTERS 12,432, 12,432 (2018) (discussing how tidal or nuisance flooding is generally caused by tides and wind events); Alexander Vandenberg-Rodes et al., *Projecting Nuisance Flooding in a Warming Climate Using Generalized Linear Models and Gaussian Processes*, 121 J. GEOPHYSICAL RES. 8008, 8008-10 (2016).

[5] Jennifer M. Jacobs et al., *Recent and Future Outlooks for Nuisance Flooding Impacts on Roadways on the U.S. East Coast*, 2672 J. TRANSP. RES. BD. 1, 1 (2018).

[6] *See id*.

[7] Ch. 51 of the Acts of Assembly (Va. 2021 Special Session I).

[8] *Id.*

resilient.[9] However, this act did not define "resilient" nor "resiliency", nor is there another definition within the Code that defines either word as related to this provision.[10]

In November 2022, the Virginia Department of Transportation (VDOT) released its Resilience Plan in response to the previously mentioned statutory mandates.[11] The goal of the Resilience Plan is to "formalize a framework for the incorporation of resilience through [climate resilience] strategies into transportation planning, project development, delivery, operations, maintenance, and asset management."[12] The Resilience Plan defines "transportation resilience" as "the capability of a transportation project or strategy to anticipate, prepare for, respond to, or recover from significant multi hazard threats with minimum damage and disruption to the transportation network, while preserving and incorporating natural and built infrastructure that helps to mitigate these threats."[13] Though not a legally binding definition of resilience, this definition provides imperative guidance as VDOT seeks to fulfill its statutory mandates.[14]

To help address the need for increased resiliency in the Commonwealth's transportation sector, and in furtherance of the goals set forth in the VDOT Resilience Plan, this white paper highlights

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[9] VA. CODE ANN. § 33.2-353 (2021) ("The Statewide Transportation Plan shall be updated as needed but no less than once every four years. The plan shall promote economic development and all transportation modes, intermodal connectivity, environmental quality, accessibility for people and freight, resiliency, and transportation safety."); VA. CODE ANN. § 33.2-214.2 (2021) ("[T]he Office of Intermodal Planning and Investment shall make public, in an accessible format, . . . (iii) whether a project has been designed to be or the project sponsor has committed that the design will be resilient . . . .") ;. *See also* VA. CODE ANN. § 33.2-214.1 (2022) (outlining the statewide prioritization project selection process subject to the mandates in § 33.2-214.2 and serving as statutory authority for SMART SCALE).

[10] *See* VA. CODE ANN. § 33.2-353 (2021); VA. CODE ANN. § 33.2-214.2 (2021).

[11] VA. DEP'T OF TRANSP., RESILIENCE PLAN 5-6 (2022), https://www.virginiadot.org/programs/resources/environmental/VDOT_Resilience_Plan_Nov_2022_FINAL_acc112222.pdf [hereinafter VDOT Resilience Plan].

[12] *Id.* at 1.

[13] *Id.* at 3.

[14] Other states have taken a similar approach to defining resilience. For example, North Carolina's Resilience Plan states that "[a] resilient North Carolina is a state where our communities, economies, and ecosystems are better able to rebound, positively adapt to, and thrive amid changing conditions and challenges, including disasters and climate change; to maintain quality of life, healthy growth, and durable systems; and to conserve resources for present and future generations." N.C. DEP'T ENVTL. QUALITY, NORTH CAROLINA CLIMATE RISK ASSESSMENT AND RESILIENCE PLAN (June 2020), https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf. However, North Carolina's Transportation Policy uses the Federal Highway Administration's transportation sector-focused definition of resiliency, stating that resiliency "shall mean the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions." N.C. DEP'T TRANSP., NCDOT POLICY F.350102, RESILIENCE (Sept. 27, 2021), https://www.ncdot.gov/initiatives-policies/Transportation/transportation-resilience/Documents/ncdot-resilience-policy.pdf. There is no definition of "resiliency," "resilience," or "resilient" in North Carolina's statutes or administrative code. Maryland has a similar disparity of resilience definitions. *Compare* MD. COMM'N ON CLIMATE CHANGE, MARYLAND CLIMATE ADAPTATION AND RESILIENCE FRAMEWORK RECOMMENDATIONS 9 (2021), https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/MD%20Climate%20Adaptation%20and%20Resilience%20Framework%20Recommendations.pdf (using the U.S. Fish and Wildlife Service's definition of "resilience", which is defined as "[t]he ability of a system to recover from a disturbance, adapting a complex network of interactions to maintain productivity and fundamental identity"); *with* MD. DEP'T TRANSP., 2040 MARYLAND TRANSPORTATION PLAN 18 (Jan. 2019), https://www.mdot.maryland.gov/OPCP/2040_MTP_Document_2019-01-31_WebSinglePages.pdf (stating an objective to "provide a resilient multimodal system by anticipating and planning for changing conditions, and hazards whether natural or man-made.").

green infrastructure and natural and nature-based features as ways to increase resilience for transportation infrastructure and mitigating impacts from climate change.[15] Additionally, this paper describes potential methods of incorporating resilient best practices with respect to Virginia's transportation infrastructure and planning decisions.

II. WAYS TO MAKE VIRGINIA MORE RESILIENT

This section identifies tangible steps Virginia can take to combat the challenges outlined in this white paper and the VDOT Resilience Plan. After a look at implementing green infrastructure and natural and nature-based features, the section will then discuss the resiliency benefits of wildlife corridors. Finally, this paper will analyze using planning tools such as vulnerability assessments and updating SMART SCALE.

A. Using Green Infrastructure and Natural and Nature-Based Features in Transportation Projects

Incorporating green infrastructure and natural and nature-based features (NNBFs) in transportation and other infrastructure projects can increase resiliency.[16] NNBFs are natural systems or engineered systems that mimic natural processes built to minimize flooding, erosion, and runoff.[17] Natural features "evolve over time through processes operating in nature" whereas nature-based features "are created by human design, engineering, and construction to provide specific services such as coastal hazard risk reduction."[18] Examples of NNBFs include wetlands, riparian buffers, and coastal dunes.[19] There are multiple, complementary benefits of NNBFs. Specifically, flood risk is reduced for coastal buildings as natural features intercept and reduce the energy of rainfall, storm surge and tidal flooding, and flood waters are stored and slowly released by trees and wetlands.[20] NNBFs are proven to be successful in increasing community resilience to climate change impacts. This section highlights the use of wetlands, riparian buffers, and coastal dunes as a means of increasing resilience for transportation infrastructure.

1. Wetlands

Wetlands are an NNBF that can be used to mitigate flood risk.[21] Wetlands are highly regulated by both federal and state agencies.[22] Wetlands can reduce peak water flow and filter

[15] To note, incorporating natural and nature-based features is one of several options which can be used to increase the resilience of transportation infrastructure.
[16] *See* VDOT Resilience Plan, *supra* note 11, at 33-35 (identifying the incorporation of NNBFs as a key strategy in increasing the resiliency of Virginia's transportation infrastructure).
[17] Eva Lipiec, CONG. RESEARCH SERV., NATURE-BASED INFRASTRUCTURE: NOAA'S ROLE 1-2 (2020), https://sgp.fas.org/crs/misc/R46145.pdf.
[18] *Nature-Based Solutions*, VA. INST. MARINE SCI., https://www.vims.edu/ccrm/research/climate_change/adaptation/nnbfs/index.php (last visited Nov. 28, 2021).
[19] *Id.*
[20] *Id.*
[21] *See id*.
[22] *See* VA. CODE ANN. § 58.1-3666 (2016) (defining a wetland as "an area that is inundated or saturated by surface or ground water at a frequency or duration sufficient to support, and that under normal conditions does support, a prevalence of vegetation typically adapted for life in saturated soil conditions, and that is subject to a perpetual easement permitting inundation by water"). The Wetland Compensatory Mitigation program under Section 404 of

water, thereby reducing pollution.[23] An acre of wetland can store one to one and a half million gallons of floodwater, resulting in reduced flood waters on adjacent roadways.[24] For example, during Hurricane Sandy, wetlands protected over 400 kilometers of Virginia's roads by reducing flood heights by an average of 0.06 meters.[25] A University of California Santa Cruz study found that wetlands reduced Virginia's state-wide losses during Hurricane Sandy by $9.9 million.[26] The ability of wetlands to store floodwaters can reduce the risk of costly property damage and loss of life—benefits with economic value.[27]

Wetlands adjacent to transportation infrastructure can help to increase the infrastructure's resilience to climate change impacts.[28] However, wetlands themselves are threatened by climate change and rising seas.[29] One option for mitigating wetland impacts is to require permanently protected pathways for upland wetland migration without impeding roadway safety.[30] The specific parameters and dimensions of these pathways are dependent upon site-specific factors such as elevation, slope, and adjacent land use.[31] These pathways will help ensure that wetlands can continue to provide ecosystem services as the waters rise.

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the Clean Water Act calls for the restoration (re-establishment or rehabilitation), establishment (creation), enhancement, and/or in certain circumstances, preservation of wetlands, streams and other aquatic resources. The purpose of compensatory mitigation is to offset unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization has been achieved. The three mechanisms for providing compensatory mitigation are mitigation banks, in-lieu fee programs, and permittee-responsible mitigation. Compensatory Mitigation for Loss of Aquatic Resources, 73 Fed. Reg. 19,593 (Apr. 10, 2008) (codified at 33 C.F.R. pt. 332); U.S. ENVT. PROT. AGENCY, *Background About Compensatory Mitigation Requirements Under CWA Section 404*, https://www.epa.gov/cwa-404/background-about-compensatory-mitigation-requirements-under-cwa-section-404 (last visited Nov. 28, 2021); *see* 33 U.S.C. §§ 1251-1387. Avoidance means "mitigating an aquatic resource impact by selecting the least-damaging project type, spatial location and extent compatible with achieving the purpose of the project. Avoidance is achieved through an analysis of appropriate and practicable alternatives and a consideration of impact footprint."; Minimization means "mitigating an aquatic resource impact by managing the severity of a project's impact on resources at the selected site. Minimization is achieved through the incorporation of appropriate and practicable design and risk avoidance measures." U.S. ENVTL. PROT. AGENCY, *Types of Mitigation Under CWA Section 404: Avoidance, Minimization and Compensatory Mitigation*. *See generally* ENVIRONMENTAL LAW INSTITUTE, THE FEDERAL WETLAND PERMITTING PROGRAM: AVOIDANCE AND MINIMIZATION REQUIREMENTS (2008), https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/Permitting/ELI.pdf.

[23] *See* U.S. ENVTL. PROT. AGENCY, FUNCTIONS AND VALUES OF WETLANDS (2001), https://www.epa.gov/sites/default/files/2016-02/documents/functionsvaluesofwetlands.pdf.

[24] *See id.*

[25] Siddharth Narayan et al., *The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA*, 7 SCI. REP. 4-5 (2017).

[26] *Id.* at 2.

[27] *See* Narayan et al., *supra* note 25, at 4-5.

[28] *See* BECK S. NARAYAN ET AL., COASTAL WETLANDS AND FLOOD DAMAGE REDUCTION: USING RISK INDUSTRY-BASED MODELS TO ASSESS NATURAL DEFENSES IN THE NORTHEASTERN USA, 13 (2016) https://conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/CoastalWetlandsandFloodDamageReductionReport.pdf.

[29] John W. Day et al., *Consequences of Climate Change on the Ecogeomorphology of Coastal Wetlands* 31 ESTUARIES AND COASTS 477, 477 (2008).

[30] Katie Spidalier, *Where the Wetlands Are—And Where They Are Going: Legal and Policy Tools for Facilitating Coastal Ecosystem Migration in Response to Sea-Level Rise* 40 WETLANDS 1765, 1772-74 (2020).

[31] J.G. Titus et al., *State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level Along the U.S. Atlantic Coast*, ENVTL. RES. LETTERS, Oct. 2009 at 1, 3-6 (2009).

2. Riparian Buffers

Riparian buffers are another type of NNBF used to mitigate flood risk and erosion.[32] Riparian buffers store water and reduce flooding by absorbing rainwater, which recharges groundwater supplies and allows storm runoff to be released more slowly.[33] This protective action reduces the intensity and frequency of flooding on adjacent roadways.[34] Added ecologic and economic benefits of riparian buffers include erosion reduction,[35] sediment filtration,[36] pollution reduction,[37] and habitat preservation.[38] Narrow buffers can generally remove sediment in runoff.[39] Since sediment can clog storm drainage pathways and sewers, sediment reduction from riparian buffers along roadways can help to reduce flooding.[40] Virginia should consider installing or preserving riparian buffers in proximity to transportation infrastructure to mitigate flood risk.

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[32] *Nature-Based Solutions*, VA. INST. MARINE SCI., https://www.vims.edu/ccrm/research/climate_change/adaptation/nnbfs/index.php (last visited Nov. 28, 2021); *see also* VA. CODE ANN. § 58.1-3666 (2016) (defining a riparian buffer as "an area of trees, shrubs or other vegetation, subject to a perpetual easement permitting inundation by water, that is (i) at least thirty-five feet in width, (ii) adjacent to a body of water, and (iii) managed to maintain the integrity of stream channels and shorelines and reduce the effects of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals").

[33] *See* ANDREW J. CASTELLE & A.W. JOHNSON, RIPARIAN VEGETATION EFFECTIVENESS 36 (National Council for Air and Stream Improvement 2000).

[34] *See id.*

[35] A riparian buffer's roots of herbaceous and woody plants strengthen the stream bank by penetrating through the topsoil and into a stream bank's weathered or fractured bedrock and other more stable strata. This increases the stream bank cohesiveness and adds a tensile strength that can resist shear stresses on stream bank soil, thus reducing erosion. *See id.*

[36] PHYLLIS BONGARD AND GARY WYATT, RIPARIAN FOREST BUFFERS FOR TROUT HABITAT IMPROVEMENT: BENEFITS OF RIPARIAN FOREST BUFFERS 2 (2009) https://conservancy.umn.edu/bitstream/handle/11299/225578/Riparian%20forest%20buffers%20for%20trout%20habitat%20improvement.pdf?sequence=1. Riparian buffers filter sediment by increasing surface friction in the riparian zone, which increases sediment deposition on land. This is especially beneficial as trapping sediments is the most effective way to reduce nonpoint source pollution. *Id*.

[37] *See* CHESAPEAKE BAY FOUNDATION, Forested Buffers: The Key to Clean Streams 1-3 (2004) https://www.cbf.org/document-library/federal-affairs/Buffers-fact-sheet-stroud-0bb8.pdf; Charles Duhigg, *Debating How Much Weed Killer is Safe in Your Water Glass*, N.Y. TIMES (Aug. 23, 2009), https://www.nytimes.com/2009/08/23/us/23water.html; William J. Staddon et al., *Microbial Characteristics of a Vegetative Buffer Strip Soil and Degradation and Sorption of Metolachlor*, 65 SOIL SCI. SOC'Y AM. J. 1136, 1136 (2001); Lara Lutz, *Minebank Run Restoration Hits Pay Dirt in Reducing Nitrogen Loads*, BAY JOURNAL (Oct. 1, 2006), https://www.bayjournal.com/news/pollution/minebank-run-restoration-hits-pay-dirt-in-reducing-nitrogen-loads/article_76b5091c-3305-5232-afce-2dc3217a0d00.html.

[38] Bongard & Wyatt, *supra* note 36, at 1-2 (discussing how riparian buffers provide shade to moderate water temperatures and provide habitat for both aquatic and non-aquatic species); *see also* Michael Pollock et al., *Stream Temperature Relationships to Forest Harvest in Western Washington*, 45 J. AM. WATER RES. ASS'N 141, 144 (2009).

[39] Seth Dabney et al., *Integrated Management of In-Field, Edge-of-Field, and After-Field Buffers*, 42 J. AM. WATER RES. ASS'N 15 (2006).

[40] *See id* at 20.

3. Coastal Dunes

Coastal dunes are an NNBF of particular importance to low-lying coastal communities located adjacent to the ocean or Chesapeake Bay, like Norfolk and Virginia Beach.[41] They are the first line of defense against oceanside flooding and prevent or reduce coastal flooding and infrastructure damage.[42] The Virginia General Assembly acknowledges that dunes provide a buffer against coastal flooding and erosion by virtue of both their location and composition.[43] During storm surges, they serve as levees protecting landward infrastructure from waves and flood waters. Dunes also provide natural erosion protection, habitat, water quality benefits and recreation.[44] Preservation of existing dunes and construction of artificial dunes may be able to play an important role in increasing resilience in Virginia Beach and other Hampton Roads or Eastern Shore communities.

B. Incorporating Wildlife Corridors in Transportation Planning

With careful planning, wildlife corridors also can be used to both increase resilience and protect wildlife from traffic impacts. They employ the use of ecological information in the transportation design process to create a more positive union between land use and the natural environment.[45] Wildlife corridors are defined in Virginia as, "an area connecting fragmented wildlife habitats separated by human activities or infrastructure."[46] They are meant to support animal migration and movement patterns that would occur naturally in a healthy environment such as the movement of animals to find food and water.[47] Benefits of wildlife corridors include reduction in accidents, greater genetic diversity of plant and animal species, connecting isolated

[41] *See Nature-Based Solutions*, *supra* note 32. *See also* VA. CODE ANN. §§ 28.2-1400 (defining a coastal dune as "a mound of unconsolidated sandy soil which is contiguous to mean high water, whose landward and lateral limits are marked by a change in grade from ten percent or greater to less than ten percent, and upon which is growing any of the following species: American beach grass (*Ammophila breviligulata*); beach heather (*Hudsonia tomentosa*); dune bean (*Strophostyles spp.*); dusty miller (*Artemisia stelleriana*); saltmeadow hay (*Spartina patens*); seabeach sandwort (*Honckenya peploides*); sea oats (*Uniola paniculata*); sea rocket (*Cakile edentula*); seaside goldenrod (*Solidago sempervirens*); Japanese sedge or Asiatic sand sedge (*Carex kobomugi*); Virginia pine (*Pinus virginiana*); broom sedge (*Andropogon virginicus*); and short dune grass (*Panicum amarum*)").

[42] Bianca R. Charbonneau, *A Review of Dunes in Today's Society*, 43 COASTAL MANAGEMENT 465, 465 (2015); J.C. Kwadijk et al., *Using Adaptation Tipping Points to Prepare for Climate Change and Sea Level Rise: A Case Study in the Netherlands*, 1 WILEY INTERDISC. REV.: CLIMATE CHANGE 729, 734 (2010); *see also* Rusty A. Feagin et al., *Going With the Flow or Against the Grain? The Promise of Vegetation for Protecting Beaches, Dunes, and Barrier Islands from Erosion*, 13 FRONTIERS IN ECOLOGY AND THE ENV'T 203, 204 (2015).

[43] *See* VA. CODE ANN. § 28.2-1410(D) (2008); VA. MARINE RES. COMM'N, VIRGINIA COASTAL PRIMARY SAND DUNES/BEACHES GUIDELINES 5 (1993), https://www.mrc.virginia.gov/regulations/dune_guidelines.pdf.

[44] VA. INST. MARINE SCI., *Natural & Nature-Based Features: Beaches and Dunes*, https://www.vims.edu/ccrm/research/climate_change/adaptation/nnbfs/_documents/3_beachesdunes_factsheet_v3.pdf (last visited Nov. 28, 2021).

[45] THE AMERICAN SOCIETY OF LANDSCAPE ARCHITECTS, *Green Infrastructure: Wildlife Habitat and Corridors*, https://www.asla.org/ContentDetail.aspx?id=43534 (last visited Nov. 3, 2021).

[46] VA. CODE ANN. § 29.1-578 (2020).

[47] *See* U.S. FISH AND WILDLIFE SERV., *Wildlife Corridors*, https://www.fws.gov/refuges/features/wildlife-corridors.html (last visited Nov. 14, 2021); AUSTRALIAN GOVERNMENT DEP'T OF AGRIC., WATER, AND THE ENV'T, *What Are Wildlife Corridors?*, https://www.environment.gov.au/biodiversity/conservation/wildlife-corridors (last visited Nov. 3, 2021).

populations, preserving habitats, and aiding migration.[48] In 2020 and 2021, VDOT was instructed through legislation to work with other government agencies to develop a Wildlife Corridor Action Plan.[49] These corridors will greatly impact transportation by keeping roads safe for both humans and animals as well as provide another natural buffer to potentially protect roads and other transportation infrastructure from flooding. This section will next discuss two case studies which highlight the use of wildlife corridors in transportation planning.

1. Arlington County, Virginia

Arlington County, Virginia is a highly urbanized region replete with skyscrapers, major roadways, and a booming population.[50] Pollution therefore is becoming more and more common as untreated stormwater from roads, parking lots, and driveways flows into storm drains and then directly to the nearest neighborhood stream.[51] However, Arlington County, in addition to being one of two Virginia counties to manage its own roads,[52] recently has taken progressive steps towards reducing pollution due to stormwater runoff through a number of different projects, including various Green Streets projects throughout the region, often in partnership with other larger Arlington County programs such as the Stormwater Management Program and the Neighborhood Conservation Program.[53]

A "green street" is defined as "a street with a vegetated area in the public right of way that reduces the volume of stormwater and stormwater pollutants . . ."[54] The location of a green street depends on ". . . where the stormwater flows and the existing configuration of the street," and therefore "may be located between the sidewalk and the curb or in a street median."[55] Green streets operate to prevent stormwater pollutants from entering nearby streams in Arlington County, which lead to the Potomac River and the Chesapeake Bay, through the capture of those stormwater pollutants by rain gardens.[56] Rain gardens are "[t]he bowl-shaped, vegetated areas in a green street . . . [that] provide a temporary place for water to collect, be filtered by the soil and plants, and soak into the ground or be released into the stormwater system."[57] Additionally, "[a]n underground pipe,

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[48] Vitaliy Soloviy, *Habitat Corridors Boost Biodiversity, a New Study Confirms*, SUSTAINABILITY TIMES (Oct. 15, 2019), https://www.sustainability-times.com/environmental-protection/study-habitat-corridors-help-to-boost-biodiversity/; ECOLOGICAL SOCIETY OF AMERICA, *Habitat Corridors Help Preserve Wildlife in the Midst of Human Society* (Aug. 2, 2011), https://www.esa.org/esablog/2011/08/02/habitat-corridors-help-preserve-wildlife-in-the-midst-of-human-society/.
[49] VA. CODE ANN. § 29.1-579 (2021). Legislation was proposed in the 2022 General Assembly session to create a wildlife corridor grant fund, but the bill was tabled in committee. S.B. 707, Gen. Ass., 2022 Session (Va.).
[50] ARLINGTON CNTY. DEP'T OF CMTY. PLAN., HOUS., AND DEV., PROFILE 2020 1-4, 11-12, 15-16 (2020), https://arlingtonva.s3.amazonaws.com/wp-content/uploads/2020/07/Arlington-County-Profile-2020.pdf.
[51] *See* ARLINGTON CNTY. GOV'T, *Environment: Prevent Pollution* (last visited Oct. 30, 2020), https://environment.arlingtonva.us/streams/prevent-pollution/.
[52] VA. DEP'T TRANSP., *Local Assistance Division: Arlington and Henrico County Secondary Construction and Maintenance Payments*, https://www.virginiadot.org/business/local-assistance-special-federal-programs-Arl%26Henrico.asp (last visited Jan. 4, 2023); *see also* ARLINGTON CNTY. GOV'T, *Transportation: Street Maintenance* (last visited Nov. 15, 2020), https://transportation.arlingtonva.us/streets/street-maintenance/.
[53] ARLINGTON CNTY. GOV'T, *Green Streets* (last visited Oct. 30, 2020), https://www.arlingtonva.us/Government/Projects/Programs/Stormwater-Projects/Green-Streets.
[54] *Id.*
[55] *Id.*
[56] *Id.*
[57] *Id.*

or underdrain," is built into the rain garden and is connected to the Arlington County stormwater system, which "ensures that the rain garden will drain in less than 48 hours . . ."[58] Arlington County maintains the rain gardens by pruning the native plants living in them, which "can tolerate both wet and dry conditions . . . [and] grow no more than 2.5 feet above the curb;" replacing the plants when necessary; and ensuring the underdrains and overflows are functioning properly.[59] Although designed to primarily address water quality concerns, the green infrastructure elements of the Arlington County Green Streets program could also be implemented to provide flood protection benefits as well.

2. City of Norfolk, Virginia

Additionally, the City of Norfolk has implemented many green infrastructure projects designed to reduce flooding that results from gradual sea level rise, which if left unattended, would inundate the local transportation networks. Norfolk is the third-most populous city in Virginia and is flanked by the Elizabeth River to the west and the Chesapeake Bay to the north.[60] Additionally, because Norfolk is a very low-lying city, surrounded by water, and the land on which it is built is subsiding,[61] it is particularly vulnerable to rising sea levels.[62] In 2012, a study commissioned by Norfolk stated that the cost of addressing a sea level rise of one foot would cost approximately one billion dollars.[63] Additional research by the Virginia Institute of Marine Science estimated that if current sea level rise forecasts hold constant, the sea at the coast in Norfolk will rise by 5.5 feet or more by 2100.[64] To plan for these impacts, Norfolk and the Green Infrastructure Center collaborated to create a plan to "help the city 'design the coastal community of the future' by using its natural assets to improve environmental and community health and to protect infrastructure, such as roads and buildings."[65]

One major opportunity to increase Norfolk's resiliency to sea level rise included the conversion of "hardened shorelines" to "living shorelines."[66] Of Norfolk's 211 miles of shoreline, 61 miles are hardened through methods such as concrete walls and rubble fill, but 35 of those miles could be naturalized with vegetated buffers.[67] Doing so would not only reduce erosion and protect property, but it would also enable wetlands' upland migration as the water rises, which could help to prevent road flooding.[68] Additionally, 22% (378 acres) of the current 50 foot coastal buffer

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[58] *Id.*
[59] *Id.*
[60] Lori Montgomery, *In Norfolk, evidence of climate change is in the streets at high tide*, WASH. POST (May 31, 2014), https://www.washingtonpost.com/business/economy/in-norfolk-evidence-of-climate-change-is-in-the-streets-at-high-tide/2014/05/31/fe3ae860-e71f-11e3-8f90-73e071f3d637_story.html.
[61] JOHN D. BOON ET AL., VA. INST. OF MARINE SCI., CHESAPEAKE BAY LAND SUBSIDENCE AND SEA LEVEL CHANGE: AN EVALUATION OF PAST AND PRESENT TRENDS AND FUTURE OUTLOOK 26 (Nov. 2010), https://www.vims.edu/GreyLit/VIMS/sramsoe425.pdf.
[62] Montgomery, *supra* note 60.
[63] *Id.*
[64] *Id.*
[65] GREEN INFRASTRUCTURE CTR., *A Green Infrastructure Plan for Norfolk: Building Resilient Communities* 1, 2 (July 2018), http://www.gicinc.org/PDFs/GreenPlan-CityofNorfolk-FinalReport%202018.pdf.
[66] *Id.* at 31-32.
[67] *Id.* at 32.
[68] *Id.* at 38.

(which spans 1695 total acres) that is in place surrounding Norfolk is not forested.[69] If left alone, 69 of those 378 acres will be lost to sea level rise by 2040.[70] However, if action were taken to convert non-forested areas to forested areas, 1402 new acres could be added to the existing 378 acres of the current 50 foot buffer.[71] The benefits associated with this strategy include environmental beautification, cleaner water, habitat restoration, and, most importantly for the purposes of this paper, flooding and storm surge protection.[72]

Additionally, wetlands that have been prevented from naturally migrating upland in response to sea level rise because of the presence of parking lots, roads, or other impervious surfaces have begun to "jump" the impervious surface and continue growing on the other side.[73] Therefore, many streets in Norfolk are becoming bordered by marshes and wetlands on either side, thus causing the street to become a new intertidal zone.[74] As such, during flooding events, water pools in the road and causes significant damage over time. However, by installing living shorelines, the City of Norfolk is working towards reducing shoreline erosion, improving water quality, and meeting stormwater management standards.[75] Specifically, the City of Norfolk has partnered with the Chesapeake Bay Foundation (CBF) to assist property owners in obtaining the necessary permits to build living shorelines, as well as installing and monitoring the living shorelines.[76] Norfolk and CBF fund these and other projects through various grants awarded by state and federal agencies, including the National Fish and Wildlife Foundation.[77] If living shorelines are not adopted and hardened shorelines and built-out land is not re-naturalized through the use of vegetated buffers as the sea level rises, natural wetlands and marshes will ultimately become isolated because of the lack of room for them to migrate due to the large amount of impervious surfaces.[78] This will in turn threaten the quality of Norfolk's transportation networks, increase flooding and erosion, and damage both public and private property.

C. Revising Virginia's Prioritization Process for Transportation Projects

In addition to identifying potential strategies to increase the resiliency of transportation assets, the VDOT Resilience Plan also proposes the development of a methodology for assessing the vulnerability of these assets.[79] This methodology will consider the exposure, sensitivity, and criticality of a transportation asset in determining its overall vulnerability.[80] In addition to implementing this vulnerability assessment, the Resilience Plan also identifies the potential need to "evaluate the integration of the vulnerability measure into the processes established for different funding programs."[81]

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[69] *Id*.
[70] *Id.*
[71] *Id.*
[72] *Id.*
[73] Chesapeake Bay Found., *BEC Learning Series: How Nature Alleviates Flooding*, YOUTUBE (Oct. 15, 2020), https://www.youtube.com/watch?v=c1Y4kKqYGZM&feature=emb_logo.
[74] *Id.*
[75] *Id.*
[76] *Id.*
[77] *Id.*
[78] *Id.*
[79] VDOT Resilience Plan, *supra* note 11, at 21-23.
[80] *Id.* at 21.
[81] *Id.* at 23.

Virginia should thus consider revising SMART SCALE—its prioritization process to "fund the right transportation projects that generate the greatest benefit for taxpayers".[82] SMART SCALE is the System for the Management and Allocation of Resources for Transportation (SMART), and the key factors it sets forth for evaluating a project's merits are improvements to Safety, Congestion reduction, Accessibility, Land use, Economic development, and the Environment (SCALE).[83] The SMART SCALE project screening currently only considers how historical flooding levels have affected travel time.[84] By focusing exclusively on historic flooding and lacking a view toward future flood risks, this approach does not accurately capture the true threat of flooding impacts that a transportation project will face over its lifespan—which is particularly critical as sea level continues to rise, at an accelerating pace, and severe storms are increasing. Furthermore, the only element of flooding considered is the extent to which it disrupts traffic.[85] Other jurisdictions have looked to metrics such as whether the transportation project will be on an evacuation route utilized for catastrophic events such as hurricanes or flooding;[86] and the elevation of the project to reduce the risk of flooding over its anticipated useful life.[87] The SMART SCALE thus should be updated to include predictive flooding[88] and assessment of flooding impacts beyond traffic delays. Additionally, evaluated causes of flooding could include nuisance flooding, extreme weather, and upland riverine flooding.

There should also be an increase in the weight of projected environmental impacts in the SMART SCALE scoring and evaluation calculus. For example, SMART SCALE should consider the impact of increased flooding when a portion of wetlands is destroyed to build a road, bridge, or other piece of transportation infrastructure. Currently, the SMART SCALE evaluation and scoring process allocates the weight of environmental impacts to be ten percent of the total score.[89] This weighting system may be insufficient to prioritize funding of increasingly more vulnerable

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[82] VA. COMMONWEALTH TRANSP. BD., *SMART SCALE: Funding the Right Transportation Projects in Virginia*, https://www.ctb.virginia.gov/planning/smart_scale/default.asp (last visited Nov. 28, 2021).

[83] *Id.*

[84] MADHAVI KULKARNI & JULIE PHILLIPS, THE RESILIENCE ADAPTATION FEASIBILITY TOOL (RAFT), SMART SCALE FUNDING FOR INFRASTRUCTURE PROJECTS 10 (William & Mary Law School, Virginia Coastal Policy Center 2018), https://raft.ien.virginia.edu/system/files/RAFT%20Smart%20Scale%20Funding%20for%20Infrastructure%20Projects.pdf.

[85] *Id.*

[86] LA. REV. STAT. § 48:229.1(C)(7) (requiring evacuation routes for flooding and hurricanes as a metric for transportation project prioritization in Louisiana).

[87] N.Y. CITY ADMIN. CODE § 3-132 (requiring that capital projects with a construction cost greater than $10,000,000, including transportation projects, meet or exceed a minimum resiliency score. Such score shall include metrics addressing the flood resiliency of a project); *see also* N.Y. CITY DEP'T TRANSP., NYCSTREETSPLAN, 52, 90 (2021), https://www.nyc.gov/html/dot/downloads/pdf/nyc-streets-plan-spread.pdf (incorporating the resiliency score mandate of § 3-132 into transportation prioritization).

[88] In particular, predictive flooding models could be used when looking at metrics that incorporate risk of flooding over an asset's anticipated useful life. This would help ensure the asset is designed to withstand future flooding impacts.

[89] VA. COMMONWEALTH TRANSP. BD., SMART SCALE TECHNICAL GUIDE 41 (2021), https://smartscale.org/documents/2020documents/technical-guide-2022.pdf; WILLIAM HOWIESON & MICHAEL TENTILUCCI, CLOSING ROADS DUE TO INCREASED FLOODING: POTENTIAL LIABILITY ISSUES IN VIRGINIA 7 (William & Mary Law School, Virginia Coastal Policy Center 2020), https://law.wm.edu/academics/programs/jd/electives/clinics/practicum_list/vacoastal/reports/transportation-paper-4-26-213.pdf.

transportation infrastructure over other projects. In time, some of the critical transportation infrastructure will become untravellable as sea level rises. Virginia also should address procedures for prioritizing and abandoning such infrastructure.[90] Finally, Virginia should develop an interactive planning portal for use by VDOT and local planning commissions. This portal should integrate the results of the vulnerability and mitigation assessments, SMART SCALE revisions, and findings from existing Virginia efforts to better understand the impacts of natural hazards on transportation infrastructure.[91] An interactive planning portal will help prioritize projects to address vulnerable infrastructure and streamline new infrastructure projects.

III. CONCLUSION

The deleterious effects of climate-related impacts on transportation infrastructure are as diverse as they are far-reaching. Potholes pepper roads as pavement softens from high temperatures, flooded roads become impassable causing traffic delays, and steel bridges corrode as brackish water stagnates around foundations during flooding. This white paper has identified many ways in which Virginia's transportation infrastructure will continue to be adversely affected by climate change if measures are not enacted to increase resilience. The impacts of climate change on roadways and bridges can be extrapolated to various other forms of infrastructure not detailed in this report. VDOT's Resilience Plan, and incorporation of a definition of resilience within such, is a significant step toward ensuring the resilience of Virginia's transportation infrastructure. The Resilience Plan in conjunction with methods for increasing resilience in the transportation sector, such as those outlined in this paper, will put Virginia on a path to protecting its most vulnerable communities from the impacts of climate change.

[90] *See generally* HOWIESON & TENTILUCCI, *supra* note 89.

[91] For example, to gain further insight into the impact of sea level rise and nuisance tidal flooding on coastal Virginia, researchers at Old Dominion University developed an updated Coastal Virginia Sea Level Rise and Recurrent Flooding Predictive Inundation Model. The model was created through analysis of the best available existing data on coastal land elevation, sea level rise projections, land subsidence, and building and transportation assets. The model incorporates the same sea level rise curve chosen by the Commonwealth for the Virginia Coastal Resilience Master Plan, and uses publicly available light detection and ranging elevation data, building site locations, road overlays, and other data to assess impacts to the coast and related assets. GEORGE M. MCLEOD ET AL., FUTURE SEA LEVEL AND RECURRENT FLOODING RISK FOR COASTAL VIRGINIA (CCRM 2020), https://www.floodingresiliency.org/wp-content/uploads/2020/03/Future-Sea-Level-and-Recurrent-Flooding-Risk-for-Coastal-Virginia-Final-Version.pdf. In addition, ADAPTVA - short for Adapt Virginia - is an information gateway on climate change adaptation for individuals, local programs, and agencies. ADAPTVA integrates best available science, legal guidance, and planning strategies. ADAPTVA includes short and long-term sea level curves and maps, flood mapping and decision-support tools, legal and policy resources, and stories that explain adaption through maps and pictures. ADAPTVA, http://adaptva.com/ (last visited Nov. 28, 2021). Finally, VIMS has produced Coastal Locality Resilience Summaries to provide localities with supporting information to keep the public engaged with coastal resilience measures and programs. The relationships between natural features and coastal buildings most vulnerable to tidal flooding can be described with simple summary statistics. A summary for each coastal Virginia locality highlights: natural and nature-based features identified in that locality below 10-feet land elevation; benefits of protecting and increasing NNBFs; and information about what is at risk. *See* VA. INST. MARINE SCI., *Nature-Based Solutions*, https://www.vims.edu/ccrm/research/climate_change/adaptation/nnbfs/index.php (last visited Nov. 28, 2021).