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Summary Report

Context Sensitive Solutions Technical Assistance: Delaware Department of Transportation

November 9, 2016

FHWA Task Order 6501-15053

Expanding the CSS/Livability Message and Targeted Technical Assistance

June 2017

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16. Abstract

The Delaware Department of Transportation (DelDOT) hosted a technical assistance (TA) meeting on November 9, 2016, sponsored by the Federal Highway Administration (FHWA). One of the objectives of the meeting was to apply a Context Sensitive Solutions (CSS) framework to the process of integrating resiliency strategies into the operations of a state department of transportation. CSS is a method used by FHWA to inform decisions and strategies that fully integrate the context and concerns of all stakeholders relative to the project at hand. This exercise with DelDOT offered an opportunity to gain new insight into how CSS can support development of more effective climate and resiliency state and local strategies.

This report documents the TA meeting by providing the meeting's background and purpose; key takeaways; agenda; list of attendees; a summary of all presentations and discussions; and DelDOT's next steps in regards to FHWA's TA program. A review and assessment of Delaware's climate change policies is provided as an appendix to the report.

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Background and Purpose

The Delaware Department of Transportation (DelDOT) hosted a technical assistance (TA) meeting on November 9, 2016, sponsored by the Federal Highway Administration (FHWA). One of the objectives of the meeting was to apply a Context Sensitive Solutions (CSS) framework to the process of integrating climate change strategies into the operations of a state department of transportation. CSS is a method used by FHWA to inform decisions and strategies that fully integrate the context and concerns of all stakeholders relative to the project at hand. This exercise with DelDOT offered an opportunity to gain new insight into how CSS can support development of more effective climate and resiliency state and local strategies.

To inform effective planning in the coming years, the State of Delaware has prepared several key studies addressing the potential impacts of climate change on Delaware communities, local economies, and natural resources. In response to the findings and anticipated impacts, the Delaware Department of Natural Resources and Environmental Control (DNREC) Division of Energy and Climate identified three key strategies (as indicated on its website):

1. Using best available science to understand current and future climate change impacts;
2. Reducing greenhouse gas emissions (GHGs); and
3. Increasing the state's resiliency.

Thus, another objective of the meeting was to examine DelDOT's current procedures alongside the key findings of the climate change studies mentioned above, and identify opportunities to integrate the three key climate strategies into transportation planning, development, and delivery, using a CSS approach. The intended output was an implementation plan and framework for integrating climate change assessment and planning into decision making at DelDOT.

Key Takeaways

- CSS is an effective method for solving problems efficiently, and for keeping community and environmental context in mind. CSS integrates elements such as performance measures, project delivery, stakeholder engagement and context-based decision-making.
- For DelDOT, CSS ensures that programs addressing climate change and sea level rise will consider land use, socioeconomic context, and local decisions.
- Within a CSS process incorporating climate change and sea level rise resilience, attention to environmental justice can help participants with the following:
    - Recognizing which communities are vulnerable to storm impacts.
    - Knowing which communities may have high difficulty relocating.
    - Assessing both immediate impacts (e.g., storm surge) and long-term gradual changes (e.g., sea level rise).
- Because of the meeting, the following items were identified as essential elements that must be established and included in a new unified and integrated climate change/sea level policy as identified by DelDOT.
    - Mission statement (problem statement)
    - Investment strategy
    - Collaborative advisory board (multi-agency)

  - Data collection
  - Goals
  - Public outreach component
  - Design guidance
  - Political mandate
  - Plan and implementation strategy
  - Roles and responsibilities
  - Information on other state's plans and initiatives
- In addition, the items below represent the next steps in working towards the development of the policy.
  - Promote reevaluation of Executive Order 41 to provide a political mandate for adaptation and mitigation planning
    - DNREC can offer technical assistance on adaptation and mitigation planning
  - Craft draft mission statement for umbrella policy
    - Requires preliminary research on other state's plans and initiatives
  - Evaluate existing performance standards
  - Begin developing strategic plan
  - Work on outreach and public relations
    - Explain to the public that DelDOT is working on climate change adaptation and mitigation
    - DNREC has a public relations presentation to help people learn how to discuss climate change and related issues with the public

Meeting Agenda

Timeframe	Activity
8:30–9:00 AM	*Check-In*
9:00–9:15 AM	Welcome and Introductions • Rob McCleary, DelDOT • Mary Ridgeway, FHWA Delaware Division • Fleming El Amin, FHWA Office of Planning, Environment, and Realty
9:15–10:00 AM	Climate Change Context in Delaware (Presentations) • Toward a More Climate Change Resilient Transportation System – Rebecca "Becky" Lupes, FHWA Office of Planning, Environment, and Realty • Implementing Climate Change Policy Through Context Sensitive Solutions Approach – Brian Urbanek, DelDOT Operations and Maintenance • Climate Change and Adaptation Strategies for the Transportation Sector CSS and Climate Change Discussion
10:00–10:15 AM	*Break*
10:15 AM –12:00 PM	Consensus-Building Workshop: Integrating Climate Change Initiatives into Program Delivery and CSS
12:00–1:00 PM	*Lunch*
1:00–2:15 PM	Break Out: Focused Topic Discussions
2:15–2:45 PM	Focus Groups Report Out
2:45–3:00 PM	*Break*
3:00–3:45 PM	Policy Integration Framework Session • Presentation: Climate Change Strategies for Delaware – Susan Love, DNREC

	• Creating a Policy Framework Exercise • Next Steps
3:45–4:00 PM	*Wrap Up*

Meeting Attendees

This TA meeting was designed to engage key DelDOT staff—maintenance and operations personnel, planners and engineers, and natural resource specialists—in laying the initial groundwork for creating an integrated climate change/sea level rise policy. In addition to DelDOT staff, the meeting included a representative from DNREC, FHWA division and headquarters representatives, and members of FHWA's CSS support team. Becky Lupes of FHWA HQ presented remotely in the first session.

First name	Last name	Affiliation	Title
Mark	Alexander	DelDOT	Director, Maintenance & Operations
Drew	Boyce	DelDOT	Planning Director
Kevin	Canning	DelDOT	Canal District Engineer, Maintenance & Operations
Sarah	Coakley	DelDOT	Project Planner, Bike & Pedestrian
Robert	Cunningham	DelDOT	Chief, Right of Way
Mike	Simmons	DelDOT	Assistant Director, Project Development South
LaTonya	Gilliam	DelDOT	Project Manager, Environmental Stewardship
Ann	Gravatt	DelDOT	Planning Supervisor
Thomas	Greve	DelDOT	Coordinator, Maintenance & Operations
Mike	Hahn	DelDOT	Byway Program Coordinator
Mark	Tudor	DelDOT	Assistant Director, Project Development
Brian	Urbanek	DelDOT	Statewide Support, Maintenance & Operations
Mark	Luszcz	DelDOT	Chief Traffic Engineer
Robert	McCleary	DelDOT	Chief Engineer
Jason	McCluskey	DelDOT	Engineer, South District Maintenance & Operations
James	Pappas	DelDOT	Assistant Director, Performance Management
Steve	Sisson	DelDOT	Program Manager
Mary	Ridgeway	FHWA Delaware Division	Division Administrator
Nick	Blendy	FHWA Delaware Division	Environmental Specialist
Yolanda	Jordan	FHWA Delaware Division	Program Development Supervisor
Fleming	El Amin	FHWA HQ	Community Planner/Office of Human Environment
Becky	Lupes	FHWA HQ	Sustainable Transport & Resilience Team
Susan	Love	DNREC	Planner
Braden	Rosenberg	Cadmus	CSS Support Specialist
Ann	Steedly	Planning Communities	CSS Support SME
Teresa	Townsend	Planning Communities	CSS Support SME

Meeting Summary

Welcome and Introductions

DelDOT Introductions

Rob McCleary, Chief Engineer at DelDOT, kicked off the meeting with an introduction to the basic principles of CSS, along with an overview of the meeting's purpose.

Delaware has the lowest average elevation of any state in the country, exposing a substantial amount of infrastructure to the potential of sea level rise and coastal flooding. As such, climate change and resulting sea level rise are certain to impact Delaware for the foreseeable future, particularly in communities along the waterfront.

The State of Delaware has taken several steps to address the anticipated effects, including the passing of Executive Order 41, which requires that climate change be incorporated into state agency planning. In response, DelDOT has worked to incorporate language regarding climate change and its impacts into design guidance and other resources.

Delaware Department of Natural Resources and Environmental Control (DNREC) also oversaw a Sea Level Rise (SLR) Vulnerability Assessment in 2012 and a Climate Change Impacts Assessment in 2013. These assessments yielded detailed SLR inundation projections for assets in Delaware, and provided abundant baseline information against which to evaluate project impacts.

To date, the question of abandonment, "When is it acceptable to stop spending money to maintain or repair transportation assets?" remains unanswered yet critical to the effectiveness of climate change policy in Delaware. If the day comes when roads are continuously underwater due to tidal influence, DelDOT will need to consider the potential impacts and importance of that asset, including:

- What is the level of access impacted by the road being closed?
- What are DelDOT's obligations to nearby communities or residents?
- What is the cost of modifying and upgrading the asset?
- Is abandoning an option?

FHWA Division and Headquarters Offices

Mary Ridgeway, Administrator of FHWA's Delaware Division, welcomed DelDOT and DNREC attendees to the CSS TA workshop. Fleming El Amin, Community Planner with FHWA's HQ Livability Team, also provided a welcome and opening comments.

FHWA has developed several resources on CSS and climate change, including:

- Context Sensitive Solutions brochure with information on the history of CSS and examples of how CSS has been and can be incorporated into transportation planning and design (e.g., economics, design flexibility, etc.), accessible at https://www.fhwa.dot.gov/livability/resources/cssbrochure.pdf
- FHWA "Building Climate Resilient Transportation Systems" guidance to help transportation agencies understand climate risks and adaptation, including information on climate change resilience pilots across the United States, accessible at https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/bcrt_brochure.cfm.

- FHWA fact sheet titled "Climate Change and Environmental Justice: Considerations for Transportation Decision-making," accessible at https://www.fhwa.dot.gov/environment/environmental_justice/publications/ej_and_climate/index.cfm
- FHWA Tech Brief, published in hard copy only, in December 2015 titled "Incorporating Climate Change Resilience into Engineering Design."

Climate Change Context in Delaware (Presentations)

Following the welcome and introductions, the first session of the workshop centered around three short presentations meant to provide the attendees with climate change context in Delaware and a discussion introducing the concept and discussing the inter-related aspects of CSS. The presentations focused on the various roles, perspectives, and priorities related to climate change at DelDOT; climate change initiatives at the regional, state, and federal levels; and the role and relevance of CSS.

Toward a More Climate Change Resilient Transportation System

Presented by Rebecca (Becky) Lupes, FHWA Office of Planning, Environment, and Realty

Mrs. Lupes discussed how climate change can be integrated throughout the transportation system, and provided an overview of FHWA's Order 5520: Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events. Order 5520 establishes FHWA's policy related to preparedness and resilience to climate change and extreme weather events. Additionally, the final rule on Asset Management Plans and Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency events was published on October 24, 2016. It requires state agencies to incorporate risks into their asset management plans and periodically evaluate facilities that repeatedly require repair and reconstruction due to emergency events.

FHWA has produced engineering guidance documents including hydraulic engineering circulars[1] relevant to coastal and riverine transportation projects that explore ways to incorporate risks from climate change and extreme weather, including levels of effort depending on the magnitude of the problem and the scale of the project.

The final rule on Transportation Planning, which was published on May 27, 2016, included several additions to the transportation planning process related to resilience:

- A new planning factor for states and MPOs to improve the resiliency and reliability of the transportation system;
- A recommendation that MPOs consult with officials responsible for natural disaster risk reduction when developing transportation plans and programs; and
- A requirement that the metropolitan transportation plan assess strategies to reduce the vulnerability of existing transportation infrastructure to natural disasters.

[1] Examples include "Highways in the Coastal Environment: Assessing Extreme Events: Volume 2 - 1st edition" published in October 2014 and "Highways in the River Environment - Floodplains, Extreme Events, Risk, and Resilience, 2nd Edition" published in June 2016. These and other hydraulic engineering circulars can be accessed at https://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm?sort=default&archived=0

Case Studies and Examples

Several examples of climate change assessments undertaken by state DOTs were presented.

- **Maryland State Highway Administration (SHA) – Screening for SLR Impacts**

  Maryland expanded their Programmatic Categorical Exclusion (PCE) reports to address climate change impacts in March of 2015. The agency identified certain geographic areas that are potentially impacted by SLR. Project leads in these areas fill out a section of the PCE related to climate change impacts. A map showing the magnitude of expected sea level rise and limits of the proposed project disturbance can also be included with the PCE. These maps were developed as part of a vulnerability assessment that FHWA helped fund.

  Maryland SHA has plans to incorporate climate change information into the early planning process, but there currently are no established standard operating procedures (SOP) for conducting a screening-level analysis of all potential project areas.

- **Washington State Department of Transportation – Statewide Vulnerability Assessment**

  The Washington State Department of Transportation (WSDOT) conducted a statewide vulnerability assessment of all department-owned assets in each region and each transportation mode, through a series of district-level workshops and in consultation with local experts. Through this detailed process, WSDOT developed an inventory of all department-owned assets and collected corresponding climate change data using geographic information systems (GIS). The researchers then developed a risk assessment method for climate change analysis using insights gained at previous workshops, and conducted a new series of stakeholder workshops with local, regional, and state experts in ferries, rail systems, aviation, and ground transportation. Finally, WSDOT developed a map of areas identified as potentially vulnerable to climate change impacts. They have incorporated that map into the state-level environmental review process. Projects located in highly vulnerable areas are required to consider climate change during project development.[2]

- **Post-Hurricane Sandy Project – Vulnerability Assessment and Adaptation Analysis**

  Hurricane Sandy caused widespread destruction on the eastern U.S. coastline in 2012. Following this event, FHWA worked with DOTs and metropolitan planning organizations (MPOs) in the three states affected by the hurricane, Connecticut, New Jersey, and New York to assess damage and destruction to multi-modal transportation systems in those states.

  First, the assessment team conducted a review of damage to transportation infrastructure from Hurricane Sandy, Hurricane Irene, Tropical Storm Lee, and a Nor-Easter from 2011. The assessment team then conducted engineering-informed adaptation assessments of 10 specific assets including bridges, roads, and rail. The assessment considered impacts due to SLR, storm surge, extreme precipitation, and heat, as well as a variety of adaptation strategies for each facility, with a focus on physical modifications.

  The assessment team also conducted a region-wide vulnerability and risk assessment. Securing the necessary data and information required collaboration with state officials, demonstrating that stakeholder engagement and outreach can help agencies collect and evaluate quantitative and qualitative data on climate vulnerabilities and impacts.

[2] See http://www.wsdot.wa.gov/NR/rdonlyres/BDF7C3DA-4F27-4CD5-8D02-6813027A928B/0/WSDOT_ClimateGuidance.pdf

FHWA is synthesizing the findings and lessons learned from the vulnerability and adaptation assessments. into a final report. Similar resources have already been released based on separate post-Hurricane Sandy assessment projects conducted by other entities, including the Hurricane Sandy Rebuilding Strategy.

FHWA has instituted a climate resilience pilot program in partnership with state DOTs and MPOs across the country and works to provide other states with technical assistance and guidance on conducting climate vulnerability and resilience assessments.

Implementing Climate Change Policy Through Context Sensitive Solutions Approach

Presented by Brian Urbanek, DelDOT Operations and Maintenance

This presentation explored how climate change and sea level change will influence "on the ground" maintenance and operations for DelDOT. Events considered included storm events that are increasing in frequency and severity—such as snow, ice, sleet, rain, floods, and wind—as well as emergency projects for addressing them, along with issues and challenges such projects may face.

"On the Ground" Examples

Three emergency projects were highlighted throughout the presentation:

1. **Henderson Hill Road (2014)**

   Henderson Hill Road is often impacted by washout during storm events that cause an overwhelmed culvert.

2. **Upper Pike Creek Road (2015)**

   Upper Pike Creek Road was impacted by embankment failure during a storm event. The road was restored and the solution for preventing future episodes was a sloping embankment. However, DelDOT did not have an opportunity to make any modifications to the creek or provide armor to protect the road.

3. **Prime Hook Road, Jonas storm event (2016)**

   This large storm event ("Jonas") affected a 70-foot bridge and caused $1.4 million in damages. The repairs involved restoring multiple dunes that had been breached (restoration conducted by U.S. Fish and Wildlife Service), and installing a box culvert to prevent water from damming against the road. This project required two levels of permits: one to remove the debris, and another to conduct a roughly 2.5-month repair job.

Issues and Challenges for Maintenance and Operations

Permitting authorities may limit repair projects only to "Restore in Kind" restoration—that is, restoring the previous structure without making any changes that could address the root cause of the damage and protect against it happening again.

Logistical challenges can include complicated permit processes, long timelines, and limited collaboration with other local agencies

Prolonged rain can introduce debris that must be continuously removed and delays progress. Water on roads can lead to road closures that last weeks or months, causing access concerns. In such cases, regular riverine or tidal flooding is the cause—not dams.

Participant Discussion

The following participant question was addressed following the presentation.

1. When you talked about NEPA, did the updated guidance discuss how to address the human environment in addition to natural resources?

   Presenter Response:

   - The guidance specifically addresses Environmental Justice (EJ) communities, which is part of the "affected environment," section of the environmental document and which specifically concerns vulnerable populations.

Climate Change and Adaptation Strategies for the Transportation Sector

This presentation focused on the state of the science regarding climate change impacts and adaptations, and included a general overview of climate impacts, both global and regional, and gradual changes and extreme events, separately.

Highlights of Technical Assistance Gap Analysis

The climate change impacts of greatest concern to Delaware are floods (riverine and coastal) and SLR, and to a lesser degree, temperature. DNREC has conducted several climate assessments, beginning with the 2012 SLR Vulnerability Assessment and associated inundation mapping. DNREC used a "bathtub" model to determine projected inundation for 0.5m, 1m, and 1.5m SLR scenarios.

DNREC also developed a Flood Risk Adaptation Map that incorporates the SLR inundation map and the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM). The Flood Risk Adaptation Map was designed as a non-regulatory tool to help planners and stakeholders understand the potential flooding associated with SLR, which is a function of both rising ocean levels and flooding from storm surge and precipitation. Other federal agencies, primarily the National Oceanic and Atmospheric Administration (NOAA), have produced SLR and storm surge products that utilize a more detailed approach than the "bathtub" model. NOAA's Sea Level Rise Viewer incorporates local land subsidence and other factors into an inundation map. Social vulnerability and flood vulnerability and magnitude are also available layers in the SLR Viewer.

The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is a numerical model used by the National Weather Service to compute storm surge for various categories of hurricanes. The data can be useful in understanding coastal vulnerability to storm surge, which is difficult to model.

Delaware Context for Climate Change Assessment and Planning

DelDOT has already been actively involved in climate change assessment and planning. A summary of these initiatives and studies follows. These examples emerged out of planning sessions with DelDOT prior to the workshop, and from the DNREC webpage on climate change.[3]

- **Executive Order 41**: Preparing Delaware for Emerging Climate Change Impacts and Seizing Economic Opportunities from Reducing Emissions, approved in 2013.
- **Bridge Design Manual and Project Development Manual:** DelDOT has incorporated climate change language into its Bridge Design Manual and Project Development Manual.

[3] Accessible at http://www.dnrec.delaware.gov/climatechange/Pages/Climate%20change%20and%20Delaware.aspx

- **GHG mitigation initiatives:** The Clean Transportation Incentive Program provides subsidies to purchasers of clean vehicles and developers willing to install clean vehicle refueling stations. In terms of GHG mitigation, several initiatives have been working—especially incorporating GHG mitigation into transportation planning. The statewide target is a 30% reduction in GHG emissions by 2030, from a 2008 baseline. The main barriers to alternative fuel vehicles include lack of refueling infrastructure, higher vehicle prices, and lack of public knowledge.
- **DNREC Climate Change Impact Assessment (2013):** This impact assessment observed and projected climate indicators and impacts on critical sectors.
- **DNREC SLR Vulnerability Assessment (2012):** The SLR Vulnerability Assessment provided an evaluation of SLR for various scenarios, and included detailed mapping for natural resources and structures (75 total).
- **DelDOT Engineering Assessment:** The DelDOT Engineering Assessment estimated that the total cost to elevate all DelDOT assets to 1.5 meters above projected sea level rise would be $1.45 billion.

Examples of Climate Change Adaptation Projects

Examples of climate change adaptation include:

- **State Route 54 East of Fenwick, DE:** This route was protected by constructing a viaduct to elevate it above nuisance tidal flooring levels. The project cost $16 million in 2001. The road could not be elevated with fill due to environmental impacts, including the anticipated disconnection of wetlands.
- **State Route 1 after Hurricane Sandy:** One section of this route was hardened against storm surge, for a cost of $1.4 million.
- **Old Corbitt Road:** This road has low average daily traffic (ADT), however, a bridge over the section struggling with tidal flooding would cost approximately $2.5 million. DelDOT planners are considering whether it is most appropriate to invest in fixing or continuing to maintain the road, or abandon it.

Additional Assessment Resources

The FHWA Vulnerability Assessment Scoring Tool provides a detailed framework for assessing the vulnerability of specific assets to climate change. Delaware has already conducted a statewide vulnerability assessment, which included inspection of some assets or regions. Expanding the assessment process to a statewide asset inventory can aid in prioritizing infrastructure investments. Prioritization is a necessity for DelDOT, due to limitations in funding.

Conducting a resilience assessment can help translate information on vulnerability into actionable initiatives and projects. A resilience assessment identifies which assets or systems are vulnerable and may also be poorly positioned to weather and recover from an incident. Identifying high-priority assets or systems that have low resilience can help DelDOT focus its efforts effectively.

Local stakeholders and community leaders can provide context, historical knowledge, and qualitative observations. Such stakeholders should be included in resilience assessments, because quantitative data on resilience is often scarce or not available.

Another available FHWA assessment resource is the Climate Change and Extreme Weather Vulnerability Assessment Framework. The guide explaining the framework draws from experiences from several state

and regional transportation agencies. It is intended for transportation agencies seeking to assess their vulnerability to climate change and extreme weather events. The guide provides an overview of key steps necessary to conduct vulnerability assessments and utilizes real-world examples to demonstrate the variety of methods available for gathering and processing information.

Adaptation Strategies

Some of the climate adaptation strategies pursued in Delaware include:

- Coordination on the use of updated floodplain maps to assist with flood mitigation activities;
- Design and implementation of restoration activities to slow loss of coastal habitats;
- Assisting suppliers of potable water (from surface water intakes and wells) in developing strategies to protect water intakes from flooding and salt water;
- Integration of climate resiliency into project development, traffic, bridge, and highway design;
- Building transportation enhancements (pathways, trails, roadscapes, etc.) to accommodate impacts of climate change; and
- Evaluating obtaining insurance to assist in recovery from catastrophic events.[4]

In partnership with FHWA, DelDOT is also taking part in a Green Infrastructure Techniques for Coastal Highway Resilience pilot project. DelDOT will "develop conceptual designs for nature-based protection such as living shorelines for five sites along State Route 1 between Rehoboth Beach and Fenwick Island. Living shorelines techniques use several shoreline protection options that allow for natural coastal processes to remain, through the strategic placements of plants, stone, sand fill, and other structural and organic materials."[5]

Other, general climate adaptation strategies include:

- **Move assets out of harm's way:** Moving assets can be costly and face additional contextual issues in siting the new location (e.g., social, and natural resources, resident's opinions, etc.)
- **Pumps for underground infrastructure:** Pumps help keep public transit systems and tunnels dry even in heavy precipitation or flooding. Some cities (e.g., Tokyo) have even installed permanent pumps. However, it is more typically considered a stop-gap emergency measure for addressing intermittent or periodic water issues.
- **Modified ventilation grates:** This is an example of small-scale adaptation projects to prevent flooding in tunnels and underground transportation infrastructure.
- **Green infrastructure for stormwater management:** Green infrastructure is a relatively inexpensive and visually appealing way to deal with stormwater runoff. It can be included as part of ongoing planning and should be incorporated into transportation projects to the extent possible.

[4] For a more comprehensive list of strategies in Delaware, and progress to date on each strategy, see http://www.dnrec.delaware.gov/energy/Documents/2016%20Climate%20Action%20Progress%20Report/Climate%20Action%20in%20Delaware%202016%20Progress%20Report.pdf.

[5] https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/pilots.cfm

- **Living levees**: The California Bay Bridge Pilot Project Engineering Assessment was coordinated with FHWA and investigated the installation of a living levee. A living levee provides direct protection from SLR and storm surge and allows marshes to form. Marches reduce wave height and power while providing habitat and an aesthetically pleasing environment.

Adaptation Resources

- **Gulf Coast Study Engineering Analysis and Assessment:** This assessment conducted by FHWA provides a feasibility and benefit analysis for SLR and storm surge adaptations along the Gulf Coast.
- **California Metro Transit Council Climate Change and Extreme Weather Adaptation Options:** This report issued by the California Metro Transit Council offers a detailed engineering assessment for SLR and storm surge adaptation, specifically for the San Francisco Bay Area.
- **Use of Natural and Nature-Based Features for Coastal Resilience:** This report issued by the United States Army Corps of Engineers (USACE) explores the use of natural features to strengthen the resilience of coastline amidst SLR and storm surge.
- **Hurricane Sandy Rebuilding Strategy:** This strategy includes high-level guidance, but does not address specific measures for improving climate resilience.

Suggested Next Steps for DelDOT

- Synthesize the findings from the DelDOT CSS TA workshop and use them to help move from guidance to actionable plans.
- Establish policies for prioritizing capital spending and target resources for high priority adaptive measures effectively, and validate capital expenditures with thorough cost-benefit analyses.

Participant Discussion

The following questions/comments were posed during the presentation.

1. What is the status of the Old Corbitt Road project?

   Response:

   - The road floods twice each day at high tide. DelDOT needs to attend a legislative briefing and hold a public workshop to discuss options, with the hope that legislators and first responders will be supportive of a short detour.
   - How can we do anything if we can't get them to approve a detour?
     - One major question that DelDOT has acknowledged as an issue is the question of abandonment. It is difficult to communicate the benefits of abandoning a road to residents, and is particularly difficult if removing a road from the system impacts emergency response time (fire/EMS). A change in fire response time affects the provider's funding, so a proposed detour may result in loss of funding for the provider.

2. Green infrastructure can't help deal with SLR though, correct?

   Response:

   - No. However, it can help in a system where periodic tidal inundation is allowed, and green stormwater systems can help manage that water as the tide recedes.

3. There are a range of SLR projections (curves showing SLR in 2035, 2060, and 2100 were displayed). Which SLR scenario should you include in your planning? The SLR curves are produced at global level and resolved to local level using local vertical land subsidence.

   Participants responses included:

   - From a planning perspective, the pessimistic scenario might be good to look at, but it costs more money to address.
   - Is everyone aware of the Delaware Environmental Observing System (DEOS) publication? Developing a Weather and Flood Monitoring System for Transportation in Delaware – this just came out the previous week.

4. If there is a road to a town that keeps flooding at what point do we decide to stop curb pouring more money into it? If it's an environmental justice community that needs to be factored into consideration as well.

   Participants responses included:

   - Sometimes we are required to reopen flooded roads expeditiously.
   - Resource and permitting agencies should be brought into the discussion earlier. DNREC has been working in South Wilmington on wetlands restoration, and has involved the U.S. Army Corps of Engineers. The project has taken a long time, but is worthwhile. Collaboration is needed between state agencies and stakeholders.
   - The big difference in maintaining and repairing infrastructure with respect to incremental SLR verses perennially-flooded areas, is that incremental SLR affects daily lives and livelihoods, while flooding from storm surge is easier to deal with because it involves a significant amount of emergency response, and at times an influx of federal resources.

Relating CSS and Climate Change (Discussion)

The participants were engaged in a facilitated discussion to close the initial presentations on the relationship of CSS and climate change. CSS is an effective method for solving problems efficiently, and for keeping community and environmental context in mind. CSS integrates elements such as performance measures, project delivery, stakeholder engagement and context-based decision-making. Put simply, CSS is a method of formulating decisions that takes the full context and all stakeholder priorities into account, and ensures that decisions aren't reached in a vacuum. For DelDOT, CSS ensures that programs addressing climate change and sea level rise will consider land use, socioeconomic context, and local decisions.

The two main objectives for FHWA's CSS TA activities are as follows:

1. Refresh, solidify, and consolidate the meaning of CSS, which is illustrated through the brochure prepared for FHWA under the CSS TA program and shared with the group.
2. Assist individual states in initiatives that are related to CSS or could be benefit from a CSS process.

Climate change and SLR may be a key consideration when defining the environmental and design context for a plan or project. FHWA considers CSS principles as closely related to other initiatives such as sustainability, livability, environmental analysis, design flexibility, performance-based practical design, performance measures, environmental justice, and stakeholder collaboration—as highlighted in the brochure.

The discussion focused on the linkage to environmental justice and design flexibility. Within a CSS process incorporating climate change and SLR resilience, attention to environmental justice can help participants with the following:

- Recognizing which communities are vulnerable to storm impacts.
- Knowing which communities may have high difficulty relocating.
- Assessing both immediate impacts (e.g., storm surge) and long-term gradual changes (e.g., SLR).

Climate change planning also benefits from design flexibility – for example, using design exceptions to deal with a storm response process.

Consensus-Building Exercise: Integrating Climate Change Initiatives in Program Delivery and CSS

This interactive, facilitated session helped participants build a common understanding of the various program delivery initiatives relevant to climate change and SLR, by convening and synthesizing the input of multiple departmental and agency perspectives. The facilitation was conducted using the Technology of Participation (TOPS) "consensus building workshop" method. Participants were asked to reflect on how they envision climate change affecting them personally and in their work.

The next question posed was:

"What elements should guide DelDOT in providing an integrated, context-based approach to climate change and sea level rise throughout Delaware?"

The facilitator then guided the participants through generating their responses; working together to categorize the responses; and working together to name the categories.

Consensus-Building Exercise Results

The table on the following page represents group responses to the focus question. Responses were generated by smaller group table discussions and consolidated into the table below. From the input multiple break-out groups resulted in some similar responses which were noted and grouped in the same column, even though the item may have represented a slightly different meaning based on that group's discussion.

Question: *What elements should guide DelDOT in providing an integrated, context-based approach to climate change and sea level rise throughout Delaware?*		
Consideration of social impacts	**Data Collection & Analysis**	**Community Outreach**
• Public safety • Loss of recreation beach/bayshore • Commercial impacts • R/W & people impacted • Communities that are impacted • Environmental justice (EJ)	• Data & modeling • Actual/projected impacts (model confidence) • Facts • Identify resources (natural, community/human, infrastructure, public/private) • Frequency & severity of flooding • Define project-related impacts	• Develop public outreach & engagement plan • Identify stakeholders • Stakeholder engagement • Local community education & outreach • Human environment • Identify needs of setting & affected communities
Innovative Design Alternatives	**Connecting People**	**Purpose & Need**
• New/innovative solutions	• Funding prioritization (dedicated funding)	• Define problem & objective

• Effectiveness of proposed solutions • Design elements • Develop alternative solutions	• Life cycle cost analysis • Cost/Benefit • Propose maintenance responsibilities/cost • Dedicated staffing climate change/public relations • The cost • Comprehensive cost of a project	• Develop decision making process • Partnerships • Build risk assessment into prioritization • Master planning related to SLR • Short term goals • Long-term goals • Define the planning scenario • Regional evaluation (no tunnel vision) Develop prioritization process
Political Environment		
• Political will and direct leadership		

Focused Topic Discussions

Participants were asked to divide into two groups and were encouraged to distribute themselves to represent a multidiscipline perspective. Each group was assigned two of the following topics to discuss in detail:

- Design Flexibility
- Economic Considerations of Climate Change
- Livability and Sustainability
- Community and Natural Resources

Facilitators led each group discussion to identify important metrics, initiatives, and strategies in creating a climate change policy framework. Participants were urged to participate across disciplines and departments in selecting their topics of interest to provide a greater opportunity for creative idea generation and sharing of unique perspectives.

Design Flexibility

Initiatives	Contextual Considerations	Relevant Metrics
• Design exception process – must follow design manuals or go through formal exception process • Replace "in kind" following emergencies • DNREC beach re-nourishment	• Cultural and environmental resources • Regulatory framework • Project approval and permitting • Vulnerability of EJ communities	• Target elevations for flood levels • Identify existing resiliency • Policies for relocation • Coordination with FEMA • Right-of-way requirements • FHWA funding limitations
Strategies		
Adaptation	**Avoidance**	**Mitigation**

• Armoring to allow inundation periodically • Structure modification to prevent wave damage • Floating structures • Ferries or amphibious vehicles	• Buy-outs of landowners • No-builds • Natural resource management to protect infrastructure • Generic method of decision-making for all communities	• If investment is made on coastal access roads, the community should provide public beach access • Write relocation policies into adaptation and development plans

Economic Considerations of Climate Change

Initiatives	Contextual Considerations	Relevant Metrics

• Engineering cost assessment ($1.45 billion)
• Tracking maintenance and operations costs
• New EAs and EISs should incorporate climate change
• Update intensity-duration-frequency (IDF) curves
• Detailed Route 9 assessment
• University of Delaware SLR assessment
• Road vacation process (no correlated policy)
	• Two related but contrasting viewpoints:
	  ○ Integration of climate change into projects
	  ○ Development of projects to address climate change
	• Surrounding roads should be considered during bridge projects
	• Homeowners and stakeholders
	• Ongoing unplanned costs
		• Information from WO database
		• Reimbursement money from FEMA
		• Design flood elevations
		• Economic impact analysis (project level)
		• Home/livelihood damage
		• Property values
		• Development scenarios/investment scenarios (multiplier effects)
		• EJ considerations and weighting investments based on impacts to EJ communities and benefits to high-income areas

Strategies		
Adaptation	**Avoidance**	**Mitigation**
• Investment strategy for coast • How do you steer evolution of certain areas? • Risk-based asset management and planning • Project economic, social, and land use costs into planning efforts	• Can you encourage/force relocation? • Buy-out	*No strategies were discussed.*

Livability and Sustainability

Initiatives	Contextual Considerations	Relevant Metrics

• Initiatives can be in conflict, and are based on current policies and regulations
• Corridor master plans and corridor preservation
• Complete Street Policies
• Trails and pathways
• "Healthy Communities" AKA RASCL (Resilient and Sustainable Communities League)
  ○ Mostly in early stages with grant funding coming soon
  ○ Focus on municipalities, smaller places, counties
• Sea level rise – EO 41 climate
• Delaware Healthy Eating Active Living (HEAL)
• DEMA – Delaware Emergency Management Authority and the Hazard Mitigation Plan (includes climate change)
• MAP-21 environmental performance measures
• Alternative fuel programs – 95 state plug-in electric vehicle (PEV) charging stations on electric vehicle (EV) corridors
• Partnership for Sustainable Communities
• Comprehensive plan process and master planning
• TID – transportation investment districts
• Prioritize state strategies and spending to assess and define "out of play" roadways
• Three electric buses added to Dover
	• Walkability (sidewalks) and bikeability
	• Land use and development at a local level (including byways/bayshores)
	• Socioeconomic and demographic considerations (e.g., health and safety, rural vs. urban, rural character, generational context)
	• Physical considerations (e.g., historic status, utilities, accessibility, and mobility)
	• Climate issues (e.g., heat, flooding)
	• People and their needs
	• Innovation
	• Ecosystem services (protection and water quality)
	• Protected lands and partners (resource agencies, local communities, special stakeholders, NGOs)
	• Economic feasibility and acceptability
	• Legal framework and political districts
	• Access to healthcare food, jobs, recreation
		• MAP-21 Performance Measures
		• % stormwater managed and impervious area
		• Walkshare/bikeshare
		• Better bus routes to Dover
		• Transit services expanded to serve socially or economically vulnerable populations
		• # of state employees riding the bus
		• CDC – demographic with state
		• Transportation and Health Tool – 14 indicators
		• NIST Economic Decision Tool
		• Crash rates and accident rates
		• # of road closures due to flooding
		• Community vision metrics
		• Ecological tool and ecological impact matrices
		• Recent legal and economic information
		• GHG reduction and fuel consumption (include in Environmental Impact Assessment (EIA) process)
		• Review recent legal cases and lawsuits regarding Level of Service (LOS) and concurrency issues

Strategies		
Adaptation	**Avoidance**	**Mitigation**
• Tie down heating oil tank and ac units (homeowner activity) • Raise roads • Pumping • Green infrastructure and retrofitting stormwater systems • Smart material use (recycled asphalt) • Changes in behavior • Over-manage stormwater	• Don't build where sea level rise is an issue • Land use is key – get climate change into comprehensive plans now • Stormwater runoff alternatives • Revisit state strategies • Legislative input • Create smart regulations • Economic development drives state • Permits – buy development rights • Broad outreach and education	• Hazard mitigation (also adaptation and avoidance) • Reduce GHG emissions by changing behaviors • Regional market bank • Cap and trade for the NE region • Cap transportation emissions and trade or auction them off as a funding source • Tax rebates • Additional incentives for EV and other alternative fuel vehicles

Community and Natural Resources

Note: There was a considerable amount of overlap between the Natural Resources and Livability and Sustainability topic discussions. Much of the information in the Livability and Sustainability table is also relevant to the Natural Resources topic area.

Initiatives	Contextual Considerations	Relevant Metrics
• Bayshore Initiative • NEPA • Collaboration (DelDOT, DNREC, EPA, USDOT, USACE) on watershed resources, wetland impact mitigation, upland watershed restoration, and stormwater retrofits • Climate indicators for coastal areas • Monitoring at sentinel sites (DNREC) • Grant programs for community resilience, habitat (byways), and energy efficiency • Water Infrastructure Advisory Council (WIAC) – cap and trade stormwater banking program (supports community gardens) • Tree Bill – DelDOT for projects	• Demographics and EJ communities (employment, health access, schools) • Historical considerations and heritage sites • Utilities and infrastructure • Community cohesion and tolerance for impacts and change • Contaminated properties – design caps • Surface water and drinking water	• EJSCREEN Tool (EPA) • EIA • Marsh subsidence
For strategies, see Livability and Sustainability Strategies (above)		

Policy Integration Framework Session

This facilitated discussion defined the foundational aspects necessary to create an umbrella policy framework addressing climate change and created a game plan and necessary next steps following the workshop. To begin this facilitated discussion, Susan Love with DNREC gave a presentation on existing initiatives and projects in DNREC related to climate change assessment and planning.

Climate Change Strategies for Delaware

Presented by Susan Love, Planner, DNREC

The building blocks of climate change policy and activity in Delaware are: the DNREC SLR Policy, SLR Maps (Flood Insurance Rate Maps, FIRM, Flood Risk Adaptation Maps, FRAM, Sea Level Rise Maps, SLRIM), DNREC's SLR Advisory Committee (which has collected a large amount of SLR data over the past five years), DNREC's Climate Change Committee, downscaled climate models (which provide high-resolution data that is very relevant for planning efforts), and pilot projects.

Altogether, these building blocks led to the enactment of Executive Order (EO) 41 (discussed in previous section, "Delaware Context for Climate Change Assessment and Planning"). EO 41 requires that infrastructure projects take on-the-ground actions to avoid flood risk, build to 18 inches above SLR levels, and use green infrastructure wherever possible. In a large survey of state residents, 71% of respondents favored spending more money on infrastructure projects if it means they will last longer, lending support to all these measures.

Regarding the longer-term necessity of GHG reduction, the goal of a 30% reduction from 2008 levels by 2030 has not been codified and remains unofficial. Reaching this goal will require political support and legislation that encourages subsidies and initiatives to reduce GHG emissions.

To help state agencies address SLR and other issues related to flooding and climate change, DNREC has developed the following guidance:

- **Flood Avoidance and Design Guidance**

  This guidance document addresses challenges that arise in applying the same standards to the various types of building and development projects in Delaware. It includes a supplemental flood risk avoidance map that is non-regulatory and used as a screening tool. It also includes maps of projected future flood impacts. New SLR maps are expected to be released soon, but they will be very similar to existing maps. Lastly, this document informs the reader about flood risks as well as how to design sites that are resilient to flooding, how to design to decrease risk of damage, how to use green infrastructure, and how to document decisions.

- **Governor's Memo to Cabinet Committee on Climate and Resiliency (CCoCAR)**

  This memo assigns responsibility to CCoCAR for developing a mechanism to track and report GHG mitigation, identifying economic costs of GHG mitigation strategies, and developing a strategy to minimize those risks.

Most other states in the region have codified GHG reduction targets, either in enacted laws or as executive orders. In certain cases, the lack of a codified GHG mitigation goal has hindered progress. Delaware has focused internally with state agencies in recent years, and can now apply externally the knowledge it has acquired internally. Additionally, the state may establish a new governance structure that includes external stakeholders who are then granted authority to mandate GHG reductions

(tracking and reporting requirements). Given the delay in progress, extending the timeline for achieving GHG targets beyond 2030 is warranted.

There is powerful momentum in Delaware for reducing GHG emissions and improving climate change resilience. DNREC is working to develop a market-based strategy for reducing the emissions from transportation fuels via a cap-and-trade program. Such a program has the potential to generate revenue for infrastructure projects, clean transportation projects, and other GHG reduction efforts. However, it must be implemented regionally; otherwise, residents will simply leave the state to buy fuel in Maryland and avoid the added cost.

Currently, there is a disconnect between individuals' concern about climate change and their daily actions. Because taking the right action requires understanding of the situation, DNREC plans to conduct training for state agencies and stakeholders to help them understand DNREC flood avoidance maps and guidance documents. The agency is working to expand grant opportunities as well, specifically related to expanding electric vehicle use by developing the necessary infrastructure. Planning can help DNREC figure out what other legislation or policies might be needed to provide incentives (land use, tax credits, etc.).

Participant Discussion

The following participant questions were addressed following the presentation.

1. What concerns DelDOT is that in the past, EPA put air quality policies in place that were tied to funding.

   Participant Response:

   - None of the other states that have passed legislation like this have had funding tied to it. It's more a process of setting the goal, coming up with a plan, and implementing it.

2. Based upon your several years of presenting studies and leading studies, how has this been viewed by insurance agencies? How do homeowners' insurance policies or homeowners' associations view sea level rise?

   Participant Responses:

   - Insurance agents locally provide flood insurance based on FEMA maps, which don't incorporate SLR. Flood insurance is a federal process.
   - Communities that flood are often taking this into consideration. Some of the smallest towns in the state are doing the best jobs in understanding and planning for climate change. SLR has been incorporated into some comprehensive development plans. DNREC is currently working in certain areas on the ground to help municipalities incorporate climate change into infrastructure, natural resources, and flood components of the comprehensive plan. Multiple municipalities have done resilience projects that incorporate or address SLR.

Policy Framework Criteria and Next Steps

The meeting concluded with a discussion of the necessary items in an umbrella policy for addressing climate change in transportation planning, and next steps for DelDOT to begin the process of developing a climate adaptation and mitigation policy.

Policy Framework – "Must Haves" The items below represent the essential elements that must be established/included in a new unified and integrated Climate Change/Sea Level Policy as identified by DelDOT.	Next Steps for DelDOT – "The Game Plan" The items below represent the next steps in working towards the development of the policy.

• Mission statement (problem statement)
• Investment strategy
• Collaborative advisory board (multi-agency)
• Data collection
• Goals
• Public outreach component
• Design guidance
• Political mandate
• Plan and implementation strategy
• Roles and responsibilities
• Information on other state's plans and initiatives
	• Promote reevaluation of EO41 to provide a political mandate for adaptation and mitigation planning
	  ○ DNREC can provide assistance
	• Craft draft mission statement for umbrella policy
	  ○ Requires preliminary research on other state's plans and initiatives
	• Evaluate existing performance standards
	• Begin developing strategic plan
	• Work on outreach and PR
	  ○ Explain to the public that DelDOT is working on climate change adaptation and mitigation
	  ○ DNREC has a PR presentation to help people learn how to discuss climate change and related issues with the public

CSS Technical Assistance Next Steps

This meeting is part of an FHWA-sponsored CSS Technical Assistance program that supports states in applying CSS to challenges they face in the transportation sector—for example, in the case of Delaware, climate change and sea level rise. FHWA is also inviting states that have completed a CSS process to join a virtual peer exchange where they can share information and lessons learned. Each state and state agency faces unique issues, but the results and key findings of these CSS efforts can offer valuable insight to other states.

The virtual peer exchange in which Delaware is anticipated to participate will focus on the nexus of CSS, climate change, and sustainability. In addition to featuring Delaware's SLR efforts, the session will include information on FHWA's Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) and some of the INVEST pilots that relate to CSS. DelDOT and FHWA Delaware Division staff are anticipated to attend this exchange and discuss the TA meeting, and any progress made on the development of a climate change/sea level policy.

APPENDIX: Delaware Climate Change Policies, Review and Assessment

Introduction

This document presents a summary of climate change research conducted by state agencies in Delaware and the response of the government and individual agencies to the results of vulnerability assessments and climate modeling. Many of the assessments and policies are applicable statewide and provide contextual information for state agencies and local communities that are attempting to proactively address resilience to the likely impacts of climate change. The summary concludes with a brief gap assessment to identify areas where DelDOT or the State of Delaware may consider additional focus, with specific attention to efforts that support actionable implementation plans and activities.

Background

The impacts of rising sea levels and storm surges associated with large coastal storms were felt profoundly by Delaware in 2012 when Hurricane Sandy struck the mid-Atlantic and Northeast coastline. Although Delaware escaped the brunt of the storm surge and associated flooding that impacted coastal New Jersey and New York City, there was still significant damage to infrastructure and livelihoods. The storm occurred only five years after Hurricane Irene resulted in up to 10 inches of rain across Delaware. Partly in response to these storms, and the increased attention in coastal resilience that followed Hurricane Sandy, the Governor of Delaware signed Executive Order 41 in 2013 to require statewide agencies to plan and design projects that increase resilience to flooding and sea level rise. The order requires state agencies to develop recommendations for adaptation options, and directs the state to set greenhouse gas (GHG) mitigation goals (30% reduction from 2008 levels by 2030). To oversee the development of guidance materials and evaluation targets, EO 41 also established the Cabinet Committee on Climate and Resiliency, with workgroups focused on adaptation, flood avoidance, and mitigation.

Climate Change Impact Assessment (CCIA)

Delaware has made significant progress towards understanding the potential climate change risks for the state and how they impact the environment, health, and infrastructure. A comprehensive evaluation of climate risks, the Climate Change Impact Assessment (CCIA), was completed in 2014, using observed climate data from 1895 to 2012 to determine historical trends in temperature, precipitation, and drought indices. The assessment was designed for policy makers, practitioners, and other stakeholders to be used as a reference and resource to inform the planning process and development of adaptation guidance. The CCIA also documents projected future changes in climate indicators related to temperature and precipitation for the state of Delaware to 2100. Using both low emission and high emission scenarios, projected changes were modeled using an ensemble of 13 global circulation models. By 2040, average annual temperature is projected to increase from 1.5 to 2.5°F, and by 2.5 to 4°F by 2060. Similarly, annual precipitation is projected to increase by up to 10%. Of potentially greater concern to state and local planners and managers, the number of extreme heat days (>90°F) and heavy precipitation days (>2 inches of rainfall) are also expected to increase. Preparing for the impacts of a changing climate requires an understanding of how these risks may affect a variety of sectors, and how the interdependencies across sectors present both challenges and opportunities for proactive and climate-resilient planning.

The CCIA identified potential impacts from projected climate changes, including impacts to infrastructure. Risks to transportation infrastructure include impacts from:

- **Temperature** – Rising temperatures and an increase in the frequency of extreme heat days' can result in deterioration of roadways and bridges, with ancillary issues associated with electricity demand and cooling water use.
- **Precipitation** – The greatest threat to infrastructure from increased precipitation comes in the form of extreme storm events, which can cause rapid erosion and flood damage to infrastructure such as bridge piers and culverts. Increased precipitation and storm frequency may result in more regular and prolonged floods than previously experienced.
- **Sea Level Rise and Storm Surge** – Rising sea level can cause significant long-term impacts to coastal road and bridge infrastructure.

Sea Level Rise (SLR) Vulnerability Assessment

The Sea Level Rise Vulnerability Assessment was completed in 2012 to provide a very detailed evaluation of SLR in Delaware including the causes of SLR, trends in Delaware and regionally, potential SLR scenarios, and a detailed mapping effort for natural resources and structures that will likely be impacted by SLR. The results of this assessment provide the foundation for a prioritization assessment of critical infrastructure. Global sea level is expected to rise by anywhere from 2.7 to 9.4 inches by 2035 and 18 to 74 inches by 2100. Compounding global changes, most Delaware has a negative vertical land movement, meaning the land surface is dropping, of between 0.04 and 0.07 inches per year, which would result in additional relative sea level rise of up to 1.4 inches by 2035 and 5.9 inches by 2100 on top of global changes.

Department of Natural Resources and Environmental Control (DNREC) Sea Level Rise Advisory Committee

Other guidance documents have been developed to supplement the CCIA and SLR Vulnerability Assessment, with the objective to provide recommendations and guidance that help practitioners understand and prepare for the impacts of climate change. The Sea Level Rise Advisory Committee of the Department of Natural Resources and Environmental Control (DNREC) developed Recommendations for Adapting to Climate Change in 2013 to supplement the SLR Vulnerability Assessment and provide recommendations to agencies, local governments, businesses and citizens on how to prepare for and adapt to climate change. The document does not focus on specific adaptation measures or initiatives, but provides a framework for ongoing planning and implementation efforts. As a follow-up to the recommendations document, a stakeholder workshop was held in 2014 focused on implementation of the SLR recommendations. Representatives from a variety of sectors were present and the workshop was structured to develop specific implementation actions. One of the breakout groups were focused on Transportation and Infrastructure and defined implementation activities specific to those sectors, although the activities are relatively broad and relevant for planning and strategy, but are not specific to increasing the resilience of transportation infrastructure to climate change. To provide more specific implementation guidance, additional resources have been developed for flood risk avoidance, including SLR, and the use of green infrastructure for stormwater planning and flood risk management.

DelDOT SLR Considerations in Project Development and Design

DelDOT has incorporated information on SLR into the Bridge Design Manual requiring construction projects to incorporate measures that increase resilience to floods, erosion, and SLR using natural systems and green infrastructure where practical. Following these guidelines, any structures within an area mapped by DNREC as vulnerable to SLR (based on the SLR Vulnerability Assessment mapping effort) are required to be designed and constructed to account for anticipated SLR during the lifespan of the structure, in addition to existing FEMA flood levels. Transportation projects should incorporate DNREC SLR scenarios into long-term planning efforts for infrastructure, facilities, land management, land use, and capital spending. Similar SLR language has been added to the Project Development Manual for DelDOT. To better understand the implications of sea level rise on transportation infrastructure and capital expenditures, DelDOT developed a preliminary cost estimate for raising the entire state's roadway network above the 1.5m predicted SLR by 2100. Engineering-based estimates were used to reflect project costs for all roads and bridges identified using the "bathtub" model method. The total estimated cost is $1.45 billion ($1.34 billion for roads; $114 million for bridges), with Priority 1 and 2 assets accounting for $946.1 million. The evaluation identified the county with the highest number of vulnerable assets (Sussex County) and the costliest reconstruction projects (Coastal Route 1 - $158 million; Route 9 - $74 million). As highlighted by this evaluation effort, DelDOT is committed to incorporating SLR and associated impacts into short- and long-term transportation planning.

Gap Analysis

Despite substantial effort being placed on quantifying and understanding climate risks and impacts in Delaware, there are still areas where additional guidance and assessments would be valuable. The gaps identified in this section are relevant to all state agencies, but are specifically tailored to DelDOT and its priorities.

Prioritization of Capital Expenditures for Asset Preservation and Maintenance

Currently, DelDOT may wish to consider developing policies that guide capital spending to protect and maintain infrastructure assets affected by SLR. These policies could match statewide policies across all agencies (EO 41). A system of prioritization can help with allocating resources to projects that may have the greatest benefit to surrounding communities and the environment. DelDOT may wish to consider developing a method or process for asset prioritization, with guiding questions that include:

- What types of infrastructure assets are most vulnerable?
- What locations are most vulnerable?
- What types of infrastructure assets are most costly to maintain? To replace?
- What is the context surrounding a specific asset, in terms of surrounding communities and ecosystems?
- What vulnerable populations may be adversely affected?

In conducting the preliminary engineering cost evaluation for adapting all parts of the roadway network to SLR, DelDOT identified the need for additional studies that combine storm surge and SLR models to determine the maximum vulnerability for all assets. This is a complicated process, but one that could help target infrastructure investments to areas at highest risk. To factor in economic concerns, Delaware could develop a model to help prioritize climate change investments for transportation infrastructure based on the use-case of the infrastructure, the average economic activity the infrastructure supports, and the likelihood of infrastructure impairment or failure as a function of climate impact. The foundation for this type of assessment could be developed from Delaware's SLR Vulnerability

Assessment. Through the lens of Context Sensitive Solutions, DelDOT may wish to consider using multiple climate and vulnerability indicators across a range of sectors (e.g., biodiversity indices, population in 100-year floodplain, percent population below poverty line, etc.) to help prioritize infrastructure investments. This type of relative vulnerability assessment can help identify areas that are particularly vulnerable to climate change across a range of sectors or concerns, thereby fostering synergy between transportation infrastructure projects and the surrounding social, economic, and environmental system.

Justification for Capital Expenditures on Resiliency

Another gap in the existing climate change research and planning is lack of a connection between capital investments and the benefits of adaptation. The documentation of climate change trends and potential impacts in the CCIA and the SLR Vulnerability Assessment currently do not provide policy guidance that can be undertaken to increase resilience to climate change impacts. Findings from these assessments could be linked with implementation strategies to decrease vulnerability to climate change risks and increase the ability of communities and the state to respond to climate impacts. Projected changes in a range of climate indicators could be incorporated into an economic analysis that monetizes the potential costs of these events on Delaware's transportation infrastructure. These costs could provide economic justification to invest in adaptive management strategies that provide overall cost-savings to Delaware. Similarly, the CCIA could be linked to a cost-benefit analysis of different adaptation policies under various funding scenarios. EPA has developed this type of tool for water and wastewater utilities, the Climate Resilience Evaluation and Awareness Tool (CREAT), which helps utilities monetize the economic consequences of different climate threats and the benefits of adaptive measures, and then calculates a monetized risk reduction to help identify if an adaptation plan is an economically-viable option. The fundamentals of this evaluation tool could be applied to transportation assets and adaptive measures to help provide a quantitative basis for investment decisions.

Conclusion

Delaware has made strides in climate change vulnerability by conducting comprehensive assessments of projected climate change and vulnerability to SLR, and by establishing statewide directives to incorporate climate change and associated risks into agency activities. Based on these assessments it appears that the state has a relatively complete understanding of potential climate change and the impact of temperature, precipitation, extreme storms, and sea level rise on state operations, infrastructure, and the livelihoods of residents. Given the abundance of existing assessments and strategic guidance, state agencies have a robust foundation from which to take the next step in planning and implementation of climate change adaptation options. A few critical gaps exist in the current state of the science in Delaware, specifically related to prioritization of assets. For DelDOT, asset prioritization is a complex activity that could account for both the transportation infrastructure and the surrounding social and environmental system. Developing a procedure for prioritizing capital expenditures based on a combination of asset vulnerability, economic cost and impact, and the relationship to priorities for interrelated sectors can help DelDOT implement proactive adaptive measures that increase the resilience of the transportation system to the impacts of climate change.