Avoiding and Minimizing Risk of Flood Damage to State Assets:

A Guide for Delaware State Agencies

Prepared by the Delaware Flood Avoidance Workgroup Under Executive Order 41

March 2016

About this Document

This document provides state agencies with guidance and step-by-step instructions for avoiding and minimizing flood risk to state assets as mandated by Governor Jack Markell's Executive Order 41: *Preparing Delaware for Emerging Climate Impacts and Seizing Economic Opportunities from Reducing Emissions.* The guidance and instructions within this document will help state agencies ensure that flood risks–both existing flood risk and future risks posed by climate change–are considered during the planning and design of public buildings and infrastructure projects.

This document will be periodically revised as new tools and techniques become available for avoiding and reducing risk of flood damage to state assets.

Acknowledgements

This document was prepared by the Executive Order 41 Flood Avoidance Workgroup for the purpose of providing a planning resource for state agency personnel tasked with building or providing funding for structures or infrastructure so that they can minimize the potential of future flood damage.

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Executive Summary

As a low-lying coastal state with 381 miles of shoreline, Delaware is vulnerable to flooding, coastal erosion, storm surge, saltwater intrusion, and tidal wetland losses. The impacts of climate change, including sea level rise and increased frequency and intensity of rainfall, will exacerbate these issues statewide. In recognition of this, Executive Order 41, in part, requires state agencies to incorporate measures for adapting to increased flood heights and sea level rise in the siting and design of their projects.

The state's Flood Avoidance Workgroup was convened to help state agencies meet this requirement. Composed of members from six state agencies, this group developed new mapping tools to aid in understanding future flood risk, identified programs and policies that should be updated, and identified methods for avoiding and minimizing the potential for flood damage to state assets.

Avoiding and Minimizing Risk of Flood Damage to State Assets: A Guide for Delaware State Agencies provides state agencies with a set of principles and step-by-step instructions for ensuring that flood risk—both existing flood risk and new risks posed by climate change—is considered during site selection and during project design.

The principles are:

- Understand existing and future flood risk on potential project sites
- Avoid project sites within areas of existing or future flood risk
- Incorporate design measures to minimize risk of flood damage where avoidance is not feasible
- Incorporate green infrastructure measures to minimize risk of flood damage
- Document the flood risk reduction measures selected and their rationale

It is anticipated that the resources contained in the guide will be used by state agencies constructing structures and infrastructure projects and by state agencies that provide grant funding or loans for these activities. The Flood Avoidance Workgroup identified eleven existing state agency policies and programs that should incorporate the principles for reducing risk of flood damage and recommended modifications. Recommendations included revising design manuals for roads and bridges, modifying criteria for revolving fund programs, and updating coastal federal consistency procedures, among others. These recommendations were approved by the state's Cabinet Committee on Climate and Resiliency in 2014.

Members of the Flood Avoidance Workgroup will be available to provide technical assistance to state agencies and others to incorporate these principles and procedures into their project planning and design process. This document will be periodically revised as new tools and techniques become available for avoiding and minimizing risk of flood damage to state assets.

Background & Purpose

As a low-lying coastal state with 381 miles of shoreline, Delaware is vulnerable to flooding, coastal erosion, storm surge, saltwater intrusion, and tidal wetland losses. The impacts of climate change, including sea level rise and increased frequency and intensity of rainfall, will exacerbate these issues statewide. In recognition of this, Executive Order 41, in part, requires state agencies to incorporate measures for adapting to increased flood heights and sea level rise in the siting and design of its projects.

Delaware's Vulnerability to Flooding and Sea Level Rise

Delaware's vulnerabilities to inland and coastal flooding and drainage challenges, coastal storms, and rising sea level pose risks to public infrastructure, private property, and human health and safety. More than 17 percent (331 square miles) of the state's land area lies within a Special Flood Hazard Area (SFHA), also known 1-percent annual chance floodplain, as mapped by the Federal Emergency Management Agency (FEMA). This flood-risk area includes more than 600 road miles and more than 18,000 structures.[1] However, these are not the only places in the state vulnerable to flood damage. Areas outside of a mapped floodplain area can experience flood damage as a result of large storms, poor drainage or upstream development patterns. In addition, floodplain maps are drawn based upon historic data; their boundaries do not reflect impacts of future development or impacts of climate change. For these reasons, using floodplain maps alone may underestimate the actual chance that a site will experience flooding.

The Great Marsh near Lewes is inundated by a high tide in September, 2014.
Credit: Susan Love, DNREC

The state has conducted significant work to develop climate change scenarios and projections and to use these to understand the potential impacts of climate change on our state's resources and quality of life. The primary effects of climate change in Delaware will be rising sea levels,

1 Delaware Floodplain and Drainage Standards and Recommendations (2013). http://www.dnrec.delaware.gov/swc/pages/floodplainanddrainagecodeworkgroupcommittee.aspx

increased intensity and frequency of rainfall, and increased average temperatures. Rising sea levels and increased potential for large rainfall events will contribute to the risk of flooding throughout the state in the coming decades.

Sea levels are rising in Delaware at a rate of between 3.4 millimeters and 3.6 millimeters per year; this is equivalent to an increase of over one foot in 100 years.[2] Accelerated rates of sea level rise are anticipated, and the state is planning for an increase in sea levels between 0.5 meter (1.6 feet) and 1.5 meters (4.9 feet) by 2100.[3] Increases in sea level will cause impacts statewide, including temporary flooding or permanent inundation of wetlands and uplands, saltwater intrusion into freshwater supplies, and rising water tables. At the highest scenario for sea level rise, 11-percent of the state's land mass could become inundated.[4]

Rainfall patterns are also changing. Historic weather data indicate that Delaware has experienced an increase in autumn precipitation. In addition, global climate models used in combination with historic rainfall data, project future increases in the frequency and amount of heavy precipitation events in Delaware.[5] Heavy rain events often result in local flooding and, when combined with high tides and the incremental impacts of sea level rise, overwhelm rivers and streams, as well as stormwater and wastewater systems, causing extensive damage to public buildings, infrastructure, homes, and businesses.

The Cost of Flooding to Delaware

In Delaware, state government bears many of the costs and responsibilities for managing and mitigating the impacts of flooding. When property owners or communities have flooding or drainage problems, the Department of Natural Resources and Environmental Control (DNREC) responds to requests for assistance. For example, between 2007 and 2011, DNREC and its three County Conservation District partners responded to more than 2,000 requests for assistance with drainage problems at the homeowner or community level. DNREC also provides assistance to individuals and communities who have difficulty getting affordable flood insurance due to noncompliant construction or floodplain maps that are inaccurate.

When flooding affects roads and highways, the Department of Transportation (DelDOT) and Delaware Emergency Management Agency (DEMA) coordinate road closures, evacuation routes, and emergency response to ensure public safety. DelDOT also bears significant costs for repair and maintenance of flood-damaged transportation infrastructure.

2 NOAA Tides and Currents (2015). http://tidesandcurrents.noaa.gov/sltrends/sltrends.html

3 Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware (2013). http://www.dnrec.delaware.gov/coastal/Pages/SLR/DelawareSLRAdaptation.aspx

4 Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment (2012). http://www.dnrec.delaware.gov/coastal/Pages/SLR/DelawareSLRVulnerabilityAssessment.aspx

5 Delaware Climate Change Impact Assessment (2014). http://www.dnrec.delaware.gov/energy/Pages/The-Delaware-Climate-Impact-Assessment.aspx

Significant public expenditures, both state and federal, have also been invested in repair and remediation of flood damage and drainage problems. For example, $65 million has been appropriated through the state's 21st Century Fund for drainage-related construction improvements since 1996.

A nor'easter in October 2015 caused tidal flooding throughout the state. In Milford, the Mispillion River overtopped its banks, flooding business and roads adjacent to the river.
Credit: Chris Bennett

Addressing Existing and Future Risks of Flooding

The state of Delaware has made significant efforts to evaluate and address existing and future risks of flooding. As an example, legislation was passed in 2011 to help the state identify actions that could be taken to address ongoing inland and coastal flooding. This legislation resulted in improvements to local floodplain ordinances statewide. In addition, the state has been a leader in assessing and preparing for future climate impacts, many of which will exacerbate existing flooding issues in the state.

The St. Jones River flooded downtown Dover during Hurricane Irene in August 2011 causing damage to a popular restaurant. The Delaware Public Archives building, on the right, is at a higher elevation and was not affected by the flooding.
Credit: Delaware Coastal Programs

Senate Bill 64

In 2011, Governor Markell signed into law Senate Bill 64, which established a Floodplain and Drainage Advisory Committee to address the state's vulnerability to inland and coastal flooding and drainage issues. The committee produced flood damage reduction standards for local land use and building code departments to consider adopting. [6] These standards are more protective than the minimum standards required to participate in the National Flood Insurance Program, which most Delaware communities had previously adopted. As of late 2014, a large percentage of communities have adopted many of these higher standards. Buildings and developments designed and built to these higher standards get lower-priced flood insurance, are far less likely to be flooded, reduce flooding impacts on adjacent areas, and decrease environmental impacts to coastal and river floodplain habitats.

6 Delaware Floodplain and Drainage Standards and Recommendations (2013). Available online: http://www.dnrec.delaware.gov/swc/pages/floodplainanddrainagecodeworkgroupcommittee.aspx

Sea Level Rise Adaptation Plan

Delaware has also completed detailed analyses to identify the state's vulnerability to sea level rise and to develop strategies to address its vulnerability. In 2012, *Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment for the State of Delaware* was completed, outlining and gauging the extent to which the state will be affected by sea level rise. This assessment includes an extensive mapping appendix depicting the exposure of seventy-nine resources to sea level rise under three scenarios. *Preparing for Tomorrow's High Tide: Recommendations for Adapting to Sea Level Rise in Delaware* was published in September 2013 and contains a set of 55 recommendations for the state and its partners to pursue to prepare for and adapt to the changes that sea level rise will bring to the state. Both documents were developed with the assistance and approval of a diverse stakeholder committee, and included significant public outreach and public engagement.

Executive Order 41

Building upon the work and recommendations of the initiatives described above, on September 12, 2013, Governor Jack Markell signed Executive Order 41: *Preparing Delaware for Emerging Climate Impacts and Seizing Economic Opportunities from Reducing Emissions*. Executive Order 41 directs the state to address both the causes and consequences of climate change by developing recommendations to:

- Reduce greenhouse gases that contribute to climate change (climate mitigation);
- Increase resilience to climate impacts, including increasing temperatures, changes in precipitation, and sea level rise (climate adaptation); and
- Avoid and minimize flood risks that increase state liability and decrease public safety (flood avoidance).

To begin implementation of Executive Order 41 (EO 41), three workgroups were formed to develop recommendations for the key issues identified in the order: The agency Points of Contact group, the Mitigation Workgroup, and the Flood Avoidance Workgroup. The agency Points of Contact group serves as the adaptation workgroup and leads the development and implementation of agency specific adaptation recommendations. They also provide oversight and coordination for the overall EO 41 effort. The Mitigation Workgroup is developing strategies to achieve a greenhouse gas reduction goal of 30% by 2030. The Flood Avoidance Workgroup is creating tools to help state agencies meet the goal of avoiding and minimizing flood risks in the siting and design of state projects. This document is one such tool. The analysis and recommendations of these three work groups are summarized in the 2015 Climate Framework for Delaware, available online at http://www.dnrec.delaware.gov/energy/Pages/Climate-Framework.aspx.

Flood Avoidance Workgroup

Executive Order 41 directs state agencies to "incorporate measures for adapting to increased flood heights and sea level rise in the siting and design of projects for construction of new structures and reconstruction of substantially damaged structures and infrastructure" (see Appendix

D). It calls for avoidance of new structures in flood-prone areas and special design standards for structures where avoidance is not practicable. It also calls for the use of "natural systems or green infrastructure to improve resiliency wherever practical and effective."

The Flood Avoidance Workgroup (FAW) was convened to develop a process and products to assist state agencies in meeting the flood risk avoidance and minimization directives of EO 41. The group was led by DNREC staff and included representatives from those state agencies most likely to be affected by the flood risk directive: Delaware Department of Education; Delaware Department of Natural Resources and Environmental Control; Delaware Department of Transportation; Delaware Office of Management and Budget; Delaware Office of State Planning Coordination; and Delaware State Housing Authority.

A permanent sign has been installed in the Primehook community in Sussex County to warn residents and visitors when the road may be impassable due to flooding. Credit: Susan Love, DNREC

Over a period of about 18 months, the FAW discussed and determined the state agencies and types of state projects affected by the requirements of EO 41. The FAW also discussed policies and procedures that could be used to help implement the requirements of EO 41 and made recommendations for changes to these policies and procedures. The FAW members also worked together to develop new digital mapping products to aid state agencies in understanding future flood risks and developed a set of instructions to guide state agencies through avoiding and minimizing flood risks.

FAW members will provide assistance as necessary to state agencies as they design projects to avoid and minimize flood risk, and will provide assistance in implementing changes to policies and procedures to incorporate flood avoidance standards.

Avoiding and Minimizing Flood Damage to State Assets

State Agencies Subject to EO 41

All state agencies are subject to the provisions of EO 41 for both construction projects and long-range planning. A definition for state "agency" is provided in Delaware Code Title 29, Chapter 69 §6902. This is the working definition used by the Flood Avoidance Workgroup during the development of this guidance document.

Projects Subject to EO 41

Projects conducted directly by a state agency that involve construction of new structures or infrastructure are subject to the requirements of EO 41. Projects conducted directly by a state agency that reconstruct "substantially damaged" structures or infrastructure are also subject to its requirements. Substantially damaged structures and infrastructure are those for which the cost of restoring the structure to its pre-damaged condition equals or exceeds 50 percent of the replacement cost of the structure.

"All state agencies shall incorporate measures for adapting to increased flood heights and sea level rise in the siting and design of projects for construction of new structures and reconstruction of substantially damaged structures and infrastructure." –EO 41 §4.a.

State agency programs that provide grants or loans to non-state entities for construction and reconstruction projects should follow, to the extent possible, the requirements of EO 41. State agency policies, procedures, and grant criteria used for selecting and allocating grant funds for structures and infrastructure should be updated to incorporate the principles listed below for flood avoidance and minimization.

In this guidance, "structures" generally refers to buildings intended for human occupation, including offices, state service facilities (e.g., health, social services, law enforcement), and other public buildings (e.g., housing, judicial, and legislative). "Infrastructure" generally refers to other structures, including transportation facilities (e.g., roads and bridges), water and wastewater facilities (e.g., wells, treatment facilities, pump and pipeline structures), water control structures (e.g., dikes, dams, and impoundments), and public use and tourism structures (e.g., wildlife viewing platforms, rest-rooms, visitor centers, and museums).

Consistency with Federal Policies

Many state projects rely on federal funding contributions. Challenges have often arisen when state and federal requirements for development within flood-prone areas are not consistent; however, recent actions taken at the federal level have ensured consistency between state requirements and federal requirements. Federal Executive Order 11988 requires federal agencies to avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. Amendments to Executive Order 11988, ordered by President Obama in January 2015,[7] require that federal agencies consider and design for the impacts climate change will have to future flood heights. These amendments align the federal standard with Delaware's existing and planned state and local standards, including EO 41.

Principles for Avoiding and Minimizing Flood Damage to State Assets

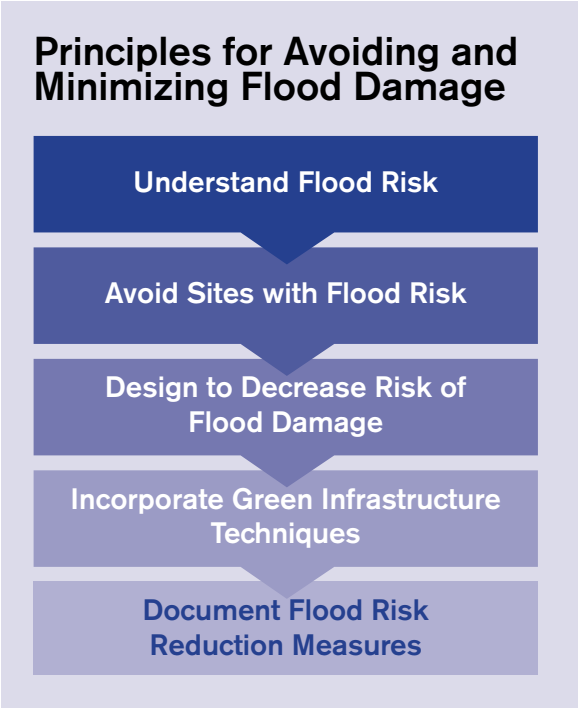
The principles for avoiding and minimizing flood damage in new and reconstructed state structures and infrastructure follow accepted practices for flood mitigation while incorporating climate

7 Information about EO 11988 as amended can be found online: https://federalregister.gov/a/2015-02284

change and green infrastructure considerations. Step-by-step instructions for inclusion of these principles into project planning and design are outlined in Appendix A.

Understand existing and future flood risk on potential project sites

State agencies should research and gain a full understanding of the existing and future flood risk that exists in and around the location of a potential project. Where several sites are being considered, each site should be researched for its flood risk. Only sites that are not at risk to flooding should be considered. A suite of mapping tools is available to assist in the assessment of flood risk. These tools are fully described in Appendix B.



Avoid project sites within areas of existing and future flood risk

The best and most effective way to reduce potential of flood damage to structures and infrastructure is to locate them in areas not subject to existing or future flood risk. When this is not feasible, flood risk can be minimized by moving the structure to minimize its intrusion into flood-risk areas, by choosing locations outside of wave hazard and erosion zones, and by choosing locations where flood depths are shallowest, where risk to human life is decreased, and where additional development in high-risk areas will not be supported.

Avoidance of flood risk may not be feasible in every circumstance. Water-dependent structures, including docks, piers, boat ramps, bridges, and beach recreational facilities, must often be located in areas at risk to flooding to meet their intended goal. Infrastructure investments will be needed within flood-risk areas to serve existing homes and businesses. Special consideration must also be given to providing necessary services and infrastructure improvements to environmental justice communities that are located within flood-prone areas. It is also important to ensure that environmental justice communities, both within and outside of flood-prone areas, are not disproportionately affected by construction of structures and infrastructure.

Design project to incorporate measures to minimize risk of flood damage where avoidance is not feasible

Where avoidance is not feasible, design measures that reduce the risk of flood damage should be incorporated into a project's design. EO 41 requires that structures constructed in areas subject to flood risk be designed a minimum of 18 inches above Base Flood Elevation. In tidal areas, structures must be designed 18 inches above Base Flood Elevation plus anticipated sea level rise. Structures can be also designed to keep floodwaters from seeping into the building and to secure tanks and mechanical equipment to avoid damage and spills. Selection of construction

Base Flood Elevation is the computed elevation to which floodwater is anticipated to rise during the 1-percent annual chance flood event.

materials should also consider tolerance of those materials to flooding. Appendix A contains instructions for obtaining Base Flood Elevation and calculating anticipated sea level rise. It also contains a list of resources for design considerations.

Incorporate green infrastructure measures to minimize risk of flood damage

Green infrastructure is a nature-based approach to address environmental challenges such as stormwater runoff, flooding, erosion, and water and air pollution. At the site scale, green infrastructure functions by mimicking the processes that occur in larger, natural systems. Incorporating green infrastructure measures like bio-swales, raingardens, and green roofs to manage water on-site can reduce a structure's vulnerability to damage from a given flood event. Green infrastructure at the larger, landscape scale should also be considered a benefit for projects adjacent to natural habitat. Forests, wetlands, and vegetated shorelines can increase climate resiliency by slowing or storing surface runoff and buffering the impacts of storm surge. The state has recently completed a stand-alone Green Infrastructure Primer to assist with the selection of appropriate green infrastructure strategies. The Primer can be downloaded online at www.de.gov/greeninfrastructure.

This rain garden at the Lewes Campus of the University of Delaware is a nature-based method to collect and store stormwater runoff from the parking lot that also provides habitat for pollinators and birds.
Credit: Delaware Sea Grant

Document flood risk reduction measures selected and their rationale

Documenting the process and rationale used to select sites and design structures and infrastructure is essential to ensuring that state agencies are following the requirements of EO 41. This documentation will be a necessary part of several state policies and procedures (outlined below) and can serve to help refine and improve this guide over time.

Using Maps to Identify Existing and Future Flood Risk

The Flood Insurance Rate Maps produced by the Federal Emergency Management Agency (FEMA) are the most frequently used mapping tool to estimate potential flood risk on a particular parcel of land. However, these maps do not take future sea levels and precipitation patterns into consideration; they utilize historic data and current conditions to depict flood risk, while flood risks are increasing over time.

These two images depict existing and future flood risk at the St. Jones Reserve. The St. Jones Reserve is owned and operated by DNREC and is one of two components of the Delaware National Estuarine Research Reserve (DNERR). Staff from the DNERR conduct research and monitoring of the estuary, and deliver this information to the public through educational programming for children and adults and training opportunities for professionals. The buildings and infrastructure located at the St. Jones Reserve are vulnerable to flooding and future sea level rise.

The map at the top depicts the area at risk of flooding today. The darker blue depicts the area that is inundated at mean higher high water; the lighter blue is the area at risk to inundation during a 1% chance annual flood event, as delineated on the Flood Insurance Rate Map (FIRM).

The map at the bottom depicts the extent of inundation expected to occur in the future. The yellow depicts the area that would be inundated at mean higher high water with 3 feet of sea level rise; the light brown is the area at risk to inundation during a 1% chance annual flood event with 3 feet of sea level rise, as delineated on the Flood Risk Adaptation Map (FRAM).

As sea levels rise, the St. Jones Reserve will have an increasing risk of flood damage to buildings and equipment. Using these maps and other climate data, DNERR staff have already completed a vulnerability assessment for their lands and facilities and will incorporate climate adaptation strategies into future capital projects.

Maps depicting potential areas of inundation from sea level rise were developed by DNREC Delaware Coastal Programs Office in 2009 and are widely used to understand potential impacts of sea level rise. However, these maps depict only where the higher mean high tide line could be in the future and do not depict the additional impact of either storm surge or rainfall.

Due to limitations of existing mapping products available for decision making, DNREC engaged the services of an engineering consultant to develop a statewide map that depicts the combined risk of sea level rise and coastal storms. This combined map, the Flood Risk Adaptation Map, depicts the extent of flooding that could occur during a 1-percent annual chance flood event if mean sea levels are 3 feet (0.9 meter) higher than they are today. Only one sea level rise scenario (a 3-foot increase in mean sea levels) was modeled due to funding limitations. This selection was recommended by the FAW technical experts as a reasonable compromise that allows users to visualize areas that would be inundated by floodwaters by late century at moderate levels of sea level rise, and by mid-century should sea levels rise at a more rapid rate (closer to the high scenario of 4.9 feet [1.5-meters]). These maps do not depict increased risks associated with changes in coastal landforms, increased wave heights associated with deeper coastal flooding, and other related hazards.

A more detailed description of each of these mapping tools, including how to download, view and use the maps, is included in Appendix B.

Instructions for Avoiding and Minimizing Risk of Flood Damage to State Assets

To help state agencies incorporate the principles above into their projects, a set of instructions for avoiding and minimizing flood damage to state assets was developed by the Flood Avoidance Workgroup. These instructions (Appendix A) guide users through a process of understanding flood risk on a site and avoiding construction of new structures and infrastructure in flood-prone areas. If it can be determined that avoidance of flood risk is not feasible, the instructions also help a user find and select the appropriate flood level and adaptation strategies.

Infrastructure designs and locations are constrained by a number of factors that are frequently different from those for structures. Infrastructure serves populations and by necessity must be located where it can provide those services. In addition, infrastructure often functions as a networked system, where relocation of one part of the system may not be feasible. The instructions prepared for state agency use reflect differences between structures and infrastructure.

The instructions for avoiding and minimizing flood risk are not meant to replace state, federal, or local codes; all state projects must continue to comply with the applicable requirements.

Incorporating the Principles into State Policies and Procedures

The FAW members identified 11 programs and policies essential to ensuring adoption of the flooding and sea level rise provisions of EO 41 into state projects and recommended they be updated (see text box). These recommendations were included in the Climate Framework for Delaware, and approved by the Cabinet Committee on Climate and Resiliency in 2014. Implementation of these recommendations requires integrating flood avoidance and design into planning and decision-making across multiple state agencies.

Recommended changes to state policies and procedures to avoid and minimize risk of flood damage to state assets

Department of Natural Resources and Environmental Control

- Modify the Preliminary Engineering Report Guidance Document required for Water Pollution Control Revolving Fund applications to incorporate the provisions of EO 41.
- Modify the Water Pollution Control Revolving Fund Project Priority List criteria to incorporate the provisions of EO 41.
- Modify Delaware Coastal Management Policies to incorporate the provisions of EO 41.

Department of Transportation

- Modify the DelDOT Development Coordination Manual to incorporate the provisions of EO 41.
- Modify the DelDOT Bridge Design Manual to incorporate the provisions of EO 41.
- Modify the DelDOT Road Design Manual to incorporate the provisions of EO 41.

Office of Management and Budget

- Modify the Final Design Review Checklist used by Facilities Management to incorporate the provisions of EO 41.
- Modify the Preliminary Review Checklist for State Clearinghouse to incorporate the provisions of EO 41.
- Consider carrying flood insurance for critical state properties in areas identified through the Flood Risk Adaptation Map.

Office of State Planning Coordination

- Modify the Preliminary Land Use Service Applicant Checklist to incorporate questions regarding sea level rise and combined flooding impacts.
- Modify the Strategies for State Policies and Spending to incorporate the Flood Risk Adaptation Map.

Statewide Implementation and Next Steps

Implementation of this guidance is already underway. Several state agencies have revised policies and programs in accordance with the recommendations approved by the Cabinet Committee on Climate and Resiliency. New mapping tools are being integrated into state map databases and planning documents. Flood avoidance and design principles have been incorporated in the siting and design planning process for several state projects.

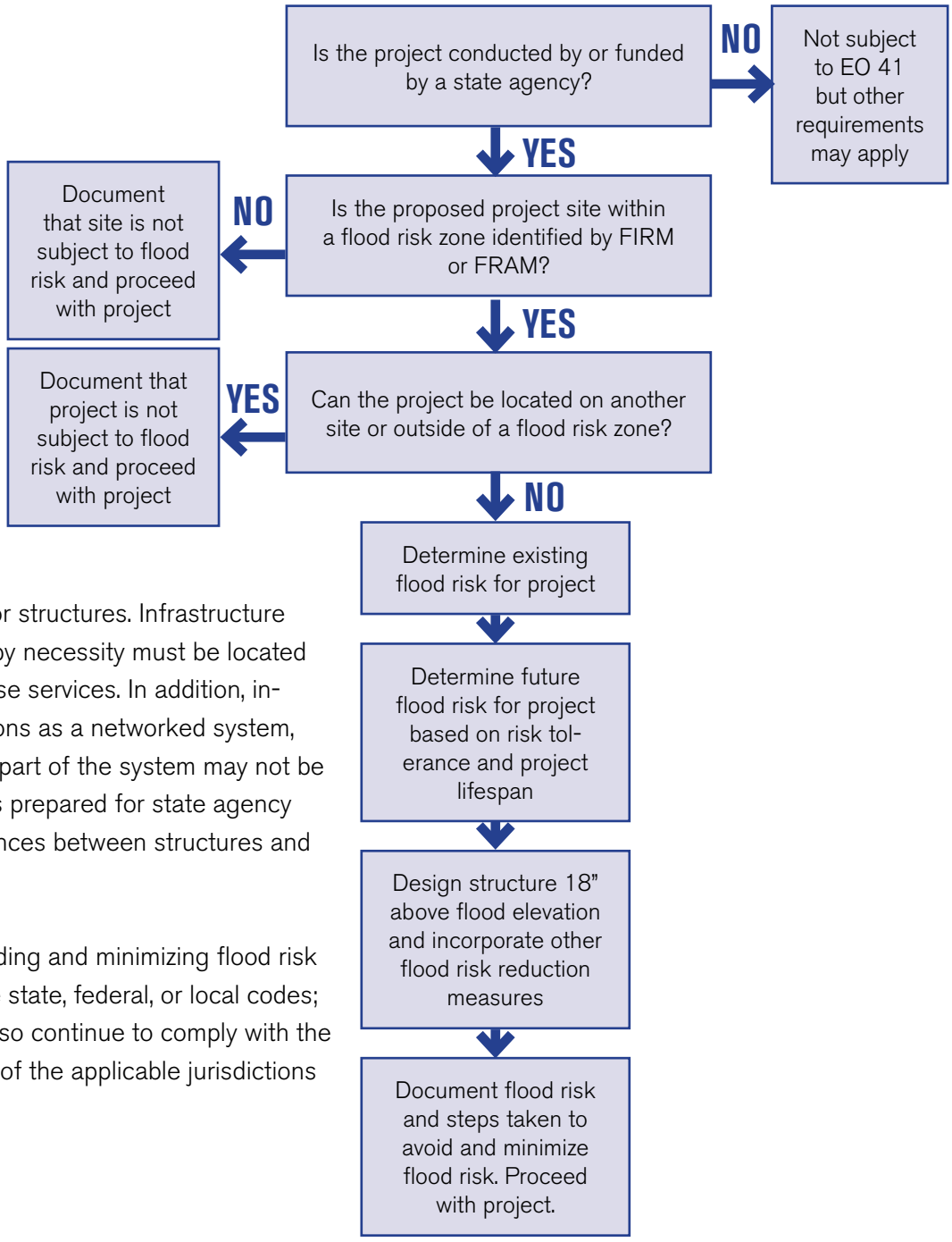
Members of the Flood Avoidance Workgroup will continue to provide technical assistance to state agencies and others to incorporate these principles and procedures into their project planning and design process. This document will be periodically revised as new tools and techniques become available for avoiding and minimizing risk of flood damage to state assets, or as the methods outlined in the step-by-step guidance are refined. Members of the FAW will periodically report progress made toward the goal of avoiding and minimizing flood damage to state assets to the Cabinet Committee on Climate and Resiliency.

Heavy Rain from Tropical Storm Henri in September 2003 caused significant flooding of the Red Clay Creek and surrounding areas. Flood waters covered Route 4 in Stanton and caused significant damage to businesses and homes.
Credit: Michael Powell, DNREC

APPENDIX A – Instructions for Avoiding and Minimizing Risk of Flood Damage to State Assets

To help state agencies incorporate principles to avoid flood risk in their projects, the Flood Avoidance Workgroup (FAW) developed this set of step-by-step instructions. The instructions below guide users through a process of understanding flood risk on a site and avoiding construction of new structures and infrastructure in flood-prone areas. If it can be determined that avoidance of flood risk is not feasible, the instructions also help a user find and select the appropriate flood level and strategies to reduce risk of flood damage.

FIGURE 1. Flowchart of Instructions for Avoiding and Minimizing Risk of Flood Damage



Infrastructure designs and locations are constrained by a number of factors that are frequently different from those for structures. Infrastructure serves populations and by necessity must be located where it can provide those services. In addition, infrastructure often functions as a networked system, where relocation of one part of the system may not be feasible. The instructions prepared for state agency use reflect these differences between structures and infrastructure.

The instructions for avoiding and minimizing flood risk are not meant to replace state, federal, or local codes; all state projects must also continue to comply with the applicable requirements of the applicable jurisdictions they are working within.

Part 1: Flood Avoidance

The best and most effective way to minimize risk of flood damage to state assets is to locate them in areas not subject to existing or future flood risk. This avoids potential flood damage to state and public assets and minimizes the state's financial liability for such damage. Use the following steps to determine if avoidance of flood risk is feasible for your project:

Flood Avoidance for Structures

Step 1: Define the function and characteristics of the structure(s) you wish to build.

The following list demonstrates several of the types of information necessary to determine if avoidance is feasible:

- Is the structure for a water-dependent use?
- What is the expected life span of the structure?
- Once built, will the structure need to be maintained in-place? If so, for how long?
- Will the structure provide housing, shelter, or emergency services or provide a critical function?
- What population will the structure serve? How many people? Does it impact an environmental justice community?
- What is the relative cost of the structure?

Step 2: Identify potential sites.

Site selection processes differ by agency and project type. Project managers are encouraged to identify several sites that can be evaluated for their suitability. While identifying potential sites, project managers should consider the following questions:

- Are the potential sites state-owned property?
- Are there existing structures or existing infrastructure on the site?

Step 3: Compare potential sites to flood risk maps.

- Evaluate existing flood risk of potential sites by locating site on the Flood Insurance Rate Map (FIRM). Access routes to the site should also be considered in this evaluation.
    - If within a flood hazard zone, note the Base Flood Elevation (BFE) and corresponding Flood Zone.
- Evaluate future flood risk of potential sites by locating sites on the Flood Risk Adaptation Map (FRAM). Access routes to the site should also be considered in this evaluation.
    - If within a CD or CE zone, note the zone and combined flood depth or combined elevation.

Step 4: Avoid sites in flood-risk areas.

- Eliminate sites in the 1-percent annual chance floodplain as depicted on the FIRM.
- Eliminate sites in areas designated as "CD" and "CE"[8] on the FRAM.
- Consideration should be given to access routes in and out of the site. For example, if a facility must be accessible during storm events and a proposed location has access routes within a CD or CE zone, the proposed site may not be suitable.
- If avoidance of flood-prone sites is not feasible, see *Part 2: Minimizing Flood Risk Where Avoidance Is not Feasible*.

Step 5: Continue following the pertinent state and federal guidance and policies for your project.

Step 6: Document your decision-making process.

Document the considerations described above to record the rationale for site selection (or site elimination). Be sure that state agencies charged with implementing and tracking EO 41 provisions can easily understand that the project is in compliance with the principles for reducing flood risk.

Agencies are also encouraged to incorporate cost-benefit determinations in their documentation when appropriate and feasible. Long-term considerations for sites with flood risk such as increased repair cost, human risk, infrastructure vulnerability and liability for response should be weighed against the upfront costs of land purchase and construction.

Flood Avoidance for Infrastructure

Step 1: Determine the function and characteristics of the infrastructure(s).

- Does the infrastructure serve a water-dependent use, or require immediate proximity to flooding sources?
- What is the expected life span of the infrastructure? Is it likely to be repaired/rebuilt/relocated or become obsolete within the next 30 to 50 years?
- Is the infrastructure resistant to flooding or inundation damage by its nature?
- Does the infrastructure provide emergency services or provide a critical function that will be affected impacted by flooding or inundation?
- What population will the structure serve? How many people? Does it impact an environmental justice community?
- What is the relative cost of the infrastructure versus costs of alternative flood-resistant siting or design?

8 *CE, or Combined Flood Hazard Elevation*, represents areas of future flood risk, based on the elevation of 1-percent annual chance storm surge plus 3 feet SLR.
CD, or Combined Depths, represents the depth of water above local ground, based on sheet flow depth, primarily related to the overtopping of dunes.

Step 2: Identify potential sites/linear routes.

Site selection processes will differ by agency and project type. Project managers are encouraged to identify several sites or linear routes that can be evaluated for their suitability. While identifying potential sites, project managers should consider the following questions:

- Are the potential sites state-owned property?
- Are there existing structures/infrastructure on the site?

Step 3: Compare potential sites to flood risk maps.

- Evaluate existing flood risk of potential site, and its access routes, by locating site on the FIRM.
    - If within a flood hazard zone, note the Base Flood Elevation and Flood Zone.
- Evaluate future flood risk of potential site, including access routes, by locating the site on the FRAM.
    - If within a"CD" or "CE" zone, note the zone and combined flood depth or combined flood elevation.

Step 4: Choose site that avoids CD and CE areas to the maximum extent practicable.

The most effective way to eliminate flood risk is to locate infrastructure outside of existing and future flood hazard areas. When this is not feasible, flood risk can be minimized by placing as little infrastructure as possible within flood-risk areas, choosing locations outside of wave hazard and erosion-prone areas, where flood depths are shallowest, where human risk is decreased, and where additional development in high risk areas will not be supported.

Step 5: Determine next steps.

- If avoidance of CD and CE areas is practicable:
    - Document your decision-making process (Step 6 below).
    - Continue following the pertinent state and federal guidelines for your project.
- If avoidance of CD and CE areas is not practicable:
    - Follow the steps outlined below in *Part 2: Minimizing Flood Risk Where Avoidance Is not Feasible.*
    - Utilize design guidance for each candidate location and select location that provides the greatest opportunity for flood risk reduction.

Step 6: Document your decision-making process

Document the considerations described above to record the rationale for site selection. Be sure that state agencies charged with implementing and tracking EO 41 provisions can easily understand that the project is in compliance with the principles for reducing flood risk.

In addition, for projects within CD or CE areas, state agencies should consider conducting a cost/benefit study. Long-term considerations for sites with flood-risk such as increased repair cost, human risk, infrastructure vulnerability and liability for response should be weighed against the upfront costs of land purchase and construction to ensure that the benefits of providing new or expanded services within a CD or CE area outweigh the long-term cost of construction and maintenance. State agencies could also consider whether a retreat and/or avoidance strategy would be cost-effective as part of a cost/benefit study.

Part 2: Minimizing Flood Risk Where Avoidance Is not Feasible

Where avoidance is not feasible, state agencies building new structures, repairing substantially damaged structures, building new infrastructure, and/or repairing substantially damaged infrastructure should:

1. Determine the existing flood risk on the parcel(s),
2. Determine future flood risk on the parcel(s),
3. Select design measures to decrease impacts from flooding, and
4. Select green infrastructure techniques to further minimize potential flood risk.

To determine flood risk, users will the FEMA Flood Insurance Rate Map and Delaware's Flood Risk Adaptation Map. Information about these maps, including how to view and download the maps, can be found in Appendix B.

Step 1: Determine existing flood risk on the site

a) Obtain Base Flood Elevation.

Obtain Base Flood Elevation (BFE) for the site(s) from the effective Flood Insurance Rate Map (FIRM).

- This elevation is the expected height that floodwaters will reach during a 1-percent annual chance storm.

b) Determine whether the site is within a tidally influenced flood zone.

Use the Flood Risk Adaptation Map (FRAM) to determine if the site(s) is within a tidally influenced flood zone. If yes, you will need to consider future flood risk in your project design as laid out in step 2. If no, skip to Step 3.

- If the site is within a CD or CE area in the FRAM, your project site is in a tidally influenced flood zone.

c) Determine exposure to wave action.

Determine whether the site(s) is within an area likely to be exposed to high or moderate wave action during the lifetime of the project.

- Sites currently mapped in the V-zone on the FIRM are subject to 3 foot or greater wave heights and are subject to mandatory V-zone design regulations
- Sites currently mapped within the Limit of Moderate Wave Action (LiMWA) on the FIRM are subject to 1.5 foot or greater wave action. It is highly recommended that either V-zone standards, or other designs, be used to protect against wave forces.

Step 2: Determine future flood risk for sites within tidally influenced areas (CD or CE areas)

a) Determine appropriate sea level rise (SLR) planning scenario.

Choose a scenario for sea level rise based on risk tolerance for flood damage or loss. The following are suggestions based upon risk tolerance for loss. Agencies are encouraged to use their best judgement:

- Use a minimum of 0.5 meter (1.6 feet) of SLR by 2100 for structures that, if damaged, would have limited to no impacts to the economic well-being and safety of the surrounding community:
  i. Docks, piers, and recreational amenities
  ii. Structures for temporary habitation (e.g., restrooms, seasonal facilities)
  iii. Storage facilities not containing hazardous materials (e.g., gas, oil, chemicals)
- Use a minimum of 1.0 meter (3.3 feet) of SLR by 2100 for structures that, if damaged, could have limited to moderate impacts to the economic well-being and safety of the surrounding community:
  i. Office buildings and visitor centers
  ii. Single or multi-family residences
  iii. Storage facilities containing hazardous materials
  iv. Healthcare facilities (non-hospital)
  v. Schools, colleges, daycares, and nursing homes
- Use a minimum 1.5 of meters (4.9 feet) of SLR by 2100 for structures that, if damaged, could have significant impact to economic well-being and safety of surrounding communities or the state:
  i. Hospitals and emergency rooms
  ii. Fire, police, and paramedic stations
  iii. Water and wastewater facilities
  iv. Power generators and industrial facilities

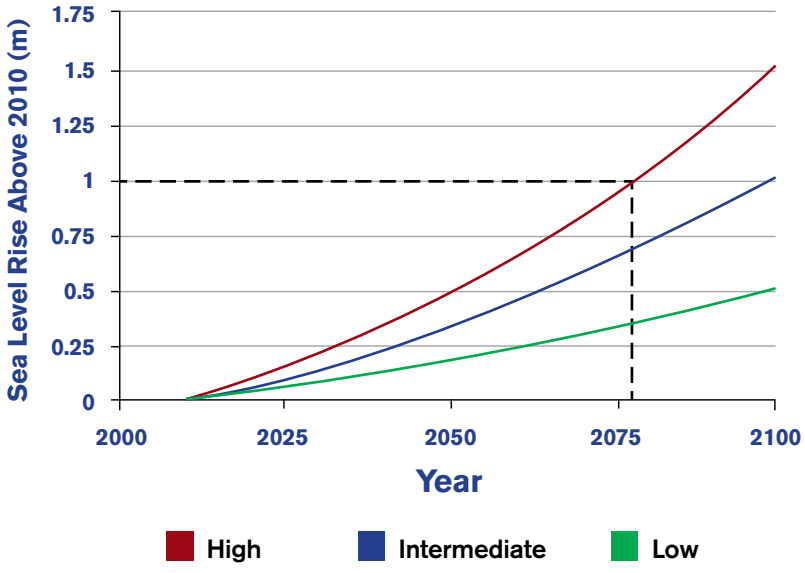
b) Determine life-span of structure.

- Determine the number of years that the structure would be expected to be useful without major renovations or upgrades.
- Agencies are encouraged to take the long view and increase the number of years of expected life span if the structure is likely to be renovated or re-built in place after its useful lifespan has expired.

c) Determine sea level rise height for project.

- The amount of sea level rise that the project should be designed to accommodate is a factor of the structure's anticipated life span and the consequences if the structure is damaged.
- Use the Sea Level Rise Scenario graph below to select the appropriate level of sea level rise to incorporate into your design:
  i. Find the final year the structure is anticipated to be in service on the x-axis.
  ii. Find the curve for the sea level rise scenario selected in step a above.
  iii. Select the sea level rise height where the curve and year intersect.
  iv. An example is highlight below on the dashed lines.
- Consider additional limiting factors:
  i. If ancillary facilities, access roads, utilities, and other supporting structures become compromised at lower SLR scenario, consider those risk factors in selecting a building useful lifespan, building design, and in the site selection process in the first place. For example, if the only road access to a proposed facility becomes inundated at 0.5 meter of sea level rise over 30 years and is unlikely to be rebuilt, the road becomes a limiting factor for the lifetime of the proposed structure, and should be considered.

DNREC Sea level Rise Scenarios



Example: If you choose to plan for 1.5m of SLR and the project lifespan is to 2077, the project should be designed for 1.0m of sea level rise.

d) Determine future flood elevation.

- Add your sea level rise height as determined in step c to the BFE to determine your future flood elevation.
- As an example, if the base flood elevation is 7 feet (2.1 meters), and your selected sea level rise height based on risk tolerance and lifespan is 3 feet (0.9 meter), your future flood elevation is 10 feet (3.0 meters).

Step 3: Select and incorporate measures to reduce flood risk.

For Structures

a) Locate the building footprint on the portion of the land parcel least exposed to flood risk.

b) Raise the structure 18 inches (1.5 feet) above the flood elevation:
   - For non-tidal areas, raise building 18 inches (1.5 feet) above BFE as depicted on the effective FIRM published by FEMA.
   - For tidally influenced areas, raise building by 18 inches (1.5 feet) above the future flood elevation as calculated in Step 2 above.
   - Note: Fill to raise the land elevation is discouraged except in certain circumstances and where it can be proven that such fill will not negatively affect adjacent or downstream parcels.

c) Employ best management practices for design and construction of structures including selection of foundation type, building materials, construction methods, utility placement, etc.
   - Selection of building design and material should consider the tolerance of materials to flooding and the potential environmental impacts of inundation and damage.
   - Refer to FEMA Technical Bulletins for specific guidance concerning best practices and building requirements of the National Flood Insurance Program (NFIP). All of the bulletins below are available online at: http://www.fema.gov/floodplain-management/nfip-technical-bulletins:
     i. *Openings in Foundation Walls and Walls of Enclosures (Technical Bulletin 1)*: Provides guidance on the NFIP regulations concerning the requirement for openings in foundation walls located below BFE.
     ii. *Flood Damage-Resistant Materials Requirements (Technical Bulletin 2)*: Provides guidance on the NFIP regulations concerning the required use of flood damage-resistant construction materials.
     iii. *Non-Residential Flood-proofing: Requirements and Certification (Technical Bulletin 3)*: Provides guidance on the NFIP regulations concerning watertight construction and the required certification for flood-proofed non-residential buildings whose lowest floors are below BFE.
     iv. *Elevator Installation (Technical Bulletin 4)*: Provides guidance on the NFIP regulations concerning the installation of elevators below the BFE.

v. *Free-of-Obstruction Requirements (Technical Bulletin 5)*: Provides guidance on the NFIP regulations concerning obstructions to flood waters below elevated buildings and on building sites in Coastal High Hazard Areas.
vi. *Below-Grade Parking Requirements (Technical Bulletin 6)*: Provides guidance on the NFIP regulations concerning the design of below-grade parking garages beneath buildings.
vii. *Wet Flood-proofing Requirements (Technical Bulletin 7)*: Provides guidance on the NFIP regulations concerning wet flood-proofing of certain types of structures.
viii. *Corrosion Protection for Metal Connectors in Coastal Areas (Technical Bulletin 8)*: Provides guidance on the need for, selection of, and use of corrosion-resistant metal connectors for the construction of buildings in coastal areas.
ix. *Design and Construction Guidance for Breakaway Walls below Elevated Coastal Buildings (Technical Bulletin 9)*: Provides guidance on the NFIP regulations concerning the design and construction of breakaway walls beneath elevated buildings in Coastal High Hazard Areas.
x. *Ensuring that Structures Built on Fill In or Near Special Flood Hazard Areas are Reasonably Safe From Flooding (Technical Bulletin 10)*: Discusses building techniques, including the use of fill, that can be used to ensure structures are reasonably safe from flooding.
xi. *Crawlspace Construction for Buildings Located in Special Flood Hazard Areas (Technical Bulletin 11)*: Provides interim guidance on minimum NFIP requirements as well as best practices for crawlspace construction in the Special Flood Hazard Area.

- FEMA deploys assessment teams following flood events to evaluate building damage. The following reports present the conclusions and recommendations for codes and standards based on these field observations:
    i. FEMA 338, Building Performance Assessment Team (BPAT) Report - Hurricane Georges in the Gulf Coast (1999). Available online: http://www.fema.gov/media-library/assets/documents/2070
    ii. FEMA 490, Mitigation Assessment Team Report: Summary Report on Building Performance 2004 Hurricane Season. Available online: http://www.fema.gov/media-library/assets/documents/943
    iii. FEMA 548, Summary Report on Building Performance: Hurricane Katrina 2005. Available online: http://www.fema.gov/media-library/assets/documents/1054

iv. FEMA P-757, Hurricane Ike in Texas and Louisiana: Mitigation Assessment Team Report, Building Performance Observations, Recommendations, and Technical Guidance (2009). Available online: http://www.fema.gov/media-library/assets/documents/15498

v. FEMA P-942, Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York (2013). Available online: http://www.fema.gov/media-library/assets/documents/85922

For Infrastructure

a) Locate infrastructure in areas least vulnerable to flood impacts, especially wave action (VE and LiMWA zones on FIRM), long term and storm induced shoreline change, debris impacts and debris deposition.

b) Employ best management practices for design, construction and maintenance of any infrastructure within a flood-risk area. Examples include:

- Raise electrical components for pumping stations above the base flood and/or future flood elevations, flood-proof any openings, and use submersible pumps.
- Size culverts and sewer pipes appropriately to accommodate anticipated future flows.
- Inspect against leaks into pipes and through manholes.
- Bury power lines and ensure that they are protected from erosion and scour.
- Set the elevation of bridges to accommodate continued navigation with increased sea levels.
- Protect against erosional forces through green infrastructure techniques. Hardening of shorelines is discouraged unless the site is prone to strong currents or heavy wave action. Any proposals for hardening of shorelines should include an assessment of related impacts such as erosion, effect on sediment budgets, habitat impacts, and future maintenance costs.

Special Considerations

a) Existing structures and infrastructure

Minor renovations and upgrades to existing structures and infrastructure are not subject to this guidance; however, all capital projects represent an opportunity to increase flood resiliency. Use of this guidance to identify best practices for reduction of flood risk is encouraged even for minor renovations and upgrades.

b) Environmental justice and vulnerable populations

Special consideration should be given to the needs of environmental justice communities and/or vulnerable populations. For example, a project could be constructed within a flood-prone area if it is necessary to serve a low-income, minority, elderly, or environmental justice community and would not be feasible elsewhere. In considering alternate locations, it is also important to ensure that environmental justice communities, both within and outside of flood-prone areas,

are not disproportionately affected by construction of structures and infrastructure. Regardless, any structure or infrastructure built within a flood-risk area to serve environmental justice or vulnerable communities should be designed to minimize risk of flood damage using the steps above.

c) Historic structures

Reconstruction of historic structures must follow this guidance. Exceptions should be the minimum necessary to maintain continued historic designation. Typically, flood reduction strategies will be used for historic structures since relocation or rebuilding above the Base Flood Elevation would affect the historic characteristics that need to be preserved. Protective structures or site-specific green infrastructure techniques may also be options for reducing the risk of flood damage to historic structures.

d) Water-dependent uses

Structures that must be located near water to meet the intended use do not need to go through an avoidance process; however, they must still be constructed to reduce risk of flood damage, as outlined in this section.

e) Flood risk of surrounding land

Land uses and future flood potential of areas adjacent to and surrounding a proposed structure, including roadways and pedestrian access, should be scrutinized and taken into consideration for site selection and design.

f) Funding and statutory conflicts

There may be unusual circumstances where funding and/or federal regulations prohibit practices outlined in this document. In these cases, state agencies may need to weigh the benefits of funding opportunities versus the future costs of higher levels of flood risk. In all cases, federal agencies should be contacted to request an allowance for the higher standards described in this guidance. Where a decision is made to waive certain provisions of this guidance due to a federal requirement, those decisions and communications with the federal agency should be documented.

Step 4: Decrease potential flooding and erosion on parcel through green infrastructure techniques

a) Green infrastructure techniques can be integrated into project design to reduce the potential damage from flood impacts. Green infrastructure practices can use site-specific or watershed-scale approaches.

b) Examples of site-specific green infrastructure include:

- Infiltration systems (e.g., rain gardens, bio-swales, green roofs, and permeable pavers)
- Rainwater harvesting practices (e.g., cisterns and rain barrels)
- Tree plantings and vegetative buffers
- Living shorelines (constructed or enhanced shoreline erosion control practices)

c) Examples of watershed-scale approaches include protection, restoration and enhancement of:
   - Riparian buffer zones
   - Wetlands
   - Forests and other natural habitats that can provide flood attenuation benefits, improve water quality, and increase wildlife habitat values

d) Additional information about these techniques, case-studies, and resources can be found in Delaware's Green Infrastructure Primer, available online at: www.de.gov/greeninfrastructure.

Step 5: Document your decision-making process

a) Document your decision-making process for use by state agency staff charged with approving your project or tracking implementation of EO 41 provisions:
   - Record the BFE and flood zone from the FIRM
   - Record the combined flood depth or combined flood elevation from the FRAM
   - Record your selected sea level rise scenario and why it was chosen
   - Record your calculated future flood elevation
   - Describe the best practices employed to reduce the risk of flood damage including raising the structure above the future flood elevation, use of green infrastructure, selection of construction materials, etc.
   - If applicable, include the results of cost-benefit analyses.

b) There is no standard format for this documentation. Agencies are encouraged to include the information most pertinent to their decision-making process.

c) Assistance is available from Flood Avoidance Workgroup members.

APPENDIX B – Mapping Tools for Assessing Flood Risk

Flood risk mapping products can provide a cost effective screening of sites for potential vulnerability to flooding. Delaware has three maps that can be used for this purpose: the Flood Insurance Rate Map (FIRM), the Sea Level Rise Inundation Map (SLRIM) and the Flood Risk Adaptation Map (FRAM). Each of these maps has its own set of assumptions and limitations, and is a useful planning tool, but cannot substitute for site-specific surveys and flood studies. Each map's uses and limitations are described in the sections below.

Flood Insurance Rate Map

The FEMA floodplain map, also known as the Flood Insurance Rate Map (FIRM), depict present-day high-risk, moderate-to-low risk, and undetermined flood-risk areas. In Delaware, FEMA floodplain maps are available for areas surrounding most streams and coastal flood-prone areas. FEMA floodplain maps are created using statistical data for storm-induced river flows, storm tides, hydrologic/hydraulic analyses, and topographic surveys.

It is important to note that the FIRM is a regulatory map. The two other maps described below are not regulatory, but can be used as planning tools for understanding areas of potential risk from future flooding and inundation by considering sea level rise.

The FIRM depicts the base flood elevations resulting from a 1-percent annual chance storm event. This is sometimes referred to as the "100-year floodplain," a term that is misleading, because the flood risk is not one time per century, but rather a 1-percent chance of occurring in any given year. These flood zones are also referred to as Special Flood Hazard Areas.

Flood risk can, and does, change over time. FEMA recently completed a coastal study to update floodplain maps in Delaware. The most recent coastal study for each county in the state is a Risk Mapping, Assessment, and Planning (Risk MAP) study that produced preliminary maps in 2013. The maps for Kent County became effective July 2014, for New Castle County in February 2015, and for Sussex County in March 2015.

While these maps are based on accepted hydrological modeling and mapping standards, flood risks can increase for reasons such as added development, increased storminess and variable precipitation patterns, and rising sea level. These factors should be considered when using FEMA maps for planning and construction designs. Incorporating a safety factor above predicted flood levels into projects to account for these uncertain and increasing risks is widely considered a standard of practice.

This map of the Roosevelt Inlet and vicinity in Lewes was created by downloading the Flood Insurance Rate Map data from FirstMap and using the data in ArcGIS. The land within the blue area is within the "AE" zone of the FIRM. The land within the pink area is within the "VE" zone of the FIRM. AE zones are areas subject to inundation by the 1-percent annual chance flood event; VE zones are also subject to inundation by these storms, but may also experience wave action. The number following each zone designation is the Base Flood Elevation (BFE).

In addition, these modeling and mapping products do not reflect certain changes related to climate change. For example, in coastal areas:

- Mapped flood risks do not include increases in flood heights related to rising sea levels.
- Many reaches of Delaware's coast experience shoreline erosion that may increase flood risk and cause inland migration of high risk areas.
- Models do not account for future dune losses or breaching of barrier islands which are possible during severe storms.
- Land subsidence is not considered.

For riverine areas, most of Delaware's streams have had flood studies performed and flood heights determined, and this data is shown on the FIRM. It is important to acknowledge the flood risk factors that are not reflected in these maps. There are a number of factors that may lead to flood heights exceeding the flood levels shown, including:

- Increased precipitation rates
- More frequent and intense storms
- Changes in watershed land use and impervious surfaces
- Age of the model (many Delaware streams have old models)
- Floodplain filling or encroachments not reflected in model

The FIRMs are available to view by clicking "flooding" on the FEMA GeoPlatform: http://fema.maps.arcgis.com/home/.

To download the data for use in GIS applications, visit https://firstmap.delaware.gov and navigate to the data section. The FIRM can be downloaded from public section of the Geospatial Services tab, under Hydrology. Or, navigate to the site directly: https://firstmap.delaware.gov/arcgis/rest/services/Hydrology.

For additional information on floodplain mapping, please contact the DNREC Division of Watershed Stewardship at (302) 739-9921.

Delaware Sea Level Rise Inundation Map

Delaware's Sea Level Rise Inundation Map (SLRIM) is a "bathtub inundation model" created by the DNREC Delaware Coastal Programs in 2009. The SLRIM depicts the limit of Mean Higher High Water (MHHW) for three future scenarios of sea level rise: 0.5 meter (1.6 feet), 1.0 meter (3.2 feet), and 1.5 meters (4.9 feet).

The SLRIM provides a readily available and understandable planning tool that estimates the magnitude of potential inundation from sea level rise. This map is not regulatory; it is a planning tool only. The SLRIM was initially created to support an internal DNREC policy regarding preparing for sea level rise, but was subsequently used to develop Delaware's Sea Level Rise Vulnerability Assessment and has been used to inform planning and project development throughout the state.

The bathtub model assumes that the tidal range will remain constant as sea levels increase and thus shows that MHHW levels will increase at the same rate as sea level rise. However, this is a significant simplification, as increasing water depth and fetch length may increase the amplitude of MHHW. The bathtub model is also limited in that it does not account for the complex natural and human processes that may accompany sea level rise, including erosion, tidal forcing, sediment accretion, and construction of new shoreline protection structures. For detailed description of the maps and how they were created, please see the Mapping Appendix of *Preparing for Tomorrow's High Tide: The Delaware Sea Level Rise Vulnerability Assessment* (available online at www.de.gov/slrva).

The SLRIM depicts areas that could become inundated by water as sea levels rise. Three scenarios are mapped—a low, intermediate, and high scenario. The timeline for the scenarios is to the year 2100. Since the scenarios were chosen in 2009, scientific consensus has coalesced around a sea level rise scenario for 2100 that is at least 1.0 meter (3.2 feet) of rise as a global average.

The SLRIM is available on First Map, the state's GIS data portal. To view the maps, visit www.de.gov/slrmap and enter the project zip code. The map will zoom to the location of interest and you can use the slider bar to view impact areas.

This map of Roosevelt Inlet and vicinity in Lewes was created by downloading the Sea Level Rise Inundation Maps from FirstMap and using the data in ArcGIS. Here, the area depicted in blue is inundated at mean higher high water (MHHW). The area depicted in green would be inundated at MHHW by 0.5 meters of sea level rise; the area in yellow would be inundated at MHHW by 1.0 meter of sea level rise; and the area in red would be inundated at MHHW by 1.5 meters of sea level rise.

To download the data for use in GIS applications, visit https://firstmap.delaware.gov and navigate to the data section. The SLRIM can be downloaded from the public section of the Geospatial Services tab, under Environmental Data. Or, navigate to the site directly: https://firstmap.delaware.gov/arcgis/rest/services/Environmental.

For additional information on the SLRIM, please contact DNREC Delaware Coastal Programs at (302) 739-9283.

This map of Roosevelt Inlet and vicinity in Lewes was created by downloading the Flood Risk Adaptation Map from FirstMap and using the data in ArcGIS. Here, the area depicted in brown depicts the extent of flooding that could occur during a 1-percent chance flood event if mean sea levels are three feet higher than they are today. The zones are labeled on the map as CE 12-16, meaning the combined flood hazard elevation is between 12 and 16 feet (relative to NAVD88).

Flood Risk Adaptation Map

The FIRM and SLRIM described above do not reflect the impact of coastal storm surge coupled with future tide; therefore, a new statewide map was developed that depicts the combined risk of sea level rise and coastal storms. This combined map, the Flood Risk Adaptation Map (FRAM), depicts the extent of flooding that could occur during a 1-percent chance flood event if mean sea levels are 3 feet (0.9 meters) higher than they are today. Only one sea level rise scenario (a 3-foot increase in mean sea levels) was modeled due to funding limitations. This selection was recommended by the Flood Avoidance Workgroup technical experts as a reasonable compromise that allows users to visualize storm impacts late century at moderate levels of sea level rise, and mid-century should sea levels rise at a more rapid rate (closer to the high scenario of 4.9 feet [1.5 meters]). The maps do not depict increased risks associated with changes in coastal landforms, increased wave heights associated with deeper coastal flooding, and other secondary hazards.

The FRAM includes three zone designations:

- *CE, or Combined Flood Hazard Elevation*: This represents areas of future flood risk, based on the elevation of 1-percent annual-chance storm surge plus 3 feet SLR plus possible wave conditions.
- *CD, or Combined Depth*: This represents the depth of water above local ground, based on sheet flow depth, primarily related to the overtopping of dunes. There is considerable uncertainty surrounding the performance of dunes during extreme

storms. To account for this uncertainty in the Risk MAP study, sheet flow zones were mapped on the landward side of dunes or other high elevation features that are adjacent to the beach or could be subject to significant wave action during a storm. Wave run-up and overtopping on these features could cause flood damage on relatively high ground.

- *OS, or Outside of Sea Level Rise Floodplain*: This represents areas of high ground that are not shown as inundated; however, this "dry land" may be completely surrounded by inundated land.

Users of mapping tools must always be mindful of uncertainties and assumptions when working with data such as the FRAM. Most importantly, users should remember that the floodplain boundaries on the map do not guarantee avoidance of future flooding, and high-sensitivity projects will warrant more detailed analyses. The major assumption of the FRAM is that the 1-percent annual chance storm surge will not significantly change in the future. This assumption is valid for short projections into the future; however, an evolving storm climate or large-scale topographical changes could diminish its validity for long-term projections. Periodic review and update of the FRAM is recommended as new information and analysis tools become available.

State agencies can access the FRAM on Delaware's First Map system. To use the data in GIS applications, visit https://firstmap.delaware.gov and navigate to the Data section. Choose the "State Services" tab, and then select "Environmental Data." Alternatively, state agency users navigate to the site directly: https://firstmap.delaware.gov/arcgis/rest/services/Environmental.

Persons wishing to use this map who are not state agency employees may obtain a map or GIS data layers by contacting the DNREC Division of Watershed Stewardship at (302) 739-9921 or the DNREC Division of Energy and Climate at (302) 735-3480.

APPENCIX C – Glossary of Terms

1-Percent Annual Chance Floodplain: A Special Flood Hazard Area that will be inundated by a flood event having a 1-percent chance of being equaled or exceeded in any given year.

Base Flood: A flood having a one-percent chance of being equaled or exceeded in any given year; the base flood also is referred to as the one-percent annual chance (100-year) flood.

Base Flood Elevation (BFE): The water surface elevation of the base flood in relation to the datum specified on Flood Insurance Rate Maps. In areas of shallow flooding, the base flood elevation is the highest adjacent natural grade plus the depth number specified in feet on the Flood Insurance Rate Map, or at least four (4) feet if the depth number is not specified.

Design Life: The period of time during which, the item is expected by its designers to work within its specified parameters; in other words, the life expectancy of the item. It is the length of time between placement into service of a single item and that item's onset of wear-out, that is, where additional maintenance is no longer sufficient to prolong its life expectancy.

Environmental Justice Community: A residential area that is exposed to multiple, disproportionate environmental health burdens, has population vulnerability such as low incomes or language barriers, and/or where there are limits to effective participation in decisions with environmental and health consequences.

Freeboard: A factor of safety that compensates for uncertainty in factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, obstructed bridge openings, debris and ice jams, climate change, and the hydrologic effect of urbanization in a watershed.

Infrastructure: Built structures, including transportation facilities (e.g., roads, bridges, bike paths), water and wastewater facilities (e.g., wells, treatment systems, pump and pipeline structures), water control structures (e.g., dikes, dams, impoundments), and public use and tourism structures (e.g., wildlife viewing platforms, rest rooms, camping sites, parking areas).

Limit of Moderate Wave Action (LiMWA): The LiMWA identifies areas that will be affected by waves with a 1.5 foot wave height or greater within the coastal A zone. While FEMA currently does not require special floodplain management standards or flood insurance purchase requirements based on LiMWA delineations, it is likely that properties and structures within the LiMWA will receive substantial damage from wave action during a one-percent-annual-chance flood event.

Mean Higher High Water (MHHW): The long-term average of the higher of the daily high tides.

Resilience: A capability to anticipate, prepare for, respond to, and recover, from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

State Agency: Every board, department, bureau, commission, person or groups of persons or other authority which directly receives monies under any budget appropriation act or supplemental appropriation act. For complete definition see 29 Del Code § 6902.

Sea Level: The level of the sea after averaging out short-term variations due to wind and waves.

Sea Level Rise (SLR): Long term increases of mean sea level. At a coastal site, sea level rise can occur both as a consequence of worldwide increases in sea level due to an increased volume of water in the oceans, thermal expansion of sea water, and due to local sinking of land surfaces (subsidence).

Sea Level Rise Vulnerability: The susceptibility of a coastal area to seasonally high-tides or prolonged or permanent inundation or submergence due to a combination of land subsidence and future rise in water level.

Special Flood Hazard Areas (SFHA): Land in the floodplain subject to a one-percent or greater chance of flooding in any given year and designated by the Federal Emergency Management Agency in Flood Insurance Studies and on Flood Insurance Rate Maps as Zones A, AE, AH, AO, A1-30, and A99, and Zones VE and V1-30.

State Projects: Projects conducted directly by a state agency or with state funds that involve construction of new structures and infrastructure.

Structures: Structures generally refers to buildings intended for human occupation, including offices, state service facilities (e.g., health, social services, law enforcement), and other public buildings (e.g., housing, judicial and legislative).

Stillwater: The 100-year floodplain elevation on a FIRM or DFIRM before wave heights and wave run-ups are added. Stillwater elevations should match the 100-year floodplain elevations is all coastal A-zones, but in areas where wave heights are included (LiMWAs and V-zones), still-water elevations do not include wave heights. For regulatory purposes, the 100-year elevation must include wave heights.

Substantial Damage: Damage of any origin sustained by a structure whereby the cost of restoring the structure to before damaged condition would equal or exceed 50 percent of the replacement cost of the structure before the damage occurred.

Water Dependent Uses: A use which cannot perform its intended purpose unless it is located or carried out in close proximity to water; the term includes docking facilities and port facilities that are necessary for the loading and unloading of cargo or passengers, and ship building and ship repair facilities, but does not include long-term storage or related manufacturing facilities.

APPENDIX D

STATE OF DELAWARE

EXECUTIVE DEPARTMENT
DOVER

EXECUTIVE ORDER
NUMBER FORTY-ONE

TO: HEADS OF ALL STATE DEPARTMENTS AND AGENCIES

RE: PREPARING DELAWARE FOR EMERGING CLIMATE IMPACTS AND SEIZING ECONOMIC OPPORTUNITIES FROM REDUCING EMISSIONS

WHEREAS, burning fossil fuels causes the release of heat-trapping greenhouse gases that contribute to a changing climate, which presents both economic opportunities for new jobs and industries, as well as challenges to protecting public health and safety, supporting a vibrant economy, and conserving natural resources; and

WHEREAS, Delaware's greenhouse gas emissions have decreased by more than any state in the nation (29.7% from 2000 to 2010) and recent investments to modernize our energy system and efforts by several of Delaware's major employers and institutions of higher learning will result in significant additional reduction, however more must be done; and

WHEREAS, initiatives to responsibly reduce greenhouse gas emissions and prepare Delaware for climate impacts present significant economic development and employment opportunities in infrastructure construction, energy efficiency, clean energy, and advanced transportation; and

WHEREAS, as a low-lying coastal state with the lowest average land elevation in the United States and significant population living along 381 miles of shoreline, Delaware is vulnerable to coastal erosion, storm surge, flooding, saltwater intrusion, and tidal wetland losses, all of which will be exacerbated by sea-level rise; and

WHEREAS, Delaware's critical infrastructure, including roads, bridges, dams, dikes, impoundments, energy distribution systems, emergency services, outdoor recreation facilities, drinking water and wastewater treatment facilities, industrial sites, and landfills are at-risk to climate change impacts; and

WHEREAS, Delaware's Bayshore and Inland Bays communities have experienced saltwater intrusion into drinking water supplies and irrigation systems, and climate impacts could negatively affect the availability and reliability of the groundwater aquifers that provide water to many municipalities, residents, and farmers; and

WHEREAS, agriculture in Delaware is an $8 billion industry which could be significantly impacted by increasingly variable temperatures, precipitation, extreme weather events, and droughts; and

WHEREAS, tourism in Delaware is an $6 billion industry supported by world-class beaches, parks, wildlife areas, cultural assets, and recreational waterways, all of which are vulnerable to more extreme storms and sea-level rise; and

WHEREAS, the State of Delaware was an original signatory to the Regional Greenhouse Gas Initiative and is working in collaboration with other states to reduce regional greenhouse gas emissions from power plants by more than 30% compared to 2008; and

WHEREAS, to coordinate the efforts of state agencies to create a clean energy economy and a sustainable natural environment, I signed Executive Order No. 18 on February 17, 2010; and

WHEREAS, under Executive Order No. 18, the State of Delaware, under the direction of and coordination by the Cabinet Committee on Energy, has reduced the number of state vehicle miles traveled by 25%; has increased its use of clean, renewable energy to 30% of its overall annual electric energy demand; and has taken important steps to reduce energy consumption, lower gas consumption and emissions from state vehicles, increase recycling, and implement environmentally-friendly procurement and building practices, resulting in millions of dollars of savings; and

WHEREAS, the State of Delaware, through the Department of Natural Resources and Environmental Control (DNREC), has developed a sea level rise adaptation policy that serves as a pilot for further statewide application; and

WHEREAS, a variety of entities—including, among others, the Floodplain and Drainage Advisory Committee, the Bay Beaches Working Group, the Wetlands Advisory Committee, the State Sea Level Rise Advisory Committee, and the Delaware Climate Change Steering Committee—have developed or are developing policies and recommendations to address various discrete issues related to our changing climate and rising sea levels; and

WHEREAS, it is important for the State of Delaware to continue to reduce greenhouse gas emissions cost-effectively, while preparing for current and emerging climate risks; and

WHEREAS, it is in the best interest of the State of Delaware to address climate change and rising sea levels in a coordinated and cost-effective manner, at the highest levels of government, using a structure similar to the one that has been employed so successfully in connection with Executive Order No. 18.

NOW THEREFORE, I, JACK A. MARKELL, by virtue of the authority vested in me as Governor of the State of Delaware, do hereby DECLARE and ORDER the following

1. There is hereby created a Governor's Committee on Climate and Resiliency (the "Committee"), which shall be comprised of the following members:

a. Each of the members of the Cabinet Committee on Energy as set forth in 29 *Del.C.* § 8054, including the Secretaries of the Department of Natural Resources and Environmental Control, Department of Agriculture, Department of Transportation, Department of Health and Social Services, Department of Safety and Homeland Security, and Department of State; the Director of the Delaware Economic Development Office; and the Director of the Office of Management and Budget;

b. The Director of the Delaware State Housing Authority;

c. The Director of the Office of State Planning Coordination; and

d. Such other persons as the Governor may from time to time appoint.

2. The Committee shall oversee development of an implementation plan to maintain and build upon Delaware's leadership in responsibly reducing greenhouse gas emissions, including identifying appropriate interim goals. The plan shall ensure that efforts have a positive effect on the State's economy, including advancing the strategy of securing cleaner, cheaper, and more reliable energy, improving public health outcomes, increasing employment in Delaware, strengthening Delaware's manufacturing capabilities, and enhancing Delaware's overall competitiveness. The Committee shall report to the Governor on the completed plan by December 31, 2014, and annually thereafter.

3. The Committee shall develop agency-specific actionable recommendations for improving Delaware's preparedness and resiliency to climate impacts on public health and safety, public infrastructure and facilities, water resources, natural ecosystems, agriculture, tourism, and other industries. The recommendations shall prioritize the use of natural systems or green infrastructure as the preferred means to improve resiliency. Recommendations shall be submitted to the Governor by December 31, 2014 and shall include, but not be limited to:

a. Actions state agencies can take both within their departments and with assisting residents to adapt to and prepare for more extreme storms and projected temperature and precipitation variations expected over the next several decades, based upon research conducted through the Delaware Climate Change Steering Committee;

b. Actions local governments can take to improve community resiliency, including assessment of infrastructure vulnerabilities, land use policies, and other adaptation strategies that may be integrated into Comprehensive Land Use Plans in coordination with the Office of State Planning Coordination; and

c. Outreach strategies to inform and prepare Delaware's residents and businesses about identified risks, vulnerabilities, adaptation strategies, and basics of climate change and its causes, with particular attention to providing strategies to help protect at-risk populations.

4. In addition to the foregoing, all state agencies shall adhere to the following requirements related to flood hazard mitigation and sea level rise:

a. All state agencies shall incorporate measures for adapting to increased flood heights and sea level rise in the siting and design of projects for construction of new structures and reconstruction of substantially damaged structures and infrastructure. Such projects shall be sited to avoid and minimize flood risks that would unnecessarily increase state liability and

decrease public safety. Construction projects shall also incorporate measures to improve resiliency to flood heights, erosion, and sea level rise using natural systems or green infrastructure to improve resiliency wherever practical and effective;

b. Where avoidance is not practicable, structures within a Federal Emergency Management Agency (FEMA) designated Special Flood Hazard Area shall be designed and constructed with habitable space at least 18 inches above current base flood elevation on a foundation appropriate for anticipated flood risk factors. If the structures are within an area mapped by DNREC as vulnerable to sea level rise inundation the projects shall be designed and constructed to account for sea level changes anticipated during the lifespan of the structure, in addition to FEMA flood levels; and

c. All state agencies shall consider and incorporate the sea level rise scenarios set forth by the DNREC Sea Level Rise Technical Committee into appropriate long-range plans for infrastructure, facilities, land management, land-use, and capital spending. DNREC shall periodically update the scenarios with the best scientific data available and distribute new guidance to state agencies.

5. The Secretary of Natural Resources and Environmental Control shall serve as chair of the Committee and, with the cooperation of other state agencies, is responsible for managing and tracking implementation of this Order. In connection therewith, the chair and the Committee shall leverage the work of leading scientists and subject matter experts, as well as any research, studies, work groups, advisory councils, and committees as may be required to complete the tasks outlined herein. DNREC shall provide support to state agencies to meet the requirements of this Order, including the development of maps illustrating areas of combined flooding and sea level rise.

6. No provision of this Order shall create any individual right or cause of action that does not currently exist under state or federal law.

APPROVED this 12 **day of** September**, 2013**

Jack Markell

Governor

ATTEST:

Secretary of State

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

Delaware Division of ENERGY & CLIMATE

FSC