A Climate Change Risk and Resilience Assessment of New Jersey's National Guard Facilities

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A Project of the New Jersey Department of Military Affairs and Veterans Affairs

Produced by:
The Jacques Cousteau National Estuarine Research Reserve and Rutgers University's Bloustein School for Planning and Public Policy

Executive Summary

The effects of a changing climate are currently and will continue to be a national security issue, impacting military installations, operational plans, and overall missions. Recognizing these threats, the New Jersey Department of Military Affairs and Veteran Affairs (NJDMAVA) engaged Rutgers University (Jacques Cousteau National Estuarine Research Reserve and the Edward J. Bloustein School of Planning and Public Policy) to prepare a Climate Change Risk and Resilience Assessment, identifying twelve (12) National Guard sites' vulnerability to climate-related risks and threats. By anticipating future climate change conditions, these sites can reduce climate impacts to missions and operations and protect real property investments by reducing exposure.

Nationally, the Department of Defense's (DoD) Directive 4715.21 stated, "mission planning and execution must include identification and assessment of the effects of climate change on the DoD mission, taking those effects into consideration when developing plans and implementing procedures, and anticipating and managing any risks that develop because of climate change to build resilience".

Following the process outlined in the Navy's Climate Change Planning Handbook: Installation Adaptation and Resilience (NAVFAC 2017), the Rutgers team assessed climate exposure impacts and incorporated this knowledge and data into findings intended to inform NJDMAVA installations' planning processes such as Real Property Development Plans. The process laid out in NAVFAC 2017 is similarly aligned with a more recently released document, the 2020 Army Climate Resilience Handbook (ACRH). The ACRH builds upon the NAVFAC guidance through a robust framework for scenario-based planning and sensitivity analysis for proposed adaptation options. The ACRH also requires an assessment of the adaptive capacity for proposed alternatives. Additional information about the NAVFAC and the ACRH is included in Appendix I.

The Rutgers Team has provided noted successes, areas of potential future challenges, and areas of potential future collaborations and partnerships. These observations are a result of looking across the site profiles, interviews with site-based staff, discussions with the NJDMAVA Environmental Management Bureau (EMB) team, onsite visits, and discussions with the Rutgers Climate Change Panel.

The resultant document provides areas of noted successes, challenges, and opportunities. Successes include NJDMAVA's current efforts to identify historic building preservation strategies and preform environmental inventories. Identified future challenges for the NJDMAVA sites include maintaining the historic nature of buildings, the management of training, HVAC systems and mold with increased high temperatures, the need for backup power generation, vector borne disease proliferation, coordination within NJDMAVA to ensure site accessibility, extreme temperature impacts on training and facilities, flooding from intense rainfall, sea level rise and coastal storms, and potential wind damage from convective and coastal storms. Climate change habitat and species monitoring was cited as an area of potential future collaboration with natural resource management agencies.

Climate change will continue to be a national security issue, with NJDMAVA needing to continuously assess their risks and adapt their practices to this evolving threat. The DoD regards climate change resilience and response efforts as a function that span all levels and lines of effort and should not be viewed as a separate initiative. The needed resources for assessing and responding to climate impacts are provided within existing DoD missions, funds, and capabilities and are incorporated under existing risk management processes. The NJDMAVA team should continue to seek and follow the best available and most up-to-date science. Individual installation site leaders will need to seek out further guidance specific to the individual installation's needs. The information provided by the Rutgers Team is sufficient to address long-term planning decisions. Further implementation of actions and solutions will require additional quantitative data on risk magnitudes and more accurate, specific, and detailed analysis on projected impacts.

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Introduction

The New Jersey Department of Military and Veteran Affairs (NJDMAVA) is a state agency responsible for supporting the New Jersey Army National Guard (NJARNG) by providing training lands and building infrastructure for the NJARNG. These sites vary in locations from historic armory buildings covering city blocks and large training installations to smaller training and vehicle maintenance facilities scattered throughout the state. In the past 10 years, New Jersey's NJDMAVA installations have sustained damage due to extreme weather events, such as the intense precipitation, high winds, hurricane and Nor'easter induced storm surge, and increasingly frequent "sunny day" (i.e., chronic) tidal flooding. These extreme weather events impact installation infrastructure, training, and readiness to deploy. As a result, climate change has been identified by the Army and Department of Defense (DoD) as a critical national security threat and threat multiplier. Observed and projected climate change impacts include more frequent and intense temperature extremes, extreme weather events (e.g., more frequent precipitation of increasing intensity), longer fire seasons with more frequent and severe wildfires, higher sea levels, and longer and more severe droughts.

> *"Rising global temperatures, changing precipitation patterns, increasing sea levels, and other extreme weather events will intensify the environmental and social aspects that NJDMAVA faces today and in the future."*
>
> – NJDMAVA, Environmental Management Bureau

Each year, the NJDMAVA is tasked with updating 10% of the inventory listed on the Real Property Development Plan (RPDP). This plan is a statewide NJARNG facility portfolio that reviews existing property conditions, includes proponent strategies, and establishes short-term and long-term plans to meet transformation goals of the NJARNG. This may include proposed additions of new buildings.
In 2020, twelve (12) sites were due for RPDP's updates:

Photo: Dunes along the Atlantic Ocean waterfront at the Sea Girt National Guard site.

The NJDMAVA team shares the DoD recognition that climate change is a serious trend that will impact national security. Because their sites are already experiencing impacts and future planning is vital to adequate preparation, NJDMAVA is determined to include a climate change assessment in future RPDP updates.

NJDMAVA's Environmental Management Bureau (EMB) administers and manages environmental policies and programs throughout all NJARNG facilities and is the manager of this Climate Change Risk Assessment project. The purpose of the project is to integrate the findings into the agency's plans, such as the RPDP, to reduce adverse effects caused by climate change. The Climate Change Risk Assessment will assist NJDMAVA to properly prepare for and sustain security of their NJARNG sites in the face of climate change impacts. Benefits from this assessment will include transportation, economic, and environmental factors, as well as increasing installation resiliency by minimizing damages. These benefits directly correlate with NJDMAVA's commitment and ability to provide security and emergency response to the community. Being able to prepare and manage associated risks is of upmost importance and serves as a model approach.

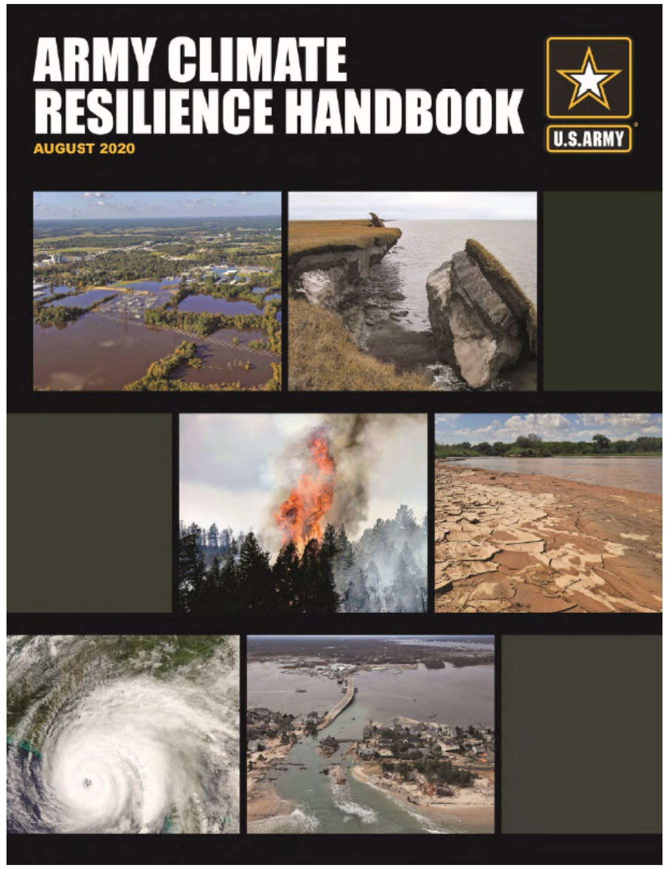
National Climate Change Assessment and National Resilience Planning Guidance

Following the process outlined in the Navy's Climate Change Planning Handbook: Installation Adaptation and Resilience (NAVFAC 2017), the Rutgers team assessed climate exposure impacts and incorporated this knowledge and data into findings intended to inform NJDMAVA installations' planning processes such as Real Property Development Plans. The process laid out in the NAVFAC 2017 is similarly aligned with a more recently released document, the 2020 Army Climate Resilience Handbook (ACRH). The ACRH builds upon the NAVFAC guidance through a robust framework for scenario-based planning and sensitivity analysis for proposed adaptation options. The ACRH also requires an assessment of the adaptive capacity for proposed alternatives. Additional information about the NAVFAC and the ACRH is included in Appendix I.

The NAVFAC and ARCH approaches are consistent with the following other national guidance:

- Department of Defense 2014 Climate Change Adaptation Roadmap that laid out a framework with three overarching goals:
    - Identify and assess the effects of climate change on the Department.

- Integrate climate change considerations across the Department and manage associated risks.
    - Collaborate with internal and external stakeholders on climate change challenges.



- DoD Directive 4715.21, Climate Change Adaptation and Resilience (2016), requires mission planning and execution to include:
    - Identifying and assessing effects of climate change on the DoD mission.
    - Taking those effects into consideration when developing plans and implementing procedures.
    - Anticipating and managing any risks that develop because of climate change to build resilience.

- The DoD Roadmap (DoD 2014a) identified areas where adaptation (also known as climate preparedness and resilience) is essential (Table 1):
    - Plans and operations include the activities dedicated to preparing for and carrying out the full range of military operations. Also included are the operating environments in the air, on land, and at sea, both at home and abroad, that shape the development of plans and execution of operations.
    - Training and testing, including access to land, air, and sea space that replicate the operational environment is essential to readiness.
    - Built and natural infrastructure.

As referenced in the 2019 National Defense Authorization Act (NDAA) climate resilience is defined as the "anticipation, preparation for, and adaptation to utility disruptions and changing environmental conditions …."

Plans and Operations
• Increased demand for disaster relief and humanities assistance. • Increased need for air, sea, and land capabilities and capacity. • Altered, limited, or constrained environments for military operations.
Training and Testing
• Increased number of black flag (suspended outdoor training) or fire hazard days. • Greater stress on threatened and endangered species and related ecosystems that are on or adjacent to DoD installations, resulting in increased endangered species and land management requirements. • Increased operational health surveillance and health and safety risks to Department personnel. • Increased Maintenance /repair requirements for training/testing lands and associated infrastructure and equipment (e.g. training roads, targets).
Built & Natural Infrastructure
• Increased inundation, erosion, and flooding damage. • Changes to building heating and cooling demand, impacting installation energy intensity, and operating costs. • Disruption to and competition for reliable energy and fresh water supplies • Increased ecosystem, wetland, sensitive species, and non-native invasive species management challenges. • Increased maintenance requirements to remain operable on extremely hot days and reduce damage from extreme heat. • Changed disease vector distribution, increasing the complexity and cost of ongoing disease management efforts and requiring changes in personnel health resources, facilities and infrastructure.

Table 1. Potential effects of climate change on the Department of Defense (adapted from Annex 2, DoD 2014 Climate Change Adaptation Roadmap)

As noted in all national guidance, there are inherent uncertainties in projecting future conditions. Therefore, the Climate Change Risk and Resilience Assessment process should be periodically updated, and adaptation and resiliency measures need to be flexible. These updates should reflect changes in installations' strategic objectives, advances in technology or climate preparedness and resilience methods, and/or new data and information about climate change impacts, risks, and vulnerabilities.

New Jersey's Climate Change Essentials

In preparation for the Climate Change Risk and Resilience Assessment, a New Jersey Climate Profile (see Appendix III) document was prepared to provide an overview of statewide climate science trends. These trends include direct meteorological phenomena (i.e., heat, precipitation, storms) and other related hazards (e.g., drought, wildfire). Extreme weather events typically experienced in the state include coastal nor'easters, snowstorms, spring and summer thunderstorms, flooding rains, heat and cold waves, tropical storms, and hurricanes. During the project, NJDEP published the 2020 New Jersey Scientific Report on Climate Change as a compilation of the best available science for state agencies and other stakeholders to reference in their planning and investment processes. The 2020 New Jersey Scientific Report on Climate Change served as a summary of the statewide scientific basis for assessing future exposures to NJDMAVA sites, assets, and mission capabilities, and was consistent with the draft panel assessment. Data sets used to represent changing climate conditions in each site profile are available through Rutgers' NJAdapt mapping platform. We summarize the main points from NJDEP (2020) below, and present site-specific projections and exposure assessments within each site assessment.

Current climate modeling efforts are based on the representative concentration pathways modeled for the IPCC 5th Assessment Report, and subsequently used in the latest United States National Climate Assessment (van Vuuren et al., 2011) These emissions are labeled as Representative Concentration Pathways (RCPs), that indicate how much radiative forcing will occur by the end of the century (National Oceanic and Atmospheric Administration, 2020). For temperature and precipitation in this analysis, the project team utilizes RCP 8.5 and RCP 4.5 to provide a range of future estimates based on future global climate policy driven emissions reductions (NJADAPT). RCP 8.5 corresponds to a high emissions future where carbon dioxide and methane emissions continue to rise because of fossil fuel use. Under RCP 4.5, emissions stabilize, and atmospheric CO2 levels remain below 550 ppm by 2100, and CO2-equivalent concentrations that include all emissions from human activities reach 580 ppm (National Oceanic and Atmospheric Administration, 2020).

<u>Temperature</u>
Since 1895, New Jersey's average annual temperature has increased by 3.5°F. Scientists project average annual temperatures in New Jersey increasing by 4.1°F to 5.7°F by 2050. Scientists also project commensurate increases in the number of days NJ residents will experience extreme heat (>95°F), with heatwaves occurring over larger areas with greater durations by 2050. More extreme heat days can directly impact human health and military training operations (NJDEP, 2020). Higher seasonal loads for cooling can impact HVAC and building system design and affect the indoor air quality within training and office buildings on NJDMAVA sites.

<u>Precipitation and Drought</u>
Annual precipitation in New Jersey is expected to increase by 4% to 11% by 2050. The intensity and frequency of heavy precipitation events will also increase. However, seasonal patterns may result in decreases in average summer precipitation creating greater potential for drought to occur (NJDEP, 2020). More intense precipitation events will increase the likelihood of flood events, including flooding from surface water runoff (pluvial), rivers (fluvial), high tides (coastal), and storm tides driven by tropical and extratropical storms. Drought conditions may result in impacts to water resources and ecological resources under management on NJDMAVA sites.

<u>Sea-Level Rise</u>
Kopp et al. (2019) serves as the statewide scientific basis for NJDEP (2020), and concludes the following:

- Relative sea-level along the New Jersey coast is rising faster than the global mean sea-level. New Jersey coastal areas are likely (at least a 66% chance) to experience SLR of 0.5 to 1.1 ft between 2000 and 2030, and 0.9 to 2.1 ft between 2000 and 2050. It is extremely unlikely (less than 5% chance) that SLR will exceed 1.3 ft by 2030 and 2.6 ft by 2050.

- Whereas near-term SLR projections through 2050 exhibit only minor sensitivity to different emissions scenarios (<0.1 feet), SLR projections after 2050 increasingly depend upon the pathway of future global greenhouse gas emissions. For SLR projections, low and high emissions scenarios correspond to global mean warming by 2100 of 2°C and 5°C above early Industrial (1850-1900) levels, respectively, or equivalently, about 1°C and 4°C above the current global mean temperature. Moderate (Mod.) emissions are interpolated as the midpoint between the high- and low emissions scenarios and approximately correspond to the warming expected under current global policies (See Table 2).

		2030	2050	2070			2100			2150		
				Emissions								
	Chance SLR Exceeds			Low	Mod.	High	Low	Mod.	High	Low	Mod.	High
Low End	> 95% chance	0.3	0.7	0.9	1	1.1	1.0	1.3	1.5	1.3	2.1	2.9
Likely Range	> 83% chance	0.5	0.9	1.3	1.4	1.5	1.7	2.0	2.3	2.4	3.1	3.8
	~50 % chance	0.8	1.4	1.9	2.2	2.4	2.8	3.3	3.9	4.2	5.2	6.2
	<17% chance	1.1	2.1	2.7	3.1	3.5	3.9	5.1	6.3	6.3	8.3	10.3
High End	< 5% chance	1.3	2.6	3.2	3.8	4.4	5.0	6.9	8.8	8.0	13.8	19.6

**2010 (2001-2019 average) Observed = 0.2 ft*

Notes: All values are 19-year means of sea-level measured with respect to a 1991-2009 baseline centered on the year indicated in the top row of the table. Projections are based on Kopp et al. (2014), Rasmussen et al. (2018), and Bamber et al. (2019). Near-term projections (through 2050) exhibit only minor sensitivity to different emissions scenarios (<0.1 feet). Rows correspond to different projection probabilities. There is at least a 95% chance of SLR exceeding the values in the 'Low End' row, whereas there is less than a 5% chance of exceeding the values in the 'High End' row. There is at least a 66% chance that SLR will fall within the values in the 'Likely Range'. Note that alternative methods may yield higher or lower estimates of the chance of low-end and high-end outcomes.

Table 2. Projected SLR Estimates for New Jersey (ft.) incorporating probabilities, decadal periods, and emissions variation, relative to the year 2000 (1991-2009 average) baseline, from Kopp et al. 2019

Sea-level rise raises the baseline water level for coastal flooding and storm-tide flooding. It can also impact the efficiency of surface water drainage systems that drain into coastal waters and exacerbate riverine flood events on tidal rivers. Absent any adaptation strategies, NJDMAVA facilities located in coastal areas, or along tidal waterways, may experience increasingly likely and frequent flood events as sea-level rises. Sensitive ecological systems (e.g., dunes and saltmarshes) may change in character and require different environmental management strategies.

<u>Coastal Storms</u>

Kopp et al. (2019) serves as the statewide scientific basis for NJDEP (2020), and concludes the following:

- *Tropical Cyclones* The science panel focused on three issues with respect to tropical cyclones (i.e., hurricanes and tropical storms): frequency, intensity and precipitation. Whereas most studies do not project an increase in the global frequency of tropical cyclones, both maximum wind speeds and the rate of rainfall during tropical cyclones are likely to increase. Changes in the frequency, wind speed, and tracks of tropical cyclones remain an area of active research, and there is no definitive consensus at this time regarding such changes specific to New Jersey.
- *Extratropical Cyclones* The global frequency of extratropical cyclones (i.e., nor'easters) is not likely to change substantially. Whereas there is some evidence for a decrease in frequency of extratropical cyclones over the North Atlantic as a whole, this is not apparent near the coast. Some research points to the possibility of changes to extratropical storm tracks in the North Atlantic, but this research is not reliably established. Changes in the frequency, wind speed, precipitation rate, and tracks of extratropical cyclones remain an area of active research; at this time, there is no definitive consensus regarding such changes.

NJDMAVA facilities are vulnerable to winds, precipitation, and the resulting flooding from coastal storm events. Erosion and wave action in coastal areas may also damage critical protective and ecological features at facilities, such as the dune system in Sea Girt. In addition to direct impacts on facilities, coastal storms may damage or destroy critical transportation routes between NJDMAVA facilities and populations in need of responders.

Convective Storms

Changes in localized precipitation and storms are uncertain for New Jersey. Heavy precipitation events have increased dramatically in the past two decades, nominally and as a percentage of total rainfall, occurring more than twice as often in recent years than during the past century. Underlying conditions in the eastern United States may be more supportive of thunderstorms, lightning, heavy rain, hail, and tornadoes in the future (NJDEP, 2020). Impacts from convective storms have historically included damages to physical structures and facilities at NJDMAVA sites. Several sites experienced roof damages, power outages, and other hazards that are commensurate with straight-line winds or tornadoes that occur along with intense precipitation events.

Wildfire

Existing literature and modeling do not provide a scientific consensus for how climate change will impact wildfires in New Jersey. The underlying conditions for wildfires will be driven by future changes in temperature and precipitation, and the prevalence of drought conditions in New Jersey. Increases in temperature, increases in the frequency and severity of storms, changes in prevailing winds, and ecological management strategies will all impact the magnitude and frequency of wildfires. The New Jersey Pinelands is currently most susceptible to fires along the wildland-urban interface, and scientists expect the Pinelands will remain most susceptible for fires in the future (NJDEP, 2020). Wildfires can impact NJDMAV facilities through direct threats to physical buildings and structures located in forested areas. Wildfires can also limit outdoor training and pose occupational safety and health risks to soldiers and civilians working outdoors at NJDMAVA facilities.

Additional Federal Climate Change Resources

More information regarding climate change, climate change impacts to the DoD, and tools to aid in resilience planning are provided below. This is an evolving list of resources:

- The U.S. Fourth National Climate Assessment provides detailed information on the causes and consequences of climate change in the U.S. Volume 1 is the Climate Science Special Report (USGCRP 2017), whereas Volume 2, Impacts, Risks, and Adaptation (USGCRP 2018), places more emphasis on regional and cross-sectoral impacts.
- The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC 2013, IPCC 2014) provides information on climate change at a global scale.
- The USACE Climate Preparedness and Resilience site has tools, information, and data to assess and adapt to the risk associated with climate change.
- State Climate Summaries are prepared by the National Oceanic and Atmospheric Administration (NOAA) and updated on a rolling basis.

DoD guidance for addressing the impacts of climate change on installations and additional related information includes:

- Updated United Facilities Criteria UFC 1-200-02, High Performance and Sustainable Building Requirements, October 2019 (DoD 2014b) incorporates climate-related impacts and provides minimum requirements and guidance for planning, designing, constructing, renovating, and maintaining high performance and sustainable buildings.
- Report on Effects of a Changing Climate to the Department of Defense, January 2019.
- Climate Change Installation Adaptation and Resilience Planning Handbook details adaptation options in the existing Navy Installation Development Plan (IDP) process, including worksheets to be used in documenting the results of planners' assessment and evaluation.
- Climate Adaptation for DoD Natural Resource Managers - A Guide to Incorporating Climate Considerations into Integrated Natural Resource Management Plans - To address climate risks, the DoD Integrated Natural Resource Management Plan (INRMP) Implementation Manual (DoDM 4715.03) specifically calls for installations to address climate when updating or revising their INRMPs. This guide has been developed to help installation managers with implementing that policy guidance.

Rutgers' Climate Change Risk and Resilience Assessment Process

The Rutgers Team's Climate Change Risk and Resilience Assessment process generally followed the framework outlined in the Climate Change Planning Handbook: Installation Adaptation and Resilience (NAVFAC 2017). In lieu of four (4) discrete Stages, the Rutgers Team's tasks and outputs followed the tasks outlined in Figure 1.

Figure 1: The Tasks in the Rutgers' Climate Change Risk and Resilience Assessment process for evaluating twelve (12) NJDMAVA sites.

Task 1: Desktop Analysis of the Twelve (12) NJDMAVA Locations and their Climate Risks

Output: Site Profiles, Survey Responses from Site's Points of Contacts

The desktop analysis consisted of site-specific analysis through GIS data visualization and literature review. To begin assessing risk at each site, the team focused on gathering data about the assets, natural resources, and mission. Data on regional climate variables as well as more local flooding scenarios, storms, and wildfire hazard were used to analyze the risk to the assets, natural resources, and mission of the site. Information was gathered from existing NJDMAVA geodatabases, publicly available GIS data, and a variety of literature sources. The result was a site profile for each of the twelve sites that contained the following:

Setting	Geography
	Transportation
	Mission and Users
	Characteristics
	Surrounding Community and Social Vulnerability
Critical Infrastructure	Armory Infrastructure
	Energy Independence/Resilience and Emissions
	Cultural Sites
Natural Resources	Coastal Management
	Wetlands
	Invasive, Threatened, and Endangered Species
Climate Data	Precipitation
	Temperature
	Cooling, Heating, and Growing Degree Days
	Convective Storms
	Drought and Wildfire
	Flooding and Total Water Levels Flood Hazard
Operational Capability Degradation (Activities)	Facility Access and Transportation
	Training Mission
	Emergency Operations
	Surrounding Community and Social Vulnerability
Physical Facility Degradation (Ecology and Assets)	Site and Buildings
	Cultural Resources
	Natural Resources

A risk questionnaire (Appendix II) was developed to further determine site specific information regarding climate change impacts at each of the 12 sites. The questionnaire was based on a questionnaire used by the Department of Defense: "Department of Defense: Climate-Related Risk to DoD Infrastructure Initial Vulnerability Assessment 2018." It was electronically sent out to designated points of contacts at the 12 National Guard facilities. Responses were collected using the online tool, SurveyMonkey. All twelve locations responded to the questionnaire. The responses were used to develop the risk matrices and further refine questions for the site visits.

Task 2: Facilitate a Rutgers Science Panel to Inform Risk Assessment and Response Options

Outputs: Climate Document and Updated Site Profiles

A Science Panel of Rutgers staff and faculty was convened to provide the most up-to-date and accurate climate science for the risk assessment. In preparation for discussions with the panel members, a draft "New Jersey State Climate Profile" was produced to provide an overview of statewide climate science trends in New Jersey. This draft document served as a summary of the statewide scientific basis for assessing future exposures to NJDMAVA assets and mission capabilities. This working document was used to generate discussion and feedback. The Climate Profiles was updated after the official convening of the Science Panel.

Panel participants spanned a range of sector-based specialties and expertise. The panel members included:

- Richard Lathrop, PhD - Johnson Family Chair in Water Resources & Watershed Ecology
- Daniel Van Abs, PhD - Associate Professor of Practice for Water, Society & Environment
- Mitchel Rosen, PhD - Associate Professor and Director, Center for Public Health Workforce Development
- David Robinson, PhD - Distinguished Professor & New Jersey State Climatologist
- Robert Kopp, PhD - Professor & Director, Institute of Earth, Ocean, and Atmospheric Sciences
- Qizhong (George) Guo, PhD - Professor, Civil and Environmental Engineering
- Marjorie Kaplan, DrPH - Associate Director, Rutgers Climate Institute

Due to COVID-19, the Science Panel members each met with two members of the Rutgers Team via individual remote, online meetings prior to coming together for a collaborative Panel meeting. The Panel agenda was split into two parts: climate science data consensus and risk assessment. Climate science data discussions focused on the questions: "What data sets?", "What time periods?", and "What measures?". During the risk assessment section, the Science Panel members discussed and agreed upon consensus approaches to climate risk assessments including the risks posed by heat, precipitation, humidity, and wildfire. They also discussed climate risk factors that were "cross-cutting" and pervasive between several sites. The deliberative New Jersey Climate Profile and Presentation utilized in the Science Panel discussion are included in Appendix III.

Following the general meeting of the Science Panel, individual members reviewed three (3) to four (4) site profiles each, assigned based on site-specific risks and vulnerabilities. Panel members' feedback resulted in updates to the site profiles and questions to be discussed during site visits and via additional desktop analysis.

Task 3: Site Visits to NJDMAVA Locations

Output: Updated Site Profiles

The Rutgers team performed site visits to nine (9) of the twelve (12) sites. Each visit consisted of two or more Rutgers team members, a representative from the NJDMAVA EMB, and at least one site-based staff member (maintenance personnel or other NJDMAVA staff). These visits allowed the Rutgers team to meet with onsite personnel, address individual site-based questions raised by the Science Panel, address lingering questions, follow up on additional inquiry resulting from the questionnaires distributed to the maintenance personnel, and follow up on questions that arose during the desktop analysis and site profile creation.

During the visits, the Rutgers team facilitated discussions using hard copies of site maps with key locations of interest and inquiry marked. Conversations were documented by members of the Rutgers team and photos were taken at each site. Another Rutgers team member ensured all site-specific questions were addressed and any follow up actions were documented. Following all site visits, the Rutgers team updated the site profiles with pictures, answers to previously identified gaps in knowledge, and utilized the results from the site visits to feed into Task 4: Production of Risk Assessment.

Fort Dix was not physically visited because the site was closed to outside visitors due to COVID-19 restrictions; alternatively, a phone call was hosted with the Rutgers team and members of the NJDMAVA team. Additionally, it was determined that the Jersey City and Newark sites did not require an onsite visit due to the lack of built and natural infrastructure located on and around the site. For these sites, the desktop analysis and follow up questions with the NJDMAVA team were deemed sufficient to produce a risk assessment.

An additional virtual meeting was hosted with Sean Burrough from NJDMAVA Medical Command to discuss overarching site-based climate health risks such as insect-borne illnesses, training thresholds for heat and humidity, and mold concerns. Discussion attendees included the Rutgers project team, the EMB team, and Dr. Mitchel Rosen (Rutgers).

Task 4: Produce Risk Assessment Response Options for Each NJDMAVA Site

Output: Risk Assessment Matrix for Each Site

At the completion of each site visit, the Rutgers team compiled the initial desktop analysis, interview notes, and site observations to assess potential physical impacts and mission impacts at each site. Impacts at each site were assessed by the Rutgers team using the scale below:

- 5 - Catastrophic - Permanent damage and/or loss of infrastructure service.
- 4 - Major - Extensive infrastructure/asset damage requiring extensive repair.
- 3 - Moderate - Widespread infrastructure/asset damage and loss of service. Damage recoverable by maintenance and minor repair.
- 2 - Minor - Localized infrastructure/asset service disruption. No permanent damage.
- 1 - Insignificant - No infrastructure/asset damage.

This scale was adopted from the NAVFAC guidance, and was paired with an emergency response table adapted from the RPDP guidance and documents. Together, the impacts scale and the emergency response tables reflected climate risk across functions and through time.

The Rutgers team assessed the impacts for each of the following phenomena:

- Pluvial Flooding – Flooding caused by surface water runoff (i.e., flash flooding) during intense precipitation events. The likelihood of these events is projected to increase as precipitation events become more intense in New Jersey.
- Fluvial Flooding – Flooding caused by rising water levels and bank overtopping along rivers. The likelihood of these events is projected to increase in New Jersey as precipitation events become more

intense. In addition, sea-level rise may cause compound impacts by raising the baseline water levels in tidal watersheds.

- Coastal Flooding – Flooding caused during especially high-tides and storm tides. The likelihood of these events is projected to increase in New Jersey as sea-level rise raises the baseline water level for flooding in tidally influenced areas of the state. The Total Water Level (TWL) approach was used, allowing for a variety climate emission scenarios and future storm conditions to be utilized in planning scenarios. The project team utilized 2030, 2050, 2070 and 2100 for planning scenarios. These horizons include near-term projections, mid-term projections consistent with the lifecycles of building structures and financing, and long-term lifecycle investments through 2070 and 2100 for large infrastructure projects.
- Temperature – Extreme temperature events include the number of days when the temperature rises above 95° F during the day. The likelihood of these events is projected to increase in New Jersey as temperatures warm. Extremely cold temperatures are days when the temperature drops below 32° F. The likelihood of these events is projected to decrease in New Jersey as temperatures warm.
- Convective Storms – Thunderstorms, tornadoes, and hailstorms that occur as part of weather systems that move through the region. Projections of the likelihood and frequency of these events in the future is uncertain for New Jersey. It is unlikely the events will decrease.
- Tropical and Extratropical Storms – Hurricanes, Nor'easters, and other hybrid storm events that occur from cyclonic activity along the coast of New Jersey. Global projections suggest that these storms will have higher wind speeds and more intense precipitation associated with them in the future. However, there is currently no scientific consensus for projections of future wind speed and precipitation for New Jersey.
- Drought – Dry conditions caused by warm temperatures and little precipitation. Drought projections for New Jersey are uncertain. However, scientific consensus suggests that precipitation patterns and changes in temperatures for New Jersey will create conditions that are more likely to result in drought.
- Wildfire – Wildfires occur as a result from arid conditions, heat, and available fuel sources. The Pinelands region of New Jersey is the most vulnerable region to wildfire, but projections for future frequency and intensity of wildfire are uncertain. However, the projection of the underlying patterns in precipitation and drought suggest an increase in the likelihood of wildfires as a precautionary planning measure.

The project team assessed impacts by evaluating available models or analyses from the desktop data collection, supplemented by on-site observations with site staff. There were few critical thresholds that site staff were able to identify in terms of specific event tolerances or discrete impacts. Where critical thresholds could not be identified by the NJDMAVA site team, impacts reflect conservative judgment based on the desktop analysis conducted by the Rutgers team. Where thresholds are available, the project team has gathered and analyzed them to provide more meaningful trigger points for actions and decision criteria. Table 3 summarizes the adapted emergency response table's example evaluation criteria that were used to assess the magnitude of the physical and mission relevant climate impacts at each site.

Task 5: Reconvene Rutgers Science Panel

Output: Finalized Site Profiles Including Risk Assessment Matrix for Each Site

The members of the Rutgers Science Panel were asked to complete final review of the updated site profiles. As in Task 2, members re-reviewed three (3) to four (4) site profiles each, assigned based on member's expertise and the site's biggest climate risks. Panel members' feedback were incorporated to produce final site profile documents.

Task 6: Final Risk Assessment and Response Recommendations

Output: Finalized Site Profiles and Summarized Response Focal Areas

The resultant outputs of the desktop analysis, creation of the site profiles, Rutgers Science Panel input, and site visits are: twelve (12) finalized site profiles with individualized climate risk assessments and this final summary document with findings related to climate risk and mission, portfolio-wide trends in climate risk and response, site specific investments, and themes for future climate adaptation and resilience planning and investments. Additionally, the Rutgers team reviewed the results and findings with the NJDMAVA EMB team and their invited guests via a virtual meeting.

Table 3: Example Impact Criteria and Measures for Site Assessments

Emergency Response Function	Description
Natural Disaster Vulnerability	**Will current and future weather events impact the physical characteristics of the site not explicitly covered under the critical assets below?** *<u>Example measures:</u> (1) Modeled or observed flood inundation, (2) Observed event impacts from storms and declared disaster events.*
Interstate Access	**Will current and future event exposures limit the local or regional accessibility of the site?** *<u>Example measures:</u>(1) Observed damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Controlled Perimeter	**Will current and future event exposures damage perimeter assets such as gates, fencing, or other physical security?** *<u>Example measures:</u> (1) Observed tree damage, power outage, or other damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Emergency Generator	**Will current and future event exposures limit generator utility or cause current equipment to become obsolete?** *<u>Example measures:</u> (1) Observed presence of a generator or interview indicates generator availability (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Drill Hall	**Will current and future event exposures limit the utility of the drill hall for normal operations or emergency operations?** *<u>Example measures:</u> (1) Observed damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Kitchen Facility	**Will current and future event exposures limit the utility of the kitchen for normal operations or emergency operations?** *<u>Example measures:</u> (1) Observed damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Tent Pads	**Will current and future event exposures limit the utility of the tent pads for normal operations or emergency operations?** *<u>Example measures:</u> (1) Observed damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Helipad	**Will current and future event exposures limit the utility of the helipad for normal operations or emergency operations?** *<u>Example measures:</u> (1) Observed damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Response Support	**Will current and future event exposures limit the ability of site personnel to respond as needed during emergency events?** *<u>Example measures:</u> (1) Observed damages or operational impacts from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Bathroom Stalls	**Will current and future event exposures limit the utility of the bathrooms for normal operations or emergency operations?** *<u>Example measures:</u> (1) Observed damages from prior events (2) Modeled or analyzed flooding and temperature exposures to critical components or systems*
Environmental Management	**Will current and future event exposures limit the effectiveness of current environmental management practices or require new or modified management practices that adjust for ecological change?** *<u>Example measures:</u> (1) Observed impacts and changes to site ecology based on prior events (2) Modeled or analyzed changes in site species and ecology based on temperature change or flood inundation*

Findings

Critical Relationship Between Climate and Mission

The effects of a changing climate are currently and will continue to be a national security issue, impacting military installations, operational plans, and overall missions. By anticipating future climate change conditions, these sites can reduce climate impacts to missions and operations and protect real property investments by reducing exposure.

Photo: Building exterior and parking at the Morristown National Guard site.

A changing climate will impact NJDMAVA's operations, such as in the way sites maintain readiness and provide support. There also may be changes to what NJDMAVA is asked to support such as humanitarian efforts after extreme storm events. At the federal level, the DoD considers climate resilience in installation planning and bases' processes to include impacts on both built and natural infrastructure. To ensure that these facilities are prepared to withstand future climate conditions and events, NJDMAVA will need to consider these findings when undertaking property development planning, site and infrastructure design, and current and future construction standards. Future projects and their respective sites within the NJDMAVA portfolio should be carefully reassessed based on the noted climate change risks for each site.

The DoD regards climate change resilience and response efforts as a function that span all levels and lines of effort and should not be viewed as a separate initiative. The needed resources for assessing and responding to climate impacts are provided within existing DoD missions, funds, and capabilities and are incorporated under existing risk management processes. All NJDMAVA branches will need to work in coordinated and strategic ways to prepare for climate change impacts at the NJDMAVA sites.

Climate Adaptation and Resilience Planning, Investments Coordination, and Partnerships

As a result of the Climate Change Risk and Resilience Assessment, the Rutgers Team is providing a series of noted successes, areas of potential future challenges, and areas of potential future collaborations and partnerships. These observations are a result of looking across the site profiles, interviews with site-based staff, discussions with the NJDMAVA EMB team, onsite visits and discussions with the Rutgers Climate Change Panel. Where possible, relevance to national-level DoD guidance and processes are referenced.

Success Stories

Historic Building Strategies
The NJDMAVA EMB team recognizes the unique nature of the historic buildings in the real estate portfolio and have developed strategies to continue to maintain the historic eligibility of those buildings and sites where historic designations apply. Such efforts help maintain the character of the sites and their surrounding communities, maintaining unique features (e.g., large drill floors) that prove essential for community functions and emergency response missions.

Photo: Historic Captain's cottage at the Sea Girt National Guard Site.

Environmental Inventories
The NJDMAVA EMB team has undertaken environmental inventories on many sites above and beyond those necessary for standard environmental management. These inventories provide essential baseline data for NJDMAVA to monitor for changing site ecology and identify subsequent changes to changes to rare and invasive species management strategies.

Potential Future Challenges

Climate Preparedness and Historic Buildings
The historic nature of several NJDMAVA buildings requires a coordinated and long-term capital planning strategy to ensure that the NJDMAVA EMB can maintain historic eligibility while providing suitable working conditions for soldiers and staff members. Based on site visits and observations at Teaneck, Morristown and Westfield, greater coordination in investment and retrofitting strategies for HVAC will be required to adapt indoor environments at these sites for warmer and more extreme future temperatures.

Increased High Temperatures - Training, HVAC, and Mold
Increases in the number of hot and extremely hot summer days and nights, longer and more intense heat waves, and increases in average winter temperatures (cold extremes will still occur) will result in challenges for the NJDMAVA sites. These changes are anticipated to affect outdoor military training and activities, change energy needs for buildings, increase the draw on HVAC systems, and damage roads. From a human health perspective, summer air quality will be reduced (NJDEP 2020; Zamuda et al. 2018). These changes will have potential impacts on soldier health and ability to train outdoors. From a natural resource perspective, these temperature extremes will potentially impact critical habitat and species of concern and will result in species shifts.

Additionally, the DoD Roadmap (DoD 2014) identifies two areas of climate change concern related to energy: (1) changing building heating and cooling demand, an impact on installation energy intensity and operation costs; and, (2) disruption to and competition for reliable energy supplies.

Specific to the 12 sites assessed, a common concern among many site maintenance personnel and staff was the HVAC infrastructure. Themes included age of units, inadequate output to meet demand, and problems with mold due to air not properly conditioned. These concerns and impacts will increase and necessitate an investment area of focus for the NJDMAVA portfolio.

Photo: Window air conditioning units at the Hammonton National Guard site.

Backup Power Generation
Rising temperatures are expected to affect both energy demand and supply. Higher temperatures will increase demand for energy resources, making blackouts and power supply disruptions more common (Zamuda et al. 2018). These extremes will result in spikes in energy demand for heating. For installations obtaining energy from regional sources, higher temperatures are also projected to drive up electricity costs, not only by increasing demand, but also by reducing the efficiency of power generation and delivery (Zamuda et al. 2018).

Only some of the NJDMAVA sites are prepared with backup power generation. Sites with backup generation should ensure the service is adequate to meet their demand needs now and into the future. Sites with no backup power generation should assess their power needs considering future demands. A portfolio-wide backup power generation strategy and implementation plan could be created to ensure power needs are continually and adequately met.

Vector Borne Disease Proliferation
Climate change is anticipated to increase heat-related health problems, with even small climate changes resulting in increases in illness and death. Higher temperatures will significantly increase the opportunity for vector-borne diseases: higher winter temperatures reduce winter vector mortality rates, whereas higher spring-fall temperatures extend the length of the breeding season, allowing for multiple reproductive cycles (USGCRP 2017). Warming temperatures have already allowed for the expansion of the geographic range and seasonal risk from vector-borne diseases in the U.S. (e.g., Lyme and West Nile virus). Climate change also has the potential to enable expansion of new disease into the U.S. from adjoining regions as climate conditions become more favorable for the disease vectors (e.g., mosquitos, fleas, ticks) (Beard et al. 2016).

For NJDMAVA sites where outdoor training and staging occurs, considerations and adaptations for changed disease vector distribution and ongoing disease management efforts will be required. NJDMAVA Medical Command currently monitors incidents among soldiers and staff members. In the future, additional monitoring, changes to personnel health resources, and available facilities may be needed to provide medical services and alternative locations for training and staging.

Regional Transportation Accessibility Coordination
The Climate Change Risk and Resilience Assessment identified several potential flood hazard impacts to critical transportation routes between NJDMAVA facilities and/or population centers. EMB and other facilities management branches should further investigate potential impacts with other NJDMAVA branches to identify any potential accessibility challenges to and from critical buildings in the portfolio.

Climate Extremes and Training Facilities Coordination
The Climate Change Risk and Resilience Assessment indicated that extreme heat days are expected to increase in frequency. Review of the medical and mission management standards, along with discussions with NJARNG Medical Command personnel indicated that such risks are actively monitored among leadership at each site where training activities are performed. NJDMAVA should continue to carefully monitor any updates in extreme temperature predictions and revisit the occupational safety topic. This includes monitoring locations where training efforts may be impacted in the future (e.g., Sea Girt, Fort Dix). Suitable indoor environments may be required in the future to accommodate training during summer months if temperatures and humidity levels become unsafe. Coordination between branches within NJDMAVA may be required to ensure such a facility is sited properly and constructed to ensure maximum indoor climate controls. These considerations should address any training risks and flooding from flash storms.

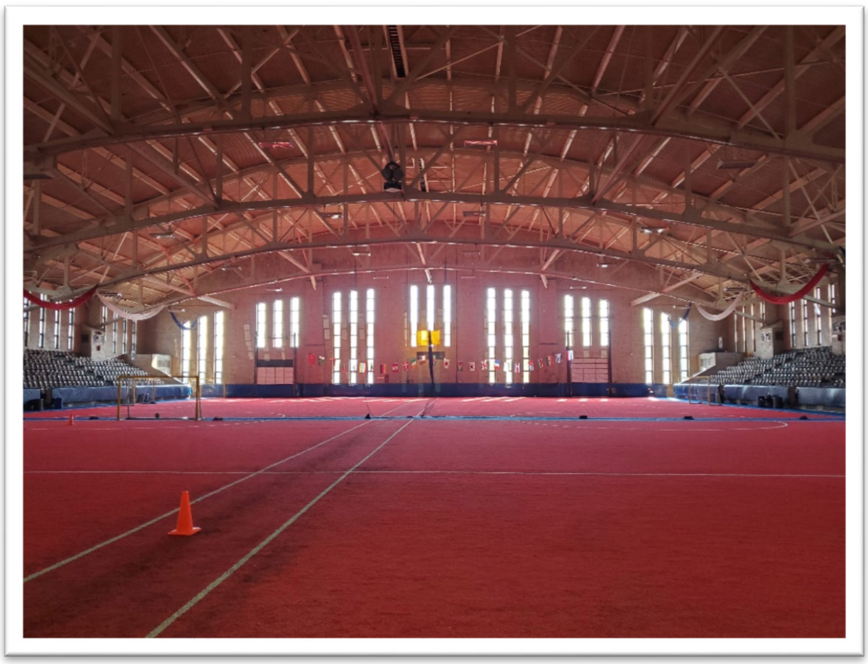


Photo: Indoor Drilling Floors at the Teaneck National Guard site.

Convective and Coastal Storms and Potential Wind Damage
NJDMAVA site staff noted damage from events including straight-line winds from thunderstorms and winds from coastal storms. There is not currently definitive consensus as to whether the intensity of winds related to either convective or coastal storms will increase in specific areas of New Jersey. Scientific consensus expects coastal storms, globally, will see increased wind speeds, whereas changes in thunderstorms and tornados are more uncertain. This uncertainty makes the impacts from such events (such as wind),

uncertain as well. Where technically and financially feasible, NJDMAVA should continue to upgrade roofs and building structures by strengthening building components to guard against future risk from more intense winds as a precautionary measure. Additionally, the use of temporary structures such as trailers and tent facilities should be minimized to reduce the risk of these structures becoming projectiles in future storms.

Potential Future Opportunities

Partnerships in Climate Change Habitat and Species Monitoring

Located in remote areas throughout the state, NJDMAVA sites could be suitable for ecological monitoring to better understand the impacts of climate change on habitats and species. Where applicable, monitoring and observations should be integrated with other natural resource management partner agency efforts (e.g., National Historic Sites, NJ Department of Environmental Protection Division of Fish and Wildlife) to monitor ecological changes overtime and/or habitat and species shifts through a coordinated and collaborative approach. A specific example was noted at Morristown, where the site's proximity to Jockey Hollow National Historic Park could pose cooperative research opportunities for both environmental and cultural studies at the state and federal level.

Photo: Seabeach amaranth (*Amaranthus pumilus*) along the Atlantic Ocean waterfront at the Sea Girt National Guard site.

Site-Specific Risks and Response Options

Based on the Climate Change Risk and Resilience Assessment, the following site-specific investments are suggested as options for NJDMAVA response. Response options are provided at sites where mission functionality was impacted to a moderate, major, and/or catastrophic level, up to 2100. Further investigations into specific engineering and design guidelines for some of these options would be necessary as a next step. Additionally, benefit-cost analyses should be conducted with all response options to ensure any investments in adaptation and mitigation activities will be worth the reduction in the risk.

Fort Dix

- Increasing temperatures and extreme high heat days will have a significant impact on building HVAC systems, and may lead to additional moisture and mold problems on site. Without a more frequent system maintenance and repair schedule, periodically unsuitable indoor environments may be more frequent.
  Response: *A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.*

Freehold

- A predicted rise in mean precipitation, and more frequent intense precipitation events has the potential to further damage buildings on the site and exacerbate existing storm water drainage issues.
  Response: *Any planned development in this portion of the site should consider storm water management alternatives that could mitigate more frequent and intense rain events.*

- Increasing temperatures and extreme high heat days will have a significant impact on HVAC systems within the facility. HVAC systems will experience higher loads due to predicted increases in cooling degree days. Without a more frequent system maintenance and repair schedule, system failures will become more common.
  Response: *A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.*

- Vector borne disease may become more prevalent due to an increase in growing degree days. Wetter conditions and standing water may compound this concern and result in increased mosquito proliferation.
  Response: *NJDMAVA and the county mosquito commission should assess future management options for the Armory.*

Hackettstown

- Lack of a backup generator may impact the site's response capabilities during storm events.
  Response: *NJDMAVA should assess the current and future backup power needs in the event of power outages.*

- Wetlands are present but are not near any structures and exist downhill, minimizing the chance for wetland expansion impacting the site.
  Response: *No response beyond current wetlands management protocols is needed to address this finding.*

Hammonton

- Lack of a backup generator may impact the site's response capabilities during storm events.
  Response: *NJDMAVA should assess the current and future backup power needs in the event of power outages.*

- Current HVAC window units may be insufficient to provide needed temperature control with increasing temperatures and extreme high heat days.
  Response: *A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.*

- Wetlands are present but are not near any structures and exist downhill, minimizing the chance for wetland expansion impacting the site.
  Response: *No response beyond current wetlands management protocols is needed to address this finding.*

Jersey City

- Increasing temperatures and extreme high heat days may have a significant impact on HVAC systems within the facility.
  Response: *A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.*

- Critical transportation routes between Jersey City and other regional facilities may be impacted during current and future storm events.
  Response: *The NJDMAVA could identify the roadways critical to getting staff and resources in and out of the site and work with responsible parties (local, state, county, and federal road, and highway departments) to survey road elevations. This information could be used in evacuation planning or flood response, or as a catalyst for road raising infrastructure upgrades. These finding could be published as part of the RPDP updates and as part of county and state hazard mitigation plan updates.*

Morristown

- A predicted rise in mean precipitation, and more frequent intense precipitation events has the potential to further erode the large gravel parking lot to the west of the main armory building. Water flowing downhill toward Wetland Series A will exacerbate this process.
  Response: *Erosion control measures should be investigated proactively, as precipitation is expected to increase in intensity. Further stormwater management measures may be necessary to reduce erosion while accommodating increased stormwater capacity.*

- Increasing temperatures and extreme high heat days will have a significant impact on HVAC systems within the facility.
  Response: *A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.*

Newark

- No critical climate vulnerabilities identified for this site.
  Response: *Currently there are no climate response options noted for this location. Future construction at the Newark site should proceed while being mindful of climate risks such as temperature extremes and increased flash rainfall events. As such, any planning and construction account for increased need for HVAC and stormwater management.*

- Critical transportation routes between Newark and other regional facilities may be impacted during current and future storm events.
  Response: *The NJDMAVA could identify the roadways critical to getting staff and resources in and out of the site and work with responsible parties (local, state, county, and federal road, and highway departments) to survey road elevations. This information could be used in evacuation planning or flood response, or as a catalyst for road raising infrastructure upgrades. These finding could be published as part of the RPDP updates and as part of county and state hazard mitigation plan updates.*

Sea Girt

- Sea-level rise will increase the likelihood that the site will experience flooding from high-tide flood events, as well as future coastal storms.
  Response: *NJDMAVA is currently moving facilities out of potential inundation areas along Stockton Lake. Natural and Nature-Based Infrastructure alternatives may provide additional resilience to flood hazards along the shore of Stockton Lake as facilities are relocated.*

- Sea-level rise and coastal storms will continue to damage and erode the protective dune system on the site. Failure of this system could prove catastrophic for the site, with significant impacts to buildings and training facilities. In addition, the dune system provides critical habitat to several managed and endangered species, in addition to critical protective functions for site facilities and operation.
  Response: *NJDMAVA, working with other Federal and State partners, should continue to monitor and manage the dune system and species as critical protective infrastructure for the site. Training assets located within and/or near the oceanfront/dune area, such as the range, should be evaluated for long-term viability. If the range function needs to be maintained into the future, an alternative location in an area west of the dunes would provide resilience to range operations.*

- Sea-level rise coupled with a predicted rise in mean precipitation has the potential to further damage buildings on the site, exacerbate existing stormwater drainage issues as well as impact vulnerable coastal and wetland habitats.

Response: *The predicted increase in flooding (coastal and stormwater) may necessitate a closer assessment of specific flooding risk areas and mitigation/adaptation options. For structures where it is not possible to elevate out of flood risk areas, relocation should be considered as an option. Whereas coastal flooding from storms poses a temporary risk, sea level rise flooding creates a permanent inundation risk. Absent areas to migrate inland, restricted coastal wetlands may become drowned and lose their natural infrastructure function. Wetland migration potential should be assessed.*

- Convective storms, tropical storms, or hurricanes have the potential to damage shingled roofs, modular buildings, and vehicles stored on site.
  Response: *Wind damage should be expected. Staging of temporary structures and modular buildings should be limited. Roofs should be proactively maintained and, where possible, vehicles should be stored in enclosed, wind resistant structures.*

- Vector borne disease may become more prevalent due to an increase in growing degree days. Wetter conditions and standing water may compound this concern and result in increased mosquito proliferation and the prevalence of West Nile Virus on site.
  Response: *Suitable indoor environments may be required in the future to accommodate training during times of increased mosquito proliferation. NJDMAVA and the county mosquito commission should assess future management options for the Armory.*

- Increased temperatures and humidity may impact outdoor training activities.
  Response: *Suitable indoor environments may be required in the future to accommodate training during summer months when temperatures and humidity levels become unsafe. Coordination between branches within NJDMAVA may be required to ensure such a facility is sited properly and constructed to ensure maximum indoor climate controls and adequate stormwater management measures. These considerations will address any training risks and flooding from flash storms.*

Somerset

- A predicted rise in mean precipitation, and more frequent intense precipitation events, has the potential to further disrupt training activities on this site.
  Response: *Current training activities occur in a stormwater drainage field behind the Somerset Armory building. To account for an increase in mean precipitation, alternate training locations should be considered for this site.*

- Increasing temperatures and extreme high heat days may have a significant impact on HVAC systems within the facility.
  Response: *A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.*

- Vector borne disease may become more prevalent due to an increase in growing degree days. Wetter conditions and standing water may compound this concern and result in increased mosquito proliferation.

<u>Response:</u> Suitable indoor environments may be required in the future to accommodate training during times of increased mosquito proliferation. NJDMAVA and the county mosquito commission should assess future management options for the Armory.

- Wetland management and flood hazard management may be necessary to maintain the utility of the southwestern portion of the site for training activities.
  <u>Response:</u> Any planned development in this portion of the site should consider storm water management alternatives that could mitigate more frequent and intense rain events.

Teaneck

- Increasing temperatures and extreme high heat days may have a significant impact on HVAC systems within the facility.
  <u>Response:</u> A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.

- Critical transportation routes between Teaneck and other regional facilities may be impacted during current and future storm events.
  <u>Response:</u>
  The NJDMAVA could identify the roadways critical to getting staff and resources in and out of the site and work with responsible parties (local, state, county, and federal road and highway departments) to survey road elevations. This information could be used in evacuation planning or flood response, or as a catalyst for road raising infrastructure upgrades. These finding could be published as part of the RPDP updates and as part of county and state hazard mitigation plan updates.

Washington

- Lack of a backup generator may impact the site's response capabilities during storm events.
  <u>Response:</u> NJDMAVA should assess the current and future backup power needs in the event of power outages.

Westfield

- Increasing temperatures and extreme high heat days may have a significant impact on HVAC systems within the facility.
  <u>Response:</u> A comprehensive HVAC assessment should be undertaken to determine if the current HVAC systems are/will be adequate and what HVAC systems will need to be replaced and/or upsized to ensure indoor temperature control will be adequate in the future. Additionally, frequent system maintenance and strategic capital investments to prepare the building envelope and systems to handle more frequent extreme (>95° F) heat days may be required.

- Storm water from increasingly intense rain events will continue to cause periodic flooding at the facility absent a redesign of the loading doors and facilities in the rear of the building.

Response: *Any planned development in this portion of the site should consider storm water management alternatives that could mitigate more frequent and intense rain events.*

- Critical transportation routes between Westfield and other regional facilities may be impacted during current and future storm events.
  Response: *The NJDMAVA could identify the roadways critical to getting staff and resources in and out of the site and work with responsible parties (local, state, county, and federal road and highway departments) to survey road elevations. This information could be used in evacuation planning or flood response, or as a catalyst for road raising infrastructure upgrades.*

Conclusions and Next Steps

Climate change will continue to be a national security issue, with NJDMAVA needing to continuously assess their risks and adapt their practices to this evolving threat. The NJDMAVA team should continue to seek and follow the best available and most up-to-date science. Individual installation site leaders will need to seek out further guidance specific to the individual installation's needs.

Resilience and climate adaptation planning is an iterative cycle. The continual nature of climatic changes and the associated impacts require Climate Change Risk and Resilience Assessments and adaptation planning to be viewed as an ongoing process, rather than as a "one-and-done" action. This process, with opportunities for continual review, evaluation, and readjustment, is consistent with DoD's longstanding commitments to addressing climate change impacts and adaptive management.

The information provided by the Rutgers Team is sufficient to address long-term planning decisions. Further implementation of actions and solutions will require additional quantitative data on risk magnitudes and more accurate, specific, and detailed analysis on projected impacts.

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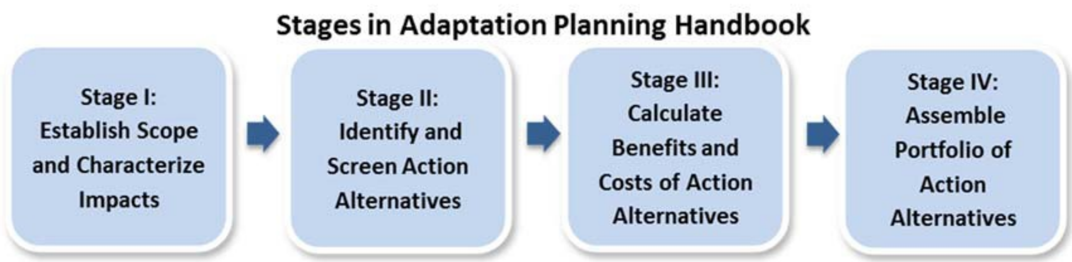
Zamuda, C., D.E. Bilello, G. Conzelmann, E. Mecray, A. Satsangi, V. Tidwell, and B.J. Walker. 2018. Energy Supply, Delivery, and Demand. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C.Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp.174–201. doi: 10.7930/NCA4.2018.CH4.

Appendix I: National-level Climate Planning Guidance

Following the process outlined in the Navy's Climate Change Planning Handbook: Installation Adaptation and Resilience (NAVFAC 2017), the Rutgers team assessed climate exposure impacts and incorporated this knowledge and data into findings intended to inform NJDMAVA installations' planning processes such as Real Property Development Plans. The process laid out in the NAVFAC 2017 is similarly aligned with a more recently released document, the 2020 Army Climate Resilience Handbook (ACRH). The ACRH builds upon the NAVFAC guidance through a robust framework for scenario-based planning and sensitivity analysis for proposed adaptation options. The ACRH also requires an assessment of the adaptive capacity for proposed alternatives. Additional information about the NAVFAC and the ACRH are included here.

The Navy's Climate Change Planning Handbook: Installation Adaptation and Resilience (NAVFAC 2017)

Navy Master Development Planners are directed "to consider" climate change in the development of Master Plans and projects. The NAVFAC Handbook provides the analytical framework, as well as tools and other guidance, to help planners understand how to consider climate change in their plans and projects for installation infrastructure. More specifically, this document leads planners through the process of identifying and assessing possible adaptation action alternatives, or methods for adapting to the impacts of climate change. These adaptation measures are intended to improve their installation's resiliency or capability to anticipate, prepare for, respond to, and recover from significant hazards.



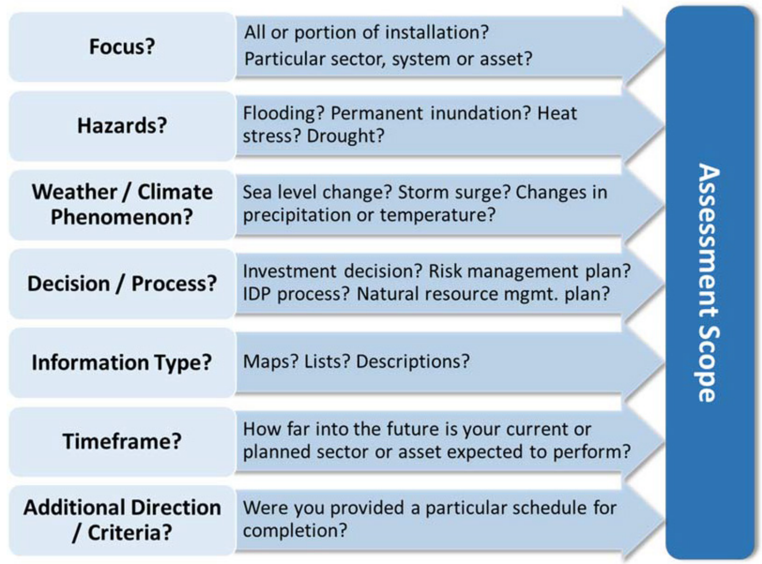
Stage 1 – Establish Scope and Characterize Impacts

This Stage sets up and guides the preliminary research steps needed to develop a problem statement. First, the assessment scope is determined by examining parameters such as: the geographic extent of the subject area, intended lifespan of the infrastructure, the climate phenomena and hazards of interest, and the kind of decision to be supported. Next, relevant information is identified and evaluated, along with the use tools and worksheets, to assess, describe, and characterize current and future climate impacts. Prior to starting to identify potential action alternatives in Stage II, Stage I develops a problem statement that characterizes the issues to be addressed.

- Step 1: Determine Assessment Scope - The assessment scope and underlying assumptions should be as clear as possible because they will help maintain focus and discipline throughout a complex analytical process and guide the preliminary research steps needed to develop a problem statement, which is the output of this stage.

- Step 2: Identify and Evaluate Information - In this step, information for your assessment (e.g., installation site information, impacts during historical weather events, and climate information requirements) will be identified and evaluated.

- Step 3: Describe and Characterize Impacts - In this step, current and future impacts will be characterized and the magnitude of those potential impacts on the infrastructure identified in Step 1 will be categorized.



- Step 4: Develop Problem Statement - In this step, all the information collected will be reviewed and problem statement(s) will be developed. These outputs will be addressed in Stage II – Identify & Screen Action Alternatives.

Stage 2 – Identify and Screen Action Alternatives

In Stage II, a list of potential action alternatives will be developed. Adaptation actions that are suitable, feasible, and appropriate responses to the installation impacts identified in the problem statement from Stage I will be identified. Each action alternative's benefits and limitations will be documented and how each of the potential actions responds to decisions under uncertainty will be characterized.

Stage 3 – Calculate Benefits and Costs of Action Alternatives

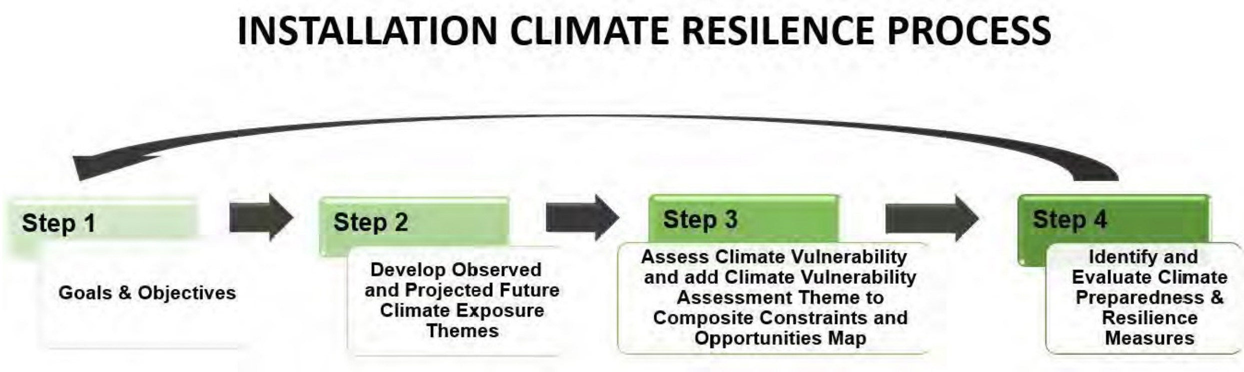
In Stage III, the information and available data for each action alternative completed in Stage II will be assembled and a preliminary portfolio of action alternatives will be developed. Using the information resources and tools cited, a benefit-cost analysis (BCA) will be completed and the calculations necessary to arrive at measures of adaptation intervention merit will be performed. These measures of merit, including benefit-cost ratios (BCR), net present values (NPV), and internal rates of return (IRR), will provide monetized metrics that can be used to preliminarily rank action alternatives.

Stage 4 – Assemble Portfolio of Action Alternatives

In Stage IV, information generated in the previous stages will be assembled into a concise summary that presents the results of the analyses conducted. The summary will be in a format that can be used by planners and decision makers to evaluate a range of options or to inform the development of alternative courses of action. A more nuanced evaluation of each alternative, in terms of future variables that may change, will be conducted. A brief statement about how each alternative addresses risk will be provided.

Army Climate Resilience Handbook (ACRH)

The Army Climate Resilience Handbook breaks the federal installation climate resilience planning process into four steps.



Federal guidance suggests that if these analyses reveal that all or part of an installation may be subject to climate impacts, this information should inform the vision plan and the long-range plan for the installation.

Step 1: Installations' Mission, Goals, and Objectives

The first planning step is to understand installation's site profile and vision plan, understand the mission and objectives of the installation 20 to 50 years out, and establish the site's goals in relation to mission success. Following risk-informed planning, this step includes site profiles with such information as the geographic extent of the subject area (installation, installation with 5 mile buffer, etc.), intended lifespan of the existing infrastructure, and the current planned construction or changes across the installation.

Step 2: Observed and Expected Future Climate Exposure Themes

Existing conditions are the current conditions of installation, including facilities, environmental resources, land use, utilities, transportation, airfields, and ranges and training lands. In gathering information about existing conditions, the current condition and demand should be evaluated, along with assessments of any gaps that may exist between current and expected future conditions.

For climate exposure assessment purposes, installations should be assessed for exposure to current and historical extreme weather events as well as projected future climate conditions (average and extremes). Because different data sets are used to assess current/historical exposure and future exposure, the analysis is divided into two steps:

- Current and Historical Exposure to Nuisance and Extreme Weather Events
- Projected Future Climate Exposure

Step 3: Creating the Climate Vulnerability Theme for the Constraints and Opportunities Map

Vulnerability is the degree to which an installation is likely to experience harm due to exposure to weather extremes and climate change (Turner et al. 2003). It consists of three factors:

- Exposure to one or more climate impacts.
- Sensitivity to this exposure, the degree to which assets will be adversely or beneficially affected by this exposure.
- Adaptive capacity, the ability to adjust to or mitigate for the impact or its consequence on sensitive assets.

Steps 1 and 2 will help identify areas sensitive to current or future climatic events. Current areas and infrastructure that are at the greatest risks of experiencing nuisance weather, weather extremes, and future climate change should be further explored.

Part of identifying the sensitivity of assets to climate impacts across sites is identifying the root causes that contribute to the assets' exposure. The cause-and-effect relationship can help identify natural and man-made constraints that are impacting climate resilience on the installations. One way to explore and build cause-and-effect relationships, from the USACE Risk-Informed Planning Manual (Yoe and Harper 2017), is the Ishikawa Diagram method. It is a great way to visually lay out the thought process behind cause-and-effect relationships.

The role of Step 3 is to assess adaptive capacity. This is an assessment of the ability of the installation to reduce the exposure of the asset. If the exposure is readily reduced—for example, reducing flood risk to a building by improving stormwater drainage—then the affected infrastructure or facility has high adaptive capacity. Adaptive capacity is considered low when exposure is not easily reduced. For example, if an airfield will become inundated 50% of the time due to sea-level rise and measures such as seawalls and relocation are infeasible, adaptive capacity may be low.

Step 4: Choosing Climate Preparedness and Resilience Measures

The last step in the process is to identify climate preparedness and resilience measures that can be used to reduce the installation's vulnerability to climate change. The purpose of this step is to develop a catalog of measures that can be implemented as funding or other opportunities become available. As better data on climate exposure and vulnerability become available, this catalog of measures should be revisited.

Appendix II: The New Jersey Risk Exposure Questionnaire

NEW JERSEY DEPARTMENT OF MILITARY & VETERANS AFFAIRS

RISK EXPOSURE QUESTIONNAIRE

Facility:
Respondent Name:
Respondent Position:
Respondent Contact Information:
How long has Respondent been working at the site:

Flooding

Please respond to questions regarding both 'on-site' impacts or areas in the surrounding community that otherwise impact site Mission requirements (ex. Flooding on local roadways off-site that prevent access).

1. Has a flood event occurred due to intense rain events like thunderstorms, derechos, or other non-coastal storms? (Yes or No Response)

If Yes:

a. What is the approximate number of occurrences per year?
b. Please describe recent or notable events, include information like dates and water levels.
c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological
d. What measures were implemented to mitigate or prevent future impacts due to flooding?
e. How has flooding related to rain events impacted training capabilities on site?

2. Has a flood event occurred during high tide (Yes or No Response)?

If Yes:

a. What is the approximate number of occurrences per year?
b. Please describe recent or notable events, include information like dates and water levels.
c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological.
d. What measures were implemented to mitigate or prevent future impacts due to flooding?
e. How has flooding related to high tides events impacted training capabilities on site?

3. Has a flood event occurred due to a coastal storm like a nor'easter or hurricane?

If Yes:

a. What is the approximate number of occurrences per year?
b. Please describe recent or notable events, include information like dates and water levels.

c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological.
d. What measures were implemented to mitigate or prevent future impacts due to flooding?
e. How has flooding related to storm events impacted training capabilities on site?

Extreme Temperatures

Please respond to questions regarding both 'on-site' impacts or areas in the surrounding community that otherwise impact site Mission requirements (ex. Brownouts during summer)

1. Has your installation been negatively impacted by extreme hot or cold temperatures?

If Yes:

a. What is the approximate number of occurrences per year? Please indicate whether they are hot or cold events?
b. Please describe recent or notable events, include information like dates and temperatures.
c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological.
d. What measures were implemented to mitigate or prevent future impacts due to extreme temperatures?
e. How have extreme temperatures impacted training capabilities on site?

Wind Damage

Please respond to questions regarding both 'on-site' impacts or areas in the surrounding community that otherwise impact site Mission requirements (ex. Downed trees blocking roadways and/or damaging power lines)

1. Has your installation been negatively impacted by wind damage?

If Yes:

a. What is the approximate number of occurrences per year?
b. Please describe recent or notable events, include information like dates, storm event, damage location, etc.
c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological.
d. What measures were implemented to mitigate or prevent future impacts due to wind damage?
e. How has wind damage impacted training capabilities on site?

Drought

Please respond to questions regarding both 'on-site' impacts or areas in the surrounding community that otherwise impact site Mission requirements (ex. Water supply)

1. Has your installation been negatively impacted by drought?

If Yes:

a. What is the approximate number of occurrences per year?
b. Please describe recent or notable events, include information like dates and duration.
c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological.
d. What measures were implemented to mitigate or prevent future impacts due to drought?
e. How have episodes of drought impacted training capabilities on site?

Wildfires

Please respond to questions regarding both 'on-site' impacts or areas in the surrounding community that otherwise impact site Mission requirements (ex. Training limitations from smoke inhalation)

1. Has your installation been negatively impacted by wind damage?

If Yes:

a. What is the approximate number of occurrences per year?
b. Please describe recent or notable events, include information like dates and duration.
c. Please describe the impacts of these events as they relate to People/Site Operations, Physical Buildings, Ecological.
d. What measures were implemented to mitigate or prevent future impacts due to wildfires?
e. How have wildfires impacted training capabilities on site?

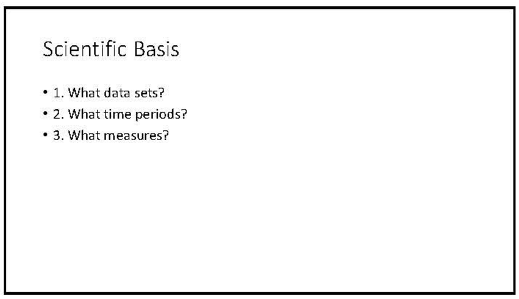
Additional Questions

1. Are there any reports or documents available that are relevant to the answers above? If yes, please attach the documents or provide a contact person that the Rutgers team can obtain the documents from.

2. Please provide any additional comments or feedback.

Appendix III: Materials for the Rutgers Climate Science Panel

Rutgers Science Panel Presentation



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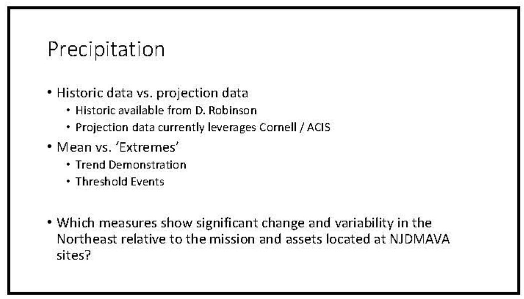

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Convective Storms

- Historic data available
- Possible projections?
- If limited / no scientific consensus for NJ, how might we structure future scenarios using historical precedents?

7

Coastal Storms

- Historic data available
- Possible projections?
- If limited / no scientific consensus for NJ, how might we structure future scenarios using historical precedents?
- Coastal Storm flooding is integrated into 'total water level' exposure assessment approach for identifying critical thresholds

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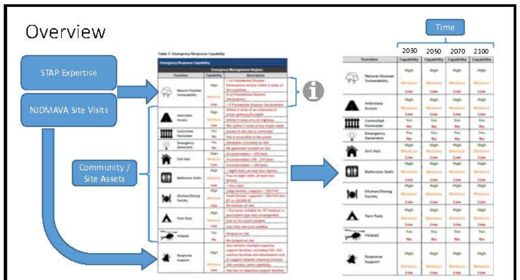

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Weather / Climate / Hazard

Weather/Climate Phenomena

- Precipitation
- Temperature
- Heat
- Convective Storms
- Sea-Level Rise
- Coastal Storms
- Drought and Wildfire → ?

Hazard

- Flooding
  - Storm tide
  - High tide / Nuisance
  - Pluvial (Surface Stormwater)
  - Fluvial (River)
- Wind
- Temperature Extremes

12

Discussion DRAFT New Jersey State Climate Profile

This statewide climate profile provides an overview of statewide climate science trends in New Jersey. These trends include direct meteorological phenomena (i.e., heat, precipitation, storms) and other related hazards (e.g., drought, wildfire). Extreme weather events typically experienced in the state include coastal nor'easters, snowstorms, spring and summer thunderstorms, flooding rains, heat and cold waves, tropical storms, and hurricanes.

The purpose of this draft document is to serve as a summary of the statewide scientific basis for assessing future exposures to NJ DMAVA assets and mission capabilities. This is a working document that will be updated after review by a Science and Technical Advisory Panel (STAP) constituted under Rutgers University. Current STAP participants include:

- Richard Lathrop, PhD - Johnson Family Chair in Water Resources & Watershed Ecology
- Daniel Van Abs, PhD - Associate Professor of Practice for Water, Society & Environment
- Mitchel Rosen, PhD - Associate Professor and Director, Center for Public Health Workforce Development
- David Robinson, PhD - Distinguished Professor & New Jersey State Climatologist
- Robert Kopp, PhD - Professor & Director, Institute of Earth, Ocean, and Atmospheric Sciences
- Qizhong (George) Guo, PhD - Professor, Civil and Environmental Engineering
- Marjorie Kaplan, DrPH - Associate Director, Rutgers Climate Institute

The STAP will begin their review in March 2020, prior to site visits and interviews.

Important Terms and Terminology

Emissions Pathways and Scenarios

Current climate modeling efforts are based on the representative concentration pathways modeled for the IPCC 5th Assessment Report, and subsequently used in the latest United States National Climate Assessment (van Vuuren et al., 2011) These emissions are labeled as Representative Concentration Pathways (RCPs), which indicate how much radiative forcing will occur by the end of the century (National Oceanic and Atmospheric Administration, 2020). Radiative forcing is the difference between the energy earth absorbs and what it releases back to space. Changing climate conditions cause the earth to absorb more energy than it releases to space resulting in warming of the planet. It is important to consider different RCPs as part of resilience planning because future is dependent on the extent to which global policies are in place to reduce climate-causing emissions. The higher the emissions, the larger and more rapid global temperature changes.

For the purposes of this analysis, the project team utilizes RCP 8.5 and RCP 4.5 to understand the sensitivity of our assumptions to future climate policy driven emissions reductions. RCP 8.5 corresponds to a high emissions future where carbon dioxide and methane emissions continue to rise because of fossil fuel use. There are significant declines in emission growth rates over the second half of the century, significant reduction in aerosols, and modest improvements in energy intensity and technology. Atmospheric carbon dioxide levels for RCP8.5 rise from current-day levels of 400 up to 936 parts per million (ppm) by 2100. Levels from other non-CO2 greenhouse gases, aerosols, and other substances reach more than 1200 ppm by 2100. Under RCP 4.5, emissions stabilize and atmospheric CO2 levels remain below 550 ppm by 2100 and CO2-equivalent concentrations that include all emissions from human activities reach 580 ppm (National Oceanic and Atmospheric Administration, 2020).

Sea-Level Rise

Throughout the document, when describing local or regional sea-level rise (SLR), the project team refers specifically to relative SLR, the rise in the height of the sea surface relative to the height of the land. Relative SLR is caused by a combination of a rising sea surface and by a subsiding land surface, whereas 'eustatic' SLR is associated solely with the increased volume in the ocean and does not account for land subsidence and other local or regional terrestrial changes (Gregory et al., 2019).

Precipitation

Over the longer term, there has been an upward trend in annual precipitation in New Jersey. Since 1895, annual precipitation has increased at a rate of 4.1 inches (or about 9%), with the post-1970 period being much wetter than the 1895-1969 period, on average. It is important to note, however, that the decade-to-decade variability in annual precipitation is quite large and can overwhelm any long-term trends. Precipitation was well below average during the drought of the early 1960s, but much wetter conditions prevailed during the 1970s. The last decade has also been unusually wet. 2018 was the wettest year since statewide records began in 1895 (Office of the New Jersey State Climatologist, 2020). The heaviest precipitation amount for three of the twelve calendar months (March, June, August) has occurred since 2010, with August 2011 weighing in as the all-time wettest month since statewide records began in 1895 (Broccoli et al., 2013; Office of the New Jersey State Climatologist, 2020).

Heavy precipitation events have increased dramatically in the past two decades, nominally and as a percentage of total rainfall, occurring more than twice as often in recent years than during the past century. There is reason to expect that this trend may continue. Annual precipitation for New Jersey has been about 8% above average over the last 10 years. The number of extreme precipitation events has also been above average over the last 10 years. During 2010–2014, the state experienced the largest number of extreme precipitation events (days with more than 2 inches) compared to any other 5-year period, about 50% above the long-term average.

In New Jersey, winter and spring precipitation is projected to increase for the 21st century; extreme precipitation is also projected to increase (See Figure 1 and Figure 2). The projections of increasing precipitation are characteristic of a large area of the Northern Hemisphere in the northern middle latitudes, as well as increases in heavy precipitation events. This may result in increased coastal and inland flooding risks in the state (NOAA National Centers for Environmental Information, 2020).

Mean monthly precipitation in New Jersey is expected to increase resulting from climate change. Mean monthly precipitation in July over the 1981 – 2010 baseline ranged between 3 and 6 inches (in) over the central portion of the state (See Figure 3b). By the 2080-2099 period, July mean monthly precipitation may increase between 0.25 to 0.75 in for RCP 4.5 or 0.25 to 1 in for RCP 8.5 (See Figure 4). Mean monthly precipitation in January over the 1981 – 2010 baseline ranged between 2 and 3 in. over a majority of NJ. By the 2080-2099 period, January mean monthly precipitation may increase between 0.0 to 0.5 in. for RCP 4.5 or 0.25 to 0.75 in. for RCP 8.5 (See Figure 5).

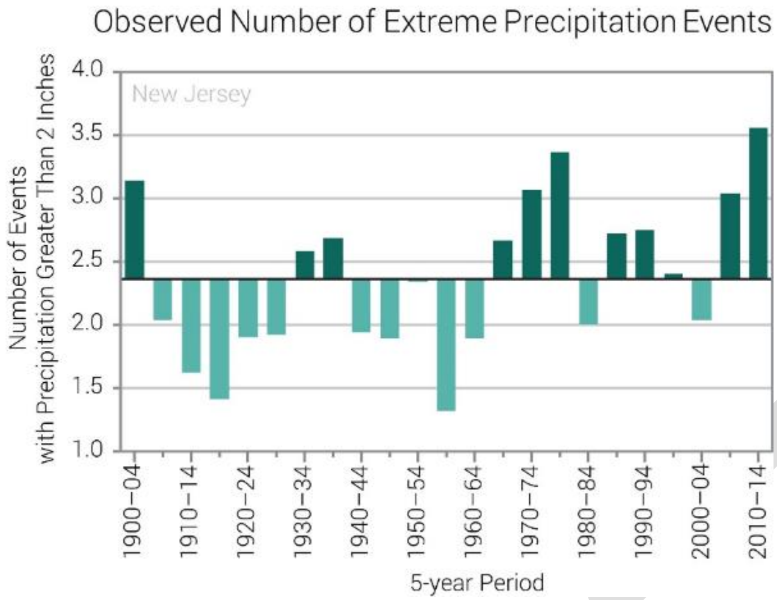

Figure 1. The observed number of extreme precipitation events (annual number of events with greater than 2 inches) for 1900–2014, averaged over 5-year periods; these values are averages from six long-term reporting stations. The dark horizontal line is the long-term average (1900–2014) of 2.4 days per year. Source: CICS-NC and NOAA NCEI.NCEI)

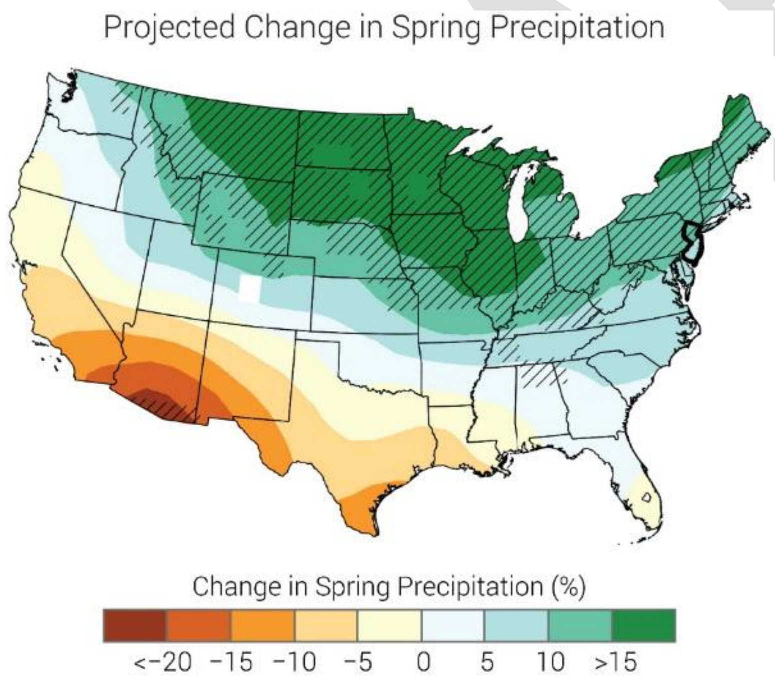

Figure 2. Projected changes (%) in spring precipitation for the middle of the 21st century (2041-2070) compared to the late 20th century (1971-2000) under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Source: CICS-NC and NOAA NCEI.

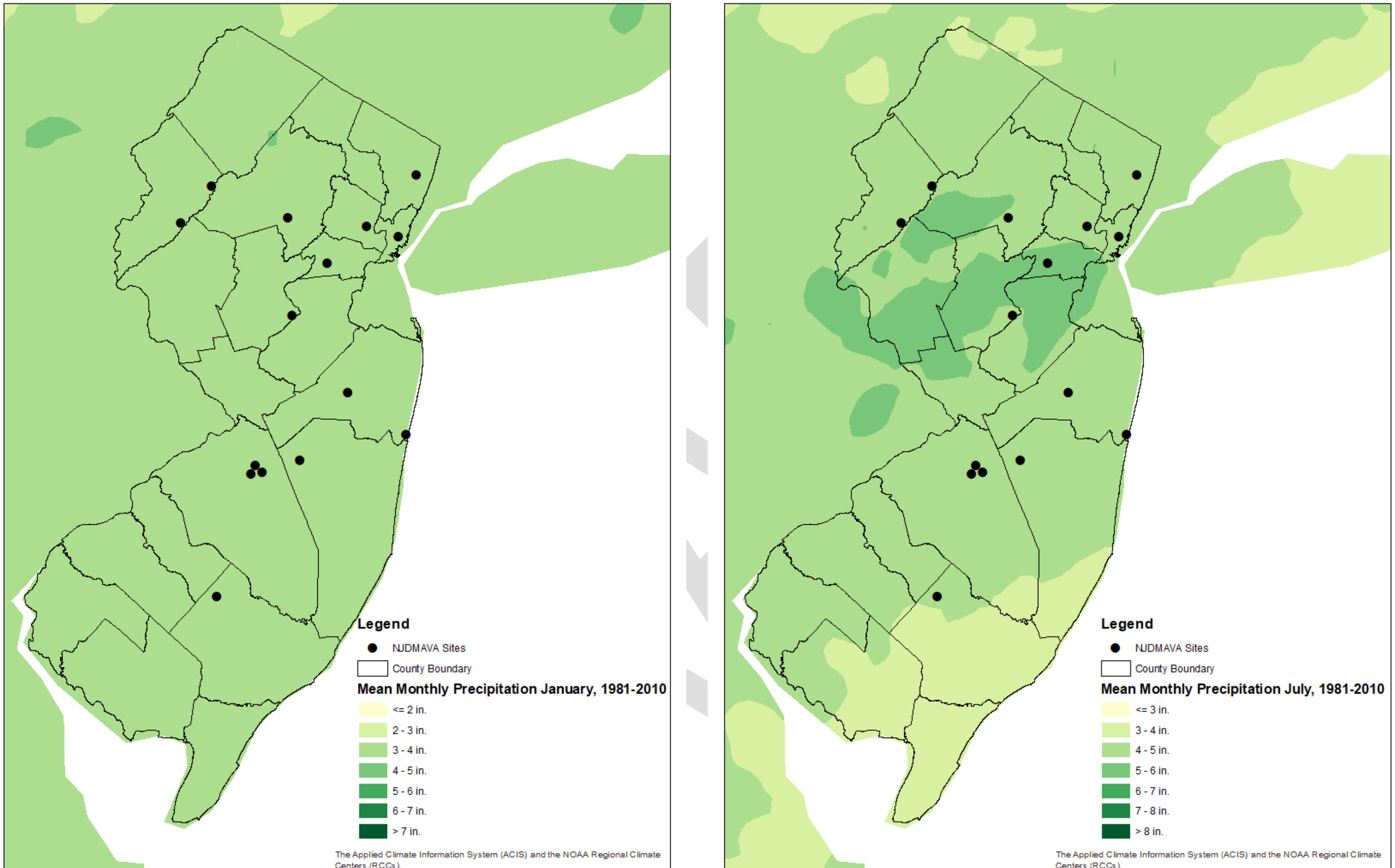

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Figure 3: Baseline (1981-2010) New Jersey Mean Monthly Precipitation in (a) January and (b) July

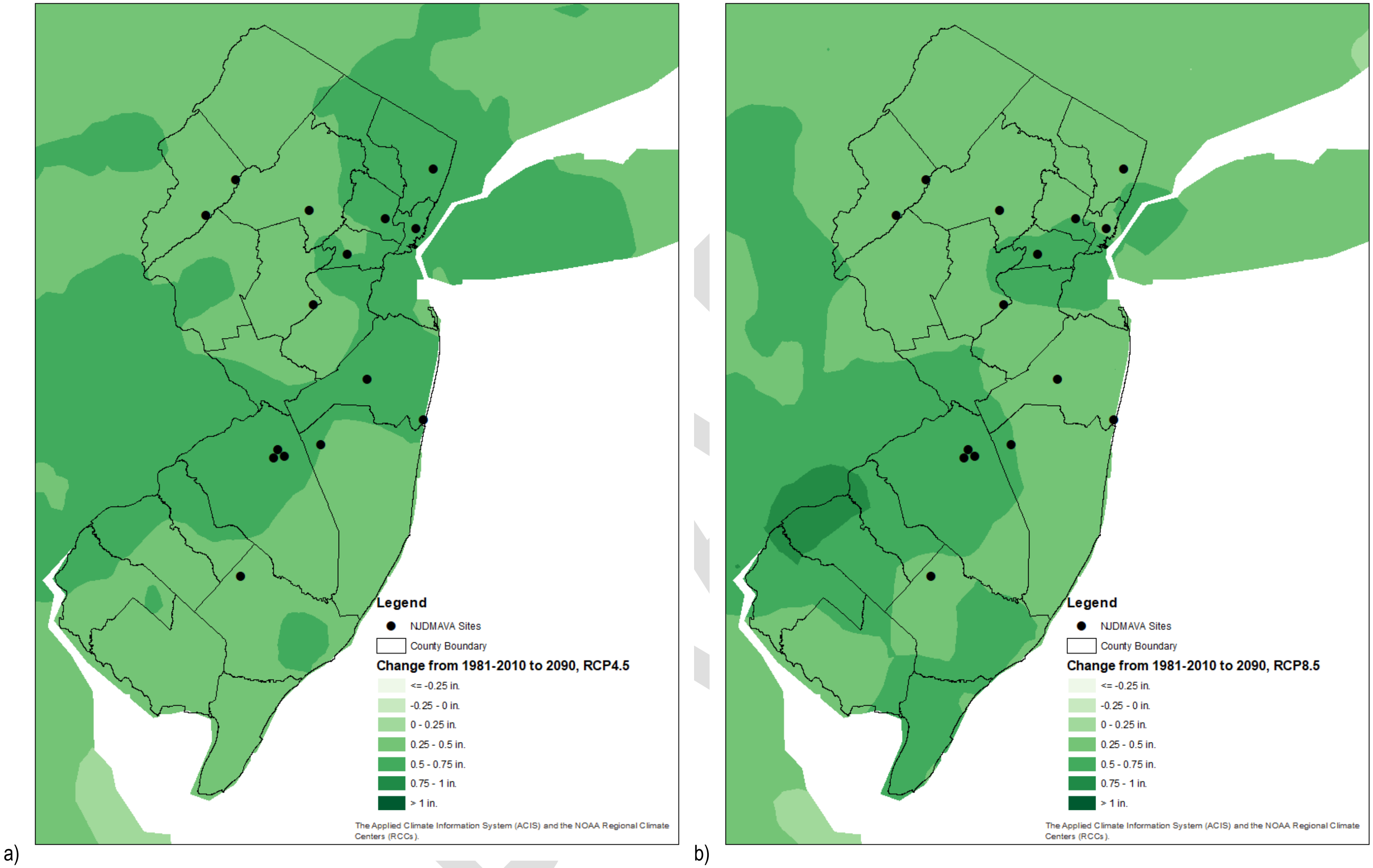

Figure 4: Projected Change in Mean Monthly Precipitation in July under (a)RCP 4.5 and (b)RCP 8.5 emissions scenarios by 2080-2099.

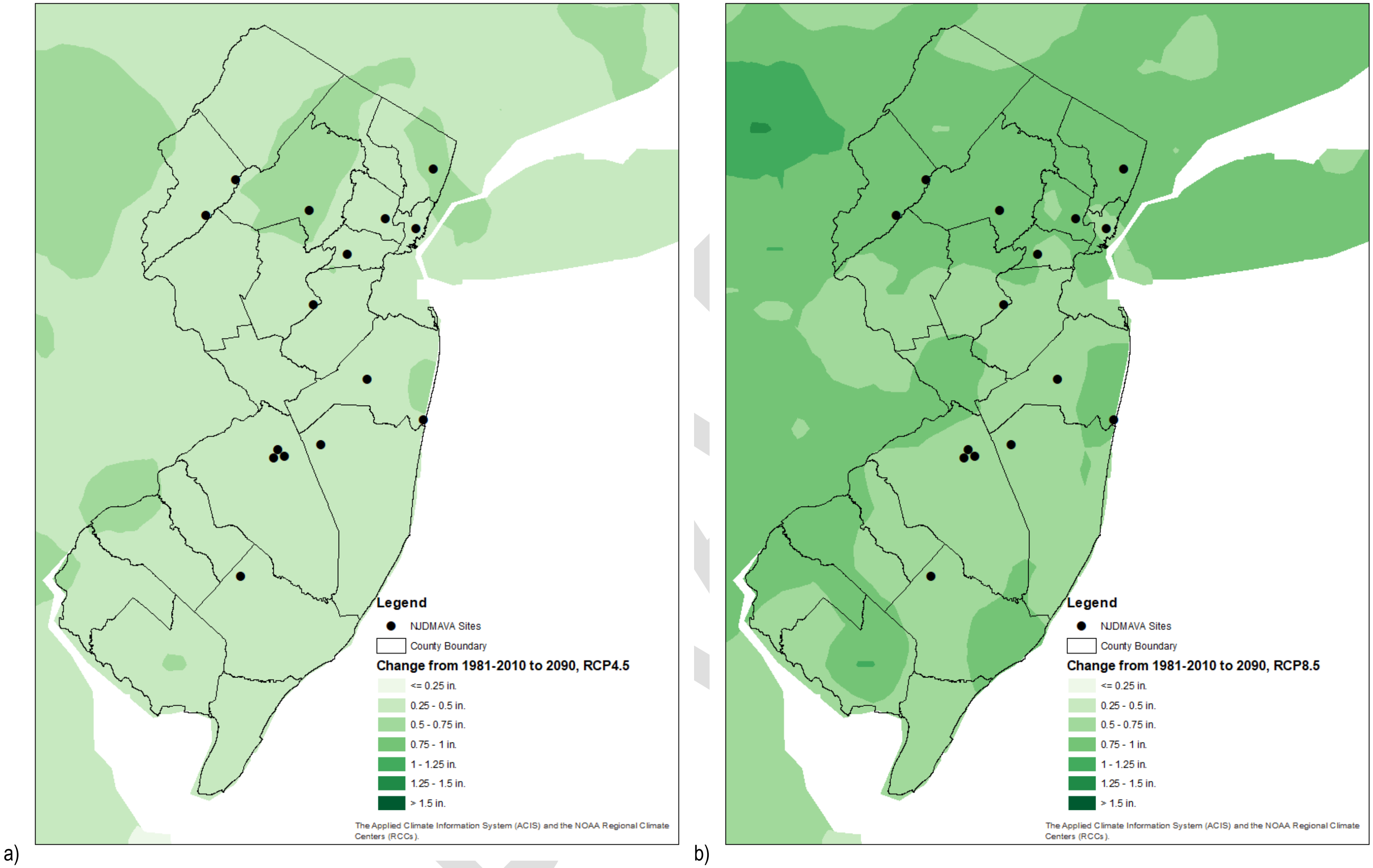

Figure 5: Projected Change in Mean Monthly Precipitation in January under (a)RCP 4.5 and (b)RCP 8.5 emissions scenarios by 2080-2099.

Temperature

Global average temperature analyses indicate that the 2018 global surface temperature was the fourth highest on record, with only 2016, 2015 through 2017 being warmer. The exact ranking varies slightly depending on which of the four major global temperature compilations is used. In all four compilations, 2018 was 0.30°–0.40°C above the average for the 1981–2010 (Blunden & Arndt, 2019). In a 2018 report, the Intergovernmental Panel on Climate Change (IPCC) concluded human activities have caused approximately 1.0°C of global warming above pre-industrial levels, and that such warming was likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). Global warming trends are expected to continue or accelerate throughout the coming decades as greenhouse gas concentrations are projected to increase.

The last decade in New Jersey has been warm. The year 2012 was the warmest since statewide records began in 1895 (Office of the New Jersey State Climatologist, 2020). The warmest mean temperatures for nine of the twelve calendar months (February, March, April, May, June, July, August, November, December) have occurred since 2010, with three of the five warmest years occurring (2011, 2012, 2016) since statewide records began in 1895. No record monthly or annual lows have occurred in NJ for almost three decades (Broccoli et al., 2013; Office of the New Jersey State Climatologist, 2020).

Mean temperatures in New Jersey are expected to increase resulting from climate change. Mean Daily Maximum Temperatures in July over the 1981 – 2010 baseline ranged between 86 and 90 °F over the central portion of the state (See Figure 6a). By the 2080-2099 period, July mean daily maximum temperatures may increase between 4 - 6 °F for RCP 4.5 or 8 - 12 °F for RCP 8.5 (See Figure 7). Mean Daily Minimum Temperatures in January over the 1981 – 2010 baseline ranged between 21 and 25 °F over a majority of NJ, with lower temperatures in the Highlands region of the state (See Figure 6b). By the 2080-2099 period, January mean daily minimum temperatures may increase between 4 – 6 °F for RCP 4.5 or 5 - 10°F for RCP 8.5 (See Figure 8).

Cooling, Heating and Growing Degree Days

Cooling and Heating degree days are used as predictors of the amount of energy used to cool or heat buildings during the summer or winter, respectively. Cooling degree days are calculated by the energy required to cool an indoor space to 65 °F from the predicted outdoor temperature. For example, to keep a building at 65°F when the outdoor temperature is 85°F, requires reducing the indoor temperature by 20 degrees. The requirement of 20 degrees of cooling multiplied by 1 day, results in a metric of 20 cooling degree days. Growing degree days are used to estimate the growth and development of flora and fauna during the growing season, higher numbers indicate longer and warmer growing conditions, the number of days times the number of degrees above the historical value indicates the duration and magnitude of growing conditions.

2011-2012 experienced the lowest annual total heating degree days, with three of the five lowest statewide total ever occurring since 2010 - 2011 (Office of the New Jersey State Climatologist, 2020). The lowest mean monthly heating degree days for six of the twelve calendar months (November, December, February, March, April, May) have occurred since 2010 - 2011 (Broccoli et al., 2013; Office of the New Jersey State Climatologist, 2020). Conversely, 2010 had the highest annual total cooling degree days; four of the five highest totals statewide ever have occurred since 2010. The highest monthly cooling degree days for six of the twelve calendar months (March, April, May, June, August, December) have occurred since 2010.

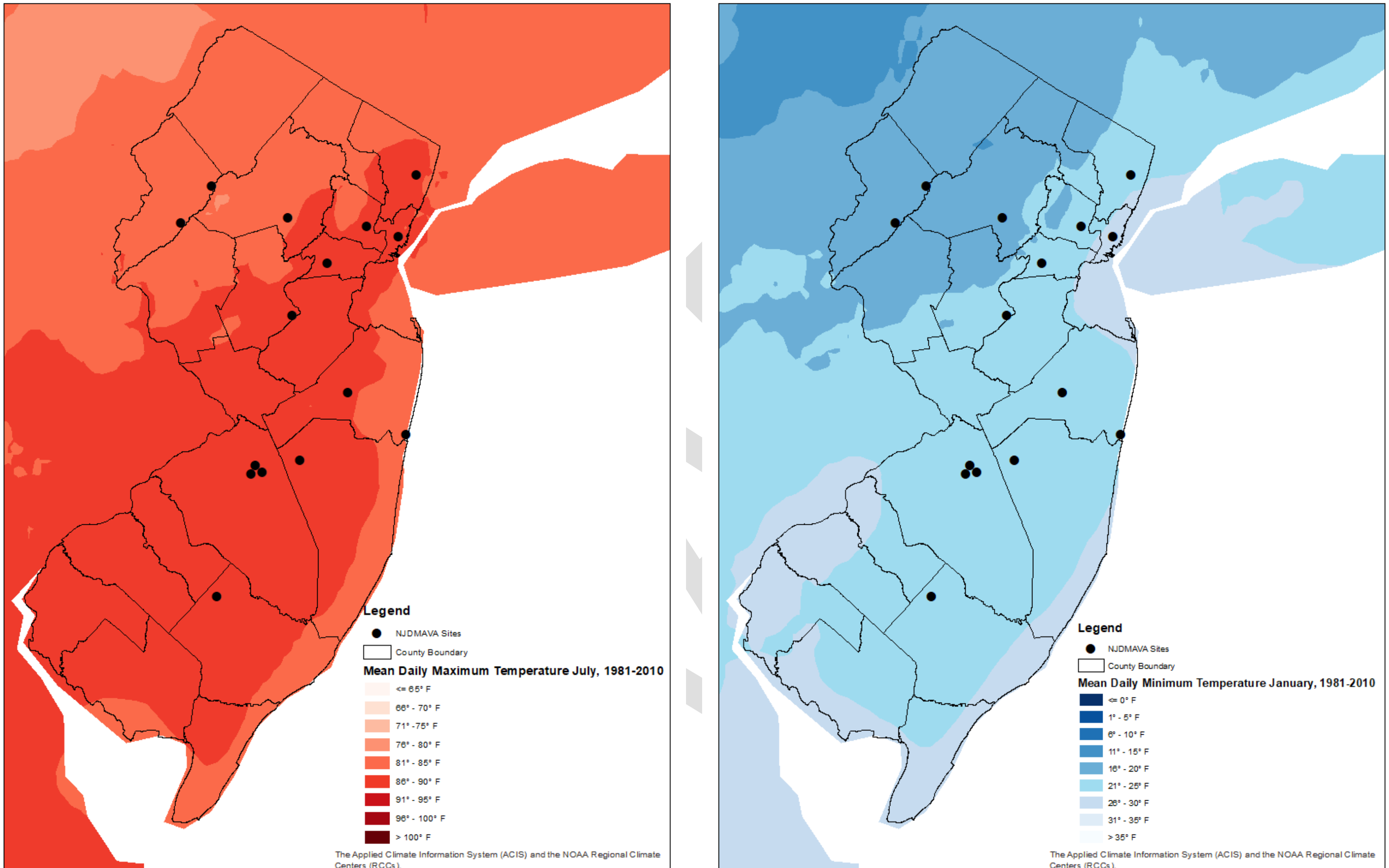

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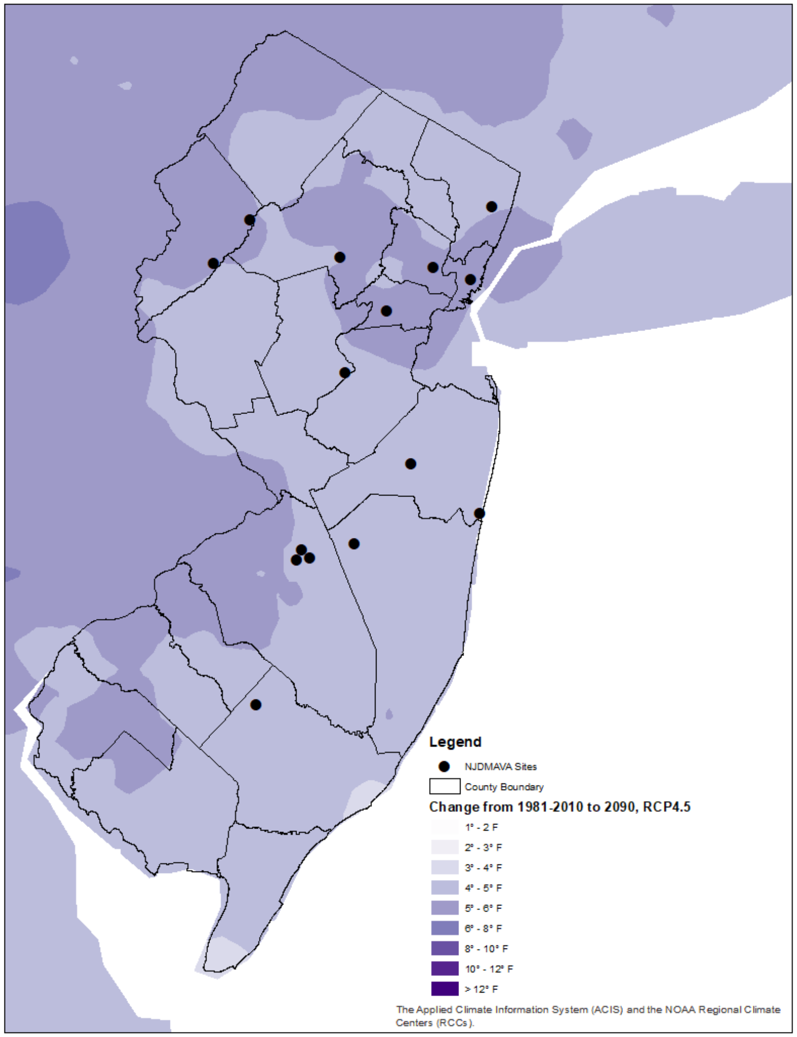
Figure 6: Baseline (1981-2010) New Jersey Temperatures (a) Mean Daily Maximum July Temperature and (b) Mean Daily Minimum Temperature in January



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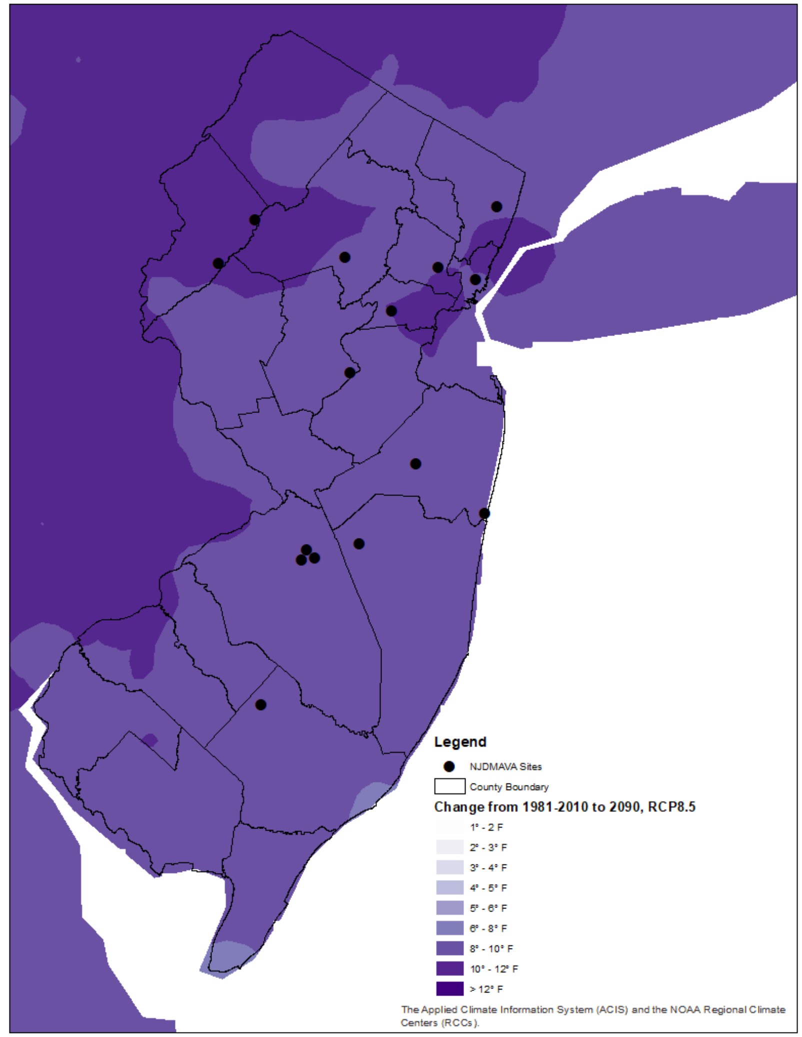

b)

Figure 7: Change in Mean Daily Maximum July Temperature under (a)RCP 4.5 and (b)RCP 8.5 emissions scenarios by 2080-2099.

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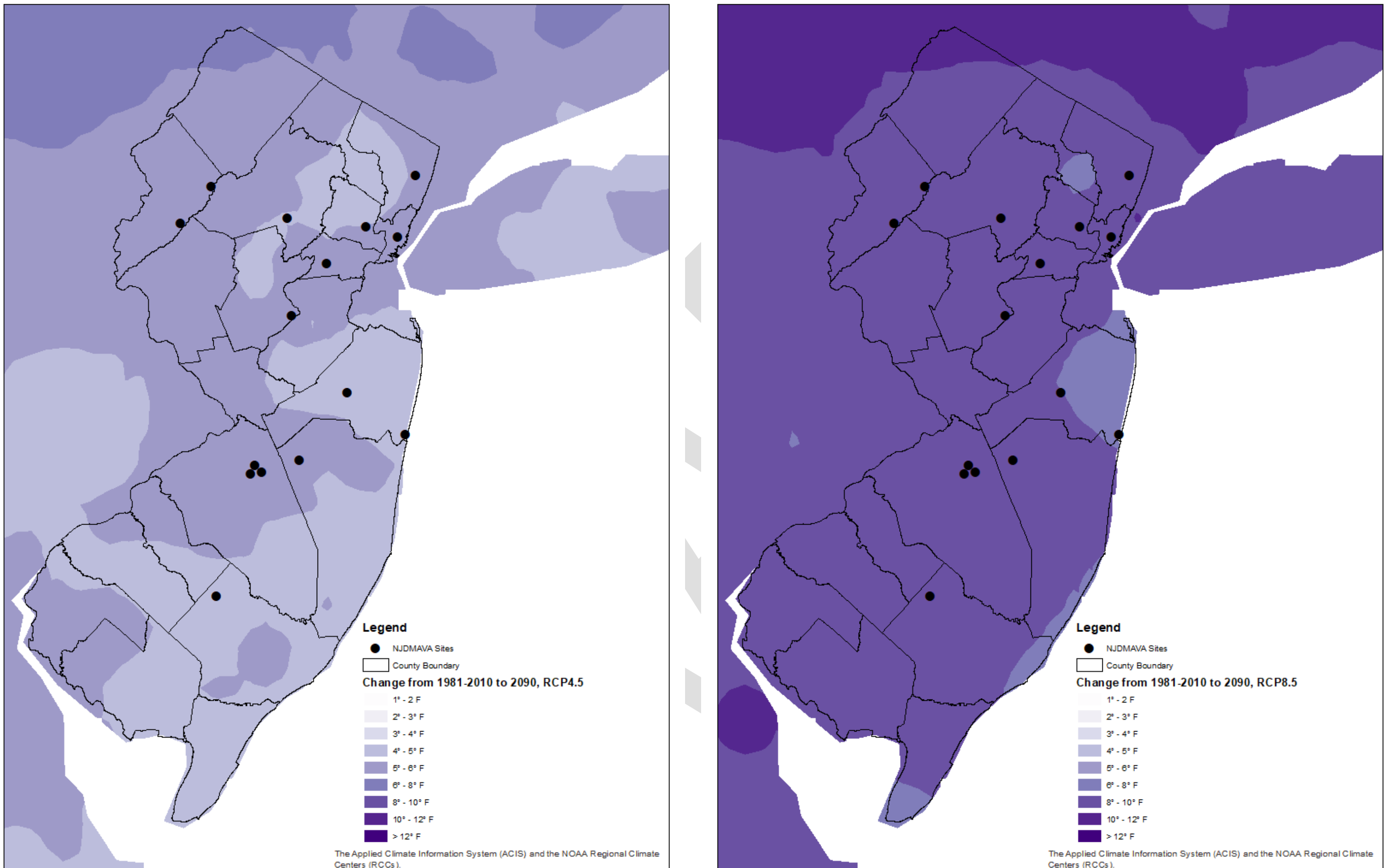

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Figure 8: Change in Mean Daily Minimum January Temperature under (a)RCP 4.5 and (b)RCP 8.5 emissions scenarios by 2080-2099.

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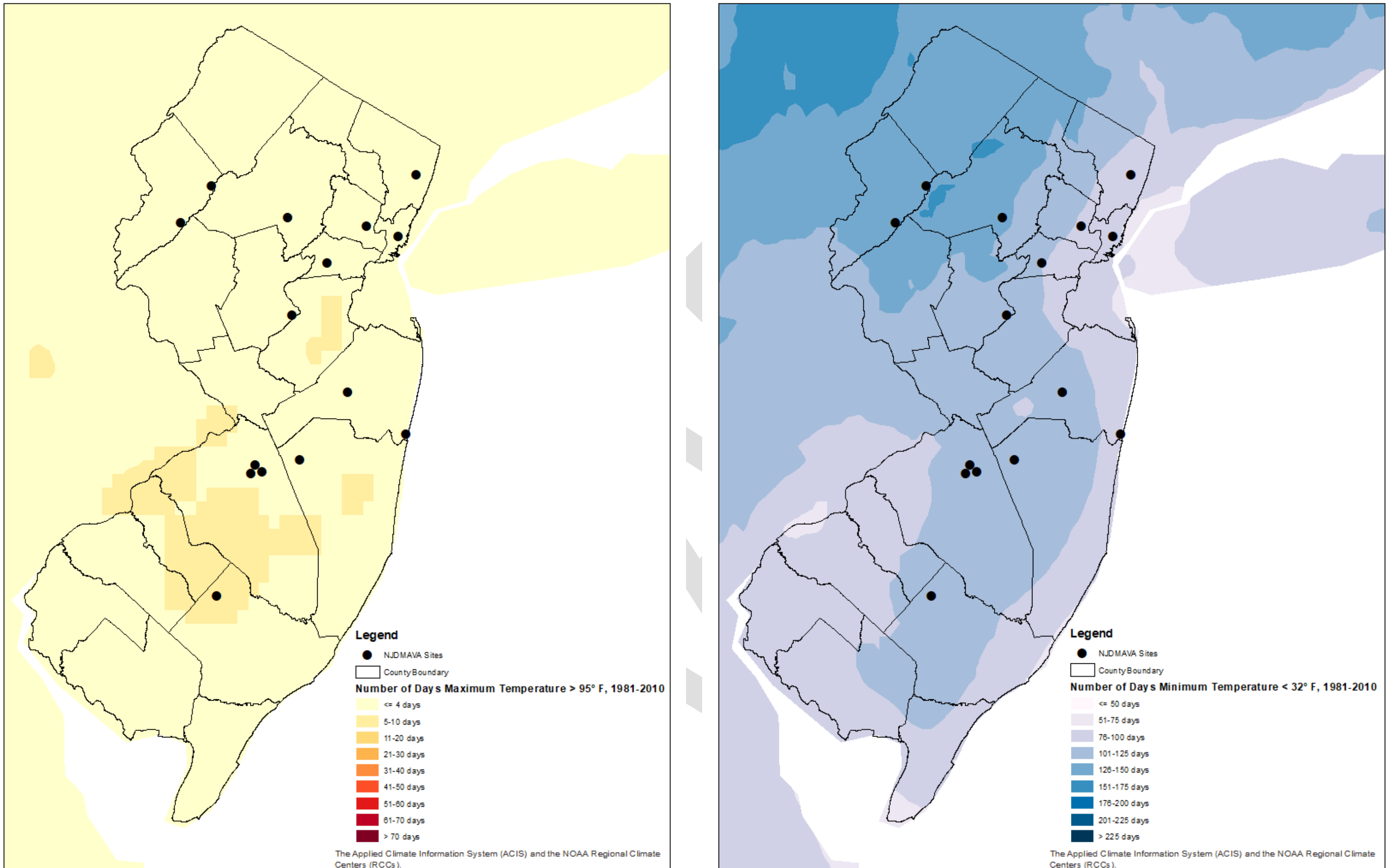

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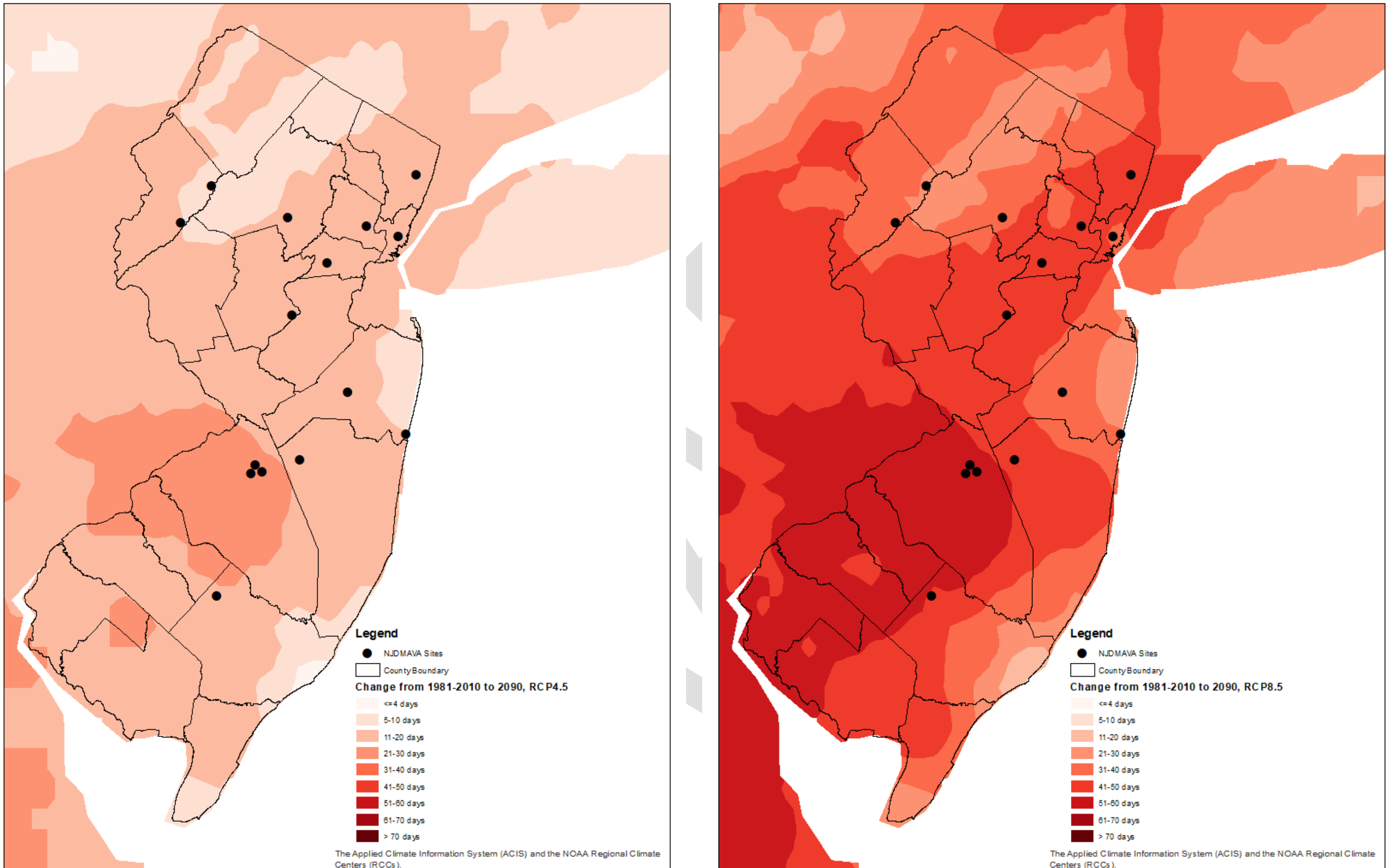
Figure 9: Baseline (1981-2010) New Jersey (a) Hot Days (Maximum Temperature >95 F) and (b) Cold Days (Minimum Temperature <32 F)



a) b)

Figure 10: Change in <u>Hot Days (Maximum Temperature >95 F)</u> under (a)RCP 4.5 and (b)RCP 8.5 emissions scenarios by 2080-2099.

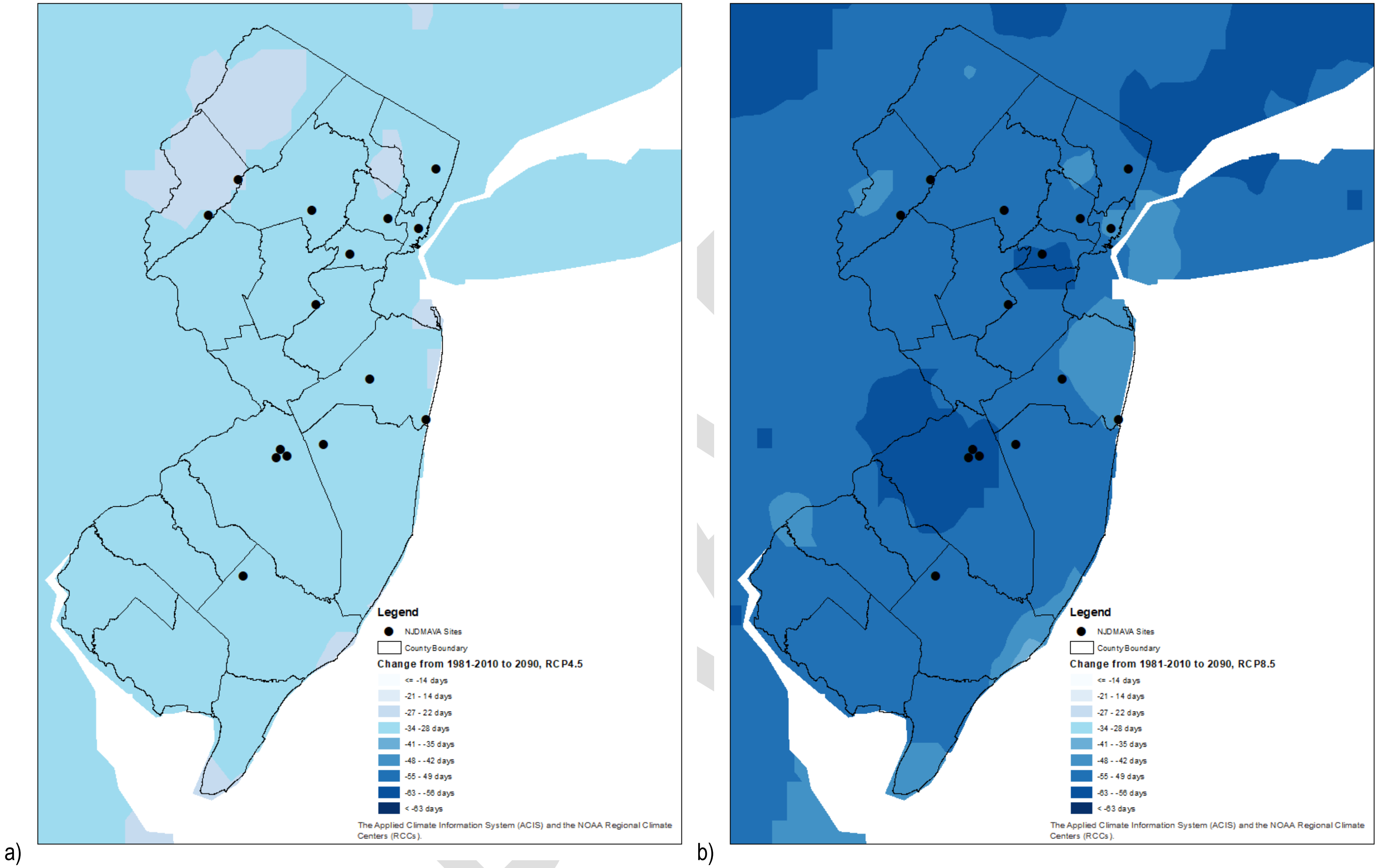


Figure 11: Change in Cold Days (Minimum Temperature <32 F) under (a)RCP 4.5 and (b)RCP 8.5 emissions scenarios by 2080-2099

Convective Storms (Thunderstorms, Hail, Tornadoes)

In North America, studies and projections of hail and (non-tornadic) thunderstorm winds have been inconclusive. Although there is evidence of an increase in the number of hail days per year, the size of the hail and associated winds are uncertain. Recent research suggests increases in very large hail are mostly confined to the central United States, during boreal spring and summer. Although increases in moderate hail are also found throughout the year, decreases occur over much of the eastern United States in summer as a result of a projected decrease in convective-storm frequency (Trapp et al., 2019).

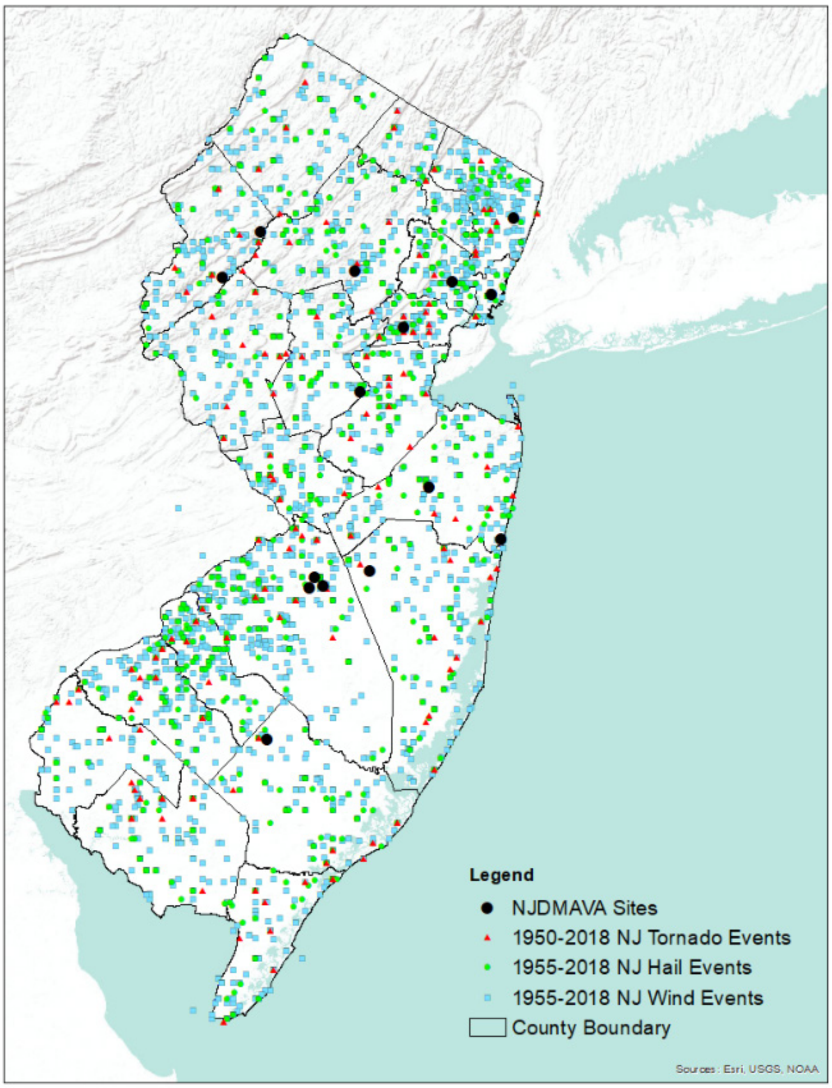


Figure 12: Historical Tornado, Hail, and Wind Events (1955-2018). Source: National Weather Service

Studies of thunderstorm winds are less reliable because a lack of visual evidence makes validation a challenge. Although the United States has lately experienced several significant thunderstorm wind events (sometimes referred to as “derechos”), the lack of studies that explore long-term trends in wind events and the uncertainties in the historical data preclude any robust assessment (Kossin et al., 2017).

For the purposes of this assessment, the project team will investigate historical data and consult with the STAP to determine reasonable future climate scenarios. Each site profile currently includes historic data for tornado occurrences and wind events recorded by the National Weather Service (See Figure 12).

Sea level Rise (SLR)

The SLR information in this overview presents summary information from Kopp et al. (2019), serving as the statewide scientific basis for planning for SLR and coastal storms in New Jersey. The report concludes the following:

From 1911 to 2019, a period of 108 years, the mean annual water level at the Atlantic City tide gauge rose 17.6 inches, compared to a 7.2-inch increase in the global mean sea level, indicative of the additional effect of our subsiding coast. Over the last forty years, from 1979-2019, the tide gauges along the New Jersey coast recorded a sea-level rise 8.2 inches, compared to a 4.5-inch increase in global mean sea-level. This more recent increase is 46.6% of the rise from the total period, but in 36.7% of the time, indicating an acceleration in sea level rise.

Sea level is projected to continue to rise along coastal NJ (Table 1), and the increased water level will displace shorelines, result in property damage along the oceansides and baysides of barrier islands, and result in property damage inland along tidal rivers. New Jersey coastal areas are likely (at least a 66% chance) to experience SLR of 0.5 to 1.1 ft between 2000 and 2030, and 0.9 to 2.1 ft between 2000 and 2050. It is extremely unlikely (less than 5% chance) that SLR will exceed 1.3 ft by 2030 and 2.6 ft by 2050.

Whereas near-term SLR projections through 2050 exhibit only minor sensitivity to different emissions scenarios (<0.1 feet), SLR projections after 2050 increasingly depend upon the pathway of future global greenhouse gas emissions. For SLR projections, low and high emissions scenarios correspond to global-mean warming by 2100 of 2°C and 5°C above early Industrial (1850-1900) levels, respectively, or equivalently, about 1°C and 4°C above the current global mean temperature. Moderate (Mod.) emissions are interpolated as the midpoint between the high- and low emissions scenarios and approximately correspond to the warming expected under the assumption that current global policies are fully implemented.

Under a high-emissions scenario, consistent with the strong, continued growth of fossil fuel consumption, coastal areas of New Jersey are likely (at least a 66% chance) to see SLR of 1.5 to 3.5 ft between 2000 and 2070, and 2.3 to 6.3 ft between 2000 and 2100. It is extremely unlikely (less than a 5% chance) that SLR will exceed 4.4 ft by 2070 and 8.8 ft by 2100.

Under a moderate-emissions scenario, roughly consistent with current global policies, coastal areas of New Jersey are likely (at least a 66% chance) to see SLR of 1.4 to 3.1 ft between 2000 and 2070, and 2.0 to 5.2 ft between 2000 and 2100. It is extremely unlikely (less than a 5% chance) that SLR will exceed 3.8 ft by 2070 and 6.9 ft by 2100.

Under a low-emissions scenario, consistent with the global goal of limiting warming to 2°C above early industrial (1850-1900) levels, coastal areas of New Jersey are likely (at least a 66% chance) to see SLR of 1.3 to 2.7 ft between 2000 and 2070, and 1.7 to 4.0 ft between 2000 and 2100. It is extremely unlikely (less than a 5% chance) that SLR will exceed 3.2 ft by 2070 and 5.0 ft by 2100.

Table 1. Projected SLR Estimates for New Jersey (ft.) incorporating probabilities, decadal periods, and emissions variation, above the year 2000 (1991-2009 average) baseline from Kopp et al. 2019.

		2030	**2050**	**2070**			**2100**			**2150**		
				Emissions								
	Chance SLR Exceeds			Low	Mod.	High	Low	Mod.	High	Low	Mod.	High
Low End	> 95% chance	0.3	0.7	0.9	1	1.1	1.0	1.3	1.5	1.3	2.1	2.9
Likely Range	> 83% chance	0.5	0.9	1.3	1.4	1.5	1.7	2.0	2.3	2.4	3.1	3.8
	~50 % chance	0.8	1.4	1.9	2.2	2.4	2.8	3.3	3.9	4.2	5.2	6.2
	<17% chance	1.1	2.1	2.7	3.1	3.5	3.9	5.1	6.3	6.3	8.3	10.3
High End	< 5% chance	1.3	2.6	3.2	3.8	4.4	5.0	6.9	8.8	8.0	13.8	19.6

**2010 (2001-2019 average) Observed = 0.2 ft*

Notes: All values are 19-year means of sea-level measured with respect to a 1991-2009 baseline centered on the year indicated in the top row of the table. Projections are based on Kopp et al. (2014), Rasmussen et al. (2018), and Bamber et al. (2019). Near-term projections (through 2050) exhibit only minor sensitivity to different emissions scenarios (<0.1 feet). Rows correspond to different projection probabilities. There is at least a 95% chance of SLR exceeding the values in the 'Low End' row, whereas there is less than a 5% chance of exceeding the values in the 'High End' row. There is at least a 66% chance that SLR will fall within the values in the 'Likely Range'. Note that alternative methods may yield higher or lower estimates of the chance of low-end and high-end outcomes.

SLR impacts depend highly on the slope and resistance of shoreline surfaces. A 2-foot SLR in an area with a slope of 1 percent (i.e., 1-foot rise per 100-foot distance) would cause routine inundation to penetrate 200 feet farther inland. For areas of higher slope at the shoreline, the same 2-foot SLR will penetrate less far, but it will increase the erosivity and power of water movement and wave action. Where adequate coastal sediments and space are available, the topography and associated ecological systems will be displaced inland. Where hard structures are within the affected area, the result can be accelerated deterioration in normal conditions, and higher potential for destruction during major storms.

Coastal Storms (Tropical and Extratropical Cyclones)

The coastal storms information in this overview presents summary information from Kopp et al. (2019), serving as the statewide scientific basis for planning for SLR and coastal storms in New Jersey. The report concludes the following:

> *STAP members concluded that there was no clear basis for planning guidance for New Jersey to deviate from the most recent examinations of the issues by the New York City Panel on Climate Change (Orton et al., 2019) and by the Intergovernmental Panel on Climate Change (IPCC), including the IPCC's conclusions regarding the need for further research to understand regional changes in future tropical cyclones and extratropical cyclones (Collins et al., 2019).*

The state's coastline is highly vulnerable to damage from coastal storms, including nor'easters, tropical storms, and hurricanes. Damaging nor'easters are most common during the months between October and April. Nor'easters tracking over or near the coast can bring strong winds and heavy precipitation. [1] Higher sea-levels will increase the baseline for flooding from high tides and coastal storms (i.e., tropical cyclones and extratropical cyclones) and, therefore, the impacts of coastal storms.

[1] https://statesummaries.ncics.org/chapter/nj/

Tropical Cyclones

Frequency: Most studies do not project an increase in the global frequency of tropical cyclones (medium agreement, medium confidence).

Intensity: Maximum wind speeds will likely increase (medium- to high-confidence).

Precipitation: Rate of precipitation during tropical cyclones is likely to increase (high confidence).

Changes in the frequency, intensity (wind speed), and tracks of tropical cyclones remain an area of active research, and there is no definitive consensus regarding such changes specific to New Jersey.

Extratropical Cyclones

The global frequency of extratropical cyclones is not likely to change substantially. There is some evidence for a decrease in frequency of extratropical cyclones over the North Atlantic as a whole, but not near the coast

Changes to extratropical storm tracks in the North Atlantic are possible but have not been reliably established. Changes in the frequency, intensity (wind speed), precipitation rate, and tracks of extratropical cyclones remain an area of active research, and the STAP concluded that, at this time, there is no definitive consensus regarding such changes.

Flood Hazards

Projected changes in SLR raise the baseline for coastal flooding and wave action impacts, independent of definitive trends and changes in coastal storms. The project team will evaluate flood hazards using two different sources. All sites will be assessed based on FEMA Flood Insurance Rate Map (FIRM) exposures on the site, that cover both inland and coastal flood hazards. In addition, the project team will use the total water levels approach in tidally flowed areas to assess the compounding effects of SLR on extreme water levels from coastal storms (Campo & Auermuller, 2018; Eastern Research Group Inc., 2013).

The total water levels approach is based on the extreme water levels (NOAA cite) and available tide gauge information at 5 locations throughout New Jersey. Whereas the different tide-gauge locations in New Jersey will experience comparable SLR, those same locations will experience different magnitudes of flooding based on local hydrology and morphology. The nearest tide gauge location is usually, but not always, the most suitable choice to represent local tide and flood event characteristics. For the purposes of this assessment and the scope of facilities, we will use the following tide gauge locations to generate flood hazard analysis as below:

- The Battery, NJ
- Jersey City
- Newark
- Teaneck
- Sandy Hook, NJ
- Somerset
- Atlantic City, NJ
- Sea Girt

At each tide gauge, we will use a baseline of several flood conditions for assessment:

- High tide
- Annual Flood
- 10 year (10%) event

- Sandy Storm tide
- 100-year (1%) event

To project future flood conditions using SLR, the project team will assess projected flood conditions for the years 2030, 2050, 2070, and 2100. This variety of planning horizons presents both near-term and long-term land use, transportation, and other infrastructure decisions that can have consequences lasting substantially longer than this time frame.

Coastal communities are locked into the range of SLR that we will see by the year 2050 regardless of whether emissions increase or decrease. As this analysis includes a 2100 planning horizon, the project team will analyze the sensitivity of their analysis using both the moderate and high-emissions scenarios when developing adaptation strategies and assessing the risks that future flood hazards could pose to NJDMAVA people, places, and assets in New Jersey based on current global policy. More specifically, the project team will consider SLR estimates in both the *likely* range and a high-end range to assess the variety of critical and non-critical assets in the community. The project team will analyze the following emissions scenarios:

- Likely Moderate Emissions (3.3 ft by 2100)
- High End Moderate Emissions (6.9 ft by 2100)
- Likely High Emissions (3.9 ft by 2100)

Specific water level exposure analyses using the above projections are conducted in each of the individual site profiles for this assessment.

Drought and Wildfire

Recent droughts and associated heat waves have reached record intensity in some regions of the United States. By some measures, drought has decreased over much of the continental United States in association with long-term increases in precipitation. However, neither the precipitation increases, nor inferred drought decreases have been confidently attributed to anthropogenic forcing. The US National Climate Assessment suggests there is little evidence for a human influence on observed precipitation deficits. There is much evidence for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. For forest fires, projected future risks are concentrated in the western United States and Alaska, with large potential impacts on both humans and ecosystems (Wehner et al., 2017).

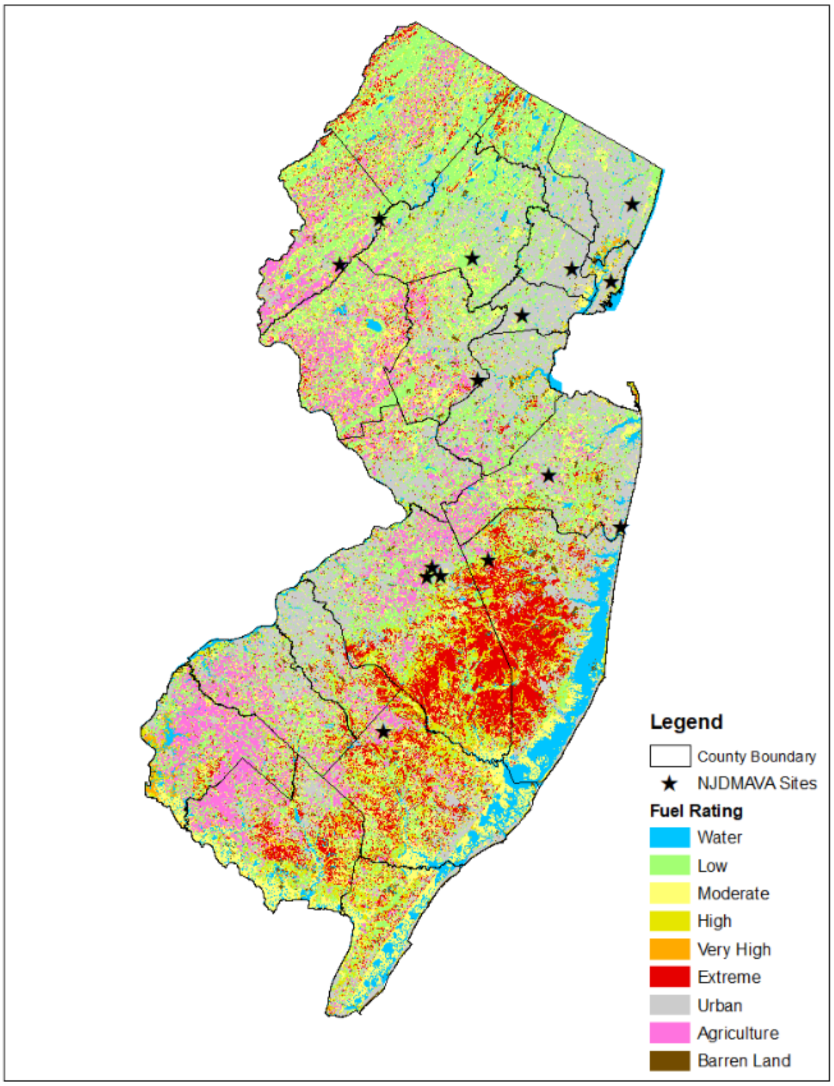


Figure 13: NJ Fuel Hazards. Source: NJ Forest Fire Service

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