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2020 Comprehensive Conservation and Management Plan: Climate Change Vulnerability Assessment

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Introduction

The Piscataqua Region Estuaries Partnership (PREP), one of 28 National Estuary Programs supported by the U.S. Environmental Protection Agency (EPA), is updating their Comprehensive Conservation and Management Plan (CCMP) for the 2020-2030 timeframe. A broad, risk-based, qualitative, planning-level climate change vulnerability assessment was conducted concurrent with this update, as directed by the Funding Guidance for this program.

EPA's Climate Ready Estuaries program published *Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans* (the *Workbook*), which provides guidance on conducting risk-based climate change vulnerability assessments and the development of adaptation action plans. This *Workbook* was used to guide the methodology for PREP's climate change vulnerability assessment (CVA) project.

It is important to note how this report differs from other CVAs. Rather than an assessment of ecological or species-level impacts due to predicted future climactic shifts, this report is an assessment of how climate change may impact PREP's ability to meet management goals outlined in the CCMP. Actions such as community education or support for legislative efforts can easily be carried out despite changes to New Hampshire's climate, however, actions such as salt marsh restoration and enhancement may be challenging in the face of sea-level rise and increased frequency and intensity of storms leading to increased erosion of marshland. This report highlights management priorities that may be hindered by climate change and provides recommendations for adaptation or mitigation actions that PREP could take in response to those challenges.

The following report describes the process PREP followed as well as the results of the assessment. The process is presented in the step-by-step methodology outlined in *The Workbook.*

Limitations and Caveats

The Workbook is part of a growing and dynamic body of literature on how to evaluate vulnerability and respond to climate change. Although risk management itself has been successfully used for decades, adaptation to climate change is a rapidly developing field. New material is constantly being published. Many governmental and non-governmental tools and publications are available that explain how to conduct community outreach, identify and comment on the severity of expected climate impacts, or provide instruction on how to assess the vulnerability of a specific species, site, or sector to a particular climate risk. This report identifies many of these helpful resources and directs readers to them.

Similarly, scientific understanding of the magnitude of climate change and its impacts is also growing as we learn more about how global and local environments are responding and how the climate is projected to change. This report points users to information about climate change from the U.S. Global Change Research Program as a primary source. It also draws on other peer-reviewed assessments and government reports.

Step 1: Communication and Consultation

The initiatives, work, and projects that are required to protect, preserve, and monitor the Great Bay and Hampton Seabrook estuaries rely upon the collective action of many partners, constructive collaboration, and shared successes. PREP's work is driven by input from a diverse and talented group of stakeholders in three different committees and is supported and implemented by a wide-ranging group of partners and 52 municipalities. The Management Committee (MC), comprising 28 members from varying governmental and non-governmental organizations, is PREP's principle governing body. Its primary function is to develop and implement the CCMP for New Hampshire and southern Maine's estuaries and coastal watershed. The MC advises on policy and priorities in the development and implementation of the Plan. It also provides input, direction, and guidance from implementing entities and interest groups for the coordination and management of the CCMP. The MC defines and advises on watershed problems, and the issues and needs communities are facing that PREP should address and develops strategies and programs to solve them that are consistent with implementing the CCMP. PREP also has a Technical Advisory Committee, which is open to all interested stakeholders, and serves as an advisory committee of experts to discuss and advise on technical, science-based issues related to the estuary program, the State of Our Estuaries Report, and the implementation of the CCMP. Collectively, these groups represent a broad cross-section of relevant actors familiar with climate change impacts in the Piscataqua Region.

Stakeholders were notified of the Climate Change Vulnerability Assessment project in a September 2018 newsletter distributed by PREP. This newsletter included notice of future opportunities to provide input during this process. These opportunities included targeted outreach to technical advisors to engage in a joint fact-finding mission for risk analysis and broader outreach through online polling to identify high-priority risks to act on and to identify where partners may be able to alleviate risks. See Steps 5 and 6 for further details on this engagement. An overview of the project, including opportunities for engagement, was provided to the Management Committee at their September 2018 meeting and to the Technical Advisory Committee at their October 2018 meeting. A project update with opportunity for input was also provided at the December 2018 Management Committee meeting.

Once climate change vulnerabilities and risks had been comprehensively considered, and reviewed by partners with technical expertise, a broader effort to understand the importance of these risks to partners was implemented. This outreach was conducted online and was open to any who wished to participate. PREP's staff, Management Committee, and Technical Advisory Committee received direct communications regarding this opportunity to engage.

Step 2: Establishing Context

The PREP CCMP has seven overarching goals:

- Water quality in the Piscataqua region watersheds supports shellfish harvesting, recreation, wildlife, aquatic life, and drinking water consistent with the Clean Water Act, and existing high-quality waters are maintained at 2010 conditions.
- Quantities of freshwater in rivers and aquifers throughout the Piscataqua Region watersheds are appropriate for humans, aquatic species, riparian wildlife, and riparian vegetation.
- Ecological function, connectivity, resilience, biodiversity, and ecosystem services of habitats are maintained and restored throughout the Piscataqua Region watersheds.
- Development patterns and practices protect watershed and estuarine water quality.
- Ecosystem functions and services provided by tidal and freshwater wetlands, floodplains, and shorelands are maintained.
- Critical upland areas sustain viable plant and animal communities and provide watershed services to maintain aquatic habitats and water quality.
- Legislative, resource management, and land use planning decisions and processes affecting the Piscataqua Region watersheds supports Piscataqua Region Comprehensive Conservation and Management goals and objectives.

Most of these goals are threatened by climate change, with the exception of the last goal, which provides an opportunity to justify consideration for climate change impacts during legislative, resource management, and land-use planning decision-making. At a kick-off meeting for the CVA project on August 14th, 2018 with PREP and EPA staff, it was decided that the project would proceed with consideration for all of the climate change stressors identified in the *Workbook*: warmer summers, warmer winters, warmer water, increasing drought, increasing storminess, sea-level rise, and ocean acidification.

Goals for this project include the identification of climate risks to CCMP goals, identification of risks that may be alleviated by existing CCMP actions, and the identification of opportunities to mitigate or avoid risks through the addition or alteration of CCMP actions.

Numerous climate change vulnerability assessment and policy reports have been published in New Hampshire. These data and publications should be reviewed and leveraged as work to address climate risks is continued throughout the state. The following reports were developed specific to the New Hampshire coast, though there are many relevant resources referenced throughout the document.

Tides to Storms: *Assessing Risk and Vulnerability to Sea-level rise and Storm Surge: A Vulnerability Assessment of Coastal New Hampshire* (Available at: http://www.rpc-nh.org/regional-community-planning/climate-change/tides-storms)

- In September 2015 the Rockingham Planning Commission completed the Tides to Storms project to assess the vulnerability of coastal municipalities and public infrastructure to flooding from expected increases in storm surge and rates of sea-level rise. The project's purpose was to develop a regional scale understanding of what and where impacts from sea-level rise and storm surge will occur on New Hampshire's coast. In addition to the regional vulnerability assessment, an assessment report and map set were prepared for each of the seven Atlantic coast municipalities. Municipalities were provided maps and an assessment of risks to roadways and supporting transportation infrastructure, critical facilities and infrastructure, and natural resources. Each report includes recommended actions that municipalities can take to help adapt and improve resiliency to changing conditions caused by storm surge and sea-level rise.

Preparing New Hampshire for Projected Storm Surge, Sea Level Rise, and Extreme Precipitation: Final Report and recommendations (Available at: https://www.nhcrhc.org/final-report/)

- Recognizing the need to prepare for existing and projected coastal flood hazards, in July 2013 the State Legislature enacted Senate Bill 163, introduced by Senator David Watters (District 4), which established the New Hampshire Coastal Risk and Hazards Commission to "recommend legislation, rules, and other actions to prepare for projected sea-level rise and other coastal and coastal watershed hazards such as storms, increased river flooding, and stormwater runoff, and the risks such hazards pose to municipalities and the state assets in New Hampshire." In response to this legislative mandate, the Commission put forward a final report and set of recommendations for state legislators, state agencies, and coastal municipalities to help these audiences better prepare for and minimize coastal risks and hazards. The report presents a summary of the best available science and vulnerability information followed by recommendations for action.

Climate Risk in the Seacoast Project (Available at: https://www.des.nh.gov/organization/divisions/water/wmb/coastal/c-rise.htm)

- Completed in March 2017, the Climate Risk in the Seacoast (C-RiSe) project developed vulnerability assessment reports and map sets detailing potential coastal flooding impacts to transportation systems, critical facilities and infrastructure, and natural resources for the 10 tidally influenced municipalities surrounding New Hampshire's Great Bay Estuary (i.e., Dover, Durham, Exeter, Greenland, Madbury, Newfields, Newington, Newmarket, Rollinsford, Stratham). Specifically, the C-RiSe project incorporated sea level rise and storm surge inundation mapping, municipal vulnerability assessments, culvert assessment, and hazard mitigation planning.

Step 3: Risk Identification

Plausible risks associated with the previously agreed upon climate stressors were considered for each CCMP objective. *Climate Change Vulnerabilities Scoping Report: Risks to Clean Water Act Goals in Northeast Sub-regions* and *Climate Change Vulnerabilities Scoping Report: Risks to Clean Water Act Goals in Habitats of the Northeast* were used to inform this identification. These reports, prepared by Battelle, were supported by the U.S. Environmental Protection Agency's Office of

Wetlands, Oceans, and Watersheds (contract number EP-C-14-017) for the purpose of informing risk-based climate change vulnerability assessments for coastal watershed management areas.

The following sources of information were used to inform the Battelle reports:

EPA. 2014. Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans. Climate Ready Estuaries, EPA Office of Water.

Melilo, J.M., T. Richmond, and G.W. Yohe, Eds. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp.

NOAA. 2013. NOAA Technical Report NESDIS 142-1, Regional Climate Tends and Scenarios for the U.S. National Climate Assessment, Part 1. Climate of the Northeast U.S. U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), Washington, D.C.

USACE. 2014. North Atlantic Coast Comprehensive Study. Department of the Army, U.S. Army Corps of Engineers (USACE), Washington D.C.

Wake, C., E. Burakowski, P. Wilkinson, K. Hayhoe, A. Stoner, C. Keeley, and J. LaBranche. 2014. Climate change in Southern New Hampshire: Past, Present, and Future. Climate Solutions New England.

Wake, C., E. Burakowski, K. Hayhoe, A. Stoner, C. Watson, and W. Douglas. 2011. Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future. Climate Solutions New England, Great Bay Stewards, and University of New Hampshire.

These sources were used to identify regionally applicable climate risks and to analyze the likelihood of occurrence and level of consequence of impact to the PREP CCMP should the risk be realized. Likelihood is the chance of the risk actually occurring, and consequence is the effect the risk would have on the objective were it to occur. Level of consequence relates to impacts to Clean Water Act and Estuaries and Clean Waters Act of 2000 goals, not necessarily overall impact to the environment.

Clean Water Act §320 goals:

- Clean-up and control point and nonpoint sources of pollution
- Maintain and improve aquatic habitat
- Protect and propagate fish, shellfish, and wildlife – including control of nonnative species
- Protect public water supplies and recreational activities, in and on the water

Estuary Restoration Act of 2000 goals:

- Promote the restoration of estuary habitat
- Develop a national estuary habitat restoration strategy for creating and maintaining effective estuary habitat restoration partnerships among public agencies at all levels of government and to establish new partnerships between the public and private sectors
- Provide Federal assistance for estuary habitat restoration projects and promote efficient financing of such projects

The following definitions were used to define low, medium, and high likelihood of occurrence and consequence of impact:

Likelihood of Occurrence	
Low	Unlikely
Medium	Possible; about as likely as unlikely
High	Probable; more likely than not

Severity of Impact	
Low	Minor impact that can be readily adapted to with little disruption to ecosystems, communities, or economy
Medium	Moderate impact that will require some effort to adapt to. Adaptation is likely to be successful and not impose high costs or disruption to other PREP CCMP objectives
High	Severe impact that may threaten PREP objectives, communities, or ecosystems; adaptation actions are likely to be expensive or disruptive.

Risks were compiled into matrices according to each CCMP objective to categorize high, moderate, and low risk vulnerabilities. Generally, vulnerabilities or stressors that are highly likely to occur and have a high consequence of impact are considered to be high-risk vulnerabilities, and those that are less likely to occur and may be readily adapted to are considered to be low-risk vulnerabilities. These preliminary risk matrices were compiled by the EPA project manager; technical experts then reviewed and expanded the matrices to ensure accuracy and completeness.

Likelihood of Occurrence (by 2050)				
	high	high likelihood of occurrence, low severity of impact = moderate risk	high likelihood of occurrence, moderate severity of impact = high risk	high likelihood of occurrence, high severity of impact = high risk
	medium	medium likelihood of occurrence, low severity of impact = low risk	medium likelihood of occurrence, moderate severity of impact = moderate risk	medium likelihood of occurrence, high severity of impact = high risk
	low	low likelihood of occurrence, low severity of impact = low risk	low likelihood of occurrence, moderate severity of impact = low risk	low likelihood of occurrence, high severity of impact = moderate risk
		low	*moderate*	*high*
		Severity of Impact		

Step 4: Risk Analysis

A Technical Review Panel (TRP) was assembled to facilitate the review and expansion of the preliminary matrices, to ensure all potential risks to the meeting of CCMP objectives have been considered and to solicit recommendations for the alteration of likelihood of occurrence and/or severity of impact rankings as well as comments, suggestions for key references, and recommendations for critical new research. This outreach and review were conducted online; a group of targeted technical experts who are engaged with climate and environmental science in the planning area were engaged. TRP members received the online form and instructions for review on Monday October 15th, 2018 and were asked to complete the review by Wednesday October 31st, 2018. To incentivize thoughtful participation in this review, PREP offered a stipend for completion by the due date.

The Technical Review Panel was comprised of the following members:

Jennifer Jacobs (University of New Hampshire)
Tom Ballestero (University of New Hampshire)
Bill McDowell (University of New Hampshire)
Stephen Jones (University of New Hampshire)
Cameron Wake (University of New Hampshire)
David Burdick (University of New Hampshire)
Alix Laferriere (The Nature Conservancy, NH Chapter)
Chris Peter (Great Bay National Estuarine Research Reserve)

Each reviewer was asked to self-identify areas of expertise within CCMP objectives, and it was requested that reviewers only answer questions relevant to objectives within their subject-matter expertise.

For each CCMP objective, the preliminary risk matrix was presented, with four comment boxes and a field to upload supporting documentation. The questions asked for each matrix review were as follows:

1) Any recommendations to change the likelihood of occurrence ranking for risks in this matrix?
2) Any recommendations to change the severity of impact ranking for risks in this matrix?
3) Are there other vulnerabilities/risks that should be included in this matrix?
4) Do you have any recommendations for critical new research on this subject?

Input from the survey was synthesized and incorporated into final consequence/probability matrices. TRP members and project staff agreed to hold two time-slots for consensus-building in the event reviewers provided conflicting suggestions or information. It turned out that the TRP was mostly in consensus in their input, and any small discrepancies were able to be worked out via emails between the relevant reviewers and the project manager.

The EPA project manager compiled TRP responses into final consequence/probability matrices for each PREP CCMP objective. These matrices are presented in this report, below, and will be included as an Appendix to the 2020-2030 CCMP. They will be used to inform updates to CCMP action plans and objectives; CCMP activities that have been informed by the CVA will be noted in publication.

These matrices may be used as a starting point for other partner organizations who are interested in exploring their own risk-based climate vulnerability.

WR 1.1: Improve water quality and identify and mitigate pollution sources so that additional estuarine areas meet water quality standards for bacteria and shellfish harvesting

Likelihood of Occurrence (by 2050)	*high*		•Nuisance flooding is increasing which, due to inundation of the built environment, may cause more frequent charges of high-concentration pathogen polluted water into coastal areas •Warmer water may lead to greater survival of bacteria •Increases in water temperatures may alter the seasonal windows of growth and the geographic range of suitable habitat for freshwater and marine toxin-producing harmful algae and certain naturally-occurring *Vibrio* bacteria •Runoff from more frequent and intense extreme precipitation events will increasingly compromise recreational waters, shellfish harvesting waters, and sources of drinking water through increased introduction of pathogens and prevalence of toxic algal blooms	
	medium	•Combined sewer overflows may increase due to increased storminess •Pollution sources may build up on land (e.g., from dog parks or nuisance bird populations) during periods of drought; rapid runoff of these sources may occur during increased high-intensity storms	•Sewage may mix with seawater in combined sewer systems due to sea level rise •Rising groundwater in coastal areas, due to sea level rise, may reduce septic groundwater separation	•Wastewater treatment plants may go offline during intense floods and high precipitation events, leading to direct sewage discharges •Increasing heavy precipitation may drive higher levels of enteric viruses as risk of failure of stormwater and wastewater systems also increases under these conditions, especially in areas with aging infrastructure
	low	•Increasing storminess (high rainfall) may lead to increased septic system failure		
		low	*moderate*	*high*
		Severity of Impact		

Sea-level rise, increasing drought, increasing storminess, and warmer waters all pose some risk to this objective. These stressors range on the spectrum of severity of impact to EPA CWA goals. Failure of WWTP operations during major storm events is the stressor of great concern to the accomplishment of this management objective. Measures should be taken to ensure WWTPs remain online during high-intensity storms. Runoff from more frequent and intense precipitation events, combined with warming waters, may lead to the perfect condition for greater survival of pathogens and toxic algae – putting Recreational and Shellfishing Uses at high risks.

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Addressing stormwater impacts
- Implement regulations to reduce stormwater runoff at the property-owner level
- Identify and apply for funds (such as the Clean Water State Revolving Fund or loan principle forgiveness programs) for Climate Adaptation Plans for wastewater systems
- Reduction of salt application for winter road treatment
- BMPs for transportation infrastructure development (e.g. on-site stormwater treatment)
- Reduce inflow and infiltration into sewer collection facilities
- Pet waste disposal and landscaping practices outreach
- Addressing nuisance flooding issues

WR 1.2: Minimize coastal beach closures due to failure to meet water quality standards for bacteria in the estuaries and the ocean

Likelihood of Occurrence (by 2050)		Severity of Impact: low	Severity of Impact: moderate	Severity of Impact: high
	high		•Increases in water temperatures may alter the seasonal windows of growth and the geographic range of suitable habitat for freshwater and marine toxin-producing harmful algae and certain naturally-occurring Vibrio bacteria •Runoff from more frequent and intense extreme precipitation events will increasingly compromise recreational waters, shellfish harvesting waters, and sources of drinking water through increased introduction of pathogens and prevalence of toxic algal blooms •Increased stormwater runoff from elevated precipitation events may increase the concentrations and recovery time of bacterial pollution at coastal beaches	
	medium	•Combined sewer overflows may increase due to increased storminess •Increasing storminess (high rainfall) may lead to increased septic system failure •Pollution sources may build up on land (e.g., at dog parks or livestock areas) during periods of drought; rapid runoff of these sources may occur during increased high-intensity storms	•Warmer water may lead to greater survival of bacteria •Sewage may mix with seawater in combined sewer systems due to sea level rise	•Wastewater treatment plants may go offline during intense floods and high precipitation events, leading to direct sewage discharges •Increasing heavy precipitation may drive higher levels of enteric viruses as risk of failure of stormwater and wastewater systems also increases under these conditions, especially in areas with aging infrastructure
	low	•More people using water for recreation during warmer summers may raise the potential for pathogen exposure		
		low	*moderate*	*high*
			Severity of Impact	

Increasing storminess, increasing drought, sea-level rise, warmer water, and warmer summers all pose some risk to this objective. These stressors range on the spectrum of severity of impact to EPA CWA goals. Failure of WWTP operations during major storm events is a stressor of great concern to the accomplishment of this management objective. Measures should be taken to ensure WWTPs remain online during high-intensity storms. Runoff from more frequent and intense precipitation events, combined with warming waters, may lead to the perfect condition for greater survival of pathogens and toxic algae.

Priority action areas identified by survey respondents:

- Identify and apply for funds (such as the Clean Water State Revolving Fund or loan principle forgiveness programs) for Climate Adaptation Plans for wastewater systems

WR 1.3: Reduce nutrient loads to the estuaries and the ocean so that adverse, nutrient-related effects do not occur

Likelihood of Occurrence (by 2050)	low	moderate	high
high	•Warmer waters may lead to increased algal growth •Warmer waters may increase the likelihood of harmful algal blooms		
medium	•Pollution sources may build up on land (e.g., at dog parks or livestock areas) during periods of drought; rapid runoff of these sources may occur during increased high-intensity storms •A longer growing season may lead to more lawn and agricultural maintenance with fertilizer (but also allows for more nutrient uptake by plants)	•Warmer summers may drive greater fluxes of ammonium from benthos with longer duration and higher rates of benthic activity as nitrogen becomes more limiting and discharge from WWTPs is lower	
low			
	Severity of Impact		

Warmer summers, warmer waters, increasing drought, and increasing storminess pose some risk to this objective. These stressors are generally expected to be low-to-moderate on the spectrum of severity of impact to EPA CWA goals. Increased algal growth in waterways will likely occur unless fertilizer controls are implemented and/or other actions are taken to reduce non-point source additions of nutrients to waterway.

Technical Review Panel recommendations for further research:

- Better nitrogen removal strategies

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Public education regarding impacts of nonpoint pollution sources
- Addressing the impact of increased precipitation and runoff from construction sites through policy
- Considering the impacts of more frequent rainfalls as well as increased rainfall amounts and durations modeling to inform more climate-appropriate criteria for designs, systems, and options for stormwater and erosion control measures at various types of development
- Study nitrogen removals across multiple reservoirs to determine which ones and types are more effective at nutrient retention

WR 1.4: Reduce sediment loads to the estuaries and the ocean so that adverse, sediment-related effects do not occur

Likelihood of Occurrence (by 2050)				
	high			
	medium		•Soil erosion, including from mudflats and salt marsh edges, may increase due to increased storminess, leading to high turbidity and greater sedimentation; greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species •Stream geometry modifications (widening, incision) may occur to accommodate additional runoff due to increasing storminess, likely resulting in an increase in sediment fluxes	•Likely to see an increase in erosion and deposition of sediments due to an increasing number of large hurricanes impacting the NH coast (taking potentially years to move through the system)
	low	•Marshes and beaches may erode from loss of protective ice due to warmer winters		
		low	*moderate*	*high*
		Severity of Impact		

Warmer winters and increased storminess pose some risk to this objective. Increased storminess is expected to be a high-consequence impact to EPA CWA goals. Erosion control measures should be implemented along riverine and estuarine shorelines to reduce sediment runoff into waterways. To avoid adverse impacts to these environments, a green infrastructure approach is recommended.

Technical Review Panel recommendations for further research:

- Assess the fate of stream form (dimension, pattern, profile) under new climate regime

Priority action areas identified by survey respondents:

- Living shoreline construction and stream restorations including dam removal and stream crossing improvements
- Soil erosion control measures in stormwater management regulations
- Modeling and information gathering to determine marsh response to sea-level rise. Overall, information about marsh response to sea-level rise lacks data about marsh elevation
- Check on construction activities whenever they occur to make sure they are using best practices to minimize sediment loading as a result of activity
- Monitor sediment dynamics at all construction sites
- Monitor sediment dynamics with dam removal
- Addressing erosion concerns while maintaining high quality natural shorelines

WR 1.5: Monitor and reduce loading of toxic contaminants and emerging contaminants to the estuaries and the ocean

Likelihood of Occurrence (by 2050)	low	moderate	high
high	•Sea level rise may lead to the flooding or shoreline erosion of contaminated sites •Changing climatic conditions may alter the distribution of pets, parasites, and microbes leading to increases in the use of pesticides and veterinary drugs		
medium	•Warmer water temperatures may increase toxicity of pollutants and may allow for higher solubility	•Increasing precipitation may lead to an increase in runoff over contaminated impervious surfaces in urban area •Urban drainage in coastal areas may be challenged by rising seas, leading to an increased concentration of contaminants in drainage basins •Elevated sea surface temperatures will lead to greater accumulation of mercury in seafood • Heavy precipitation events may lead to a breakdown of wastewater treatment and cause increased discharge of toxic chemicals into coastal waters	
low	•Increasing precipitation may drive an expansion of freshwater wetlands, and thereby their anaerobic processes, potentially resulting in an increased delivery of methylated mercury to estuarine waters	•Longer growing seasons, as a result of warmer summers and winters, may increase nuisances to lawns and parks, prompting an increased use of pesticides, algicides, insecticides, fungicides, and rodenticides that may runoff into waterways	
	low	*moderate*	*high*
	Severity of Impact		

Sea-level rise, warmer water, warmer summers, warmer winters, and increased storminess all pose some risk to this objective. These stressors are generally expected to be low-to-moderate on the spectrum of impact to EPA CWA goals. Measures should be taken to reduce and improve infiltration of stormwater runoff in urban areas, and to ensure WWTPs stay online and functional during large storms.

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Public education regarding the use of emerging contaminants, and not to flush unused materials into the waste stream

- Address sea-level rise risks to hazardous waste sites

WR 1.6: Improve the water quality in streams, rivers, lakes and groundwater to support recreation, aquatic life, and drinking water throughout the watersheds and maintain high quality fresh waters at 2010 conditions

Likelihood of Occurrence (by 2050) / Severity of Impact	low	moderate	high
high	•Greater algae growth may occur with warmer water temperatures, including harmful algal blooms	•Less snow and more rain due to warmer winters may change the runoff/infiltration balance; base flow in stream may change •Increases in water temperature associated with climate change will alter the seasonal windows of growth and the geolographic range of suitable habitat for freshwater and marine toxin-producing algae and certain naturally occurring *Vibrio* bacteria	•Warmer water may hold less dissolved oxygen •Warmer water may promote the spread of invasive species or disease •Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems
medium	•High surface water temperatures may lead to stratification in the water column •Pollutant concentrations may increase if sources stay the same and flow diminishes due to increased drought •Rivers may no longer freeze with warming winters; a spring thaw would be obsolete •Increased intensity of precipitation due to increased storminess may yield less infiltration •Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies •Higher summer temperatures may lead to greater evaporation and lower groundwater tables •Saltwater intrusion into groundwater may be more likely under future sea level rise	•Parasites and bacteria may have greater survival or transmission in warmer waters •Increased density stratification due to increased runoff from increased storminess may lead to more severe hypoxia •Lower summertime flows - resulting from less snowmelt, hotter summers driving more evaporation, and a longer growing season - will likely lead to longer periods of low-flow •CDOM and DON delivered from the watershed may increase with higher temperature	•Warmer water may result in the loss of SAV habitat •Hypoxia may become more common and widespread in warmer waters •Stream erosion due to increased storminess may lead to high turbidity and greater sedimentation •Saline water may move further upstream due to sea level rise, causing some freshwater habitats to become brackish •Decreased freshwater flows in streams due to short term seasonal drought may not support aquatic life or recreational uses •An increase in seasonal short term drought may cause groundwater tables to drop •Short term seasonal drought may cause stream water to become warmer
low	•New water supply reservoirs may affect the integrity of freshwater streams	•Increased human use of groundwater during drought may reduce stream baseflow	

Warmer water, increasing drought, warmer winters, increasing storminess, warmer summers, and sea level rise all pose some risk to this objective. There are many risks associated with this objective, ranging across the spectrums of likelihood of occurrence and severity of impact. The most likely to occur risks with high severity impacts relate to shifts in the distribution of species and changes to water chemistry. Other high-risk vulnerabilities include a decrease in freshwater flows, warming and potentially hypoxic aquatic habitats, and saltwater intrusion upriver. These changes would result in severe impacts to riverine and coastal ecosystems, as well as failure to meet Aquatic Life Use designations in affected waterbodies. Decreased flows and warmer waters may also lead to Recreational Use impairments, as these conditions are more likely to support bacteria and algae.

Technical Review Panel recommendations for further research:

- Examine long-term trends in DOC and DON in the various Great Bay watersheds, and link that to any changes in these parameters that can be inferred from Great Bay buoy data on CDOM.
- Understand how DOC, DON, NO_3, and CDOM are related in rivers and potentially Great Bay, and how they are likely to change over time.

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Work with towns to establish stormwater and buffer ordinances
- Use TNC's water resources conservation layers analysis to identify land to protect for drinking water purposes

WR 2.1: Maintain instream flows and groundwater levels that support aquatic life and recreation, human populations, and the hydrologic integrity of coastal streams and rivers

Likelihood of Occurrence (by 2050)				
	high		•Increases in water temperature associated with climate change will alter the seasonal windows of growth and the geolographic range of suitable habitat for freshwater and marine toxin-producing algae and certain naturally occurring *Vibrio* bacteria	
	medium	•Saltwater intrusion into groundwater may be more likely under future sea level rise	•An increase in seasonal short term drought may decrease base flows in streams, potentially leading to changes in stream geomorphology affecting aquatic habitat •An increase in seasonal short term drought may cause groundwater tables to drop •Less snow and more rain due to warmer winters may change the runoff/infiltration balance; base flow in stream may change, potentially leading to changes in fluvial geomorphology •Lower summertime flows - resulting from less snowmelt, hotter summers driving more evaporation, and a longer growing season - will likely lead to longer periods of low-flow	•Saline water may move further inland due to sea level rise, causing some freshwater habitats to become brackish •Changing freshwater inputs with increasing drought may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat)
	low	•Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters •Higher summer temperatures may lead to greater evaporation and lower groundwater tables	•Increased human use of groundwater during drought may reduce stream baseflow, potentially leading to changes in fluvial geomorphology •Rising coastal groundwater, due to sea level rise, may impact salinity regimes (moving inland)	
		low	*moderate*	*high*
			Severity of Impact	

Warmer waters, increasing drought, sea-level rise, warmer winters, and warmer summers all pose some risk to this objective. Most of these stressors are expected to be of low-moderate impact to EPA CWA goals. However, there are three high-risk vulnerabilities associated with this objective, primarily related shellfish bed habitat. Aquatic Life Use and Shellfishing Use designations are likely at risk as waters warm and salinity distribution shifts are likely to lead to shifts in shellfish bed distribution and higher occurrence of toxic bacteria and algae. As saltwater intrudes inland, there will also be areas of freshwater ecosystem loss.

Technical Review Panel recommendations for further research:

- Study the influence of coastal sea-level rise on instream flows and groundwater levels.
- Need to model and understand the low flow conditions of the future.

Priority action areas identified by survey respondents:

- Living shoreline construction and stream restorations including dam removal and stream crossing improvements
- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Understanding impacts to and protecting drinking water sources
- Understanding the potential for saltwater intrusion into groundwater supplies
- Determining if there is a sustainable water supply capacity to meet demand into the future

WR 2.2: Minimize catastrophic flooding risks due to development and climate change, and restore or maintain geomorphologic balance in river and stream systems

Likelihood of Occurrence (by 2050)		low	moderate	high
	high	•Water infrastructure may be vulnerable to flooding due to increased storminess	•Increased frequency and intensity of flooding events may result in erosion of floodplains and riparian habitat •Clearance under bridges may decrease with sea level rise and flood events from increased storminess	
	medium	•Water infrastructure may be vulnerable to inundation or erosion due to sea level rise	•Sea level rise may lead to an increase or decrease of floodplains or riparian habitat •Increased frequency and intensity of flooding events due to increasing storminess may result in the loss of existing floodplains and the formation of new floodplains	•Storm surge associated with increasingly frequent intense storms, such as hurricanes, may have severe impacts to coastal and riverine infrastructure and ecosystems
	low	•Rivers may no longer freeze with warming winters; a spring thaw would be obsolete •There may be more frequent freeze/thaw cycles due to warmer winters, potentially impacting infrastructure		
		Severity of Impact		

Increasing storminess, sea-level rise, and warmer winters all pose some threat to this objective. These vulnerabilities represent a range of risk in terms of likelihood of occurrence and consequence of impact to EPA CWA goals. High-risk vulnerabilities associated with this objective are primarily related coastal and riverine infrastructure and ecosystem loss as a result of increased frequency of intense storms, storm surges, and flooding events. Marine transportation and navigability are at risk where low-clearance bridges are likely to be impacted due to sea level rise and coastal storm surge.

Technical Review Panel recommendations for further research:

- There have been very few studies on floods in our region and no very recent studies; this work should be continued, particularly with a focus on the snowmelt signal.
- Detailed hydrological and hydraulic modeling of change in future flood risk in all the tributaries that flow into Great Bay resulting from different scenarios of climate change and land use change. This has only been completed for Lamprey River and a portion of the Oyster River. Then follow on analysis of specific impacts to communities, our economy, and ecosystems.
- Integrated modeling of the impacts of enhanced freshwater flooding, sea level rise, and storm surge

- Improving community preparedness to deal with increased frequency/intensity of storms/floods

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Living shoreline construction
- Implementation of flood ordinances that restrict development in existing and future floodplains
- Promote the use of FEMA Hazard Mitigation grants to help offset the cost of improving/reconstructing critical infrastructure that is at risk
- Support development of a buyout program to return high-risk areas to natural state
- Plans and tools for infrastructure resilience and emergency recovery at the statewide, regional, and local level

LR 1.1: Increase the abundance of adult oysters at the six documented beds in the Great Bay Estuary to 10 million oysters and restore 20 acres of oyster reef habitat by 2020

Likelihood of Occurrence (by 2050)		low	moderate	high
	high		•Warmer water is likely to lead to an expansion of epizootics (MSX, Dermo) and invasive species •Increase in water temperature and decreased flow during periods of drought may lead to harmful algal blooms, some of which may be deleterious to oysters (e.g., cyanobacteria)	
	medium	•Warmer water could cause changes in predator populations, for example range expansion of green crabs which may affect the survival of oysters •Warmer water could cause changes in the natural food assemblages of oysters, which may affect survival and growth •Changes in the salinity regime due to sea level rise is likely to change the distribution of shellfish habitat	•Increased water temperatures may affect the spawning of oysters which in turn may result in asynchrony between larval development and food supply •Warmer water is likely to increase incidence of marine and estuarine ecosystem-borne oyster and other shellfish disease •Increased water temperature could affect reproduction and growth of oysters •Increase in drought could reduce freshwater inflow and affect the salinity regime, which may affect the distribution of oyster reefs •An increase in estuarine salinity due to sea level rise may promote the upstream migration of shellfish epizootics and disease •Sea level rise may result in a reduction of availability of intertidal habitat, due to the "coastal squeeze" phenomenon resulting from infrastructure conflicts. This may limit the amount of habitat available for some species such as oysters •Increased storminess and precipitation may increase acidification levels through increased runoff of acidifying compounds and nutrients, reducing the ability of the system to buffer against acidity.	•Greater soil erosion due to increasing storminess may increase sediment deposition in estuaries, with potential for smothering nascent reefs or shell substrate required for settling •Oysters and other mollusks may be adversely affected by ocean acidification during developmental stages that involve shell-building through pH-sensitive calcification processes • Recreational shellfishing may be threatened or lost due to ocean acidification
	low	•Increased water temperature may result in dissolved oxygen levels sufficiently low to stress oysters •Increased storminess may exacerbate exposure to pathogens from runoff and sewage overflows from storm events		
		low	*moderate*	*high*
		Severity of Impact		

Warmer waters, warmer winters, warmer summers, increasing drought, increasing storminess, and sea-level rise all pose some risk to this objective. These stressors are generally expected to be moderate on the spectrum of severity of impact to EPA CWA goals. There are three high-risk vulnerabilities associated with warmer waters, increasing drought and sea level rise, related primarily to shifting habitat distributions and expanded growing season for toxic algae and bacteria. Oyster bed restoration will likely be challenged due to these changing climactic conditions.

Technical Review Panel recommendations for further research:

- Oyster larval and recruitment studies to identify population sources, potential effects of ocean acidification on oyster larvae, densities, and survival of recruitment.
- What is limiting oyster survival at restoration sites? Predation studies examining native and invasive crab species and oyster drills should be conducted.
- Continued and more extensive sediment mapping in the Great Bay to examine sediment change and dynamics in and around native oyster reefs and restoration sites.
- Develop a monitoring plan to improve our understanding of aragonite saturation state variability in NH waters and where these vulnerabilities overlap with biological processes related to ecosystem services such as oyster farming, oyster restoration, and fish biology.
- Develop a research agenda that will address gaps in knowledge relevant to NH vulnerabilities to the effects of ocean acidification. This agenda should include further research on all life history stages of vulnerable species in NH of high economic and ecosystem value.
- Explore potential mitigation strategies for ocean acidification relevant to NH waters.

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Monitoring *Vibrio*

LR 1.2: Increase the number of adult clams in the Hampton-Seabrook Estuary to 5.5 million clams by 2020

Likelihood of Occurrence (by 2050)	Severity of Impact: *low*	Severity of Impact: *moderate*	Severity of Impact: *high*
high		•Warmer water is likely to lead to an expansion of epizootics (MSX, Dermo) and invasive species •Increase in water temperature and decreased flow during periods of drought may lead to harmful algal blooms, some of which may be deleterious to clams (e.g., cyanobacteria)	•Clams and other mollusks may be adversely affected by ocean acidification during developmental stages that involve shell-building through pH-sensitive calcification processes • Recreational shellfishing may be threatened or lost due to ocean acidification
medium	•Warmer water could cause changes in predator populations and natural food assemblages which could influence shellfish quality and survival	•Increased water temperatures may affect the spawning of clams which in turn may result in asynchrony between larval development and food supply •Warmer water is likely to increase incidence of marine and estuarine disease •Increased water temperature could affect reproduction and growth of clams •Increase in drought could reduce freshwater inflow and affect the salinity regime, which may affect the distribution of clam beds	
low	•Increased water temperature may result in dissolved oxygen levels sufficiently low to stress clams •Increased storminess may exacerbate exposure to pathogens from runoff and sewage overflows from storm events		

Warmer waters, increasing drought, increasing storminess, sea-level rise, and ocean acidification all pose some risk to this objective. These stressors range across the the spectrum of severity of impact to EPA CWA goals. The most high-risk vulnerabilities to this objective are related to increased water temperature and ocean acidification. Clams will be at a higher risk for disease and may experience developmental challenges due to acidification, making clam bed restoration more difficult.

Technical Review Panel members noted their research recommendations for LR 1.1 would also be applicable and replicable in clam species.

LR 1.3: Increase the areal extent of eelgrass cover to 2900 acres and restore connectivity of eelgrass beds throughout the Great Bay Estuary by 2020

Likelihood of Occurrence (by 2050)				
	high	•Stronger storms will cause more intense flooding and runoff, potentially increasing nutrient loads that could result in eutrophication	•Greater soil erosion due to increasing storminess may increase sediment deposition in waterways, increasing turbidity and decreasing water clarity •Warmer summers may lead to latitudinal migration of SAV species •Warmer winters may lead to latitudinal expansion of invasive SAV species •Increased overwash and breaching of barrier islands due to sea level rise could negatively impact local SAV populations by smothering existing beds. However, inundation of shorelines could create new SAV habitat areas •Sea level rise may lead to increased salinity up-stream; a shift in salinity regime may affect the distribution of SAV •Increased areas of hardened shoreline - a likely response to sea level rise - may exacerbate the effects of sea level rise on seagrass beds by preventing landward migration and causing scour, leading to a decreased availability of suitable habitat for SAV •Large storms may result in periods of poor water clarity and reduced light penetration to eelgrass beds for extended periods of time	•Warmer summers may result in the latitudinal expansion of invasive species and disease •Warmer summers may lead to warmer coastal water, possibly exceeding SAV temperature tolerance •Warmer water is likely to increase incidence of marine and estuarine epizootics and disease, such as eelgrass wasting disease
	medium		•Warmer winters may result in asynchrony of vegetative growth and bird migrations	•Increased wave action from increasing storminess may damage eelgrass beds •Certain species of SAV are sensitive to large fluctuations in water temperature. Warmer water may exceed temperature tolerance of some SAV species, resulting in the loss of SAV habitat
	low	•Increased acidification of coastal waters may exceed the pH tolerance of some SAV species	•Sea level rise may pose significant threats to SAV habitat due to potential implications of increased water depth and reduction in light penetration to existing beds	
		low	*moderate*	*high*
			Severity of Impact	

Increasing storminess, ocean acidification, warmer summers, warmer water, warmer winters, and sea-level rise all pose some risk to this management objective. Most of these vulnerabilities are moderate to high on the spectrum of severity of impact to EPA CWA goals. Highest-risk vulnerabilities are related to the expansion of invasive species and diseases, such as marine tunicates and eelgrass wasting disease. Areas of high-risk where PREP may have some ability to mitigate impact include implementation of erosion control measures at areas of shoreline adjacent to eelgrass beds and the removal of hardened shorelines to allow for landward migration of coastal ecosystems in response to sea-level rise.

LR 1.4: Restore native diadromous fish access to 50% of their historical mainstem river distribution range by 2020, and improve habitat conditions encountered throughout their life cycle

Likelihood of Occurrence (by 2050)		Severity of Impact: low	Severity of Impact: moderate	Severity of Impact: high
	high		•An increase in long-term and seasonal short-term drought may decrease base flows in streams •Increased drought may result in the warming of streams •Warmer waters may impact fish reproduction that requires cold temperatures; other reproductive cycles are tied to water temperature •Warmer water may impact the coastal food web base •Lower summertime flows - resulting from less snowmelt, hotter summers driving more evaporation, and a longer growing season - will likely lead to longer periods of low-flow •Lower summer flows and longer periods of low-flow may impede aquatic organism passage	•Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems •Changing freshwater inputs with increasing drought may affect salinity distribution in estuaries
	medium			•Warmer water may impact the coastal food web base
	low			

Warmer summers, warmer water, and increasing drought all pose some risk to this objective. All vulnerabilities are high-risk to meeting the objective of diadromous fish restoration. Lower summer time stream flows, combined with warming water temperature, are very likely to result in a shift in cold-water species habitats. Given the likelihood that climate change will cause shifts to traditionally observed species ranges, this goal may need to be reconsidered or reworded. To mitigate these risks, PREP could advocate for or implement shoreland buffer restoration and riverine tree planting to increase shading over important spawning rivers and stream crossing improvements to reduce barriers to stream flow and aquatic organism passage.

Priority action areas identified by survey respondents:

- Stream restorations including dam removal and stream crossing improvements
- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes

LR 1.5: Document existing populations of Eastern brook trout and protect or restore the integrity of the sub-watersheds that support them

Likelihood of Occurrence (by 2050)	Severity of Impact: low	Severity of Impact: moderate	Severity of Impact: high
high			•Increased drought may result in the warming of streams
medium	•Warmer summers may result in a latitudinal shift in species	•An increase in long-term and seasonal short-term drought may decrease base flows in streams	
low			

Warmer summers and increasing drought both pose some risk to this objective. The two high-risk vulnerabilities are both related to increasing drought impacts on stream flow and temperature, which may pose a challenge to the maintenance or restoration of Eastern brook trout populations.

Priority action areas identified by survey respondents:

- Field identification and mapping of in-stream barriers to aquatic organism passage due to poorly designed and/or malfunctioning stream crossings and impoundments

LR 1.6: Maintain a stable and diverse population of shorebirds and saltmarsh breeding birds in Piscataqua region estuaries

Likelihood of Occurrence (by 2050)	Severity of Impact: low	Severity of Impact: moderate	Severity of Impact: high
high		•As sea level rises, salt marshes will migrate landward - this migration will be affected in areas where hard infrastructure impedes landward movement. This may result in a significant loss of coastal marsh habitat, and resultant loss of habitat for saltmarsh-dependent species (e.g., Nelson's and Sharp-tailed sparrows) •If the rate of sea level rise increases dramatically, salt marshes may not be able to keep up with vertical accretion of marsh peat and may be drowned/lost. This may result in a significant loss of coastal marsh habitat, and resultant loss of habitat for saltmarsh-dependent species •Increased frequency and intensity of coastal storms may impair coastal wetlands through wind, wave, and surge effects •Increased frequency and intensity of coastal storms may increase coastal erosion, potentially leading to loss of coastal wetland and marshes, and resultant loss of habitat for saltmarsh-dependent species	
medium		•Wetland species that can't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems •Food supplies and bird migrations may be mistimed due to warmer winters •Warmer winters may result in asynchrony of vegetative growth and bird migrations	
low	•Shellfish predators may not survive disappearance of shellfish due to ocean acidification •The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain •A decrease in precipitation may lead to the oxidation and formation of highly saline marsh soils. Hypersaline conditions on the high marsh may decrease marsh production and habitat support		

Ocean acidification, sea-level rise, increasing storminess, warmer summers, increasing drought, and warmer winters all pose some risk to this objective. Most vulnerabilities are moderate on the spectrum of severity of impact to EPA CWA goals, with a low-to-medium likelihood of occurrence. Sea-level rise and increasing storminess are projected to cause the most high-risk impacts, related primarily to habitat loss due to inability of salt marsh habitat to accrete peat at a fast-enough pace to keep up with sea level rise or to migrate landward due to coastal armoring or development. Loss of salt marsh habitat area will negatively impact the ability of the Piscataqua Region to maintain a stable and diverse population of saltmarsh breeding birds.

Priority action areas identified by survey respondents:

- Living shoreline construction
- Identifying and protecting resilient salt marsh habitats
- Promoting natural and nature-based approaches to coastal protection

LR 1.7: Inventory, evaluate, and restore natural vegetative buffers along degraded reaches of tidal shorelands, riparian zones of all stream orders, and wetlands

Likelihood of Occurrence (by 2050)	low	moderate	high
high		•Increased frequency and intensity of coastal storms may impair coastal wetlands and their upland buffers through wind, wave, and surge effects •Increased frequency and intensity of coastal storms may increase coastal erosion, potentially leading to loss of coastal wetlands and buffer area •Increasing storminess combined with sea level rise may result in increased flooding and impacts to adjacent upland habitat •Sea level rise may change the salinity regime of inland bays, thereby affecting the distribution of salinity-sensitive flora and fauna	•Land owners/managers may react to sea level rise and/or increased erosion rates by installing hardened shorelines - eliminating existing and future buffer area vegetation. The hardening of naturally eroding shorelines also removes a source of sediments •As sea level rises, coastal ecosystems will migrate landward - this migration will be impacted in areas where hard infrastructure impedes landward movement. This may result in a significant loss of coastal marsh buffer habitat
medium		•Intense storms may result in significant damage to or loss of the coastal/marine forest community of the barrier islands	
low	•Stress from excessive heat and decreased water may result in vegetative die-off in terrestrial upland areas		
	low	*moderate*	*high*
	Severity of Impact		

Warmer winters, warmer summers, increasing storminess, sea-level rise, and increasing drought all pose some risk to this objective. Most vulnerabilities are moderate-to-high on the spectrum of severity of impact to EPA CWA goals, with a high likelihood of occurrence. Increasing storminess and sea-level rise are the dominant stressors related to this objective. Changes in salinity regimes of estuaries and changing or loss of availability of suitable habitat area for vegetative species are of primary concern.

Technical Review Panel recommendations for further research:

- We need to understand the process of wetland and buffer migration landward with sea-level rise – both upland plant loss and wetland plant establishment.

Priority action areas identified by survey respondents:

- Living shoreline construction and promotion
- Work with wetland permit applicants to increase natural vegetation in wetland buffer areas
- Limit development near all rivers and streams

LR 1.8: Identify and address stream and shoreline modifications that have significant negative impacts on the physical, chemical, or biological integrity of waterways

Likelihood of Occurrence (by 2050)	Severity of Impact: low	Severity of Impact: moderate	Severity of Impact: high
high		•Bulkheads, sea walls, and revetments may become more widespread along floodplains and riparian areas due to rising sea levels, resulting in loss of natural shoreline habitat and decreased water quality •Beaches and dunes that currently lie adjacent to developed land will not be able to migrate landward in response to sea level rise, potentially resulting in the loss of beach and dune habitat •As sea level rises, marshes will migrate inland, however this ability to migrate will be affected in locations where man-made structures, e.g., bulkheads, interfere with migration	•Stream crossings may already impede natural movement of waterways (e.g., tidal flows); the impacts of this restriction to water movement will increase as infrastructure is challenged by sea level rise or increased precipitation due to increasing storminess
medium			
low			

Sea-level rise and increased storminess pose risk to this objective. All vulnerabilities are high on the spectrum of severity of impact to EPA CWA goals, with a high likelihood of occurrence. The primary concern associated with this objective is the high likelihood that additional hard structures may be constructed in response to climate change. It is especially important to meet this objective in dynamic habitat areas (such as tidal salt marshes) that are trying to shift in response to climate change stress.

Priority action areas identified by survey respondents:

- Living shoreline construction and stream restorations including dam removal and stream crossing improvements
- Protect dune/beach/marsh habitat and facilitate migration where possible

LR 1.9: Identify vulnerabilities of upland and aquatic habitats to anticipated climate change impacts and take appropriate actions to mitigate or adapt to impacts

Significant steps are being taken towards the accomplishment of this objective through the implementation of the climate change vulnerability assessment for the 2010 CCMP, to inform action items in the 2020 CCMP update.

LR 1.10: Restore or enhance an additional 300 acres of salt marsh by 2020 through removal of tidal restrictions or invasive species management

Likelihood of Occurrence (by 2050)	*high*	•Invasive species that have less salt tolerance than Spartina will pose less of a threat with SLR, but may be supported by greater freshwater runoff due to increasing precipitation	•An increase in sea level will lead to greater susceptibility to storm surge. Shoreline erosion is likely to lead to loss of wetlands and salt marshes. •In some cases where tidal range increases with increased rates of sea level rise, there may be an overall increase in the acreage of tidal flats •Warmer winter temperatures may promote the northern migration of southern invasive species (e.g., marsh burrowing crab species such as fiddler and purple marsh crabs that can contribute to marsh degradation/loss) •Warmer winters may facilitate the survival of invasive species, epizootics, and disease •Warmer summers are likely to promote the northern migration of southern invasive species •Dense stands of *Phragmites* may block tidal flood exchange in high marsh and upland areas; this impact combined with sea level rise may lead to high marsh loss and limited marsh migration	•Bulkheads, sea walls, and revetments are likely to become more widespread as sea level rises •Increasing the size of culverts and bridges to accommodate rising sea levels and more intense coastal storms will be more difficult if the public feels increasing tidal exchange is a threat to private lands and infrastructure •If the rate of sea level rise increases dramatically, salt marshes may not be able to keep up with vertical accretion of marsh peat and may be drowned/lost
	medium			
	low	•Marshes may erode from loss of protective ice due to warmer winters •Increases in atmospheric CO2 and freshwater inputs (from greater likelihood of storms) may increase the spread of *Phragmites*		
		low	*moderate*	*high*
		Severity of Impact		

Sea-level rise, warmer winters, increased storminess, and warmer summers all pose some risk to this objective. Most vulnerabilities pose a high-risk to EPA CWA goals. The primary concern associated with this objective is the high likelihood that additional hard structures may be constructed in response to climate change, hindering the ability of these dynamic systems to migrate and shift in response to sea level rise. Other high-risk concerns are related to the highly likely spread of invasive species, such as *Phragmites,* posing a real challenge to invasive species management. An opportunity identified through this exercise is the possibility of the identification of areas where there may be an overall increase in tidal flat areas, due to increasing tidal ranges. If these areas can be identified and protected, they may eventually play host to tidal salt marsh habitat.

Technical Review Panel recommendations for further research:

- Embrace and cultivate techniques for the creation of new salt marshes.
- Experiment with temporary marsh edge erosion protection techniques until more permanent living shorelines can be designed and constructed.
- Monitor impact of restoration on existing salt marsh systems.
- While restoring tidal exchange to marshes is still needed, the plan should promote marsh survival in broader terms. For example, marsh resilience to sea-level rise could be enhanced by removing legacy effects of intense ditching (ditch remediation and runnels) or supporting research studying placement of dredge spoil on marshes to increase marsh longevity.
- Continuation and expansion of salt marsh accretion monitoring paired with local high-accuracy tide data.
- Monitor the implementation effects of more novel restoration approaches to marshes susceptible to drowning – e.g., thin layer placement of sediment, facilitating marsh migration to abutting upland, encouraging/creating habitat for salt marsh sparrows.

Priority action areas identified by survey respondents:

- Living shoreline construction and stream restorations including dam removal and stream crossing improvements
- Use NHDES Coastal Program data to prioritize culvert/bridge replacement projects; this data could also be used to apply for grants such as the ARM fund to help offset the costs of replacement
- Modeling and information gathering to determine marsh response to sea-level rise. Overall, information about marsh response to sea level rise lacks data about marsh elevation.
- Support/facilitate marsh migration where possible

LR 1.11: Monitor and control the extent of invasive nuisance species throughout the Piscataqua Region watershed and estuaries

	Severity of Impact		
Likelihood of Occurrence (by 2050)	*low*	*moderate*	*high*
high		•Warmer winter temperatures may promote the northern migration of southern invasive species •Warmer summers are likely to promote the northern migration of southern invasive species •Changing climate may result in stresses leading to greater changes to variation/abundance of native species populations thereby allowing invasives to colonize more easily •Multiple climate change conditions have allowed for the invasion of more pathogenic strains of *Vibrio parahaemolyticus* than indigenous strains; one strain, ST36, has established itself and now causes 70-80% of all illnesses from this species in New England	•Nuisance species may invade from more southern waters due to warmer waters •Parasites and diseases are enhanced by warmer water •Warmer summers may result in the latitudinal expansion of invasive species and disease •Increased incidence of epizootic and disease expected with sea level rise •Increased incidence of Dermo, MSX, and mud blister worms are expected due to multiple climate change factors
medium			
low			

Warmer water, warmer winters, and warmer summers all pose some risk to this objective. All vulnerabilities are moderate-to-high on the spectrum of severity of impact to EPA CWA goals, with a high likelihood of occurrence. Changing climatic conditions are likely to promote the spread of invasive species, making the control of these species more difficult. There have been invasions of *Vibrio parahaemolyticus* strains that are much more pathogenic than indigenous strains. ST36 is the leading cause of shellfish borne disease in New England and the world. It has not yet established itself in New Hampshire waters, yet there are signs that its influence is starting to show up.

Technical Review Panel recommendations for further research:

- Participating in a region-wide monitoring program for invasive species would provide early warning information and reduce risk.

Priority action areas identified by survey respondents:

- Implement management strategies for plant and insect invasives
- Limit migration of perennial pepperweed
- Reducing green crab populations

LR 1.12: Minimize impacts to benthic habitats from direct alterations to submerged lands

Likelihood of Occurrence (by 2050)	*high*			•Bulkheads, sea walls, and revetments are likely to become more widespread as sea level rises, potentially leading to coastal construction and impacts to benthic habitats
	medium			
	low			
		low	*moderate*	*high*
		Severity of Impact		

Sea-level rise poses some risk to this objective. Coastal armoring is more likely to occur under future climatic conditions, which poses a high-risk to the meeting of this objective. Coastal armoring projects are likely to impact benthic habitats. Objectives LR 1.10 and LR 1.8 reference potential modifications to existing tidal/riverine restrictions – reconstruction or removal activity may result in alterations to benthic habitats.

Priority action areas identified by survey respondents:

- Living shoreline construction and promotion

LR 1.13: Restore degraded natural freshwater wetlands and priority upland habitats

Likelihood of Occurrence (by 2050)				
	high		•An increase in long-term and seasonal short-term drought may decrease base flows in streams and/or cause groundwater tables to drop	
	medium		•Some invasive species and disease are expected to expand into the Northeast forests due to warmer summers •The absence or decrease of snowmelt may lead to a decrease of vernal pool habitat	
	low	•Stress from excessive heat and decreased water may result in vegetative die-off in terrestrial upland areas, leading to an increase in degraded habitat areas •Higher temperatures may lead to greater evaporation and lower groundwater tables		
		low	*moderate*	*high*
			Severity of Impact	

Increasing drought, warmer summers, and warmer winters all pose some risk to this objective. Vulnerabilities are low-to-moderate on the spectrum of severity of impact to EPA CWA goals. Likelihood of occurrence of these vulnerabilities ranges from low-to-medium. The only high-risk impact is associated with increasing drought and the high likelihood that base flows in streams will decrease and groundwater tables will drop. This will pose challenges to the restoration of wetlands and upland habitat.

Technical Review Panel recommendations for further research:

- Wetter climate could result in an increase in freshwater wetlands and vernal pools – are the regulatory protections currently in place sufficient for the protection of the future extent of these ecosystems?

Priority action areas identified by survey respondents:

- Improving stormwater management strategies by reducing runoff from impervious surfaces and incorporating stormwater BMPs during land use changes
- Improve the diversity and composition of trees for disease resistance along roadways and in parks
- Help Conservation Commissions identify opportunities to restore priority buffer habitats

LR 1.14: Improve implementation capacity for restoration projects

This objective is not expected to be impacted by climate change. There may be opportunity to leverage additional funds in the future for restoration following a natural disaster or as storm protection buffering for natural hazard mitigation.

LU 1.1: Promote sustainable land use practices in both new development and redevelopment of existing sites

This objective is not expected to be impacted by climate change. Sustainable land use practices should be carefully defined and designed with consideration for climate change impacts to the development areas.

LU 1.2: Promote regional strategies for consistent use of ecologically protective planning, regulation, development, and enforcement standards

This objective is not expected to be impacted by climate change. Consider requiring the application of conservation subdivision design theory[1] to new development.

[1] Carter, T. (2009). Developing conservation subdivisions: Ecological constraints, regulatory barriers, and market incentives. *Landscape and Urban Planning*, *92*, 117–124. https://doi.org/10.1016/j.landurbplan.2009.03.004

LU 2.1: Protect floodplains, wetlands, shorelands, and associated fluvial erosion hazard zones to maintain their function and value

Likelihood of Occurrence (by 2050) / Severity of Impact	low	moderate	high
high		•As sea level rises, salt marshes will migrate inland. The ability to migrate will be affected in locations where man-made structures, e.g. bulkheads, interfere with migration •Increased frequency and intensity of flooding events may result in erosion of floodplains and riparian habitat •As sea levels rise, groundwater tables within 20 feet elevation of mean high tide will also rise. This may lead to increased wetland size (some substantially) and a decrease in ability of wetlands to store floodwaters. •Drainage networks not currently connected to tidal areas may become flooded with tidal and/or river water under sea level rise conditions even without precipitation. Given the increases in precipitation intensity existing freshwater drainage flooding will likely increase in the future.	•An increase in the rate of sea level rise may result in significant loss of coastal salt marsh habitat
medium	•Increased frequency and intensity of flooding events may result in the loss of existing floodplains and ecosystems	•Sea level rise may lead to an increase or decrease of floodplains or riparian habitat •Sea level rise may result in drowning of bay wetlands •Increasing strong storms, such as hurricanes, combined with sea level rise, will result in increasing damage to coastal habitats (erosion, flooding, etc.)	•An accelerated rate in sea level rise may transform salt marshes into mostly low marsh habitat; coastal squeeze has a higher impact on high marsh as it exists at a much narrower elevation range than low marsh
low			

Sea-level rise and increasing storminess pose some risk to this objective. Most vulnerabilities post high-risk to the meeting of this objective. High-risk actions are primarily related to the loss of wetland habitats due to erosion, sea level rise, and inability to migrate. To maintain function and value of these resource areas, steps should be taken now to identify and remediate areas threatened by coastal squeeze.

Technical Review Panel recommendations for further research:

- We need to understand the impacts of sea-level rise on groundwater and the process of inland migration of shorelines as sea-level rises.

Priority action areas identified by survey respondents:

- Living shoreline construction
- Implementation of municipal ordinances to protect floodplains, wetlands, and shorelands
- Find grant funding for the development of a coastal hazards adaptation chapter to the Town Master Plan
- Culvert replacement and improvements that restore natural flow and substrate
- Study the effects of dam removal and flow regime interaction

LU 2.2: Promote improved protections for low order streams

This objective is not expected to be impacted by climate change.

LU 3.1: Implement the Land Conservation Plan for New Hampshire's Coastal Watersheds and Land Conservation Plan for Maine's Piscataqua Region Watersheds and protect 75% of lands identified as Conservation Focus Areas by 2025

This objective is not expected to be impacted by climate change

LU 3.2: Implement strategies from the NH Wildlife Action Plan, NH Wildlife Connectivity Model and Maine's Beginning with Habitat Program to protect and manage key species at risk and critical habitats identified in those plans

This objective is not expected to be impacted by climate change

LU 3.3: Support land stewardship and land management actions for conservation lands and key areas that maximize quality habitat and watershed services

As evidenced by the vulnerability assessment of management objectives, climate change stressors will have an impact on and change the composition of existing landscapes. Protecting ecologically-connected and diverse abiotic "stages" will allow for the preservation of complex landforms and may also allow for the natural flow of species in response to climate change pressures[2]. Areas of high biological integrity today are more likely to remain high integrity into the future[3].

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LU 3.4: Protect the quality and quantity of current and future drinking water supplies through land protection and land use regulation

Likelihood of Occurrence (by 2050)				
	high	•Saltwater intrusion into groundwater may be more likely under future sea level rise •Evaporation losses from reservoirs and groundwater may increase		
	medium	•Increased growth of algae and microbes due to warmer waters may affect drinking water quality •Summer water supplies that depend on winter snow pack may disappear	•Warmer temperatures may drive greater water demand	•Increasing heavy precipitation may drive higher levels of enteric viruses as risk of failure of stormwater and wastewater systems also increases under these conditions, especially in areas with aging infrastructure
	low	•Groundwater tables may drop due to increasing drought •Coastal aquifers may be salinized from higher demand on groundwater supplies due to increasing drought •Coastal aquifers may be salinized from insufficient freshwater input due to drought		
		low	*moderate*	*high*
		Severity of Impact		

Sea-level rise, warmer summers, warmer water, warmer winters, and increasing drought all pose some risk to drinking water supplies. Vulnerabilities are generally expected to be minorly impactful to the objective, though there is one high-risk vulnerability related to higher levels of enteric viruses in water due to potential failure of stormwater and wastewater systems. To ensure continued protection of human health and the environment, action should be taken to ensure aging drinking water, wastewater, and storm water infrastructure is retrofitted to withstand the pressures of increased heavy precipitation events. Land protections and land use regulations are not impacted by climate change, but climate projections should be considered as they are implemented into the future. Long-term impacts to drinking water supplies include saltwater intrusion and salinization; efforts should be made now to identify and preserve those water supplies with less likelihood to be impacted by these risks.

Technical Review Panel recommendations for further research:

- Model potential changes in daily or hourly soil moisture resulting from changes in temperature and precipitation.

Priority action areas identified by survey respondents:

- Purchase property around municipal wells and enact aquifer protection ordinances to regulate uses near wells and aquifers

- Develop outreach and educational materials on legacy toxin issues
- Implement increasing rate blocks for water and sewer rate structures to encourage water conservation
- Help Conservation Commissions and Open Lands Committees identify areas to conserve for the protection of drinking water resources

WS 1.1: Promote the use of economic valuation of ecosystem services and functions by coastal watershed decision-makers

This objective is not expected to be impacted by climate change.

WS 1.2: Provide access to science-based information about Piscataqua Region estuaries and watersheds to coastal watershed decision-makers

This objective is not expected to be impacted by climate change.

WS 1.3: Improve state and local capacity to develop and enforce measures that protect and restore aquatic habitats in PREP focus area

This objective is not expected to be impacted by climate change.

Step 5 and 6: Risk Evaluation and Establishing Context for an Action Plan

There were many climate risks PREP's CCMP identified through this exercise. Some of these risks are seemingly inevitable, and beyond the capacity of the organization to prevent (e.g., changing salinity distribution regimes and distributional species shifts). However, there may be ways PREP could help their communities and ecosystems adapt to these impacts. Other impacts may be mitigatable through policy and remediation actions. It won't be possible for PREP to address all of these potential risks through their CCMP; to provide some context for decision-making around these vulnerabilities into the 2020-2030 planning cycle, risks have been synthesized into the following lists:

- High-risk vulnerabilities already addressed by action plans,
- High-risk vulnerabilities which may be mitigatable but are not addressed by existing action plans, and
- High-risk vulnerabilities where some more research may be required before an Action Plan can be developed.

High-risk vulnerabilities already addressed by Action Plans

- Failure of stormwater and wastewater systems during high precipitation events

  This high-risk vulnerability to WR 1.1 and WR 1.2 is addressed by Action Plan WR-12, identified as "highest" priority ranking. WR-9 could be altered to include nutrient *and* *bacteria* loads to provide further support to address this vulnerability in the stormwater system. Implementation of Action Plan LR-12 would help to identify the most at-risk areas to prioritize for retrofit.

- Increased precipitation and flood events resulting in increased delivery of bacteria and pathogens to waterways

    This high-risk vulnerability to WR 1.1 and WR 1.2 is addressed by Action Plans WR-1, WR-6, WR-7, and LU-5. The creation of stormwater utility districts (LU-5) is currently a "moderate" priority, which could be increased in order to help fund stormwater infrastructure retrofits and control systems.

- Marine transportation and navigability are at risk where low-clearance bridges are likely to be impacted due to sea level rise and coastal storm surge

    This high-risk vulnerability to WR 2.2 is addressed by Action Plan WR-35. PREP may want to work with state and local transportation planners to identify those existing structures that are likely to be impacted by climate change, and work towards the re-design of those structures.

- As sea-level rises, coastal ecosystems may be pressured to migrate landward to accommodate for loss of light penetration to SAV beds or ability of salt marshes to accrete peat

    This high-risk vulnerability to LR 1.3, LR 1.6, and LR 1.7 is addressed by Action Plans LR-13, LU-7 and LU-8, with a "highest" priority ranking. LR-13 should be implemented congruously with NR3 (non-regulatory municipal planning target), which targets the protection of previously-identified Conservation Focus Areas, to ensure maximum benefit from the conservation investment. There are no Action Plans associated with the removal of barriers to coastal ecosystem migration; PREP might consider developing an action plan around the relocation of shoreline-abutting parking lots or other structures which may impede migration. PREP might also consider the development of a regulatory municipal planning target which limits development in projected marsh migration areas.

High-risk vulnerabilities not addressed by Action Plans, but may be mitigatable

- Warmer waters may lead to greater survival of pathogens and toxin-producing algae, as well as decreased support for cold-water fisheries

    This high-risk vulnerability to WR 1.1, WR 1.2 WR 1.6, WR 2.1, LR 1.1, LR 1.2, LR 1.3, LR 1.4, and LR 1.5 is not addressed by any existing Action Plans. PREP should consider developing an action plan around riverine shading, and the promotion of tree and shrub plantings along rivers to keep them shaded from the sun. A cooler supply of riverine inputs to coastal waterways may also help to keep coastal waters cooler. Warmer water may also hold less dissolved oxygen, be less supportive of eelgrass, and promote the spread of invasive species.

- Increased erosion and deposition of sediments due to an increasing number of large storms impacting the NH coast

    This high-risk vulnerability to WR 1.4, WR 2.2, LR 1.1, LR 1.3, LR 1.7, LR 1.10, and LU 2.1 is not addressed by any existing Action Plans. PREP should consider developing an action plan for sediment-runoff control at coastal or riverine-adjacent roadways and other armored shoreline areas. Action Plan LR-13 is somewhat supportive of this objective in that it works towards the protection of undeveloped coastal land to allow for shoreline and marsh migration; the preservation of flood and storm-attenuating ecosystems such as eelgrass and saltmarsh is critical to mitigate impacts from this impact.

- Loss of high marsh areas in coastal salt marshes due to sea-level rise and spread of *Phragmites*

    This high-risk vulnerability to LR 1.10 and LU 2.1 is not addressed by any existing Action Plans. Dense stands of *Phragmites* may block tidal flood exchange in high marsh and upland areas, which, combined with sea-level rise and the threat of "coastal squeeze", could lead to the loss of high marsh area in salt marshes invaded by *Phragmites*. The coastal squeeze phenomenon occurs when coastal ecosystems are unable to migrate landward in response to sea-level rise due (usually due to the presence of hard infrastructure) and are "squeezed out" of existence between the sea and the structure. High marsh is much more susceptible to coastal squeeze as it exists at a much narrower elevation range than low marsh. PREP should consider the formulation of an Action Plan which includes the identification of tidal salt marshes threatened by coastal squeeze and *Phragmites* and formulation of a restoration plan for those identified marshes.

High-risk vulnerabilities which require further research before Action Plans can be developed

- Oysters, clams, and other mollusks may be adversely impacted by ocean acidification

    This high-risk vulnerability to LR 1.1 and LR 1.2 is not yet addressed by any Action Plans. Further research must be conducted to understand what the limiting factor to mollusk development is when faced with coastal/ocean acidification stressors, and what the most effective mitigation strategies are likely to be. PREP should look to other research conducted in this field by partners such as the Casco Bay Estuary Partnership, who is working the Maine Coastal Program and with the University of Southern Maine to develop and pilot a shell recycling program with local restaurants. The idea is to collect, clean, and then deploy shell waste near shellfish beds to provide an extra supply of calcium carbonate to developing shellfish larvae. This shell deployment may also be useful as substrate to encourage settling of shellfish spat, or as a structural material in "living shorelines" and "nature-based solutions" to shoreline erosion.

- Groundwater rise resulting from sea-level rise, and the potential salination of coastal aquifers

  This vulnerability to LU 3.4 is not yet addressed by any Action Plans. PREP should incorporate groundwater rise into future hydrodynamic modeling efforts in the PREP region. The implementation of Action Plans WR-30 and WR-31 would provide data to feed into the model. It will be important to understand the interactions of groundwater and sea-level rise, especially as it related to drinking water supplies. PREP should consider editing Action Plan LR-12 to include groundwater and to specifically identify those vulnerable aquifer areas.

Step 7: Deciding a Course

This step is dedicated to the identification of priority actions PREP will take to either mitigate or adapt to risks, through the alteration or addition of CCMP actions.

Generally, there are four approaches PREP can take to respond to any given risk:

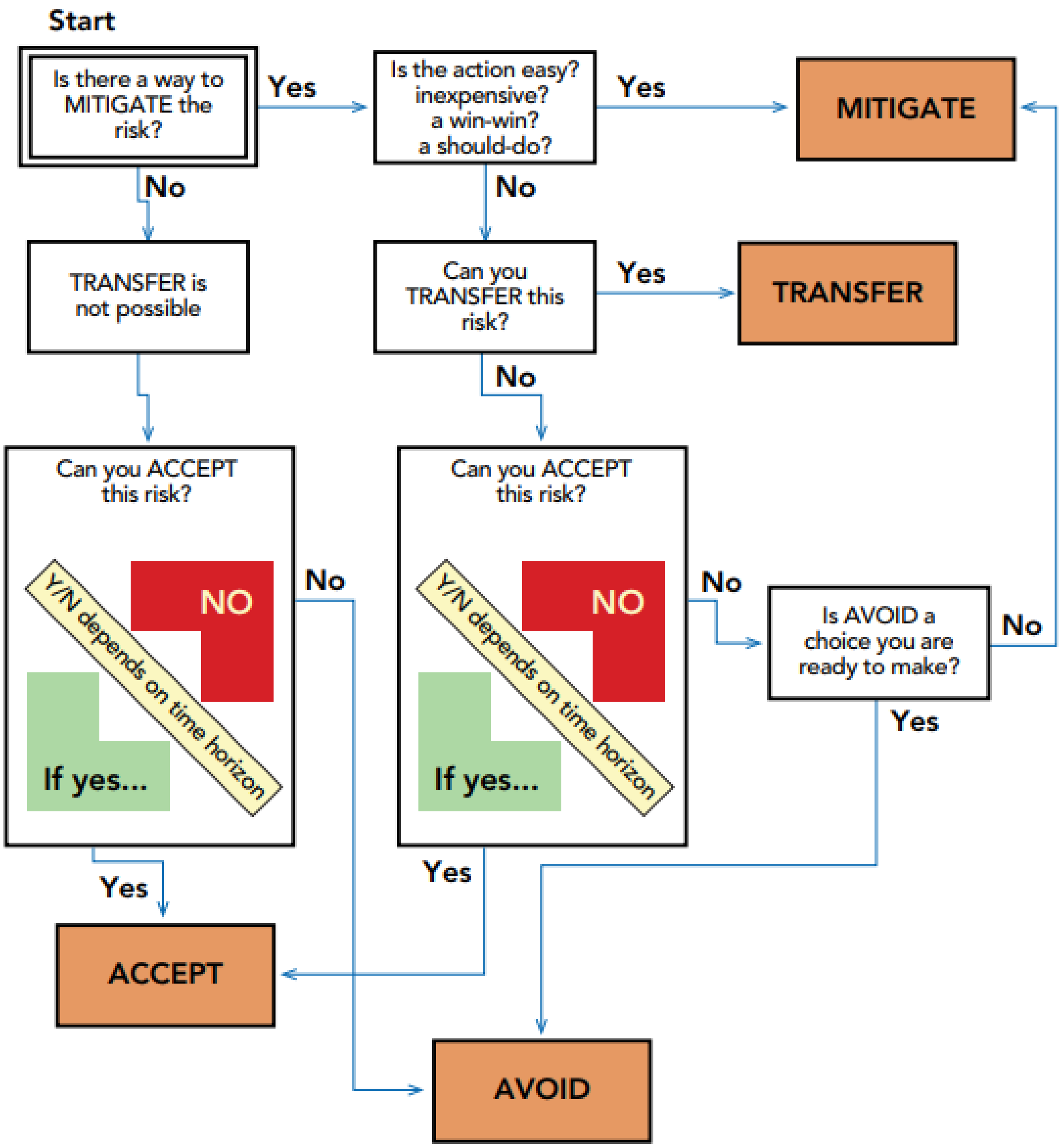
Mitigate: Mitigating a risk involves taking actions to reduce the likelihood and/or consequence of the threat to your goals.

Transfer: "Transfer" is a technical risk management term for having another organization take responsibility for reducing the risk; your risk is mitigated by another party.

Accept: Accepting a risk means that organization will continue with business as usual and run the risk, dealing with the impact if/when it does occur. You might choose to accept a risk for some time, and work towards mitigation later.

Avoid: Typically, avoiding a risk involves eliminating its root cause. However, since PREP itself cannot stop climate change from occurring, and cannot relocate its planning area, avoiding a risk in this context requires a shift in objectives and/or planned action items so that you are no longer exposed to the risk. Avoiding a risk does not mean the impact to the resource or to your place goes away – this is an administrative handling of risk in which you move away from the objective/goal and will no longer be putting resources toward it. This means you may be pulling back from work that you thought was important.

Some suggested actions to mitigate risks were provided in the previous section. Upon receipt of this Climate Vulnerability Assessment, PREP will review the identified risks and may assign one of these responses to each risk, if the organization finds that to be a useful exercise. The following flow-chart was provided in the Environmental Protection Agency *Workbook* to aid in this exercise:



Step 8: Finding and Selecting Adaptation/Mitigation Actions

PREP staff should brainstorm a range of feasible actions (regulatorily, economically and politically palatable) that could be taken to adapt to or mitigate each of the identified risks. These actions should reduce the likelihood of risk occurrence by 2050 and/or the severity of impact should the risk be realized. A 2009 resource produced by the EPA Climate Ready Estuaries program, titled "Synthesis of Adaptation Options for Coastal Areas," could be used identify these actions. Some suggestions are provided in Step 5/6.

Potential adaptation/mitigation options should be reviewed comprehensively to identify actions which may alleviate more than one risk (i.e., there are co-benefits to the action). These actions should be considered for higher priority than those that only address one risk (though, if the action would cause great risk reduction in one category but only minor reductions in multiple categories, preference should be given to the action that causes the greatest risk reduction). Potential adaptation/mitigation actions should also be reviewed for robustness. Given the uncertainty about the future climate, will the action perform well under a range of potential conditions? Can it be modified at a future date if the climate changes differently than expected?

All Action Plans should also be reviewed comprehensively to identify any actions that may be maladaptive. Consider whether implementing the action could threaten other management objectives. Any action that could be maladaptive should be removed from the list.

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